EUROPEAN COMMISSION

Community research

Plants for the future

2025

A European vision for plant genomics and biotechnology

Table of contents

Foreword by Philippe Busquin

Plants have always been the most important resource for humankind, not only for food and feed, but also for other important biomaterials, such as oils, fibres, energy, and wood for building houses and ships. Plant cells produce biomass from simple chemical building blocks in the air and the soil, including carbon dioxide, nitrogen and water, using the sun as a 'for-free' energy source. The cultivation of plants some 10 000 years ago can be seen as the starting point of modern civilisation. The exploitation of plant-based fossil resources – such as petroleum, gas or coal – made the industrial revolution possible in the 19th century, and led to the creation of the chemical industry in the 20th century.

Today, in the face of important challenges at the European and global levels, we must pay renewed attention to plants. A growing world population has to be fed, and increasing demands for high-quality, safe and affordable food have to be met. Fossil resources – limited in availability and a major source of greenhouse gas emissions threatening our climate and our health – will need to be replaced with renewable resources. The transition to a sustainable economy based largely on renewable resources – the 'bio-based' economy – is as inevitable as it is desirable.

Scientific and technological progress, especially in plant biotechnology and genomics, will have to play a role in achieving this transition, in particular under the constraints of limited availability of arable land, climate change and increased seasonal weather instability. Biotechnology can help to breed plants that are more drought resistant and stress tolerant, and to increase agricultural productivity, while reducing such inputs as fertilisers, pesticides and water to ensure long-term sustainability.

Europe's scientific and technological capabilities will also strongly determine the competitiveness of some of its largest industries. This concerns the agro-food industry in the first place, which with more than €600 billion in annual turnover, is the leading industrial sector in the EU. But it is also important for the chemical and energy industries. Our S&T capacity will likely change the face of agricultural production, which employs 8% of the EU25 workforce and counts 17 million farms.

Maintaining and strengthening our scientific and technological basis is of critical importance. We need to become an incubator for top researchers and innovative companies, who are often tempted to develop their activity elsewhere. This is not the task of one organisation or of one country. It is only through the commitment of all stakeholders, working together in a coherent fashion at the European level, that we will be able to address these challenges.

For this reason, I very much welcome the **Plants for the Future** vision paper. The goals it sets out are very much in line with the EU's objectives of becoming the most competitive and sustainable knowledge-based economy by 2010. The March 2003 European Council explicitly called for the strengthening of the European research and innovation area to the benefit of all in an enlarged Europe by creating technology platforms bringing together all relevant stakeholders – including researchers, industry, regulators and financial institutions – to develop a strategic agenda for leading technologies, among them plant genomics.

This vision paper is an early milestone towards realising this recommendation. The **Plants for the Future** technology platform – comprising an Advisory Council and working groups, open to the stakeholders supporting this vision paper, Member States and other interested partners and experts – will be established within the coming months with the goal of delivering a strategic research agenda by the end of this year.

I would like to thank the entire group of personalities that are supporting this vision and the behind-the-scenes team who drafted it and shepherded it through its various stages of evolution. Its implementation will depend on the continuing involvement and commitment of all stakeholders and the effective coordination of all instruments and available resources, including Community programmes, to achieve a critical mass in terms of financial, scientific and technological resources.

I wish the technology platform every success. Europe needs it.

Philippe Busquin
European Commissioner for Research

Disclaimer

This vision has been drawn up through a collaborative effort by a group of experts (the Genval Group) and endorsed by the Group of Personalities representing various stakeholders (see page 4). It is neither exhaustive nor comprehensive and covers only selected aspects of broader issues. The vision, views and information expressed in this document are those of the group as a whole and do not necessarily reflect the opinions of any single member, their organisations, or of the European Commission. Neither the signatories nor the European Commission is responsible for the use which might be made of the information contained in this publication.

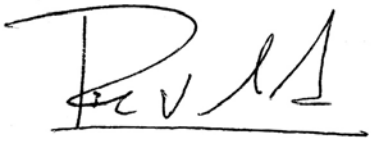
This vision paper suggests the creation of a technology platform called **Plants for the Future**. The goal of this platform is to bring together representatives of all interested stakeholders – including scientists, industry, consumers, environmental organisations, regulatory bodies, political decision- and policy-makers at EU, national and regional level, and other interested stakeholders – to co-operate pragmatically to refine this vision, to identify strategic priorities, and to define and support the implementation of a coherent and dynamic research agenda.

Group of Personalities

Philippe **BUSQUIN,** EU Research Commissioner
Feike **SIJBESMA**, President of EuropaBio, DSM board member
Marc **ZABEAU,** President of EPSO
Jim **MURRAY**, Director of BEUC
Mohamed H.A. **HASSAN**, Executive Director of the Third World Academy of Sciences
Federico **MAYOR**, former Director-General of UNESCO, Autonomous University of Madrid, President of the Foundation for a Culture of Peace (ES)
Jean **MARTIN**, President of CIAA
Eggert **VOSCHERAU**, President of Cefic, Vice-chair of the Board at BASF
Jochen **WULFF**, former CEO of Bayer CropScience
Pierre **PAGESSE**, Presidium Member of COGECA, President of Limagrain (FR)
Ricardo **SERRA ARIAS**, Vice-President of COPA, Vice-President of ASAJA (ES)
Sten **MOBERG,** President of the European Seed Association, CEO Svalöf Weibull Seed Group (SE)
Andrzej **LEGOCKI**, President of the Academy of Sciences, Poland
Richard B **FLAVELL**, CSO of Ceres, former Director of John Innes Centre
Christiane **NÜSSLEIN-VOLHARD**, German Nobel Prize laureate
Peter **GRUSS**, President Max Planck Society (DE)
Tim **HUNT**, UK Nobel Prize laureate
Julia **GOODFELLOW**, CEO BBSRC (UK)
Marion **GUILLOU**, Director-General of INRA (FR)
Peter **FOLSTAR**, Director of the Netherlands Genomics Initiative and coordinator of ERA-NET Plant Genomics

