An Overview of Biotechnological Approaches for Crop Plant Improvement

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Abstract
Conventional crop breeding is being restricted due to the use of only closely related species and it takes many generations to initiate significant improvement. Biotechnology is getting a great interest as basic techniques for tailoring crop plants as per specific requirement. It allows researchers to shorten this time and this imitate the evolutionary process but in highly selective way. As a biotechnological approach, genetic manipulation strategy is something like tearing out a page of the instruction manual for one organism and gluing it into the instruction manual of another organism. Around the globe, this emerging science is playing an imperative role to help agricultural productivity. In this review, biotechnological approaches that are commonly used for the improvement of crop plants are highlighted and briefly described.

Keywords
Biotechnological approach; Crop improvement; Conventional crop breeding

Introduction
The expected crash of performance of world trade organization, industrial liberalization and free market economy has formed extraordinary risk for various countries to protract even at low economic profile. Therefore it may not be matter-of-fact to rely on industrial sector for economic boost and expansion. Under this state of affairs it becomes indispensable to strengthen other possible assets like agriculture. Agriculture is one of the promising sectors which offers marvelous potential for sustainable growth and can play a key role in helping to sanctuary the economy of the country. Furthermore, a threatening increase in the world population and limited food supply strained and anxious biologists to introduce and advance agriculture management and modern technologies along with conventional practices to attain highest possible crop productivity.

With the development of plant molecular biology, genetic transformation has become one of the innermost issues in molecular breeding (Vasil, 1994). Lack of a stout and vigorous regeneration system to regenerate transformed plants at a satisfactory rate is still the key factor which seriously restricts the enhancement of crops through genetic transformation (Popelka and Altpeter, 2003). Establishment of putative regeneration system, target genome, a candidate gene, and a vector to carry the gene, modification of foreign DNA to enhance its expression, transformed cell identification and characterization of aspirant plants at the molecular levels are the pre-requisite for genetic transformation (Sharma et al., 2000).

Methods for site specific integration in nuclear genome of plants have not been developed but in situ introduction of small mutation in known gene has been described by Zhu et al (1999) and Beetham et al (1999). Biological and physical parameters optimization may increases the effectiveness of these processes (Jefferson, 1987). Stable transformation efficiency and increased transient expression can be attained by particles bombardment (Finer et al., 1992) of target tissue treated with osmoticum (Vain et al., 1993).

The intricacy in the development of gene transfer methods may be due to the deficiency in various cellular responses essential for transformation (Potrykus, 1985). Genetic engineering offers an additional source of disparity through which breeders can develop new
resistant varieties and introduce the genes which confer resistance.

Plant Tissue culture studies

Plant tissue culture techniques have become a powerful tool for studying and solving basic and applied problems in plant biotechnology (Villalobos, 1987). From the last three decades micropropagation and other in vitro techniques have routinely used in horticulture and agriculture for rapid mass multiplication of crop plants (Dodds, 1991; Das et al., 1996). Effectual exploitation of biotechnological approach such as somaclonal variation, somatic hybridization and genetic transformation, rely on proficient and unswerving regeneration systems.

A tissue culture system provides considerable quantities of highly regenerable target tissue. Numerous protocols for somatic embryogenesis and organogenesis from callus have been established. But a swift callus induction has been achieved from immature leaves and immature inflorescences. Minimal genetic changes, has been noticed in regeneration through axillary buds even though it is utilized for plant multiplication (Hendre et al., 1983; Taylor and Dukic, 1993). Indirect embryogenic have been induced by going through callus or undifferentiated mass of cells. This has been done by taking leaf or floral parts as starting material also called ex-plant (Bower and Birch, 1992; Gallo-Meagher and Irvine, 1993; Snyman et al., 1996; Ingelbrecht et al., 1999).

