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Emerging Technologies for Potato

Emerging technologies have the potential to fundamentally alter traditional potato production systems worldwide. This issue of *RAFI Communique* takes a look at three new developments: 1) True Potato Seed; 2) Rapid multiplication technologies for seed potatoes; 3) Genetic engineering of potatoes. But first, an overview of one of the world's most important food crops.

"The true treasure of the Andes was not the gold the Spanish conquerors sought but the potatoes they trampled."[1]

Overview: The potato originated in the Andean highlands of South America, where it is still the most important staple food. Before the Spanish conquest, the Incas cultivated more than 100 different potato varieties. There are over 175 wild species of potato in the Americas, and 8 cultivated species native to South America. Our report focuses on the species most widely grown in the world today (*Solanum tuberosum*).

Until recently, the potato was considered primarily a regional or temperate crop, but today it is the world's premiere vegetable, and the 4th most important food crop (in monetary terms) after rice, wheat and maize. The annual crop is worth an estimated $106 billion (at retail prices). The farmgate value is an estimated $40 billion worldwide.

The International Potato Center in Peru (Centro Internacional de la Papa--CIP) is the leading international center for research on potato and sweet potato. CIP scientists refer to the potato as "a forgotten crop in a world with a grain mentality." Potatoes, they believe, offer enormous potential for increasing food production and farm income in tropical countries because they are highly nutritious and can be grown in much less time than cereal crops. Potatoes produce more calories and high quality protein per square meter in less time than any major food plant. In addition, potatoes can be grown in an extraordinarily wide range of agroecological conditions--from hot, humid tropics to cold, dry highlands.

Today, developing countries produce nearly one-third of the world's potato crop, (approximately 82 million tons/year). In Africa and Asia, production of potatoes is increasing faster than any major world food crop. In India and China, for example, a quick growing crop of potatoes can be squeezed in between two crops of rice or wheat. Over the last 30 years potato output in India has quadrupled, and in China the crop has doubled.

Because of high vulnerability to insect pests, fungi, viruses and bacterial disease, potato crops receive more agricultural chemicals than any other food crop. Globally, potato farmers spend an estimated (US) $1.5 billion on fungicides and insecticides to control major pests and diseases. CIP estimates that these costs will exceed $4.5 billion by the end of the decade![2] In industrialized countries high levels of manufactured inputs (pesticides and fertilizers) are typically required to maximize production. Late blight (phytophthora infestans) is the most deadly potato disease--the same fungus responsible for the Irish potato famine of the 1840s.

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Although more than 3,000 varieties of potatoes are known, only a handful are grown commercially. In the Netherlands, the largest potato exporting country in the world, 25% of Dutch arable land is devoted to potato production. A single variety, Bintje, accounts for 40% of total potato output.

Approximately 60% of the North American potato crop is devoted to processed food products (fast foods and snack products). A major factor in the spread of potato cultivation to Asia (especially Japan and Southeast Asia) is the international spread of American fast food and snack products.

More than three-quarters of the commercial potatoes grown in the U.S. come from only 6 varieties (a single variety, Russet Burbank, accounts for approximately 60% of the commercial potato production in the U.S.). The handful of commercial varieties that dominate Northern hemisphere potato production are extremely vulnerable to pest and disease because they have been bred primarily for good processing traits for chips and fries. According to CIP, these genetically uniform potato fields "could easily fall prey to a chemically uncontrollable disease or pest."[3]

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1. Dr. John H. Dodds, former CIP scientist, quoted in New York Times, 9 October 1990.
2. Estimates on pesticide use provided by Dr.K.V. Raman, Program Leader, IPM, International Potato Center.
3. Anonymous, "CIP Backgrounder: Facts, Figures and Miscellania," September, 1991.

NOTE: Throughout this issue of *RAFI Communique* we frequently use the term virus-free or disease-free. While this phrase is commonly used, it is important to note that even new technologies cannot, in all cases, completely rid plants of all traces of diseases.