Signatories to 2025: a European vision for plant genomics and biotechnology

Philippe Busquin



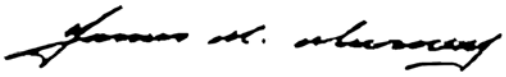
Ricardo Serra Arias

Feike Sijbesma

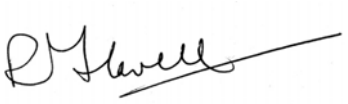
Sten Moberg

Marc Zabeau

Andrzej Legocki



Jim Murray

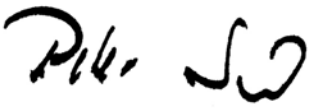


Richard B. Flavell

Mohamed H.A. Hassan

Christiane Nüsslein-Volhard

Federico Mayor



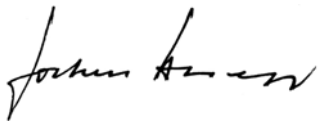
Peter Gruss

Jean Martin

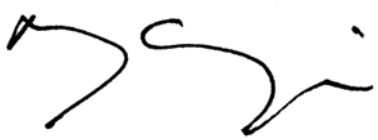
Tim Hunt

Eggert Voscherau

Julia Goodfellow

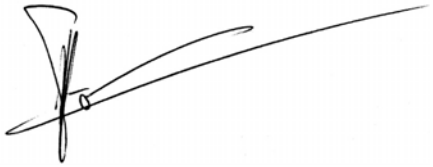


Jochen Wulff



Marion Guillou

Pierre Pagesse



Peter Folstar

Executive summary

Green revolutions and evolutions

Since time immemorial, plants have been crucial to our survival and prosperity. From the world's first 'green revolution' – the invention of agriculture – in the Middle East, to today's high-tech agribusiness, plants have been at the centre of our diets, economy and much more.

Plants are not only our food and fodder for animals but we also use them to make clothes, paper, paints, oils, medicines, and biodegradable plastics, among many other things. We all know that money does not grow on trees, but plants are a big part of our economic prosperity. The agro-food industry in the EU represents a €600 billion annual turnover, utilising a fifth of the Union's land. It is the continent's third largest employer, with 2.6 million jobs – excluding farmers – mainly in small to medium-sized enterprises (SMEs). The European food and drinks industry transforms more than 70% of the agricultural raw materials produced in the EU and exports in excess of €45 billion. Forestry and its related industries employ more than 3.5 million Europeans and contribute more than €200 billion to the EU economy[1].

We have come a long way since a 19th century Augustinian monk named Gregor Mendel found in plants that biological traits were passed on from one generation to the next by discrete 'factors'. Now known as 'genes', they form the basis for the scientific study of genetics upon which a growing part of modern science, medicine and technology is based. In the half century since the double helix structure of DNA – the 'king of molecules' and building block of genes which transmits genetic, or hereditary, information from parents to their offspring – was discovered, our understanding of the life sciences has progressed in leaps and bounds. Scientists have already painstakingly mapped out the entire human genome – the billions of sequences of DNA that constitute the genetic make up of our bodies. Although the exact functions of many of these strands is still not known, our growing knowledge of the molecular mechanics of organisms will one day yield vast health rewards. Genomics and biotechnology hold great promise of uncovering effective treatments for health problems.

Scientific investigation of the genome has not been limited to humans, but encompasses many other animal and plant species. Although the focus of research has tended towards human genomics, investing more in researching plant genomics will pay potentially huge dividends. The EU has long been a trailblazer in this area. Europe, for instance, was a key member of the international team which mapped out the first complete plant genetic sequence – that of *Arabidopsis* (a genus of the mustard family). Our expanding knowledge of the genetic make up of plants could dramatically change our approach to agriculture. Genetics will continue to pave the way to increasing agricultural yields, lowering our dependence on fertilisers, making crops more resistant to diseases, and more. In addition, we are now aware that we are taking advantage of only a small fraction of Nature's genetic diversity. There are enormous opportunities to use plants much more effectively to meet the challenges and demands facing European society in an environmentally friendly and sustainable way. Europe possesses a unique geographic and climatic diversity, a tremendous wealth of cultivated and undomesticated plant species, and long-standing plant breeding experience. Europe should build on the excellence it has achieved in this area by promoting new initiatives to make the most of this vital natural resource. Plant-based oils, lubricants, fibres and polymers – which, unlike synthetic plastics, can be broken down quickly by natural processes – could help to slash pollution.