Callus cultures establishment and maintenance is a labor demanding and the regenerated plants are ready for greenhouse planting in at least 36 weeks (Bower et al., 1996). From cell, tissue and organ cultures, production of somatic embryo-like structures may happen either directly or indirectly (Reinert et al., 1977 and Warren and Fowler, 1977). Physical separation of the globular, heart and torpedo stages of embryogenesis has been achieved through somatic embryogenesis, using glass beads to screen the cultures. Somatic or asexual embryogenesis is the production of embryo-like structures from somatic cells, a process which can occur directly from an explant or indirectly via a callus stage. The resulting somatic embryos are independent bipolar structures that can develop and germinate to form plants in a manner analogous to their zygotic counterparts (Ammirato, 1987). As described by many workers (Ho and Vasil, 1983; Ammirato, 1987), the embryogenic areas were compact, nodular and white and comprised relatively small, thin-walled, richly cytoplasmic, basophilic cells with prominent nuclei, whereas the friable and yellow non-embryogenic calli consisted of large, thick walled, highly vacuolated and irregularly-shaped cells. Indirect somatic embryogenesis occurs when the explant is exposed to an auxin, which causes the formation of callus from which plantlets can be regenerated (Ho and Vasil, 1983).

Organogenesis is complicated process involving cellular, molecular and tissue level change in the metabolism. The unorganized mass of cells differentiates into shoots by undergoing modifications in the metabolic reaction etc. It is necessary to study the metabolic change by investigating glucose utilization pattern. However there are no reports on C14 glucose uptakes studies in 3 organogenetic stages. During short term feeding the highest glucose activity is observed in callus stage and it declines as the tissue dedifferentiates into shoots. Similar pattern is observed during long term exposure. It indicates that C14 glucose utilization pattern depends on the organogenetic stage and its requirements are higher at the initial callus stage than in the completely regenerative shoots.

Genetic transformation of crop plants via Agrobacterium

Agrobacterium mediated gene delivery method for genetic transformation of plants is ineffective in monocotyledonous crops, because of host range specificity of Agrobacterium which is a bacterium of dicotyledonous plants (Weising et al., 1988). Several alternative approaches have been developed for monocot transformation e.g. electroporation (Fromm et al., 1986), silicon carbide fiber (Keappler et al., 1990), polyethylene glycol (Iorz et al., 1985) microinjection (Crossway et al., 1986) and gene gun delivery system (Klein et al., 1987). In dicots, gene transfer through Agrobacterium is proficient than gene gun delivery.
system but in monocots, transformation via Agrobacterium is limited (Elliot et al., 1998). In monocots for gene transfer via Agrobacterium different successful attempts have been made recently such as in rice (Park et al., 1996), and banana (May et al., 1995).

Agrobacterium present quite a lot of merits, such as technical simplicity, nominal genome rearrangements in transformants, low copy number and the capacity to transfer long stretches of DNA. In maize plants, bar gene expressions at a high degree was reported (Gordon-Kamm et al., 1990) and have integration of approximately 20 copies of intact gene. Gene transfer methods intricate in Poaceace and this may be due to the lack of various cellular responses which are essential for transformation (Potrykus, 1985). Protoplast regeneration and Agrobacterium host range were the major bottlenecks for the production of transgenic in many crops and this problem has been solved by microprojectile mediated gene delivery system (Rathus and Birch, 1992).

Genetic transformation of crop plants via Gene bombardment

Microprojectile mediated genetic transformation open up the ways which have blocked by the problem of Agrobacterium host range and protoplast regeneration for production of transgenic plants. A boost up in transient expression frequency has been observed in some species and tissue types by bombarding target tissue twice (Wang et al., 1988) but a reduction in frequencies was observed in others (Kartha et al., 1989; Reggiardio et al., 1991). This showed condition for gene gun method should be optimized for each type of tissue. The first report of transgenic production was published by Bower and Birch (1992) and described the applicability of micro-projectile, gene delivery system for transformation of grass family in which embryogenic callus could easily be established. To avoid, inhibition in expression of introduced gene, a low copy number is desirable but complex integration patterns are commonly found in Microprojectile-mediated transformation.