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THE 10 LARGEST POTATO PRODUCING COUNTRIES (IN MILLION TONS)

COUNTRY	1988-90 PROD. 000+ MT
1. FORMER USSR	66,203
2. POLAND	35,137
3. CHINA	31,597
4. USA	17,070
5. GERMANY (WEST AND EAST)	16,891
6. INDIA	14,558
7. NETHERLANDS	6,878
8. UK	6,555
9. FRANCE	5,997
10. SPAIN	5,079

TOP TEN POTATO PRODUCING COUNTRIES IN THE DEVELOPING WORLD

COUNTRY	1988-90 PROD. 000+ MT	% CHANGE OVER LAST 30 YEARS
1. CHINA	31,597	145%
2. INDIA	14,558	412%
3. TURKEY	4,237	183%
4. ARGENTINA	2,656	69%
5. COLOMBIA	2,560	285%
6. BRAZIL	2,222	97%
7. KOREA DRP	2,042	184%
8. IRAN	1,984	526%
9. EGYPT	1,729	342%
10. PERU	1,651	14%

Source: FAO Statistic

True Potato Seed

ISSUE: True Potato Seed (TPS), is an alternative to planting potatoes from tubers, could make low-cost, uniform and virus-free planting material widely available to farmers in tropical countries.

IMPACT: For Third World farmers without access to a seed tuber distribution system, true potato seed could be an efficient, low-cost source of virus-free planting material. Reliance on true potato seed, however, could create dependency on commercial seed sector. Proprietary seeds will sell at a premium. Widespread distribution of TPS in centres of potato diversity could inadvertently cause genetic erosion of potato germplasm.

PARTICIPANTS: Centro Internacional de La Papa (CIP--International Potato Center) is developing TPS for developing countries. ESCAgenetics (San Carlos, California, USA) is a biotechnology company developing commercial TPS product.

ECONOMIC STAKES: The annual market for seed potatoes worldwide is estimated at (US) $20 billion (1991).

WHEN: ESCAgenetics is conducting field trials of TPS in Egypt, Mexico, Argentina, Colombia, Venezuela and Indonesia. CIP's TPS is now being used by 40 national potato programs in the developing world, with commercial use in Nicaragua, Paraguay, Peru, India, Bangladesh, Egypt and Indonesia.

"If perfected, the true-seed method could revolutionize potato growing."-- CIP

Traditional Planting: Potato Seed Tubers

The universal method used by farmers to grow potatoes is to plant "tubers" saved from the previous potato harvest. This method is called vegetative reproduction. Generally, about 20% of a potato crop is saved for re-planting. While small-scale and subsistence potato farmers continue to practice this traditional method, large-scale and commercial potato farmers more commonly buy "certified" disease-free tubers for planting from seed potato suppliers. In formal seed potato production systems such as the Netherlands and Canada, for example, potato farmers are frequently required to plant only certified disease-free planting material. Certified planting material must be re-introduced on a regular basis because potato tubers are highly susceptible to viral, fungal and bacterial disease. In many areas of the world, due to severe pest and disease problems (both pre and post-harvest) it is difficult to cultivate tubers through enough generations to produce sufficient planting material while maintaining disease-resistant stock. Many countries thus depend on imported potato tubers.

What is True Potato Seed?

Potato plants produce flowers and berries that contain potato seeds. But the seeds do not breed true, meaning they germinate into seedlings with varied characteristics that are not genetically true to the plants that produced them. However, in recent years, scientists have overcome some of the barriers posed by the potato seed by developing "true potato seed" (TPS) that can produce high-yielding potatoes with uniform characteristics. But TPS seed is not sown directly into the field like maize or wheat. Seeds must first be established in a seedbed, and later transplanted into the field as seedlings, or the TPS seedlings can be grown to produce small "minitubers" which can then be planted directly in the field. The additional time and labor costs required to transplant seedlings, or to produce small minitubers, rather than sow seeds directly into the ground, are a significant economic disadvantage of the TPS technology.

It is important to note that TPS is not a new technology. Inca farmers of the Andes experimented with true potato seed over 3000--4000 years ago. Their descendents, the subsistence potato farmers of the Andean highlands often continue the practice of growing a few seedlings from true potato seeds as a technique for experimenting with variability and developing new varieties. But nearly all of their staple potato crop is still grown from tubers. In China, TPS has been used for large-scale production since the 1970s. Today, about 20,000 hectares of potatoes are produced in southern China with TPS produced in northern China.

