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Crops and robbers

biopiracy and the patenting of staple food crops

preliminary findings of an ActionAid investigation

"The relentless march of intellectual property rights needs to be stopped and questioned."

United Nations Development Programme, Human Development Report 1999

ActionAid's international food rights campaign aims to safeguard poor peoples' right to food. At the centre of this is the goal of global food security, where everybody has access to food. ActionAid's campaign aims to ensure that international agriculture trade benefits the poor. An important part of the campaign is to protect farmers' rights to seed and plant resources. These are the staple food crops which will feed the world's hungry.

This report marks the beginning of ActionAid's work and investigation in this area. While these are preliminary findings, they are of sufficient interest to be brought to public attention before the World Trade Organisation (WTO) makes decisions about patents on plants.

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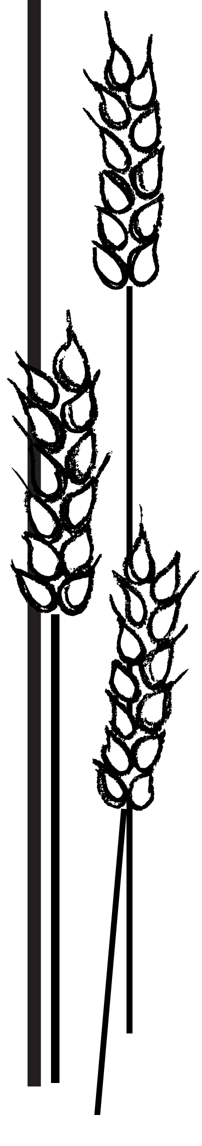
What is ‘Biopiracy’?

ActionAid’s understanding of the term ‘biopiracy’ is the granting of patents on plant varieties or individual genes, proteins and gene sequences from plants in the South by commercial and industrial interests.

This privatisation of living organisms often involves companies taking indigenous plant varieties from developing countries and using these species for:

- the extraction of genes, or;
- genetically modifying (GM) existing plants – many of which are also indigenous to the South.

The South is the source of 90 per cent of the world’s biological wealth – India, for example, has 81,000 species of fauna and 47,000 of flora, including 15,000 plant varieties unique to the country – and yet industrial countries hold 97 per cent of all patents worldwide and are driving the rush to patent plant genetic resources.



executive summary

The findings:

1. ‘Biopiracy’ patents claiming genes or gene sequences from crops and plants, including cassava, cocoa, jojoba, millet, nutmeg, rice, rubber, sorghum and sweet potato.
2. Corporate control extending over the world’s staple crops through patents on maize, potato, soybean and wheat.
3. Biotechnology patents on genes from cocoa and rubber which could be used to substitute the crop so that it does not need to be grown in the South. Mars UK has two patents on the flavour gene from West African cocoa which could be used to produce cocoa flavour artificially in the laboratory.
4. The corporate race to map the ‘genomes’ of the staple crops could be the next target for patenting.

This paper shows that as a result of genetic engineering and a change in the world’s patent regime, ‘biopiracy’ is taking place on staple food crops important to the South. Plant genetic material is moving into private ownership – against the wishes of many Southern countries.

The world’s agri-business and biotechnology industry own most of the patents on staple food crops. Patents on rice, wheat, sorghum, cassava, maize, millet, potato, soybean and wheat are falling into company hands. The higher prices of patented seeds and accompanying royalties are likely to outweigh any possible benefit of genetically modifying (GM) plants to poor farmers. This raises questions for food security.

Of grave concern to ActionAid is evidence that biotechnology patents are being granted which could allow companies based in the North to substitute crops grown in the South.

With advances in mapping the ‘genome’ (or entire genetic code) of the world’s staple food crops, this trend to patent is set to continue. We are in the midst of an explosion of activity in this area. Despite some work by the public sector, it is clear that private corporations are racing to complete the majority of this ‘mapping’. Never in history has so much information about the genetic make-up of plants been available. If patents are granted on ‘prize’ genes from staple food crops, the losers are likely to be poor farmers in the South.

The Director of GeneWatch UK, Dr Sue Mayer, was the consultant on this report. Contact: www.genewatch.org

The Economic implications of patents and biopiracy

There are clear economic arguments against patenting staple food crops. First, poor farmers who rely on farmer-saved seed cannot afford to go back to market to buy patented seed every year – but this is how patented seed works. The farmer using patented seed would then have to buy pesticides and herbicides and risk “becoming caught in a chain of biological and licensing controls.”[1]

And patented GM crops are moving South. The majority of the 34million ha of GM crops grown in 1999 was in the North. But by 2002 , 550million ha out of a worldwide total of 900million ha is projected to be grown in the South. The full force of the economic impact on poor farmers is likely to be felt in the near future.

The patents system is weighted against the poor in the developing world. It can cost $1 million to secure a patent on a plant or gene. This precludes poor communities from protecting their genetic resources through patents. And challenging a patent is costly. In 1999, when US-based company RiceTec secured a patent on Basmati rice, Pakistani rice growers were thwarted from mounting a legal challenge when US lawyers demanded a downpayment of £300,000.[2]

Last, the threat of substitution through genetic engineering is of utmost importance to the developing world. For some countries indigenous crops like cocoa, rubber and palm oil are a major export earner and the economic consequences of losing them are considerable.

In looking at our results (see Table 3) one could infer potential benefits for developing countries and poor people e.g. protein enhanced rice. But seed saving is a way of life for 1.4billion farmers across the developing world and ActionAid fears the privatisation of control over crops, and the tying of farmers into financial and chemical dependence on a company through patented seed, is likely to outweigh and deny access to any potential benefits from these technologies.

Recommendations

ActionAid’s findings spell out potential risks. The economic impact of such patents will be felt only when these techniques are commercialised and genetically engineered into the seeds of staple food crops and spread across the developing world’s farming community. There is still time to prevent this happening.

ActionAid:

- believes the WTO must support an amendment to Article 27.3(b) of the Trade-Related Aspects of Intellectual Property Rights (TRIPs) provisions that would enable WTO members to exclude all genetic resources for food and agriculture from the agreement;
- calls on the members of the WTO to recognise the primacy of the Convention on Biological Diversity (CBD) over TRIPs. CBD gives national states sovereign rights over their biological resources and allows the protection of indigenous knowledge and rights;
- calls on governments to introduce a five year freeze of patenting in food and farming until the socio-economic and environmental impacts can be evaluated;
- calls on companies who hold patents which could be used to substitute southern crops to confirm that these patents will not be commercialised in this way;
- calls on companies involved in patenting staple food crops to place that information into the public domain. Publicly-funded human genome mapping projects have signed an accord to this effect, and negotiations are afoot for a US/UK “joint high-level statement of support”. We believe a similar accord should be signed to promote public research into the staple food crops;
- calls on companies wishing to introduce GM products to conduct full socio-economic and environmental impact assessments of those products.

Is Biopiracy happening?

ActionAid carried out this investigation to confirm that biopiracy is taking place on the world's staple food crops.

To conduct the research ActionAid used the Derwent GENESEQ[3] and Biotechnology Abstracts database (which covers 42 countries). We searched for patent applications made between 1991–99 on crops, including: cassava, cocoa, jojoba, maize, millet, nutmeg, potato, rice, rubber, sorghum, soybean, sweet potato and wheat. We asked Dr Sue Mayer, director of GeneWatch UK, to analyse them for us.

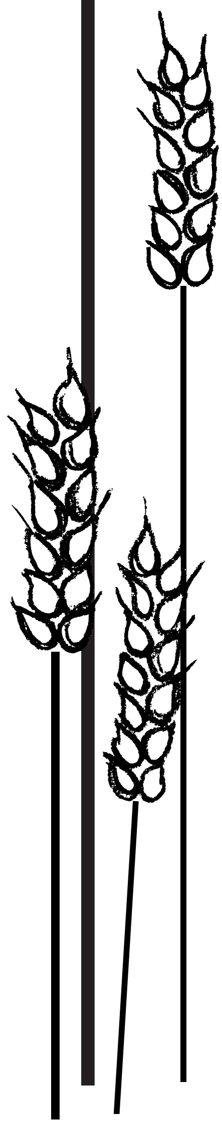
In searching for biopiracy, we examined patents claiming genes or gene sequences or proteins from plants and divided them into three categories. We also looked at the impact of plant genomics. This report will discuss issues in four areas.