A low copy number of the introduced gene is enviable for practical genetic engineering to avoid probable tribulations of co-suppression of expression caused by multiple gene copies (Smith et al., 1990). Transformation efficiency and frequency may be affected by bombardment distance (Taylor and Vasil, 1991) and velocity of the micro-projectile. These factors may damage the plant tissue physically (Gambley, 1993). Gene delivery methods have been employed in scutellar tissues of maize, wheat and rice (Napoli et al., 1990; Smith et al., 1990; Fromm et al., 1990; Gordon-Kamm et al., 1990).

For micro-projectile mediated transformation embryogenic callus cultures are ideal targets because regenerable cells are not extremely secured, and can be arranged to occupy most of the target area. After bombardment of scutellar tissue of immature embryos (Christou et al., 1991) regeneration of transgenic plants is a beautiful approach for cereals, which are propagated by relatively large seeds.

Conclusions

Plant biotechnology presents considerable improvement in almost every area of crop production with possible profit for farmers, industries and consumers. The growth in the world population, their demands for food and clear consumer preference for environmentally sustainable agriculture will extend biotechnology’s role in food production. Successful applications of various biotechnological tools offer great promise to crop plants in future.

References

Ammirato P.V., 1987, Organizational events during somatic embryogenesis. In the series analytic: Plant tissue and cell culture/edited by Green C.E., Somers D.A., Hackett W.P., and Biesboer D. D., Proceedings of the VIth International Congress, August 3-8, 1986, University of Minnesota, New York, pp.57-81

Beetham P.R., Kipp P.B., Shweisky X.L., Arntzen C.J., and May G.D., 1999, A tool for functional plantgenomics: Chimeric RNA/DNA oligonucleotides cause in vivo gene specific mutations, Proc. Natl Acad. Sci. USA., 96(15): 8774-8778 http://dx.doi.org/10.1073/pnas.96.15.8774

Bower R and Birch R.G., 1992, Transgenic sugarcane plants via microprojectile bombardment, The Plant J., 2(3): 409-416 http://dx.doi.org/10.1111/j.1365-313X.1992.00409.x

Bower R., Elliott A.R, Potier B.A.M., and Birch R.G., 1996, High-efficiency, microprojectile-mediated co-transformation of sugarcane, using visible or selectable markers, Mol. Breed., 2: 239-249