However, Europe's research and development (R&D) efforts have so far been fragmented and have suffered from the lack of a coherent strategic vision. Regional, national and European research programmes, as well as public-private R&D partnerships, have not delivered enough successful applications or spin-offs. The EU's ambition is to build the world's most competitive knowledge-based economy. One important outlet for this cutting-edge knowledge should be what may be referred to as the 'bio-based economy'. Given the importance of the sector, the consequences for Europe of failing to act could be dramatic. We urgently need to place the European agricultural, forestry and food industries on more competitive ground – founded on a scientifically and ethically sound science and technology base – and enhance its ability to underwrite global food security and create new bio-based products.

[1] These figures are for the 15 Member States of the pre-May 2004 European Union.

The future competitiveness of Europe's agricultural and food processing industries will depend on plant genomics, biotechnology and their smart application. These areas are developing rapidly around the world, and Europe risks losing the competitive edge it once possessed as the mantle of innovation passes to the United States. Investments in plant biotechnology in Canada, Asia, India and South America are also accelerating rapidly as these countries seek to solve their food security problems and to capture a bigger share of agricultural trade. In contrast, Europe's position is declining as a consequence of the political inertia caused by the polarised and increasingly heated debate between opponents and advocates, with a sceptical and confused public caught in the crossfire.

If Europe is not to fall behind its major global competitors in this crucial area of innovation and future prosperity, the legitimate concerns of both critics and advocates need to be addressed. For instance, risk assessments carried out in recent years have uncovered no adverse health effects from genetically modified (GM) crops. We need to take a more holistic approach – used as part of a broader system, modern biotechnology can be a helpful addition to our current agricultural mix, although their misapplication could potentially have some adverse health and environmental effects Europe should proceed responsibly in developing biotechnologies while minimising any adverse effects.

The future is, of course, uncertain. Plant genomics and biotechnology is neither a magic wand that will wave away all our problems nor will it wreak havoc and disaster. To fully appreciate the potential benefits and pitfalls, and to chart a safe course through them, requires a publicly supported road map. That is the purpose behind the proposed creation of the **Plants for the Future – tapping the potential of plant technology** platform. There will undoubtedly be successes and set backs, but the potential rewards for our health and prosperity are too great for us to take a 'wait and see' approach.

Visionary platform

Plants for the Future will bring together all relevant stakeholders: researchers, policy-makers, environmental and consumer groups, industry, and farmers. These partners will co-operate in a pragmatic, non-dogmatic manner to reach a consensus on common priorities and draw up action plans to implement them.

This will be a challenging task but the payoff for sharing and acting upon a common vision could be enormous: a competitive, independent and sustainable bio-based European economy that will address the specific needs and choices of European consumers not only in terms of agriculture and food, but through applications in a wide range of fields, including plant-based pharmaceuticals, chemicals and energy.

The aims of this platform would be to suggest ways of (see chapter four for full details):

- Securing a high quality, safe and diverse food supply for European consumers
- Creating a sustainable European agricultural base for the production of food and feed, as well as other renewable, bio-based products
- Strengthening the competitiveness of the European agri-food sector to ensure a strong domestic European food supply and consumer choice

The platform proposes that these goals can be reached by:

- Promoting societal consensus based on a mutual understanding and communications between stakeholders
- Suggesting a coherent legal framework for the sector's development
- Boosting public and private R&D investment and enhancing the transparency of European research at regional, national and European level
- Strengthening industry support for the platform's research agenda
- Developing a pertinent strategic research agenda – based on the identification of the sector's priorities – pursuing a multidisciplinary approach covering such areas as genomics, physiology, agronomy, ecology, bioinformatics and other emerging skills.

Chapter 1: Introduction

Sowing the seeds of modern civilisation

Plants form the basis for almost all life on Earth, as living organisms in their own right or as food for animals. By catching solar energy, unlike animals, they actually add to the Earth's net store of energy. The unique process of photosynthesis which converts atmospheric carbon dioxide, the main 'greenhouse gas', into carbohydrates via a solar energy-driven process produces the biomass needed by most living organisms.

When people first started cultivating plants in the Middle East some ten thousand years ago, it profoundly altered their way of life. With the birth of agriculture, humanity moved away from the hand-to-mouth existence of the hunter-gatherer and was able to store food for leaner times. No longer needing to chase their food, people were able to abandon nomadic life and live in settled communities, sowing the seed for modern civilisation.

Today, plants are used not only as food for humans and feed for cattle, but as industrial raw materials. They are also valuable sources of vitamins, antioxidants, oils, fibres and carbohydrates. They provide the ingredients for most drugs and are a major traditional energy resource. The petroleum that keeps modern society ticking is also of plant origin, while modern biofuels promise to reduce the pollution caused by fossil fuels.

Rising populations and living standards are not only straining the world's food production capacity, they have led to the increasing use of non-renewable resources and synthetic materials, such as plastics (a petroleum product). This has meant that more greenhouse gases – such as carbon dioxide – are being pumped into the atmosphere, contributing to climate change. It has also meant that the world is producing waste faster than the Earth can break it down. Environmental concerns and finite supplies of fossil fuels are making biomaterials – which can be broken down easily by natural forces – and biofuels attractive alternatives.