- BIOPIRACY: details of patents on genes and plants that indicate some form of biopiracy is taking place. We found biopiracy patents on cassava, cocoa, jojoba, millet, nutmeg, rice, rubber, sorghum and sweet potato – crops grown mainly in developing countries and important to their economies.

- CORPORATE CONTROL: how corporate control is extending over the world's staple food crops. We found patents on maize, potato, soybean and wheat. Although these crops are grown globally, they originated in developing countries and the varieties grown today rely upon germplasm (plant cells) given freely in the past.

- SUBSTITUTION: how genetic engineering may intensify substitution of locally grown crops. These genetic engineering patents may damage poor rural communities in developing countries. Crops produced locally could be substituted and grown in developed countries or even be produced artificially in the laboratory in the North.

- GENOME MAPPING: the explosion of research into 'genome mapping' of staple food crops. New technology enables companies to identify useful genes and patent the most interesting ones they find. We looked at how public investment in plant genome mapping is overshadowed by private investment, and show how the world's food crops could now be patented by private interests.



Introduction: patents, biotechnology and food security

About three quarters of people in the developing world depend on agriculture, either directly or indirectly. The issue of food security is vital to them. Food security means the poorest have the ability to grow, eat, sell and buy sufficient food for themselves and their families.

Farmers in the South have developed many varieties of staple food crops over the generations through cross breeding. But under US and Japanese patent law, and new legislation in Europe [see box], unless communities obtain patents on these varieties, they have no effective rights over them. Plant varieties could not previously be patented because they did not count as 'inventions'. While there is ambiguity over the EU legislation [see box] the US and Japanese patent offices have been granting patents in these areas.

With advances in biotechnology and pressure from multinational companies, plants engineered through genetic engineering *can* now be patented. Even in the EU, patent law has been extended to microorganisms and genes of plants, animals and humans. If a company, for example, owns a patent on a gene from a rice variety, it can now obtain a patent on any new rice plant engineered with that gene.

Techniques to decode and identify the best plant genes to patent are accelerating at an unprecedented rate. The biotech industry is racing – and with stealth – to 'map' the genomes of the world's staple food crops with a view to patenting the vital and most interesting genes. Some liken this silent race to a landgrab for 'green gold'.

Only 10 per cent of seed is bought commercially in the developing world and many poor farmers buy seed only once in five years. Agriculture is a way of life for farmers in the countries where ActionAid works. We believe the right to livelihood – a basic human right – is threatened by patents on life in food and agriculture. Our analysis is that these patents pose a threat to farmers' livelihoods and global food security. They may decrease farmers' access to affordable seed, reduce efforts in public plant breeding, increase the loss of genetic diversity and prevent traditional forms of seed and plant sharing. The headlong rush to patent must cease for five years until we can assess the impact of patents on poorer farmers.

Intellectual property rights and the WTO: Opposition by Southern governments

"The thrust is on ensuring that the patent laws are globally harmonised making it easier for the rich and the industrial countries to amass biological wealth and the traditional knowledge that comes along with it.

The TRIPs Agreement is very cleverly asking member states to grant legal monopolies over the very basis of food security: crop biodiversity."[4]
– Dr Devinder Sharma, Food and Trade policy analyst, New Delhi

The US patenting system allows patents on plants, plant varieties, genes and transgenic plants. About 10,778 patents on plants have been registered in the US since 1985. In Europe there are two conflicting pieces of patent legislation which both have the potential to allow the patenting of plants. The new European Patents Directive allows for the patenting of plant and animal varieties.

However, this is in conflict with the European Patent Convention, which outlaws patents on plant varieties. As a result, the European Patents Directive is being challenged by the Dutch, Italian and Norwegian Governments in the European Court. Both the EU and the US now wish to impose a global patents system through the WTO to ensure that all countries allow patents on plants.

Continued over page

The WTO's TRIPs provisions allow for countries to set up alternative intellectual property rights to patents; a '*sui generis*' (of there own) system to protect plant varieties. The US and EU say any *sui generis* system should be based on the model provided by the Union for the Protection of New Varieties of Plants (UPOV). But UPOV also accepts patents on *transgenic* plant varieties to which the developing world objects.

The Kenyan Government, on behalf of the 'Like Minded Group' of countries – which includes the African Group (a coalition of African states) and a large number of developing countries – argue that the WTO rules will have a major impact on the traditional rights of farmers to save, exchange and sell seed. They say TRIPs does not recognise communities' rights over their resources but favours individuals and companies claiming plants as their own 'inventions'.

Southern countries have proposed a substantive review of the TRIPs legislation to rule out patent protection for plants, animals or microorganisms. The Kenyan Government states:

> *"The review process should clarify that plants and animals as well as microorganisms and all other living organisms and their parts cannot be patented, and that natural processes that produce plants, animals and other living organisms should also not be patentable."*[5]

Kenya argues that this is necessary to:

> *"Satisfy their [developing countries] need to protect the knowledge and innovations in farming, agriculture and health and medical care of indigenous people and local communities. The resolution of this issue affects the food security, social and economic welfare, and public health of people in developing countries."*

According to US patent law, no invention can be patented if described in printed publications more than one year prior to the date of the patent application. However, India argues that its ancient indigenous knowledge is based on a strong oral tradition, and that this must also be recognised by the WTO.

The governments of Bolivia, Colombia, Ecuador, Nicaragua and Peru stated to the WTO recently that:

> *"The entire modern evolution of intellectual property has been framed by principles and systems which have tended to leave aside a large sector of human creativity, namely the traditional knowledge possessed by local and indigenous communities. In many cases this traditional knowledge is linked to the use and application of genetic, biological and natural resources, or the management and conservation of such resources and the environment, in ways that have economic, commercial as well as cultural value."*[6]

UK Policy

The UK Government supports the TRIPs Agreement. Along with the US and EU, the UK refuses to review the WTO's patent rules. US, Japanese and European legislation is now virtually in line, and these countries want to apply the patent rules to the rest of the world through the WTO.

The UK government is also negotiating a US/UK "joint high-level statement of support" on the patenting of human genes, an area where technology is rapidly enabling private interests to map the entire human gene sequence.

While ActionAid takes no position on human genes, we see parallels in this process. Many scientists engaged in public human genome mapping projects argue there is a public interest to keep 'discoveries' from that work in the public domain; they have vowed not to patent them. We argue that discoveries from the genome of the staple crops should also be in the public domain and not privately patented. In the case of patents on plants and plant genes, we are at an historic juncture. Never before has so much plant genetic material been up for grabs.

Recently there has been a consolidation of the agricultural, biotechnology and seed industry which has seen the emergence of giant, agri-business corporations such as Monsanto, Novartis and AstraZeneca, that are gaining control over world markets for grain, farm inputs (fertilisers and pesticides), seed and processed foods. This vertical integration is creating monopolistic conditions for global food production and distribution. The top five 'gene giants' (AstraZeneca, DuPont, Monsanto, Novartis and Aventis) account for 60 per cent of the global pesticide market, 23 per cent of the commercial seed market and virtually 100 per cent of the transgenic (GM) seed market.

These companies are currently seeking patent protection on gene sequences, proteins, plants and seeds. A patent gives the 'inventor' exclusive rights to use the 'invention' commercially for 17–20 years. Others wishing to use the patented invention must negotiate a licence with the patent holder and normally pay royalty fees in exchange. Patents can be applied for on a national or regional (e.g. European) basis and can be registered internationally through the World Intellectual Property Organisation (WIPO).

Recent research shows that three quarters of patents on plant genes were by the private sector. Almost half of 601 patents on plant DNA were filed by just 14 multinational companies.[7]

Although patented plants and genes may have evolved in developing countries, there is no system of informed consent to notify the communities involved of the intentions of genetic collectors. This is the case even if the 'invention' relies upon the knowledge and insight of local people. This is characterised by countries in the developing world as '*theft*' of knowledge and natural living material.