Christou P., Ford T.L., and Kofron M., 1991, Production of transgenic rice (Oryza stiva L) uplants from agronomically important indica and Japonica
varieties via electric discharge particle acceleration of exogenous DNA into mature Zygotic embryo, Bio/Technology, 9: 957-962
Crossway A., Oakes J.V., Irvine J.M., Ward B., Knauf V.C., and Shewmaker C.K., 1986, Integration of foreign DNA following microinjection of tobacco mesophyle protoplast,Mol. Gen. Genet., 202: 179-185
Das S., Jha T.B., and Jha S., 1996, Strategies for improvement of cashew nut through tissue culture. In: Plant tissue culture, Islam AS (ed.) Oxford and IBH Publishing CO. Pvt. Ltd., pp.1-7
Dodds J.H., 1991, In vitro methods for conservation of plant genetic resources, Book, Published by Chapman and Hall, London, pp.247
Elliot A.R., Campbell J.A., Bretell R.I.S., and Grof C.P.L., 1998, Agrobacterium mediated transformation of sugarcane using GFP as a Screenable marker, Aust. J. Plant Physiol. 25(6): 739-743
Finer J.J., Vain P., Jones M. W., and McMullen M.D., 1992, Development of the particle inflow gun for DNA delivery to plant cells, Plant Cell Reports, 11(7): 323-328
Fromm M.E., Morrish F., Armstrong C., Williams1 R., Thomas1 J., and Klein T.M., 1990, Inheritance and expression of chimeric genes in the progeny of transgenic maize plants, Nature Biotech., 8: 833-839
Fromm M.E., Taylor L.P., and Walbot V., 1986, Stable transformation of maize after gene transfer by electroporation, Nat., 319: 791-793 http://dx.doi.org/10.1038/319791a0
Gallo-Meagher, M., and Irvine J. E., 1993, Effects of tissue type and promoter strength on transient GUS expression in sugarcane following particle bombardment, Plant Cell Rep., 12(12): 666-670
Gambley R.L., Ford R., and Smith G.R., 1993, Micro-projectile transformation of sugarcane meristems and regeneration of shoots expressing β-Glucuronidase, plant cell Rep. 12: 343-346
Gordon-Kamm W.J., Spencer T.M., Mngano M.L., Adams T.R., Daines R.J., Start W.G., O’Brian J.V., Chamber S.A., Adams W.R. Jr., Willetes N.G., Rice T.B., Mackey C.J., Krueger R.W., Kausch A.P. and Lemaux P.G., 1990, Transformation of maize and regeneration of fertile transgenic plants, Plant cell, 2(7): 603-618 http://dx.doi.org/10.1105/tpc.2.7.603
Hendre R.R., Iyer R.S., Kotwal M., Khusse S.S., and Mascarenhas A.F., 1983, Rapid multiplication of sugarcane by tissue culture, Sugarcane, 1: 5-8
Ho W.J., and Vasil I.K., 1983, Somatic embryogenesis in sugarcane (Saccharum officinarum L.) I. The morphology and physiology of callus formation and the ontogeny of somatic embryos, Protoplasma, 118(3): 169-180
Ingelbrecht I.L., Irvine J.E., and Mirkov T.E., 1999, Post transcriptional gene silencing in transgenic sugarcane. Dissection of homology dependent virus resistance in a monocot that has a complex polyploid genome, Plant Physiol, 19(4): 1187-1198 http://dx.doi.org/10.1104/pp.119.4.1187
Jefferson R.A., 1987, Assaying chimeric genes in plants: The GUS gene fusion system. Plant Mol. Bio. Rep., 5(1): 387-405
Karthi K.K., Chibbar R.N., Geoges F., Leung N., Caswell K., Kendall E., and Qureshi J., 1989, Transient expression of chloramphenicol acetyltransferase (CAT) gene in barley cell cultures and immature embryos through microprojectile bombardment, Plant Cell Rep., 8(8): 429–432
Keappler H.F., Gu W., Somers D.A., Rines H.W., and Cockburn A.F., 1990, Silicon carbide fiber medicated DNA delivery into plant cells, Plant cell Rep., 9: 415-418
Klein T.M., Wolf E.D., Wu R., and Sanford J.C., 1987, High-velocity microprojectiles for delivering nucleic acids into living cells, Nature, 327: 70-73 http://dx.doi.org/10.1038/327070a0
Lorz H., Baker B., and Schell J., 1985, Gene transfer to cereal cells mediated by protoplast transformation, Mol. Gen. Genet., 199(2): 178-182
May G.D., Afza R., Mason H.A., Wiecko A., Novak F.J. and Arntzen C.J., 1995, Generation of transgenic banana (Musa Acuminata) plants via Agrobacterium-mediated transformation, Biotechnology, 13: 486-492 doi:10.1038/nbt0595-486
Napoli C., Lemieux C., and Jorgensen R., 1990, Introduction of a chimeric chalcone synthase gene into petunia results in reversible co-suppression of homologous genes in trans, Plant Cell, 2(4): 279-289 http://dx.doi.org/10.1007/BF00041397
Popelka J. C. and Allpeter F., 2003, Evaluation of rye (Secale cereale L.) inbred lines and their crosses for tissue culture response and stable genetic transformation of homozygous rye inbred line L22 by biolistic gene transfer, Theor. Appl. Genet., 107(4): 583-590 http://dx.doi.org/10.1007/s00122-003-1314-0
Potrykus I., Saul M.W., Petruska J., Paszkowski J., and Shillito R.D., 1985, Direct gene transfer to cells of a graminaceous monocot, Mol. Gen. Genet., 199(2): 183-188
Rathus C., and Birch R.G., 1992, Stable transformation of callus from electroporated sugarcane protoplasts, Plant Sci., 82(1): 81–89 http://dx.doi.org/10.1016/0168-9452(92)90010-J
Reggiardo M.I., Arana J.L., Orsaria L.M., Perningeat H.R., Spitteler M.A., and Vallejos R.H., 1991, Transient transformation of maize tissues by microprojectile bombardment, Plant Sci., 75(2): 237-243 http://dx.doi.org/10.1016/0168-9452(91)90239-5
Reinert D.M., Bajaj Y.P.S., and Zheu L.J., 1977, Aspects of organogenesis, embryogenesis, differentiation, In: H. E. Street (ed.). Plant Tissue and Cell Culture, 2nd ed., Oxford, Blackwell Scientific Publications, pp 339-427
Sharma H.C., Sharma K.K., Seetherma N., and Ortiz R., 2000, Prospects for using transgenic resistance to insects in crop improvement, Electronic J. Biotec. 3(2): 76-95
Smith C.J., Watson C. F., Bird C.R., Ray J., Schoch W., and Gierson D., 1990, Transformation of maize cells and regeneration of fertile transgenic progeny of transgenic maize plants, Nature Biotech., 8: 833-839
Stith W.G., O’Brian J.V., Chamber S.A., Adams W.R. Jr., Willeton N.G., Rice T.B., Mackey C.J., Krueger R.W., Kausch A.P. and Lemaux P.G., 1990, Transformation of maize and regeneration of fertile transgenic plants, Plant cell, 2(7): 603-618 http://dx.doi.org/10.1105/tpc.2.7.603