Green economics

The economic importance of plants and plant-derived products in Europe is huge in terms of turnover of associated industries, employment and trade:

- The European seed market, worth €8.4 billion annually, is the largest regional market (30% of the global market)
- Europe carved out a 28% share of the €26.6 billion global agrochemical market in 2003
- European forestry and its related industries employ more than 3.5 million people with an annual turnover of over €200 billion
- There are nearly 7 million farms, with an average size of 18.4 hectares and employing nearly 15 million people, in the 15 older EU Member States (EU15). With enlargement, the number of farms has more than doubled to 17 million, and the proportion of farmers in the workforce has grown from around 4% (EU15) to nearly 8% (EU25)
- Livestock production in Europe consumes 400 million tonnes of feed, including grazing land, of which 90% is produced in Europe
- The EU imports €66.6 billion worth of agricultural products and exports €55.7 billion
- The European food and drink industry is the leading EU industrial sector with over €600 billion of production and €145 billion of added value. With 2.6 million workers, it is the Union's third largest employer
- Europe currently accounts for only 10% of the fast-growing markets for crop-derived fibres and raw materials, which increased globally from 50.9 to 70 million tonnes over the past five years

Plant genomics and biotechnology

Genomics and biotechnology are the modern tools for understanding plants at the various biological and environmental levels, as well as boosting classical plant breeding techniques. An array of novel technologies have emerged that are now permitting researchers to identify the genetic underpinnings of crop improvement, namely the genes that contribute to the improved productivity and quality of modern crop varieties.

The much-debated genetic modification (GM) of plants is one of the biotechnologies used, depending on the specific challenges to be addressed, but we should not make the fundamental mistake of equating agricultural and plant biotechnology with GM alone. Genetic modification of plants is not the only technology in the toolbox of modern plant biotechnologies.

Application of these technologies will substantially improve plant breeding, farming and food processing. In particular, the new technologies will enhance our ability to improve crops further and, not only make them more traceable, but also enable different varieties to exist side by side (known as crop co-existence) – enhancing the consumer's freedom to choose between conventional, organic and GM food. Taking advantage of the genetic diversity of plants will not only give consumers a wider choice of food, but it will also expand the range of plant-derived products, including novel forms of pharmaceuticals, biodegradable plastics, bio-energy, paper, and more.

Plant genomics and biotechnology could potentially transform agriculture into a more knowledge-based business. This could strengthen the sector's sustainability and profitability by reducing uncertainty and the dependence of farmers on variable ecological and climatic conditions. Critics fear that modifying the genetic make up of some plants could lead to the possible emergence of such complications as 'superweeds' or toxic food. Although scientific investigation in new fields is never risk-free, with due scientific precaution and diligence, constant and careful monitoring, and strict regulation, adverse developments can be prevented.

A strong European science and industry base in this important sector will allow Europe to address a number of socio-economic challenges:

- **Securing a healthy and safe food supply**

Improving living standards, particularly in developed countries, and a growing world population are rapidly boosting global demand for high quality and safe food. Food shortages and famines are currently localised phenomena and can be addressed by improving the distribution of the world's food output. However, as the globe's 6 billion inhabitants climb to more than 9 billion over the next half century, not only will this mean there are more mouths to feed but there will be less arable land with which to do it. This means that food distribution will have to become more equitable and farming will need to become both more productive and diversified. In addition, to respond to consumer expectations, the quality of plants has to be improved and their nutritional value boosted.

- **Sustainable agriculture**

We urgently need to make today's chemical-intensive agriculture more sustainable while maintaining its productivity. In fact, we need to increase yields and simultaneously reduce or optimise the amount of fuel, fertilisers, pesticides and water used up in the process. The dual challenges of global climate changes and increased seasonal weather instabilities are placing additional strains on the world's agricultural capacity, particularly as more marginal land is farmed.

- **Green and pleasant land**

Agricultural waste can be reduced to a minimum through the efficient use of bio-waste to produce biomaterials and bio-energy. As we run down our supplies of fossil fuels and their environmental impact grows, we will need to substitute them with renewable and environmentally friendly fuel sources. In addition, efficient land management will become increasingly necessary to ensure diversity of agricultural production, protection of the environment and conservation of natural resources and biodiversity.

- **Competitiveness and consumer choice**

A competitive global position for the EU in agriculture, biotechnology and food production will benefit employment and economic growth across the Union. Developing new technologies and agricultural products can help the environment and have a positive impact on rural development. In addition, it would ensure a strong domestic and sustainable European food supply offering consumers a wide choice of healthy and diverse food.

Picking the fruits of the bio-economy

A time traveller to 2025 might find that the bio-based economy that has emerged has helped to confront some of the major challenges facing Europe and humanity as a whole. Below are some of the features of that future world.

The seeds of wealth

It is said that money does not grow on trees, but more of our economic prosperity in 2025 will be based on agricultural produce. Not only will farmers grow food for a larger population, but much of the economy will also be based on the raw materials they grow: new foods, biofuels, and biomaterials. They will become the gatekeepers of the bio-based economy.

Developing green fingers

The premium on agricultural land and exciting investment prospects in the valuable raw materials it produces will help reinvigorate the farming sector and provide new opportunities in an enlarged Europe.

Escape to the country

With the attractive careers and investment prospects, farming and its spin offs will trigger a migration away from the cities and back to the countryside. This new agricultural class will make up the backbone of a prosperous and lively rural community away from the stress of urban life.