1. BIOPIRACY

Sixty two patents show some evidence of biopiracy. These are listed in Table 1 according to crop type. In these cases patent protection has been claimed for naturally occurring compounds, genes or gene sequences with a variety of functions.

Rice

Rice is the major staple crop for nearly half the world's population. In Asia, rice accounts for 80 per cent of the daily calorie intake and is the key to food security. Rice is the world's third most important staple with an annual production of 561million tonnes in 1998[8]. Thirty four patents claiming genes from rice were discovered. These patents are predominately owned by Japanese chemical companies. They cover a huge range of genes including those that influence the expression of other genes, genes which code for flower development or sterility, genes which target production of a protein to one part of the cell, and genes which alter the protein, sugar or starch content of rice.

Jojoba, nutmeg, camphor and cuphea

Calgene has seven patent applications for naturally occurring genes in jojoba, nutmeg, camphor and cuphea (a plant from Mexico). All these involve genes which result in characteristic oils being produced by the plants which could be used in other oilseed rape crops to alter their fatty acid profiles and reduce the need for specialist oils.

The three jojoba patents cover a gene for an enzyme which gives jojoba oil its special qualities. The group of four patents covering nutmeg, camphor and cuphea involve a gene found in these plants which means that the oil they produce contains high levels of compounds favoured by the cosmetics industry. Calgene (a subsidiary of Monsanto) wants to transfer these genes into oilseed crops such as soya and oilseed rape to grow them in developed countries.

Sorghum

Other patents found on crops from developing countries include one patent on sorghum, two on sweet potato, two on cassava and one on millet. Sorghum is the fourth most important cereal crop after wheat, maize and rice and a staple for millions of the world's poorest in the Sahelian zone of Africa, the Near and Middle East and India and China. Some West African types are known as 'poor man's rice' and in India it is popularly used in *roti* (bread)[9]. The patent by Novartis on sorghum (which also covers the same gene in cassava) claims the gene for an enzyme, which plays a role in the production of the toxic compounds known as glycosides, and glucosinolates, which are found in sorghum, cassava and some other crops. The intention is to switch off production of such compounds making crops safer to eat or to use the gene to make other crops resistant to insect attack. However, by patenting the gene, the seeds for any 'safer' crops developed may be too expensive for poor farmers.

Cassava

Cassava was first domesticated in Mexico and Guatemala, and is a staple in most regions of Africa where it is crucial to food security. The main producers are Nigeria, Brazil, Congo, Indonesia and Thailand[10]. The two cassava patents cover a natural disease resistance gene (University of California) and a gene which affects the type of starch produced (National Starch and Chemical Co). These naturally occurring cassava genes will then be used in other crops to give them these cassava qualities.

Sweet potato

The plant of this edible root is native to tropical America and is an important food staple in Rwanda, Kenya, Irian Jaya and Papua New Guinea. Sweet potato is more popular than potatoes in Africa and Asia and has grown in popularity in the Middle East and North Africa. The two sweet potato gene patents are for a protein known as sporamin. Japanese companies own these patents. By transferring the sweet potato genes to other crops, they will be able to alter their protein production.

Millet

Millet is a tall grass cultivated as a grain crop. The important species are pearl millet, finger millet, proso millet and foxtail millet. It is grown in India, China, Nepal and Pakistan and, in Africa, the major producers are Nigeria, Niger, Burkina Faso, Mali, Senegal and Sudan. Ethiopians cook extensively with a millet called 'teff' and pearl millet is 'critically important' for food security in some of the world's hottest and driest cultivated areas[11]. The millet patent is owned by the US Secretary of Agriculture and covers the natural gene which allows millet to reproduce asexually – a process known as apomixis, where a plant can produce seed without having to be pollinated, i.e. like a natural plant cloning system. The use of this system has been proposed as a way of rapidly increasing the seed available from a particular variety although its use could also result in increased genetic uniformity. Apomixis could prove a very valuable tool to seed companies who would be able to quickly expand production of one line. The US could profit enormously from privatising genetic material freely given in the past.

Cocoa

A British-based company, Mars UK, has two US patents (US 5,770,433 and US 5,668,007) on genes from a West African cocoa plant (the *Amelonado* subspecies) which are thought to be responsible for the distinctive flavour associated with cocoa from this region. Likewise, Aarhus Olifabrik , a Danish company, has two similar patents, which also concern flavour genes from cocoa. Mars Inc US and a research institution have three claims for patent protection on compounds isolated from cocoa with medicinal properties. This could also be considered a form of biopiracy, if there is traditional knowledge of its medicinal properties.

2. CONTROL: patents on staple crops

We found a total of 132 patents where genes have been patented from crops that evolved in developing countries but which are now commonly grown worldwide. There were 68 for maize genes, 17 for potato, 25 for soybean and 22 for wheat. Maize and potato evolved in South America, soybean in south-east Asia and wheat in the Middle East and North Africa. Developed countries have benefited from germplasm given freely by developing countries to improve varieties now grown in the North.

Two thirds of the US wheat crop in 1994 used germplasm from CIMMYT (the International Maize and Wheat Improvement Centre – an international organisation with a large stock of germplasm, much of it from developing countries). In the same year, all US genes giving resistance to rust (a fungal disease) in wheat were of African origin[12]. Wheat and maize germplasm from such sources are estimated to contribute over $4.6 billion annually to the food economy of the developed world.[13]

The patents on maize, potato, soybean and wheat genes are many and diverse. As with the rice gene patents, these include genes which control the function of other genes, those that alter the starch, sugar or fatty acid composition, others which control growth and reproduction, as well as disease and herbicide resistance genes. By patenting genes, not only may further benefits accrue to the developed nations, but the original donors of the germplasm may be excluded from using it financially.

The patents show that staple food crops increasingly are coming under patent control. In addition, GM crops are likely to be covered not just by one patent but by a whole array. The patents in Tables 1 and 2 claim genes as described and also claim patent protection for the plants to which these are transferred. Many other patents involving a GM technique claim its application to a host of staple food crops – sometimes they can be claimed for use in *any* plant.

Furthermore, in the process of genetically modifying a crop, several genes will be used, including genes which control the expression of other genes (they switch them on or off), and also the genes of interest (such as herbicide resistance) and 'marker' genes. Because a wide variety of genes are now patented (see Tables 2 and 3) – including such 'promoter', 'terminator' and 'marker' genes – any new crop variety produced through genetic modification is likely to contain many patented genes. Plant breeders wishing to use such genetic material may have to negotiate licence agreements with the companies owning that sequence. This could be expensive. Of course, the use of a gene could be denied; there is no requirement for a licence to be given.

3. SUBSTITUTION: replacing Southern crops through biotechnology

The patent applications indicate that genetic engineering may intensify the problem of substitution. For example, it is feared that crops such as oilseed rape which are modified to produce an altered oil composition (useful for soap manufacturers) could displace palm and coconut oil producers in the developing world.[14]

Several of the patents listed in Table 1 show how this may arise:

- Four cocoa patents are for processes which could result in cocoa flavour being produced artificially. Mars UK's two US patents on genes from the West African cocoa plant (*Amelonado*) are thought responsible for the distinctive flavour associated with cocoa from this region. This is intended to be used to produce the flavour artificially by transferring the genes into a micro-organism (such as yeast) and then extracting the flavours after fermentation. Or the genes could be transferred to other (cheaper) varieties of cocoa grown in other parts of the world that do not have the characteristic West African cocoa flavour. The Danish company Aarhus Olifabrik has two similar patents which also relate to flavour genes from cocoa and producing cocoa flavour artificially.