CIP's Work on TPS

Building on the traditional knowledge of Andean farmers, scientists at the International Potato Center (CIP) began developing TPS for tropical countries in the 1970s. According to CIP, the principal factor limiting expansion of potato production in the developing world is the high cost of planting material. Reliance on costly, imported tubers makes potato production too expensive. In some developing countries, the cost of planting material can represent nearly 50% of the total costs of potato production. CIP's goal is to develop a low-cost TPS technology that can be used by Third World farmers in areas where clonal seed is difficult to produce (because of disease problems) and/or imported seed tubers are too costly. Ideally, the use of TPS could overcome the storage, shipping and disease problems that are associated with the use of seed tubers in many Third World countries.

Consider, for example, that it generally requires one to two tons of seed tubers to plant one hectare of potatoes. By contrast, the same area can be planted with the seedling transplants or tubers produced from only 40 grams (a handful) of TPS. In addition, farmers do not have the added cost of maintaining seed tuber storage facilities. Tubers which otherwise would have been used for seed, can be eaten or sold. CIP estimates that farmers can use TPS for about half the cost of imported seed tubers.[1]

Dr. Noel Pallais of CIP reports that the adoption and use of TPS is expanding rapidly in some tropical areas. The Potato Center produces and donates TPS to interested countries upon request. Close to 40 developing countries are now involved in TPS research, and several are using TPS commercially. In Nicaragua, for instance, about 40% of the potatoes currently available were produced with TPS-derived planting materials donated by CIP. Due to the higher yields of TPS seed tubers, potato imports from Guatemala have fallen from 50% to only 10%.[2] An estimated 300 hectares of potatoes will be grown with TPS in Nicaragua by the end of 1992.

Dr. Pallais reports that TPS hybrids from CIP that have been tested by small farmers in Paraguay, Indonesia, India and Bangladesh, consistently produce up to 2 times the yields of locally available seed tubers. Some TPS progeny show much slower degeneration rates (decrease in quality or yield potential after each successive field multiplication) than locally used clonal varieties, because they have greater disease resistance. Dr. Pallais states that:

"In fact, the genetic variability implied in a TPS progeny protects the crop naturally against pest and pathogen infestations that would be catastrophic to a uniformly susceptible clonal variety."[3]

Some potato scientists caution against over-optimism on the future of TPS, pointing out that there are some basic production problems to be overcome. Dr. John S. Niederhauser, an internationally-renowned potato expert, points out that:

"TPS may have a place to play in sophisticated agricultural systems--but the logistics still need to be proven. There are very good reasons why the subsistence potato farmers of the Andes (and their husbands!) today don't rely on TPS to produce their primary food supply. If they plant TPS, it lengthens their growing season, and they run more risk due to frost. And because of the need to transplant, TPS requires more time and labor. The economic advantage of TPS, through transplants or microtubers, is yet to be proven. There may be a niche for TPS, but there are still many agronomic and logistical problems to be solved." [4]

In addition, RAFI is concerned that widespread availability of TPS in traditional centers of potato diversity could inadvertently cause genetic erosion of potato germplasm. In the Peruvian highlands, CIP has donated more than 5 kg of TPS to subsistence potato farmers. In this case, the TPS variety was produced from a traditional potato variety used in pre-Inca times (Ccompis), and is now being used by more than 1,500 poor families.[5] The concern is that availability of attractive "new" TPS-derived varieties could, in the future, inadvertently displace other traditional potato varieties. CIP reports that interest in TPS is growing in the Peruvian Andes. Another project involves teaching TPS technology to children of poor farmers located in 80 different rural schools.

ESCAgenetics and Commercial TPS

ESCAgenetics, a small biotechnology company based in California (USA), has developed a hybrid TPS for commercial markets with the long-term goal of capturing a substantial share of the world's seed potato market (valued at over $20 billion).[6] The company's methodology for producing large quantities of TPS was provided by CIP in 1987.[7] ESCAgenetics has since developed 9 proprietary potato hybrids that can produce genetically uniform hybrid seed, and the company is now producing hybrid TPS in southern Chile, where climate and virus--free conditions combine to produce tremendous flower production. ESCAgenetics has already conducted field trials in Egypt, Mexico, Argentina, Colombia, Venezuela, Brazil and Indonesia, and expects to sell seed commercially beginning in 1993. According to ESCAgenetics:

"The Company's strategy for marketing TPS is to establish an international network of producer/distributors which would purchase TPS from [ESCAgenetics] and grow hybrid seed tubers (HST) for sale to farmers. The Company will seek to negotiate arrangements whereby it receives direct revenues from the sale of TPS, a royalty on hybrid seed tuber sales and a sharing of the cost savings realized by producer/distributors."[8]

According to Mario Sepulveda, General Manager of ESCAgenetics' TPS Inc., the benefits of commercial TPS are that seeds can be made available at a significantly lower price than tubers, and it will be "absolutely clean material--100% disease free."[9]

Conclusion: TPS--What Role for Developing Countries?