Futuristic diets

It has long been said that you are what you eat. Medical research will have identified exactly how our diets affect health. The knowledge this scientific insight brings will mean that breeding by design will be used to create novel food crops which are optimised to reduce the negative side effects of certain types of food and offer balanced nutritional value.

The right reaction

Plant genomics may also have unlocked the secrets of how allergic reactions to plants – such as hay fever and food allergies – work, unearthing ways of halting this growing problem.

Consumer connoisseurs

As more wild plants are cultivated and new food products are created, culinary culture will witness an unprecedented renaissance. Consumers will have a bountiful choice of tasty fruit and vegetables with good shelf life. As enjoying and experimenting with good food becomes an important part of culture, interest in junk food will wane.

Vintage toast

Europeans will need their fine wine to accompany their tasty diet. By 2025, the European wine industry will be progressively facing up to the challenges posed by climate change and volatile weather patterns. 'Old world wines' will be in the process of combining classic subtleties with consistent taste-filled vintages.

The right chemistry

As we run down our fossil fuel stocks and environmental concerns grow, chemicals and fuels extracted from plants will become – along with other renewable resources – much more important. By 2025, we will see the emergence of sophisticated green chemical, biodegradable polymers and biofuels. These will help Europe meet its emissions obligations, create a more sustainable environment and improve EU citizens' quality of life.

The best medicine

The plant kingdom already offers the raw material for many drugs. By 2025, our understanding of the genetic make up of a larger pool of plant species will help researchers create medicines – in particular, medical treatments tailored to the specific needs of individual patients – to tackle many of the major diseases we have to contend with today.

Developing capacity

Agriculture in developing countries will become more productive, competitive and sustainable. This will be particularly essential in view of the exponential growth in food demand in East Asia. Higher and better yields in these countries, and exports from Europe and North America, will be essential to meeting fast-growing demand in China.

Chapter 2: Between prosperity and paradox

Europe has been at the forefront of plant genomics and biotechnology R&D. However, its leading position is deteriorating on the back of public concern over the health and environmental impact of these new technologies. This controversy threatens the EU's ability to reap the rewards of this research and puts the Union at risk of falling further behind its main global competitors, mainly the USA and Japan. Europe is in danger of creating another 'European paradox' – as occurred with semiconductors and computer technologies – in which it is unable to capitalise on an excellent science and technology base by bringing innovative products to market.

New sciences and emerging technologies always present a challenging array of scientific and moral uncertainties. Neither sceptics nor advocates can be absolutely certain what the long-term biological and environmental impact of genetic modification will be. However, more than fifteen years of close monitoring and testing have so far uncovered no adverse effects to the environment or human health. Nevertheless, there are many Europeans who remain sceptical of the benefits that genetic modification can deliver or who, for perceived quality reasons, prefer conventional or organic foods. They have an unquestionable right to have access to the food they wish to consume. This means that the EU must ensure that GM, conventional and organic crops can be grown side by side using a balanced approach that neither prevents nor favours any of them.

The ethical dilemmas are harder to pin down and resolve. Questions of how far we can and should go in reconfiguring the natural order – some might call it 'tampering with' others may describe it as 'exploiting' nature's genetic pool – are never easy to answer. Opinions on what is and what is not morally acceptable vary widely and there are grey areas where few would be willing to offer a hard and fast judgement. In fact, EU surveys show that many Europeans would support the cautious development of such potentially beneficial fields. Ethical studies have also emphasised the "moral imperative" of making these technologies available to the developing countries that want them.

Europeans should not lose sight of the enormous social, economic and environmental rewards of this cutting-edge field. With appropriate regulatory and scientific controls in place, the EU can draw maximum benefit out of these new technologies while avoiding the potential environmental and ethical pitfalls. This can only be achieved through a mature and sober public debate that weighs up all the pros and cons to help chart an optimal course forward.

Food for thought

The last three decades have seen radical changes to our diet as consumers enjoy an unprecedented variety of high quality, inexpensive local and imported food all year round. In terms of plant science, many of these improvements are based on crop breeding and genetics developed in the 1950s to 1970s. As a means of building on this scientific and technological base, both at EU and national level, the European Commission has funded plant genomics and biotechnology R&D under successive research programmes since 1982.

Early recognition of the need for investment in crop biotechnology and genomics by EU and national funding agencies has led to the establishment of Centres of Excellence in universities and research institutes, and the development of new platform technologies and research breakthroughs by the European research community. The Union is home to a number of pioneering SMEs, such as Plant Genetics Systems (PGS), and Keygene. Newer companies – such as AgroGene, CropDesign, Meristem, Biogemma, and Metanomics – continue this innovative tradition, albeit at a slower pace than in the USA.

European companies – such as Bayer, BASF and Syngenta, which are among the world's top six agribusinesses – have committed significant funding to strategic research in crop biotechnology and genomics. They have also developed, either in house or through collaborations, key technologies for particular crops and methodologies. The EU seed sector has major players including Limagrain, Advanta, KWS and DLF-Trifolium. Europe hosts two of the top four global food companies. Unilever and Nestlé have strong product development expertise and experience in a diverse set of crops and products. They also have a tradition of research in plant sciences and have followed the evolution of plant genomics and biotechnology.