  The Mars UK patents are directed at the distinctive flavours of West African cocoa favoured by European chocolate manufacturers. If these are made artificially, the cocoa market in West African could suffer. Amelonado cocoa is the main variety grown in Ghana and Nigeria; each country produced 370,000 and 175,000 tonnes of cocoa respectively in 1998.[15]

  Cocoa is vital to Ghana. The crop contributes 35–40 per cent of Ghana's foreign exchange earnings, 18 per cent of GDP, and employs 45 per cent of the agriculture sector. The are 600,000 cocoa farmers in Ghana – the majority peasant farmers and smallholders – and each farm supports 15 or so dependants.[16]

- Calgene's jojoba patents seek to allow the production of wax esterase (usually only produced in jojoba) to be made in oilseed crops grown in developed countries. This could undermine the Southern market for jojoba products in pharmaceutical and cosmetics industries.

- Calgene's nutmeg and cuphea patents could also undermine markets for tropical oils such as palm oil by improving the ability of crops grown in developed countries to produce laurate and myristate – much in demand by the soap and cosmetics industry.

- Six rubber patents aim to produce rubber proteins artificially – potentially undermining rubber production in south-east Asia and elsewhere. Two US Universities, Arizona State and Michigan State, a chemical company, Chemie Linz Deutsche GMBH and the Goodyear Tire and Rubber Company have a total of eight patents which claim natural rubber genes for proteins which give rubber its rubbery qualities and protect against insect attack. Six of these patents are for genes from the rubber tree, *Havea brasiliensis*, and the other two (from Arizona State) are from a desert shrub, known as guayule (*Parthenium argentatum*). The aim of these 'inventions' is to be able to produce rubber artificially and to increase rubber production in rubber trees and protect other plants against insect attack.

  Clearly the possibility of producing rubber artificially is of concern to the developing world. Thailand, Indonesia and Malaysia produce three quarters of the world's natural rubber, with almost half the balance from India and China. Other producers whose economies might be adversely affected include Sri Lanka, Vietnam, Nigeria, Ivory Coast, Philippines and Cameroon.[17]

- Other patents not involving crops originating in developing countries show how substitution may gather pace through the use of genetic engineering. Many patents examined are concerned with altering the fatty acid composition of oilseed crops (e.g. see soybean patents in Table 2). Judging by the patent applications, Du Pont and Calgene are particularly active in this area of research. The aim of such research partly is to make processing of foods easier, partly to make 'healthier' oils, and partly to provide a substitute for oil produced in developing countries – especially palm oil and cocoa butter. One example is a Du Pont patent (US 5,945,585) for an oilseed rape enzyme gene which alters the level of palmitic and stearic acid. The intention is to use the gene in soybean which will then be '*useful as a cocoa butter substitute*'. Thus cocoa producers could face a patent 'double whammy'; they may find they lose their high value market for cocoa butter as well as that for cocoa flavour.

4. THE FUTURE: Genome Mapping

Brief research into the future of patenting genes brings a new technology into the fore: genome mapping. This process involves identifiying the entire genetic code of an organism (known as its genome). There has been rapid progress and huge investment into genome mapping technology.

Genome mapping involves identifying and sequencing the genes of an organism. Changes to patent legislation mean that companies can patent useful gene sequences identified during the genome mapping process. The significance of this move is that, with the changes in patent legislation, 'useful' gene sequences identified during genome mapping can be patented by the company who 'discover' them.

We examined two areas where genome mapping is occurring, human and plant, and we looked at differences in policy on both areas.

4.1 Human Genome Mapping: keep it public

Changes to US and European patent regimes allowing patents on genes and organisms brought scientists together in 1996 concerned that privately-held patents on human genes would inhibit medical research. Private ownership of key pieces of information could force up costs for public research centres. The subsequent accord – 'The Bermuda Accord' – was signed by The Wellcome Trust, the UK Medical Research Council, the US Department of Energy, the European Commission and the Human Genome Project of Japan. It was agreed all human genome sequence information…

> *"should be freely available and in the public domain in order to encourage research and development and to maximise its benefit to society."*[18]

Signatories agreed that, instead of patenting human gene sequences, information would be released into the public domain as soon as it was confirmed, often on the Internet. This was:

> *"In order to prevent such centres establishing a privileged position in the exploitation and control of human sequence information."*[19]

As a result of lobbying by the human genome projects, the US and UK Governments agreed in 1999 to negotiate a "joint, high-level declaration of support" to the Accord. The negotiations are headed in the UK by Government Minister for Industry, Lord Sainsbury, and the Government's chief scientist, Sir Robert May. In a statement to *The Guardian* the UK Department of Trade and Industry said:

> *"We believe this information is of shared value to mankind and we support the way in which the scientists participating in the project are making data as openly and freely available as possible."* [20]

But in October 1999 US-based company Celera Genomics said it intended to patent parts of the human genome before the US/UK accord came into effect.

4.2 Plant Genome Mapping

ActionAid believes an accord similar to the one struck on the human genome must be struck on the patenting of the world's staple food crops. This must be done urgently.

The race is on to map the genomes of the major staple crops. The intention with mapping is to give a comprehensive picture of which genes are present in a plant species, where they are found on a chromosome, and what they do. This information can then be used as the basis for genetic manipulation of crops.

Genome mapping is an enormous task. Genes are made of sequences of DNA composed of chemical parts called 'bases'. The tobacco genome, which is relatively small, has 1.6 billion base pairs. Wheat and maize are more complex with around 5.9 and 15 billion base pairs respectively.[21] To map a genome completely, the order and location of these bases has to be precisely determined.

The primary goal of the plant genome mapping race is to identify genes of agricultural and economic importance. Once mapped, sequenced and patented, a company can monopolise their use – the real prize. We demonstrate how basic plant genetic resources – recently considered a shared public heritage – are rapidly becoming privatised.

4.3 Plant Genome Mapping

Plant genome mapping is taking place in the public and private sectors and in ventures combining both private and public institutions. We examine all three.

4.3.1 Public Sector

The USDA's Agriculture Research Service co-ordinates the US public sector work in this area which began in 1989. The focus is on producing a database of genome information on maize, soybean, and small parts of wheat and forest species. The US's 'National Plant Genome Initiative' (NPGI) was established in 1998 with funding of $320 million for five years and in principle has said that all data and material should be openly accessible.[22]

It has funded 38 Collaborative Research and Infrastructure Projects, including 13 genomics projects on maize (a US$55million commitment), plus four on *Arabidopsis* and three on the rice genome.

The USDA has also established its own in-house genomics capacity. This year it set up a Center of Bioinformatics and Comparative Genomics at Cornell University and equipped the centre with eight top-of-the-range automated gene sequence machines.[23]

The USDA website [24] lists 100 publicly funded plant genome mapping projects in North America, Europe, Australia and Africa. While this may be only the tip of the iceberg, this site shows how efforts are being made to map the genomes of all the major food and feed crops including wheat, rice, maize, grasses, rye, sorghum, soybean, apple, peanut, alfalfa, tomato, onion, peach, oat, cotton, barley and potato. The largest international co-ordinated effort, including the US and Europe, is the *Arabidopsis* Genome Initiative. The aim is to sequence the genome of *Arabidopsis* (thale cress) by 2000.[25] This plant is used extensively in genomics research because it has only five chromosomes and around 120 million base pairs. The data from this plant will underpin research efforts on other plant species.

The European Union supports plant genomics through the Directorate-General Research of the European Commission under two programs, Biotechnology I (1990–1994) and Biotechnology II (1994–1998). It has invested £40million so far. Most research has been on *Arabidopsis*, rice, maize, tomato and conifers.[26]

The UK Government's Biotechnology and Biological Science Research Council (BBSRC) has invested £7 million since 1994 on 36 projects relevant to genome mapping of plants and animals, including work on *Arabidopsis*, cereals (including wheat and maize), grasses, legumes and brassicas. A further £4.5 million will be spent between 1997 and 2000 on genome analysis of agriculturally important traits of crops and animals.[27] Work at the John Innes Institute in Norwich includes genome mapping projects on pearl millet (funded by DfID), rice, *Arabadopsis* and wheat.[28]

Similar initiatives are taking place in other countries. India announced it will invest $4million to sequence the chickpea genome[29] at Jawaharlal Nehru University in New Delhi. Japan is funding a project on the rice genome (see below). Germany is spending DM150 million on its genome analysis of the plant biological system (GABI) project.[30]

4.3.2 Private Sector Genome Mapping

Industry is unwilling to disclose details of its research, but it is clear that efforts are being made by the large biotechnology companies to undertake genome mapping of the major food crops. Very often mapping is conducted by genomics firms part-owned or in partnership with the large biotechnology companies (see Table 1).