There are clear advantages to the introduction of TPS in Third World countries where access to seed tubers is severely limited, or too expensive. Commercial TPS developed by ESCAgenetics is not likely to be well--adapted to the needs of resource poor farmers, however. ESCAgenetics' TPS has been successfully grown in Egypt where 5,000 metric tons of irrigated potatoes were raised in the desert. But resource-poor farmers seldom have irrigated fields or ideal growing conditions. As CIP observes, "Many growers in developing countries are far less concerned about producing uniform plants than about growing a lot of food cheaply."

According to CIP, ESCAgenetics' hybrid TPS sells for approximately $3000 (US)/kg., while CIP's hybrids are available at $700-1000 (US)/kg. CIP scientists are now collaborating with public and private concerns in Chile, Turkey and India to develop large-scale production ventures for TPS.

The challenge for CIP will be to continue to make accessible TPS progenies that are compatible with low-input farming systems, and that can be locally adapted by small farmers to meet a variety of local needs and diverse farming conditions.

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1. According to Dr. Noel Pallais, CIP, first generation TPS seed tubers cost about (US) $580/hectare compared to $990/hectare for imported or locally-multiplied seed tubers. About 73% of the cost involved with TPS tubers is labor. In Nicaragua, farmers have been able to produce up to 7 successive generations with TPS derived planting materials.
2. Information provided by Dr. Noel Pallais, CIP, to RAFI, September, 1992.
3. Ibid.
4. Personal communication with Dr. John S. Niederhauser, September, 1992.
5. Dr. Noel Pallais, CIP.
6. It is worth noting that ESCAgenetics' initial work with TPS was a joint venture with Pioneer Hi-bred Intl., the world's largest seed corporation. In January, 1991, Pioneer announced that it was selling its share of the TPS joint venture to ESCAgenetics.
7. Dr. Noel Pallais, CIP.
8. ESCAgenetics Corporation, Form 10-K, for the fiscal year ended March 31, 1992.
9. Personal communication with Dr. Mario Sepulveda, August, 1992.

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Genetic Engineering of Potatoes: A Report on Work in Progress

ISSUE: Potatoes are a major target of genetic engineering in Europe, the United States, Australia and Japan.
IMPACT: Third World potato germplasm serves as a vital source of genes for commercial biotechnology. Genetic engineering has the potential to deliver potato varieties with important traits such as insect and disease resistance, as well as improved processing traits. Ultimately, the question remains: Will transgenic potatoes be accessible, and relevant to the needs of Third World farmers--or primarily biased towards the needs of commercial growers and the potato processing industry? Will Third World farmers benefit from their germplasm which is being developed primarily in the private sector and subject to patenting?
PARTICIPANTS: Calgene (USA); Calgene Pacific (Australia) Frito-Lay (a subsidiary of Pepsico); Kirin Brewery (Japan); Mogen (Netherlands); Monsanto (USA), Plant Genetic Systems (Belgium); as well as many public sector researchers in Europe, U.S. and Australia. CIP (International Potato Center), Peru.
WHEN: Field testing now widespread; some transgenic potatoes will be available commercially by mid-1990s.

Introduction

Traditional breeding of potatoes is a costly and time consuming process. According to CIP, "From the time a breeder makes the first cross towards a new variety it normally takes a full 25 years in North America or Europe to reach a production of only 4,000 hectares annually." Despite many "inherent difficulties" which have hampered development of new potato varieties using classical breeding, genetic engineers consider the potato an "ideal candidate for molecular manipulation."[1]

CIP's Role in Genetic Engineering--"Brokering" Potato Germplam

The International Potato Center (CIP) in Peru maintains the world's largest bank of potato germplasm, including about 1,500 samples from 100 wild species collected in eight Latin American countries, as well as about 3,000 traditional varieties of cultivated potatoes.[2] Potato germplasm housed at CIP is invaluable as a source of genes that can improve domesticated potatoes throughout the world. Because it is already collected and inventoried, CIP's germplasm is perhaps the most commercially valuable source of potato genes. In addition, CIP's collection is constantly expanding as plant collectors search for new species throughout Central and South America.