Falling behind

European investment in plant genomics and biotechnology has stalled in recent years. This is partly as a result of a more restrictive political and regulatory framework compared with that of its major competitors in the USA, Japan and China. European biotech SMEs are increasingly turning to non-EU customers, while firms of all sizes are relocating their research activities and investments to these three countries, and even India and Argentina. These countries have a long-term strategy for exploiting the potential of plant genomics and strengthening their positions in related markets. The USA and Japan, in particular, are developing forward-looking policies to forge for themselves a leading position in the emerging biomaterials and bio-energy markets. Europe risks losing out on its investment in plant genomics and biotechnology as the exploitation of its science and technology base will increasingly be done outside the EU.

The huge potential of plant genetic diversity can only be unlocked through sustained investment in research. While US biotech firms spend €650 million a year on R&D, their EU counterparts invest only €400 million. Last year, the American government launched a National Plant Genome Initiative with a total budget of €1.1 billion from 2003 to 2008. EU15 support is estimated to be around €80 million annually. In addition, strict European health and safety regulations have shifted popular resistance from health concerns to the potential environmental impact of the release and use of GM crops. In the meantime, global use of these plants is on the rise, with 99.5% grown outside the EU.

What is at stake for Europe?

European industry, consumers and farmers will all be affected by the emerging plant genomics and biotechnology innovation gap between the EU and its main global competitors. As a recent study showed, the impact on Europe's science and technology base is already considerable: 27% of European research projects in this area have been aborted in recent years and, for industry, the figure was a massive 63%. New GM-derived products will be allowed to enter the European market soon. Further market development will depend on whether European retailers and consumers will consider the potential benefits in terms of price and improved quality outweigh the hypothetical risks. This in turn will affect more than 15 millions European farms in 25 Member States and the European food industry, in particular the large number of SMEs which account for half of the industry's output and three-fifths of its workers.

In a scenario where EU agricultural output is less technologically competitive, European farmers will likely find that their shrinking share of conventional and GM markets will not be offset by the growth of alternative niches, such as the organic food market. Fierce global price competition may also lead to a shift from European products to imports that may be less diverse. Although imports can be and are beneficial, this may limit the range of EU consumer lifestyle and health choices. This might lead to pressure for more EU agricultural subsidies, although the Union is attempting to scale back such aid according to its obligations under world trade agreements.

The deterioration of the EU's scientific base, the loss of markets for European agricultural products and an increased dependence on food and feed imports are at stake. Europe's ability to respond to the policy challenges of sustainable agriculture and to secure global food supply may diminish. This could also severely restrict European industry's ability to contribute to non-food agricultural innovations and a bio-based economy. Twenty years from now, European consumers are at risk of being left with the limited choice of buying local products at much higher prices or cheaper imports. Although imports are essential to economic efficiency, fair competition and consumer choice, allowing agricultural imports to rise above a certain level may leave Europe vulnerable or, at least, dependent on produce in which the incorporated technology reflects very different cultural, scientific and lifestyle priorities. The question is whether Europe will facilitate the careful development of plant genomics and biotechnology within the EU to reflect the Union's high standards in new product design.

Eliminating a costly paradox

Europe cannot afford to miss out on the benefits offered by plant genomics and biotechnology. Justified environmental and health concerns have to be balanced against tolerable risks, likely economic impacts and employing the new technology to help respond to major social and environmental challenges. A technology platform, such as the one proposed in this document, can help inform the R&D regulatory and policy framework process to make the most of these new technologies for the prosperity and well being of Europe's citizens, economy and environment. This requires concerted action on the part of all stakeholders, including researchers, farmers, industry, consumers, regulators and policy-makers.

Open, frank and balanced public dialogue on such a sensitive issue will not be an easy task. But the pay off for sharing and acting upon a common vision can be enormous. Europeans owe it to themselves and future generations to build a scientifically solid and ethically sound foundation for developing this exciting field.

Chapter 3: A vision for 2025

Food trends and challenges

Europe, like other developed countries, is facing the challenges linked to changing lifestyles and an ageing population. Rising living standards and an abundance of food have pushed obesity and heart disease up the list of avoidable causes of deaths in the industrialised world. As Europeans continue to enjoy longer and more comfortable lives, the importance of food quality and safety will increase enormously over the next two decades. Access to a wide variety of healthy and affordable high quality food will help ensure this. In addition, safe food production is not only about human health but must take into account the health of cattle and other animals, as recent food scares have so clearly illustrated.

- **Changing lifestyles**

Improvements in medical science and health care have meant that people in Europe and other developed countries live longer and healthier lives. These advances have also meant that lifestyle choices are playing an increasingly decisive role in our well-being. While the burning issue of smoking is being brought gradually under control, poor diets are claiming more and more lives in Europe and other rich countries. The need to increase the nutritional value of food products and encourage healthy dietary choices is an important component in reducing heart disease, cancer and obesity, which are becoming the biggest causes of avoidable deaths in developed countries.

- **Greying societies**

Slowing birth rates and longer life expectancy in Europe, Japan and the United States have led to a rapidly ageing population – if present trends continue, there may be more people over 60 than children by 2025. There is also a fast growing awareness among the citizens of these same countries of the health problems associated with eating habits. In fact, the older people get, the more important a balanced and healthy diet becomes. The right balance of food can reduce a person's risk of suffering from a heart attack, a stroke, and even cancer. The agricultural and food industries have a unique opportunity to contribute to solving these problems through improving the health promoting properties of crops and derivative food products.