Monsanto, for example, is investing in soybean and maize genome mapping with GeneTrace and Cereon Genomics and has a US$25million plant genomic centre in Bangalore, India; AstraZeneca is involved in wheat, maize, rice and soybean with Incyte ; Du Pont in maize, wheat, soy and rice with Lynx Therapeutics; and Novartis in rice with Clemson Genomics. The money invested is considerable (see Table 1). Companies have also set up in-house facilities. Novartis admitted in 1998 it would spend $600 million over ten years in establishing the Novartis Agricultural Discovery Unit in San Diego emphasising plant genomics.[31]

Rhône-Poulenc Agro (France) and IMA (from Singapore) are working on rice; Pioneer Hi-Bred

See over page for Table 1

Agreements between plant genomic and biotechnology companies[33]

Date	Value of agreement ($ millions)	Company	Subject
Jan 1996	16	Pioneer Hi-Bred* and Human Genome Sciences	Maize gene sequences for exclusive use by Pioneer.
March 1997	Undisclosed	Pioneer* and Affymetrix	Affymetrix to array maize genes found by HGS on chips for screening.
June 1997	25 (minimum)	Pioneer* and Curagen	Curagen to share gene-expression technology and bioinformatic systems.
October 1997	218	Monsanto and Millennium	Millennium agree to establish joint plant genomics company, Cereon.
March 1998	Undisclosed	Monsanto and GeneTrace	Monsanto gets exclusive licence on all GT's genomic technologies.
June 1998	45	AgrEvo and Oxford GlycoSciences	Genomics for agricultural biotech.
Nov 1998	60	Du Pont and Lynz Therapeutics	Genomics for agricultural biotech.
May 1999	Undisclosed	Rhône-Poulenc and Institute of Molecular Biology (Singapore)	Rice genes for disease resistance.
May 1999	Undisclosed	RhoBio	Three year collaboration on maize genomics.
June 1999	12.5	Novartis and Diversa	Diversa to discover and optimise genes for Novartis.
Sept 1999	33.5	Novartis and Myriad Genetics	Genomic research in cereal crops.

** Pioneer is now owned by Du Pont.*

is focusing on gene function and expression, in particular with maize. Du Pont has a lead in wheat genomics and has already “identified 80% of the DNA sequencing in corn genes.”[32]

4.3.3 Public – private sector interaction

There are also co-operative enterprises between the public and private sectors. At the John Innes Centre, Du Pont are investing £10–15 million in funding work on wheat genomics and AstraZeneca has invested £50 million in a ten-year collaboration with the laboratory. There was uproar when Novartis entered a $50 million agreement with the University of California's Department of Plant and Microbial Biology at Berkeley in exchange for first rights to negotiate between 25–33per cent of all discoveries made in the department. The European Union recently funded a £1.7 million programme on comparative mapping of cereals and grasses with industry partners, including PBI-Cambridge (owned by Monsanto) and the seed company Advanta, part-owned by AstraZeneca.[35]

In France, a $227 million project named ‘Gènoplante’ has been launched to promote plant genomics. This is a pubic/private sector venture involving the major French research institutes together with Biogemma, Bioplante and Aventis (the recently merged Rhône-Poulenc and Hoechst). French scientists have criticised the project because it intends to claim patents for the genes it identifies. They are concerned that plant breeding and farmers' rights will be compromised.[36]

Disturbingly, companies have set themselves up in direct competition with publicly funded efforts to sequence plant genomes. Celera Genomics, founded by Craig Venter, has announced it plans to sequence the entire rice genome in six weeks and then make its commercial databases available to companies for $30 million on a five-year contract.[37] To do this Celera will use 300 high-speed automated DNA sequencers – a figure which dwarfs by a factor of ten the hardware available to the $200 million publicly funded Rice Genome Sequencing Project, which expects to complete sequencing by 2008. The Rice Genome Sequencing Project – involving 11 nations, including Japan, the US and Europe – intends to release sequence data immediately but pressure may now build for them to consider patenting some of their findings.

4.4 Issues for Developing Countries

This review of plant genome mapping shows how the genomes of the major food crops are being mapped. Private companies are anxious to patent not only genes, but also shorter partial gene sequences if they can attribute some function to them. Celera's Craig Venter is an aggressive pursuer of patent protection. In October 1999, Celera announced that it had filed 6,500 patent applications from its work on the human genome.[38]

Although some of the plant genome initiatives seek to make their data widely available, even work from publicly funded genomics research may be patented. Some reports on European Community funded plant genomic work indicate that patents have been applied for as a result of research on *Arabadopsis*[39] – data that may be a basic tool for further research.

The potential consequences for food security of patenting genes are serious. Plant breeders who produce crops for use by small farmers in developing countries will have neither the resources nor the funding to negotiate complex licensing agreements. If they use patented genetic material without an agreement they risk financial penalties. Research in the US shows 48 per cent of plant breeders there have had difficulties accessing genetic stocks from private companies and 45 per cent felt this had interfered with their research.[40] These effects will be felt more intensively in developing countries.

ActionAid was instrumental in calling for a Five Year Freeze and moratorium on the commercial planting of GM crops in time for governments, regulatory bodies, farmers and the public to assess the implications of these technologies. We respect the public interest arguments of those who do not believe that human genes should be patented. This logic must be extended to staple crops for food and farming. A five year freeze on patents on genetic resources for food and farming is in the best interests of the poor in the developing world.

Recommendations

ActionAid's findings spell out *potential* risks. The economic impact of such patents will be felt only when these patents are commercialised and genetically engineered into the seeds of staple food crops and spread across the developing world's farming community. There is still time to prevent this happening.

ActionAid

- believes the WTO must support an amendment to Article 27.3(b) of the Trade-Related Aspects of Intellectual Property Rights (TRIPs) provisions that would enable WTO members to exclude all genetic resources for food and agriculture from the agreement;
- calls on the members of the WTO to recognise the primacy of the Convention on Biological Diversity (CBD) over TRIPs. CBD gives national states sovereign rights over their biological resources and allows the protection of indigenous knowledge and rights;
- calls on governments to introduce a five year freeze of patenting in food and farming until the socio-economic and environmental impacts can be evaluated;
- calls on companies who hold patents which could be used to substitute southern crops to confirm that these patents will not be commercialised in this way;
- calls on companies involved in patenting staple food crops to place that information into the public domain. Publicly-funded human genome mapping projects have signed an accord to this effect, and negotiations are afoot for a US/UK "joint high-level statement of support". We believe a similar accord should be signed to promote public research into the staple food crops;
- calls on companies wishing to introduce GM products to conduct full socio-economic and environmental impact assessments of those products.