CIP endorses genetic engineering of potatoes as one tool for meeting the needs of poor farmers of the Third World.[3] Rather than developing extensive in-house capabilities, however, CIP has initiated collaborative efforts with private and public researchers:
"Because of the high cost of obtaining laboratories, equipment and brains to carry out the more sophisticated research of biotechnology, CIP is cooperating with private research and development companies who have proven expertise in various aspects of genetic engineering."[4]

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Dr. John H. Dodds, former head of genetic resources at CIP, explains that CIP has a "comparative advantage in germplasm availability."[5] Based on this approach, CIP has entered into agreements with several private corporations whereby CIP provides Third World germplasm in exchange for access to information, technology or improved germplasm. The following are just two examples:

In 1991, CIP signed an agreement with Plant Genetic Systems of Ghent, Belgium that enables the biotechnology company to use potato germplasm made available by CIP for use in the development of a transgenic potato with resistance to potato tuber moth. While Plant Genetic Systems would retain exclusive rights on the potato in Europe and North America, CIP would be able to distribute freely the resistant germplasm to farmers in the developing world. "The unusual thing about this agreement," explains Dodd, "is that for the first time CIP would be restricted from honoring requests for this germplasm from the developed world."[6]

Another CIP agreement was forged with Frito-Lay, a subsidiary of Pepsico Corporation (Texas, USA). Frito-Lay is the largest snack food company in the world, with annual sales of $5.5 billion in 23 countries. One of the company's goals is to double the size of international operations in the coming years. To facilitate this expansion, the company is investing "in raw materials." For example, in 1988, the company began programs in Korea and Taiwan to "produce high quality potatoes for the local markets on a year-round basis."[7]

In the late 1980s, scientists from Frito-Lay travelled to CIP where they screened the Center's potato germplasm at their own expense in search of novel traits for processing potatoes. In return, CIP got free information on the processing qualities of their potato germplasm. According to Dr. John Dodd, "Everyone benefitted from the deal. CIP benefitted and national programs benefitted because we learned about processing qualities for local potato production. Frito-Lay benefitted because they ultimately get access to cheaper raw materials--potatoes that can be grown in developing countries to meet local processing needs."

The two examples given above illustrate a disturbing trend in public/private collaboration involving the brokering of Third World germplasm in exchange for information or technology. These examples raise numerous questions about the sovereign right of Third World nations to make decisions regarding their own germplasm, the lack of accountability of the CGIAR system in negotiating with private corporations on behalf of Third World farmers, and the injustice of taking steps to release or restrict access to germplasm according to written contracts with private corporations. Traditionally, CIP's policy on germplasm is to make material available "free upon request provided it has been first tested and declared disease-free."[8] The CIP/PGS agreement described above violates this longstanding policy.

CIP readily acknowledges that, in some cases, genetically engineered potato varieties may be inappropriate for direct transfer to national programs in the developing world. CIP scientists[9] explain that, "improved germplasm resulting from these technologies may be of fundamental importance in breeding, leading to the release of new improved materials for national programs."[10] But will Third World farmers and CIP have guaranteed access to improved germplasm developed by the private sector and subject to breeders' rights or other patent regimes?

Monsanto Company's (USA) recent donation of proprietary, virus-resistant genes for a Mexican potato variety, *Alpha*, is another example of private/public technology transfer we are likely to see in the future. According to one North American potato scientist, resistance to potato virus X and Y is not the most pressing need of Mexican potato farmers. Monsanto's "out-and-out donation" of the transgenic potato technology is undoubtedly good for public relations, but does not jeopardize the commercial interests of the company.[11] Monsanto's donation to the Mexican government has the added restriction that the Mexicans are not allowed to export the transgenic potato to countries where Monsanto has financial interests.[12]

PART II. Summary of Current Research Goals

In the United States, genetically engineered potatoes have been the subject of more field tests than any other crop except tomatoes. Between 1987 and September, 1992, 50 field tests of transgenic potatoes were conducted by Monsanto, Frito-Lay (subsidiary of Pepsico), the U.S. Department of Agriculture (USDA) and several agricultural universities.[13] In Europe, where there is even greater emphasis on potato molecular research, transgenic potatoes have been field tested in the Netherlands, and the United Kingdom. The Dutch Centre for Plant Breeding and Reproductive Research (CPRO) is preparing a genetic map of the potato. In Australia, both CSIRO and Calgene Pacific are conducting research on transgenic potatoes.