- **Global demographics**

There are some 6 billion people in the world today. Despite declining rates of population growth, the global population is increasing by about 80 million a year – equivalent to the population of Germany – and is projected by the UN to reach 9 billion by 2050. Around 95% of this increase is taking place in the developing world and not in Europe. To be able to feed all these unborn mouths, new and sustainable ways of producing high quality food and feed must be developed. In addition, the world needs to produce more food but, just as importantly, the international community needs to develop the political mechanisms to guarantee that it gets to the people who need it.

High economic growth rates in developing countries have significantly raised living standards there. The most spectacular change has occurred in Southeast Asia and, specifically, in China. However, societies in Europe and North America are also becoming richer, albeit at a slower pace. With more people who are richer and older to sustain than ever before, the demand for high quality and varied food will spiral in the coming years.

Sustainability – a means and an end

There is a limit to how much our planet can take. To guarantee our well-being – and that of future generations – we must make sure that we live in a sustainable manner. This means that sustainability is both a means of ensuring our prosperity and a constant goal to strive for in the future.

Europe must enhance the sustainability of its agriculture and forestry sectors. It also needs to develop plant-based renewable resources to improve the environmental performance of industry and transportation. Biomaterials and bioenergy will – along with fuel cells, as well as wind and solar power – reduce our dependence on polluting fossil fuels.

- **Environmental concerns**

In recent decades, European citizens have become more aware of their environment and exhibit a growing concern about the countryside and its biodiversity. European citizens are becoming more vocal in their calls for action to protect the environment, maintain biodiversity and conserve natural resources, especially soil and water.

Europe has a diverse countryside, especially when compared with the vast farming regions in the Americas where hundreds – even thousands – of square kilometres of farmland might be given over to one crop. Centuries of local agricultural, woodland and forest management have led to a great deal of regional variation across Europe.

Over the past two centuries, industrialisation has led to the growth of large cities where, in many EU Member States, the majority of citizens now live and work. Nevertheless, this has not reduced the importance of rural areas. In addition to producing food, the countryside forms a key component of European cultural heritage.

As agricultural practices have changed so has the countryside and the biodiversity it supports. The productivity of European land has risen dramatically over the past 50 years. However, modern farming techniques, along with urbanisation, have taken their toll on rural biodiversity. Global warming is causing a change in the distribution of plant pathogens and pests. This will lead to new challenges in developing plants that are resistant to diseases, pests and more volatile weather systems. It is also important to strike the right land management equilibrium, both in terms of the varieties of plants and how they are grown.

- **Sustainable industrial processes**

Within Europe, the development, establishment and increase in industrial production over the past two centuries has resulted in a number of environmental concerns. These include climate change which is potentially exacerbated by rising greenhouse gas emissions. The quality of the air we breathe, the water we drink and the soil in which we plant are all directly or indirectly affected by industrial processes and their by-products.

The production of bioenergy, biofuels and novel biomaterials is not yet common but it offers great opportunities to move towards a sustainable bio-based economy. It can also help boost rural development by enabling local communities to participate in the value creation chain.

- **Energetic future**

In the first two decades of the 21st century, world energy consumption is expected to rise by more than 50%. A major share of that growth is expected to occur in developing countries – especially in Asia and Central and South America – where energy demand could rise at a rate of about 4% a year. A large number of independent projections forecast that this increased energy usage will lead to serious global warming.

Although the EU puts much greater emphasis on other sustainable energy sources, in principle, plants can contribute in two ways to solving the energy problem. On the one hand, the direct combustion of plants results in a five-fold net energy gain in terms of the input/output ratio. However, converting the plant into liquid biofuels currently results in a loss of energy. Improving plants by making the conversion process less energy-intensive represents a useful line of attack for future research. Despite the challenges ahead, developing more efficient biofuels is a worthwhile pursuit because plants have no impact on the carbon dioxide balance. How much Europe can depend on biofuels to meet its energy needs will depend on how far the technology to extract them advances and the amount of available land left over from other, higher priority functions.

- **Loss of land**

The world's agricultural land is being degraded. In fact, arable land is losing its fertility owing to salination, desertification, as well as soil erosion and nutrient depletion. The maintenance of common property – including rangelands, fisheries, forests and genetic resources – is under increasing pressure owing to the pressure of population growth. Rapid urbanisation and the need to produce more food mean that huge areas of natural forest are being deforested, leading to more soil erosion and flooding. Meeting the growing demand for food and plant-derived products will become even more challenging as this is accompanied by a decrease in the global arable land base.

Competitive research policy

Europe's scientific heritage and culture provides a unique opportunity for global economic leadership in the emerging knowledge-based economy. The EU's cultural and scientific diversity will provide it with a key advantage over its global competitors. Although farming has a quaint and rustic image, agriculture is rapidly turning into one of the most high-tech sectors of the economy. Here, too, Europe's diversity gives it a competitive edge.

There is a high degree of regional agro-ecological variety in the EU. There are also big differences in the economics of the agricultural sector – from the degree of farming automation to the importance of local agricultural service industries. This diversity is well reflected in the great variety of food and feed used in Member States. This is in sharp contrast with the situation in some parts of the United States, Argentina and Brazil where vast tracts of land are used to grow just a few crops, particularly maize and soybean.