Patents on genes or natural compounds from plants which are traditionally grown in developing countries

Plant	Patent Number	Company	Gene(s) or Natural Compounds	Notes
Cassava	WO 9820145	National Starch and Chem.	Starch branching gene.	To alter starch qualities in crops.
	WO 9909151	University of California	Disease resistance gene.	Similar genes from rice, maize and tomato also claimed.
Cocoa	US 5668007 – granted September 1997	Mars UK	Gene coding for flavour producing proteins in cocoa.	To allow cocoa flavour to be produced artificially.
	US 5770433 – granted June 1998	Mars UK	Gene coding for flavour producing proteins in cocoa.	
	EP 832103 A1	Aarhus Oliefabrik A/S	Genes coding for flavour producing proteins in cocoa.	To generate cocoa flavours artificially.
	WO 9638472	Aarhus Oliefabrik A/S	Genes coding for cocoa flavour precursors.	
	W0 9736497	Mars Inc.	Compounds from cocoa with anti-cancer, anti-microbial and anti-oxidant activity.	Genes **not** claimed. Compounds to be used in medicines.
	W0 9736597	Mars Inc.	Compounds from cocoa with anti-cancer, anti-microbial and anti-oxidant activity.	
	WO 9827805	Co-operative Research Centre for Tropical Plant Pathology	Gene sequence coding for an anti-microbial protein.	Claims similar gene sequences from Queensland nut (Macadamia), cotton, soybean and peanut.
Jojoba	US 5370996 – granted December 1994	Calgene Inc. (owned by Monsanto)	Gene coding for long chain fatty acyl-CoA reductase (wax synthetase).	A group of patents covering the ability of jojoba to produce particular oils. The intention is to alter the fatty acid composition of jojoba as a source of wax ester for other crops to substitute for use in pharmaceuticals, cosmetics etc.
	US 5445947 – granted August 1995	Calgene Inc. (owned by Monsanto)	Wax synthetase gene.	
	WO 98556232	Calgene Inc. (owned by Monsanto)	Wax synthetase gene.	
Millet	WO 9710704	US Secretary of Agriculture	Gene coding for apomixis (asexual reproduction).	To transfer the ability to reproduce asexually to other crops.
Nutmeg, camphor and cuphea	US 5654495 – granted August 1997	Calgene Inc. (owned by Monsanto)	Gene for enzyme preferentially hyrolysing C14: O acyl-ACP.	A group of patents relating to genes from plants which are able to synthesise myristate and laurate – fatty acids in demand by the soap and cosmetics industry. The intention is to transfer the genes into oilseed crops grown in developed countries to improve supply.
	WO 9220236	Calgene Inc. (owned by Monsanto)	Thioesterase gene.	
	WO 9623892	Calgene Inc. (owned by Monsanto)	Gene for enzyme preferentially hyrolysing C14: O acyl-ACP substrates.	
	US 580022 – granted December 1998	Calgene Inc. (owned by Monsanto)	Gene for enzyme preferentially hyrolysing C14: O acyl-ACP.	
Rice	WO 9914350	University of Singapore	RANK-1 protein gene.	Rice blast resistance.
	WO 9911800	Hokko Chemical Industry Co & Japan MAFF	Anthraline synthetase gene.	Improving nutritional value by increasing tryptophan content.
	WO 9909151	University of California	RKK gene(s).	Disease resistance.

Plant	Patent Number	Company	Gene(s) or Natural Compounds	Notes
Rice	JP 08289789	Mitsui Toatsu Chem Ind	Rice ADP-glucose pyrophosphorylase gene.	To increase starch synthesising ability.
	WO 9741239	Pioneer Hi-Bred	Prolamin gene.	To improve protein quality.
	WO 9611566	University of Washington State Research Foundation	Rice MADS1 gene.	Key gene in controlling flower development.
	JP 08066193	Nissan Chemical Industry Ltd.	Rice NADPH-dependent reductase gene.	Microbial disease resistance.
	JP 07184657	Japan Tafu Gurasu Ltd	Copy gene of rice pyruvate orthophosphate dikinase (PPDK) gene. Rice leaf and arista promoter genes.	To alter photosythetic pathway and to direct expression of gene to growing period or to leaf.
	WO 9511979	Japan Tobacco Inc.	Carbonic anhydrase gene from rice or maize.	To improve nitrogen fixation in plants.
	WO 9509922	Miller Brewing Co.	Rice pullulanase gene.	To enable pullulanase (used in food processing for altering starch) to be produced by bacteria.
	WO 9509234	Japan Tobacco Inc.	Rice phospholipase D (PLD) gene.	To enable lipase (used in food processing to breakdown fats) to be produced by bacteria.
	JP 07059575	Mitsubishi Corp	Gene controlling expression of genes and use in vector with rice waxy gene.	To manipulate components of rice seed.
	JP 07023790	Nissan Chemical Industry Ltd	Rice malic acid enzyme.	To increase content in plants.
	JP 06277068	Mitsui Toatsu Chemical Industry	Rice sucrose phosphate synthetase gene.	To alter sucrose content in plants.
	JP 06269286	Mitsui Gyosai Shokubutsu Bio Kenkyusho	Rice plant sieve protein gene.	To transfer proteins to the sieve.
	JP 06261767	Mitsui Gyosai Shokubutsu Bio Kenkyusho	Rice starch branching enzyme gene and seed promoter gene.	To increase starch content of plants.
	JP 06225774	Mitsui Gyosai Shokubutsu Bio Kenkyusho	Rice resistance-specific lipoxygenase copy gene.	Disease resistance.
	JP 06197767	Norinsuisan Gijutsu Joho Kyokai Sh.	Rice mitochondrial gene fragment.	Cytoplasmic sterility for use in hybrid seed production.
	JP 06153963	Mitsui Gyosai Shokubutsu Bio Kenkyusho	Rice protein kinase gene.	To increase protein production in seed.
	JP 06098656	Mitsui Gyosai Shokubutsu Bio Kenkyusho	Rice starch branching enzyme gene and seed promoter gene.	To increase production of amylopectin and mass production of various proteins.
	JP 06070779	Mitsui Gyosai Shokubutsu Bio Kenkyusho	Soluble rice starch synthetic enzyme gene and transit peptide gene to amylopasts.	To target expression to one part of the cell – the amyloplast.
	JP 05317057	Mitsui Gyosai Shokubutsu Bio Kenkyusho	Copy gene for rice starch branching enzyme.	To alter starch content.
	JP 050260975	Pola Chemical Industry Inc.	Gene coding for protein with functions similar to some animal brain specific proteins.	For diagnostics/research.

Plant	Patent Number	Company	Gene(s) or Natural Compounds	Notes
Rice	DE 4222407	Max Planck	Plant promoter including part of rice actin gene.	To increase gene expression.
	JP 05168482	Mitsui Toatsu Chemical Industry Inc.	Gene promoter of rice allergen protein.	To improve rice quality.
	JP 05153981	Mitsubishi Kasei Corp.	Vector including rice starch synthetase gene.	To alter rice composition.
	JP 05137581	Mitsui Toatsu Chemical Industry Inc.	Copy gene of rice mitochondria ATP beta sub-unit.	Male-sterility – for use in hybrid production.
	JP 05068564	Nogyo Seibutsu Idenshi Kozokaiseki	Rice green leaf peroxidase gene.	
	WO 9213956	Plant Genetic Systems (owned by AgrEvo).	Rice stamen specific promoter and chimeric gene containing it.	Male-sterility system for hybrid production.
	JP 04117287	Mitsui Toatsu Chemical Industry Inc.	Gene coding for rice allergen protein.	To produce low allergen rice.
	JP 04104791	Mitsui Gyosai Shoku	Rice waxy gene.	Starch modification.
	JP 04094687	Mitsui Gyosai Shoku	Rice lipoxygenase gene.	Disease resistance and production of the enzyme lipoxygenase in micro organisms for industrial production.
	JP 03277291	Mitsui Toatsu Chemical Industry Inc. & Norinsho KK.	Rice photosynthesis-related gene (light-harvesting Chlorophyll a/b protein gene).	Altering photosynthesis.
	WO 9109948	Cornell Research Foundation	Rice actin gene promoter.	To increase expression of genes.
Rubber	EP 675202 A	University of Arizona State	Guayule rubber particle protein gene clone.	To produce rubber proteins artificially in other plants and bacteria. Genes from the guayule shrub, not the rubber tree.
	EP 509768 A	University of Arizona State	Guayule rubber particle protein gene clone.	
	US 5633433	University of Arizona State	Guayule rubber particle protein gene.	
	US 5187262 – granted February 1993	University of Michigan State	Genes for hevein and maltose binding proteins.	To protect against insect attack and regulate hevein production. Genes from the rubber tree.
	US 5399668 – granted March 1995.	University of Michigan State	Genes for the rubber protein hevein, and maltose binding proteins.	
	US 4983729 – granted January 1991	Goodyear Tire and Rubber Co.	Rubber polymerase gene.	To produce rubber artificially. Gene from the rubber tree.
	DE 19529116	Chemie Linz Deutsche	Gene sequence coding for (S)-hydroxynitralase.	To use in production of cyanhydrin. Gene from the rubber tree.
	WO 9703204	Chemie Linz Deutsche	Gene coding for (S)-hydroxynitralase.	
Sorghum	WO 9516041	Ciba Geigy (now Novartis) & Royal Veterinary and Agricultural University.	Genes coding for cytochrome P-450 mono oxygenases.	To modify production of toxic glucosides and glucosinolates and thus to improve nutritive value of food or for pest control.
Sweet Potato	JP 03072826	Kirin Brewery KK	Gene coding sporamin.	Altering protein quality.
	JP 61219388	Mitsubishi Chemical Industry	Copy gene coding sporamin.	