The following section briefly reviews some of the major research goals in genetic engineering of potatoes:

1. Improved Processing Traits -- Companies like Frito Lay and Monsanto are actively pursuing research to facilitate production and processing of commercial potatoes. The following are just a few examples: Monsanto is working with potato chip and french fry manufacturers to develop high-solid, high-starch potatoes that require less oil in processing. USDA is developing potatoes with greater resistance to bruising; Frito-Lay is testing a potato that will not accumulate reducing sugars in cold storage (the goal is to prevent browning during processing).

2. Insect Resistance -- Both public and private sector research focuses on engineering insect resistance. One target is the potato beetle, a worldwide pest that causes significant damage to potato crops. Worldwide, farmers spend an estimated $180 million per year to control this beetle which threatens to become a more destructive pest because, in some areas, it has developed resistance to chemical insecticides. The vast majority of research on insect resistance focuses on introducing the toxic gene from the bacterium *Bacillus thuringiensis (B.t.)*--a naturally-ocurring microbe that lives in the soil and in insects. When certain insects like the potato beetle ingest B.t., the protein is turned into a toxin by enzymes in the insect's stomach, causing paralysis and death.
Special Concern: The focus on biological pest controls is a welcome alternative to the use of chemical insecticides on potato crops. Despite the obvious need, there is concern about the long-term efficacy of genetically engineered B.t. genes because of the development of toxin-resistant insects. B.t. insecticidal genes are being engineered in a wide range of crops worldwide, including rice, maize, cotton, tobacco and vegetable crops. The problem is that if insecticidal B.t. genes are widely introduced into homogeneous varieties, pests will adapt to them, and this valuable natural insecticide could be rendered ineffective.

3. Virus Resistance -- Numerous European and U.S. researchers are active in developing transgenic potatoes with built-in resistance to potato viruses X and Y, and potato leaf roll virus. In field trials, both MOGEN and Monsanto have produced transgenic potatoes that are highly resistant to infection by potato viruses X and Y. (Virus Y is highly contagious and can wipe out as much as 80% of a potato crop. Virus X is less destructive, but very common.) Scientists at MOGEN Inc. and the Scottish Crops Research Institute have thus far met with limited success in crafting transgenic potato varieties with resistance to leaf roll virus (a virus transmitted by aphids that affects both yields and crop quality).
Special Concern: Among scientists there is "substantial disagreement" about the potential adverse effects of using "coat-protein mediated protection" to develop ge-

netically engineered virus-resistant crops. At an international meeting held in Scotland last year on the subject of "Safeguards for Planned Introduction of Transgenic Potatoes," concerns were voiced about this issue.[14] Given the likelihood that, "within 5 years literally millions of transgenic plants may be growing on thousands of acres in major potato producing areas,"[15] potential problems with virus-resistant plants are a serious matter.

A few years ago, scientists unexpectedly discovered that a viral coat protein gene spliced into the genome of a plant can make the plant resistant to infection by the virus from which the gene was infected. But the exact mechanisms behind this phenomenon remain a mystery. Dr. Jane Rissler, a plant pathologist with the National Wildlife Federation summarizes potential problems relating to genetically engineered virus-resistant plants:
"Some scientists are concerned that widespread use of transgenic virus-resistant plants in agriculture may lead to the development of new strains of viruses to cause more severe diseases. The new strains may arise from the interactions between the coat protein gene engineered into a plant and other viruses that may have infected it at the same time. For example, the coat protein from the transgenic plant may enclose another virus infecting the cell, thus conferring on that virus some of the properties of the virus from which the coat protein was taken. This hybrid virus may have a different host range than the original virus infecting the cell."[16]

4. Disease Resistance -- Though still in early stages, scientists are experimenting with transgenic potatoes resistant to tuber soft rot, blackleg and bacterial ring rot. These are major bacterial diseases that claim as much as 20% of the harvested potato crop. In 1992, researchers at Frito-Lay will field test potatoes resistant to late blight *(Phytophthora infestans)*, a fungal disease which is perhaps the most destructive of all potato diseases worldwide. Researchers in the Netherlands are pursuing the same goals.