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Snyman S.J., Meye G.M., Carson D.L. and Botha F.C., 1996, Establishment of embryogenic callus and transient gene expression in selected sugarcane varieties, South African Journal of Botany, 62(3): 151-154
Taylor M.G., and Vasil K., 1991, Histology of, and physical factors affecting transient GUS expression in pearl millet (Pennisetum glaucum L. R. Br) embryos following microprojectile bombardment, Plant Cell Reports, 10: 120-125
Taylor P.W.J., and Dukic S., 1993, Development of an in vitro culture technique for conservation of Saccharum spp. hybrid germplasm, Plant Cell Tiss. Organ Cult., 34(2): 217-222
Vain P., McMuen M.D., and Finer J.J., 1993, Osmotic treatment enhances particle bombardment-mediated transient and stable transformation of maize. Plant Cell Reports, 12(4): 84-88
Vasil I. K., 1994, Molecular improvement of cereals, Plant Mol. Biol., 25: 925-937
Villalobos I., 1987, Induccion Y multiplicacion de callos In vitro en tres cultivares comerciales de caña de azúcar (Saccharum spp.), Agron. costarricense 11(1): 39-44
Wang Y.C., Klein T., Fromm M., Cao J., Sanford J.C., and Wu R., 1988, Transformation of rice wheat and soybean by the particle bombardment method, Plant. Mol. Biol., 11: 433-439
Warren G.S and Fowler M.H., 1977, A physical method for the separation of various stages in the embryogenesis of carrot cell culture, Plant Sci., 9(1): 71-76 http://dx.doi.org/10.1016/0304-4211(77)90013-X
Weising K., Schell J., and Kahl G., 1988, Foreign genes in plants. Structure, expression and applications, Rev. Genet., 22: 421-477 http://dx.doi.org/10.1073/10.1146/annurev.ge.22.120188.002225
Zhu T., Peterson D.J., Tagliani L., Clair G.S., Basczynski C.L., and Bowen B., 1999, Targeted manipulation of maize genes in vivo using chimeric RNA-DNA oligonucleotides, Proc. Natl Acad. Sci. USA, 96(15): 8768-8773 http://dx.doi.org/10.1073/pnas.96.15.8321