Genes patented in crops which originated in developing countries but which are now grown globally.

Plant	Patent Number	Company	Gene(s)	Notes
Maize	WO 9937789	Pioneer Hi-Bred	Poly ADP-ribose polymerase gene.	To alter metabolic rate
	WO 9936543	Pioneer Hi-Bred	Hm2 gene(s).	Disease resistance
	WO 9929875	Pioneer Hi-Bred	UDP-glucose dehydrogenase gene.	Increasing extractability of starch and altering nutritional value.
	WO 99 24575	Iowa State Research Foundation	Starch synthetase enzyme gene.	Altering starch production in plants.
	WO 9914332	Japan Tobacco	Regulatory protein gene.	To increase resistance to environmental stress.
	WO 9906571	University of Missouri	Cytokinin oxidase gene.	Disease resistance.
	US 5866791	AstraZeneca	Cinnamyl coenzyme A reductase gene.	To alter lignin synthesis.
	DE 19732926	U Fleugge	Glucose-6-phosphate translocator gene.	Regulation of starch and protein content.
	US 5856177	Mycogen	Phosphoenolpyruvate carboxylase gene.	For gene expression in green tissue.
	WO 9856934	Du Pont	Histone-acetyl transferase gene.	Claims same gene in rice and wheat too.
	WO 9856921	Dow Agrosciences	Regulatory sequences from the cationic peroxidase protein gene.	Gene regulation.
	WO 9850553	Du Pont	Glycogenin or water stress protein gene.	Claims same gene in wheat and rice.
	US 5850018	Pioneer Hi-Bred	ZMDJ1 promoter gene.	Gene expression.
	US 5837849	Agrigenetics & CSIRO	Alchohol dehydrogenase promoter gene.	Gene expression.
	US 5837848	AstraZeneca	Root gene promoter.	To target gene expression.
	WO 9845459	Du Pont	4-alpha-glucanotransferase gene.	For starch preparation.
	WO 9840505	DeKalb Genetics	Bx1 gene.	Pest resistance.
	WO 9837021	Cold Spring Harbor Lab	Gene controlling floral induction.	To control flowering
	EP 849359	Sumitomo Co.	Raffinose synthetase gene.	‘Crop improvement’
	EP 834558	Sumitomo Co.	Aldehyde oxidase gene.	‘Crop improvement’
	US 5824790	AstraZeneca	Soluble starch synthetase gene.	Modifying starch synthesis.
	DE 19709775	Planttec Biotechnologie GMBH	Starch phosphorylase protein gene.	Alteration of starch synthesis.
	DE 19653176	Planttec Biotechnologie GMBH	Starch associated protein gene.	Alteration of starch synthesis.
	FR 2751987	Biochem & INRA	Phytase gene.	Increasing phytase levels in plants to improve starch extraction.
	WO 9747745	CSIC – Madrid	Retinoblastoma protein gene.	Disease resistance.
	WO 9746078	University of California	AP1 floral meristem identity gene.	Controlling timing of flowering and seed production.
	WO 9720936	AstraZeneca	Copy soluble starch synthase gene.	Increased starch production.
	WO 9704114	Rhone Poulenc Agrochem.	H3.3-like histone gene intron -1.	Gene expression.
	EP 807685	Roussel – UCLAF	Sucrose phosphatase gene.	Altered sucrose supply.

Plant	Patent Number	Company	Gene(s)	Notes
Maize	WO 9619918	Planttec Biotechnologie GMBH	Starch synthetase type I protein gene.	To alter starch synthesis.
	DE 19608918	Planttec Biotechnologie GMBH	De-branching enzyme gene.	To produce the debranching enzyme for use in food processing.
	US 5656496	Mycogen Plant Science	Cab gene.	Light sensitive regulation of gene expression.
	US 5650557	University of Florida	Mutant ADP-glucose pyro phosphorylase enzyme genes.	Increasing seed weight.
	US 5639952	Mycogen Plant Science	Cab binding protein gene.	Light inducible expression.
	US 5633436	Du Pont	Zein protein gene.	Part of chimeric gene with other elements.
	US 5633363	University of Iowa State Research Foundation	ZRP2 promoter gene.	Root promoter gene.
	DE 19601365	Planttec Biotechnologie GMBH	Starch synthetase gene.	Modifying starch synthesis.
	WO 9712982	INRA	Cinnamoyl CoA gene.	To alter lignin synthesis and improve digestibility.
	WO 9711184	Ciba Geigy	Geraniol/nerol-10-hydroxylase gene.	Insect resistance.
	WO 9637615	Pioneer Hi-Bred International (now owned by Du Pont)	Maize insecticidal protein 5C9 gene.	Disease resistance.
	WO 9631609	University of Minnesota	Maize acetyl co-A carboxylase gene.	Herbicide tolerance or altered oil content.
	US 5552140	University of North Carolina State.	Gene for ribosome inactivating protein.	
	US 5545545	University of Minnesota	Maize di hydro di picolinic acid synthetase mutant gene.	Improving nutritional content.
	DE 19501840	Bayer	Gene for glutathione-S-transferase IIIc.	Herbicide resistance.
	US 5519125	Ciba Geigy (now Novartis).	Gene for adenylosuccinate synetase.	Screening for herbicide resistant genes.
	US 5498544	University of Minnesota	Acetyl CoA carboxylase gene.	Herbicide resistance or increased oil content.
	WO 9605369	Japan Tobacco Co.	Gene coding for cold-resistant pyruvate phosphate di-kinase.	Cold tolerance.
	WO 9600291	Research Corp technologies	UDP-glucose indol-3-yl acetyl glucosyl transferase gene.	To control plant growth.
	WO 9535383	Pioneer Hi-Bred International (now owned by Du Pont)	Anther ear genes for cyclase.	To control height and fertility.
	WO 9530005	Dekalb Genetics Corp & University of Yale	Maize wilt gene segment.	Resistance to drought.
	WO 9518859	Ciba Geigy (now Novartis)	Mazie anti-fungal protein.	Disease resistance.
	WO 9511979	Japan Tobacco Co.	Maize carbonic anhydrase gene.	Improved carbon fixing.
	EP 652286 A	Rhone Poulenc (soon to be Aventis)	Maize alpha-tubulin gene.	Herbicide resistance.
	WO 9507989	Pioneer Hi-Bred International (now owned by Du Pont)	Maize disease resistance gene Hm1.	Disease resistance.