5. Herbicide tolerance -- Both public and private researchers in the United States have the goal of engineering potatoes to withstand spraying of chemical herbicides. Applications for field testing include potatoes with resistance to 2,4-D, bromoxynil and glyphosate.
Special Concern: Beyond health and safety concerns of developing new uses for dangerous chemical herbicides, RAFI is concerned about the potential for unintentional gene transfer in centres of diversity (the Andes and in Mexico) where the potato has many wild relatives.[17] According to Norman Ellstrand of the University of California, "If cultivated crops even have a limited opportunity to cross with related wild, weedy relatives, the escape of engineered genes that might prove beneficial to the weed is virtually inevitable."[18] Ultimately, without appropriate safeguards, the introduction of transgenic potato varieties could result in the loss of valuable potato germplasm in Third World centres of diversity.

Conclusion
In the preceding pages, RAFI raises a number of concerns related to the social and environmental impacts of genetically engineered potatoes for Third World agriculture. Ultimately, the bigger issue relates to control and access to new technologies. There is no question that insect and disease resistance are extraordinarily valuable traits that are important to potato farmers worldwide. But research and development on genetic engineering of potatoes is highly concentrated in industrialized nations and controlled largely by the private sector. These companies are developing proprietary technologies, and their research priorities will not be determined by the needs of resource-poor farmers.

1. Belknap, W.R., and M.E. Vayda, 1992, "The Emergence of Transgenic Potatoes as Commercial Products and Tools for Basic Science," in Transgenic Research, 1, 149-163.
2. Anonymous, "CIP Backgrounder on the World Potato Collection," September, 1991.
3. Anonymous, "CIP Backgrounder on Genetic Engineering," September, 1991.
4. Ibid.
5. Dodds, John H., 1990, "Collaborative Research at the International Potato Center on Genetic Manipulation for Potato Improvement," in Review of Advances in Plant Biotechnology, 1985-1988, p. 285.
6. Personal communication with Dr. John Dodds, September, 1992. Dr. Dodds left CIP at the end of 1991, and is now at Michigan State University (USA).
7. Pepsico Inc., 1988 Annual Report.
8. Anonymous, "CIP Backgrounder on the World Potato Collection," September, 1991.
9. Dodds, John H., 1990, "Collaborative Research at the International Potato Center...," cited above, p. 276.
10. Information on U.S. field tests provided by National Biotechnology Policy Center, National Wildlife Federation, Washington, D.C.
11. Gershon, D.,"Programme Aids Developing World," Nature, Vol. 356, 30 April 1992.
12. Anonymous, "Biotechnology Services for Thrid World Agriculture: New International Initiatives," Biotechnology & Development Monitor, No. 9, December, 1991.
13. "Workshop on Safeguards for Planned Introduction of Transgenic Potatoes," A Report of a Meeting held in St. Andrews, Scotland, August 16-17, 1991. Edited by John P. Helgeson and Howard V. Davies.
14. Ibid.
15. Excerpted with permission from The Gene Exchange, 3(2), July, 1992. A publication of the National Wildlife Federation.
16. There are many wild Solanum species in the United States as well, though these are not considered sexually compatible relatives.

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New Advances in Rapid Multiplication Systems for Seed Potato

ISSUE: New advances in commercial-scale production of "microtubers" has potential to alter traditional seed potato production systems in industrialized countries from soil-based to in-vitro multiplication methods.
IMPACT: Formal seed potato systems in the Northern hemisphere--particularly Netherlands, U.K. and North America would be most immediately affected. Multiplication of disease-free potato varieties could be made possible in a fraction of the time, and transport would be easier. If commercially successful, several generations of seed potato multiplication (in greenhouses and by farmers) would become unnecessary--eliminating some jobs in elite seed multiplication sector.
PARTICIPANTS: Sappora Breweries of Tokyo with Coop Agrico of the Netherlands (largest potato supplier in the EEC); Kirin Brewery Co. (Tokyo) with Plant Genetics and Calgene (California, USA); Small Potatoes World (Wisconsin, USA) and Rayyan International (Netherlands).
WHEN: Several companies in process of scaling-up new technology, with commercial microtubers available for sale as early as 1993. A single company, Small Potatoes World, predicts sales of (US) $47.9 million by year 2000.