Plant	Patent Number	Company	Gene(s)	Notes
Maize	WO 9505732	University of Yale	Maize tasleseed 2 gene.	Sterility systems for hybrid production.
	WO 9413825	Pioneer Hi-Bred International (now owned by Du Pont)	Maize disease resistance gene Hm1.	Disease resistance.
	WO 9401572	Pioneer Hi-Bred International (now owned by Du Pont)	Maize pollen-specific polygalacturonase gene promoter.	To restrict gene expression to pollen.
	WO 9322441	Max Plank	Benzoxanzinone synthetase gene.	Protection against pests.
	JP 05244995	Kyowa Hakko Kogyo	Gene sequence from maize	Genetic fingerprinting of plants.
	WO 9305159	AstraZeneca	Cinnamyl alcohol dehyrogenase genes.	Modification of lignin synthesis.
	WO 9214822	Du Pont	Genes for high methionine storage protein.	Improved nutritional content.
	US 5086169	University of New York	Pollen-specific promoter.	To target gene expression to pollen.
	DE 4124537	Hoechst	Fragment of maize sucrose synthetase gene.	Increased gene expression.
	EP 466995 A	Roussel Uclaf	Sucrose phosphate synthetase gene.	Improved yields.
	EP 452269 A	Ciba Geigy (now Novartis)	Metallothion gene.	
	US 4997930	Ciba Geigy (now Novartis)	Maize nitrile reductase gene.	Study of regulation of plant behaviour.
	JP 03087186	Suntory Ltd	Ferredoxin Fd1 gene.	
	EP 353908	AstraZeneca	Chlorophyll a/b binding protein gene.	To target gene expression to leaves.
Potato	WO 9912950	National Starch and Chemical Investment Holding Corp.	Isoamylase debranching enzyme gene.	To modify starch content.
	WO 9906575	Plant Bioscience	Starch debranching enzyme.	To modify starch production.
	DE 19644478	BASF	Leaf specific fructose-1,6-bisphosphatase gene promoter.	Targeting gene expression.
	EP 779363	National Starch and Chemical Investment Holding Corp.	Soluble starch synthase gene.	Altering starch synthesis.
	WO 9621030	Mogen Int	Chimeric gene including terminator sequence from proneinase inhibitor II gene of potato.	To produce the food additive trehalose.
	WO 9619581	Institut fur Genbiologische Forschung	Debranching enzyme gene.	To modify starch content.
	WO 9614421	Monsanto	Potato bound starch synthetase promoter gene.	To improve protein expression in tomatoes.
	DE 4441408	Inst Genbiologishe Forschung	Soluble starch synthase gene.	To modify starch content.
	WO 9612814	Danisco & Frost Pederson	Promoter gene.	Cold inducible promoter to aid in alteration of plant composition.
	WO 9612813	Danisco	Alpha-amylase promoter gene.	Gene expression control.
	WO 953586	Scottish Crop Research Institute	Expression control gene sequence from spliceeosomal protein gene promoter.	To control expression of other transferred genes.

Plant	Patent Number	Company	Gene(s)	Notes
Potato	WO 9524487	Hoechst – Schering AgrEvo	Citrate synthetase gene.	To control flower formation.
	DE 4408629	Hoechst – Schering AgrEvo	Coding sequences for citrate synthetase gene.	
	WO 9505457	Japan Tobacco Inc.	Cold-resistant ATP-dependent fructose-6-phosphatase 1-phosphotransferase gene.	Alter sugar content at low temperature.
	DE 4220758	Inst Genbiologishe Forschung	Gene coding for potato sucrose phosphatase.	To alter sucrose content.
	WO 9211373	Amylogene	Gene for potato granule-bound starch synthetase.	To allow increased production of amylopectin.
	WO 9119808	Calgene Inc. (now owned by Monsanto)	Portion of patatin gene to control gene expression.	Used with other genes to produce cyclodextrins in plants.
Soybean	US 5840558	Indiana Crop Improvement	Peroxidase SEP1a gene.	Probe for research.
	WO 9715656	Indiana Crop Improvement	Peroxidase gene(s).	To monitor peroxidase activity.
	CA 2186833	Agri-Food Canada	Soya seed coat peroxidase gene.	Use in genetic modification.
	WO 9732011	Novartis	Protporphyrinogen-oxidase gene.	Herbicide resistance.
	WO 9732007	Purdue Research Foundation	Cysteine protease inhibitor genes	Insecticide.
	WO 9606936	Du Pont	Palmityl-ACP-thioesterase gene	Altered fatty acid content of oil.
	US 5633436	Sandoz	Acetolactase synthase gene	Herbicide resistance.
	US 5443974	Du Pont	Soybean stearoyl-ACP desaturase gene.	Altered fatty acid content of oil.
	JP 066319567	Mitsui Gyosai Bio Kenkyusho & Norinsuisansho Shokuhin Sogo	Phoshoenol pyruvate carboxylase gene.	Altered protein and fat content.
	US 5362865	Monsanto	Chimeric gene containing sequences from soybean heat shock protein gene HSP17.9.	To improve gene expression in monocotyledenous species.
	WO 9411516	Du Pont	Fatty acid desaturase gene.	To alter fatty acid composition of oilseed crops.
	WO 940531	Mitsui Gyosai Shokubutsu Bio Kenkyusho	Lipoxygenase L-4 gene.	
	EP 571741 A	Sumitomo Chemical Co	Storage protein glycinin gene.	To direct gene expression.
	WO 9311245	Du Pont	Fatty acid desaturase enzyme genes.	To alter fatty acid composition of oilseed crops.
	WO 9310240	Du Pont	Beta-keto acyl-ACP synthetase II gene.	Alteration of fatty acid content.
	WO 9302196	Du Pont	Galactinol synthase gene.	Improved cold tolerance.
	JP 04320631	Otsuka Kagaku Yakuhin KK	Beta-1, 3-endoglucanase gene.	Disease resistance.
	WO 9216632	Elf Sanofi	Beta-1, 3 glucanase genes.	Disease resistance.
	WO 9211373	Du Pont	Acyl-ACP tioesterase copy gene.	Altering fatty acid content.
	JP 04144687	Mitsui Gyosai Shokubutsu Bio Kenkyusho	Structural gene of lipoxygenase.	Disease and pest resistance.

Plant	Patent Number	Company	Gene(s)	Notes
Soybean	WO 9118985	Du Pont	Sterol-ACP desaturase enzyme gene.	Alteration of fatty acid content.
	JP 02100679	Mitsui Toatsu Chemical Inc.	Liopxygenase regulator gene.	Disease resistance.
	EP 349338 A	Lubrizol Genetics	EnoD2 gene regulatory region.	For gene expression in the root nodule.
	EP 330479	Lubrizol Genetics	Gmhsp 26-A gene.	Stress inducible regulatory element for use in environmental stress conditions.
	JP 64002578	Norinsho KK	Promoter gene.	To control gene expression.
Wheat	WO 9915667	Plant Bioscience	VP1 gene	Dormancy to inhibit sprouting..
	WO 9909174	Plant Bioscience	Anti-growth polypeptide gene.	To inhibit growth.
	WO 9906575	Ice-Biotech	Antifreeze protein gene.	Freezing tolerance.
	JP 10327886	Showa Sangyo Co.	Cysteine protease gene.	Improving gluten for baking.
	FR 2757538	Italian Min. Univ Ricerca Sci & Technologica	Durum wheat low molecular weight glutenin gene.	Improving quality of wheat.
	DE 19525284	Inst. Pflanzengenetik & Kulturpflanzenfor	Microsatellite markers.	For genome mapping.
	CA 2196834	National Research Council of Canada	Type-I starch branching enzyme gene fragment.	Altering starch synthesis.
	US 5801233	Arch-Develop.	Acetyl-CoA-carboxylase gene	To regulate tissue oil content.
	WO 9745545	Hoechst-Schering-AgrEvo	Starch synthetase enzyme gene	To modify starch production.
	WO 9732011	Novartis	Proto-porphyrinogen oxidase enzyme gene.	Herbicide resistance.
	EP 335528 A	University of Oregon State	Promoter gene.	To control gene expression.
	US 5525713	University of Michigan State	Sorting peptide genes.	To direct protein production to the plant vacuole.
	WO 9612797	University of California	L-isoaspartyl protein methyltransferase gene.	
	WO 9605722	University of California	High affinity potassium uptake transporter gene.	To modulate alkali metal uptake in plants.
	WO 9603505	INRA, France	Thioredoxin h gene.	Flour additive.
	CA 2104142	Sarhan	Freezing tolerance protein genes.	Cold tolerance.
	WO 9423027	AstraZeneca	Partial gene sequence for acetyl co A carboxylase.	Herbicide resistance.
	WO 9418334	CNRS, France	Protein from ATP synthase complex (ATP9) gene.	
	US 5276269	University of Michigan State	Lectin gene.	Pest resistance.
	EP 562836	Takara Shuzo Co	Endo-xylo glucan transferase gene.	Regulation of morphology.
	WO 9113991	Advanced Technologies and others	Promoter gene.	Control of gene expression.
	JP 03127984	Ajinomoto KK & Tosoh Corp	Di hydro picolinate synthase protein gene.	

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