Today, tissue culture technology is a standard technique for rapid multiplication of potato varieties. Potato tissue can be grown in sterilized conditions *in vitro* (refers to reactions taking place in test tubes, laboratory containers or other artificial systems) and then tiny cuttings can be used to produce plantlets that can be grown in simple seedbeds or in climate-controlled greenhouses. The small seed tubers produced via tissue culture are commonly refered to as "minitubers." In both Third World countries and industrialized nations, tissue culture is routinely used to produce millions of disease-free potato clones.

Recently, private companies in Europe, Japan and North America have announced significant breakthoughs in commercial-scale production of potato "microtubers." Microtubers are small, pea-sized tubers produced completely in vitro. The entire process is carried out in a giant fermentation tank (or bioreactor) where light, temperature and other environmental conditions are completely controlled. In contrast to the production of minitubers, which are grown out in greenhouses or seedbeds, microtubers involve very little labor. If microtubers can be produced on a commercial scale at a cost that is competitive with minitubers, new potato seed stock can be introduced rapidly, eliminating many of the initial field generations that are typically required to produce certified seed potatoes in the formal seed sector.

Last year, Kirin Brewery announced that its virus-free microtubers could be produced within months, vs. the three years usually required to produce seed potatoes.[1] Most companies working on development of commercial microtubers intend to market them as elite seed material which can be used in the production of basic seed potatoes. Small Potatoes, Inc. (USA)

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aims to cut production costs and increase the size and vigour of its microtubers, allowing them to be directly seeded in the field on a commercial scale.[2]
If commercially successful, microtubers will substantially reduce the number of field generations necessary to produce certified seed potatoes in the commercial seed sector.

In 1990, Nick Young of CEAS Consultants, U.K., predicted: "The industry is on the brink of further developments in plant propagation which will change the balance of cost between in vitro and soil-based methods. These will have the greatest impact at the top of the multiplication pyramid where in vitro techniques are more competitive. The prospect is for shortening of the multiplication chain and contraction of the high-grade seed sector. Adjustment will be difficult where there are few alternative crops giving similar economic return."[3]

Rapid multiplication technologies for seed potato will play an important role in scaling up new, genetically engineered potato varieties. It will also give the commercial seed sector greater control over the seed multiplication process and the development of proprietary varieties.

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1. Anonymous, "Virus-Free Potato Tubers," 1991, Bio-Venture View, June, 1991, p. 22.
2. Anonymous, "Small Spuds Start-Up to Shake Seeds Sector?," in European Biotechnology Newsletter, No. 127, January, 1992.
3. Young, N., 1990, Seed Potato Systems in Developed Countries: Canada, The Netherlands and Great Britain, Lima, International Potato Center, viii.

News and Updates from RAFI

National Institute of Health Denied Patents on Human Genes: In late September, the United States Patent Office rejected an intial attempt by the National Institute of Health (a U.S. government institute) to patent thousands of gene sequences for the human brain. The patent application sparked intense controversy, particularly because the NIH scientists had no idea how the human gene sequences could be used, or what role they played in the human body.

Update on biosynthesis of vanilla: ESCAgenetics, the company that is producing natural vanilla in the laboratory via cell culture, has received two U.S. patents covering its work on biosynthesis of vanilla. More significantly, the company has entered into a collaboration agreement with Quest International, a division of Unilever, to scale-up production of PhytoVanilla in Quest facilities for product development and market analysis. According to ESCAgenetics' press release, Quest Intl. "has a major position in the world flavor industry."

Following release of RAFI's Communique on pyrethrum in June, 1992: Earlier this year, RAFI published a *Communique* warning Kenyan pyrethrum growers of the efforts of a U.S. biotechnology company, AgriDyne Technologies Inc., to produce genetically engineered pyrethrins in the laboratory. RAFI warned that, if commercially successful, this technology could displace almost 200,000 small farmers who grow pyrethrum flowers, with a potential loss of up to (US) $100 million annually in foreign exchange earnings. AgriDyne's President, Eric B. Hale, wrote RAFI a letter commenting: "The article was well written and, from our point of view, closely represented the facts both published and unpublished by AgriDyne Technologies." Mr. Hale goes on to say: "We disagree, however, with the conclusion that the small scale farmers in East Africa will be placed in immediate peril. On the contrary, the development of a reliable and stable supply of pyrethrum would serve to increase the worldwide demand for the insecticide..." Meanwhile, RAFI's Communique received extensive coverage on Kenyan television, the Nairobi papers, and in the international press.