The long tradition of European innovation, coupled with the diverse crop types and production methodologies, provides Europe with a good opportunity to develop a larger number of crop types that not only perform well across a wide area of climatic zones, but are also able to meet special needs on a regional basis.

In order to maintain its prosperity and autonomy, Europe needs to remain competitive. Competitiveness is not simply limited to basic research, but extends across the board: R&D, field production, and end-product applications.

Coherent policy framework

In order to enhance its competitiveness, the EU must develop and establish a long-term holistic and coherent policy for plant genomics, biotechnology, and their applications. Through a broad dialogue, it must develop and set in place the necessary policy delivery tools that will enable the EU to carry out high quality R&D. The technology platform can provide an important contribution towards forming such a coherent framework by furnishing relevant scientific advice and information.

Regulation is essential as it protects the citizens against exploitation and ensures a level playing field for businesses. The wrong mix of regulations can leave innovators bound up in red tape. The right mix and it rolls out the red carpet for them. Although the regulatory arena in Europe is complex, regulation itself plays a crucial role in supporting basic research and the application of knowledge.

If the EU is to participate in and benefit from research into plant genomics and biotechnology (and from the resulting products), then regulatory frameworks must be carefully considered and developed in a cohesive and inclusive manner. This also implies better communication with the public, i.e. regarding the results of risk assessments. European regulation must be consistent in design and operation and be transparent both to the European citizenry that it is established to benefit, and to the research and industry sectors whose activities are being regulated.

As an example of the importance of consistent and fair implementation of regulation, the EU now has a comprehensive framework in place for the safety assessment and placing on the market of GM crop plant varieties – although co-existence is still an issue of debate. If EU institutions and Member States fail to implement this legislation consistently and transparently, the present reluctance of both the public and private sectors to invest in biotech R&D will remain – and the broad objectives set out in this paper will be unattainable.

The right blend of regulations could lead to massive improvements in our quality of life and its sustainability. Below is a vision of what new knowledge generated by European research could potentially lead to over the next two decades.

Ambitious research agenda (2005-2025)

Research into plant genomics – handled with appropriate caution and public support – can result in major benefits for Europeans over the coming two decades. Through well-targeted basic research into plant genomics and its biotechnological applications, we believe it is possible to:

Improve understanding of plant metabolisms
Basic research can enhance our understanding of metabolic pathways in plants and how these pathways are affected by environmental conditions. It can also help cast light on photosynthesis, plant architecture, sink-source distribution of energy and other plant development factors. In addition to furthering the human quest for knowledge, this improved understanding could potentially pay enormous dividends in terms of health, the environment, and industrial yields.

Secure a healthy, high quality food/feed supply
This can be achieved by, for example, developing plants containing more essential macro and micro-nutrients (carbohydrates, starch, essential fatty acids, oils, vitamins, amino acids, antioxidants, fibres, etc), and that result in end products with less natural contamination from fungal mycotoxins, anti-nutritional compounds and environmental pollutants.

Improve plant yield potential and security
These two important goals will help ensure global food security by ensuring we can produce enough to feed a growing world population. This can be tackled from two angles: increasing land productivity and reducing crop losses caused by disease and volatile weather patterns. Increases in productivity – particularly of marginal land – will provide a wider range of choices in countryside management. Research into plant genomics can help boost crop yields without the need for chemical fertilisers and make plants more resilient to fungal infections, viruses, insects and other blights, as well as abiotic stress and toxic compounds in soil. It can also help improve the harvestability, storability and processability of crops. This will help prevent the massive losses that occur during the food/feed processing chain.

Increase the amount of useful plant matter
This can be achieved by developing plants that – after harvesting, transportation, storage and processing – provide the maximum quantity of desired end products (i.e. metabolites).

Improve countryside biodiversity
This can be done by developing plants that can be grown with reduced cultivation, inputs and end product processing. This would help prevent soil erosion and reduce the use of agricultural inputs, energy and water.

Improve the genetic diversity of crop plants
Agriculture has only just scratched the genetic surface of plants. Research into plant genomics can help expand the variety of crops we cultivate. This will give us access to new types of food with all that implies in terms of taste and nutrition.

Reduce the environmental impact of agriculture
This can be done by developing plant varieties that need less fertilizer, water and other agro-chemical inputs while producing the same high yields.

Enhance crop monitoring
Research into plant genomics can also help farmers to monitor their crops more effectively. Better knowledge of the molecular mechanics of plants will enable scientists to develop tools – such as agro-climatic models integrating genetic data – to forecast crop performance and detect problems early on. By reducing waste and providing an early warning system, such tools will help reduce the impact of agriculture on the environment and to improve crop quality.

Improve crop co-existence
To ensure consumer and farmer choice, GM, conventional and organic crops will need to exist side by side. This can be achieved in a number of ways, such as applying appropriate agricultural practices and cultivating GM plants containing biological characteristics that reduce gene flow. These include engineering cleistogamy (which prevents plants from pollinating) or cytoplasmic male sterility into 'specialty' crops so that they retain the purity of their special features without running the risk of mixing with other plants.

Develop renewable materials
This can be achieved by developing plant types that can be grown as sources of renewable materials. This will help cut down on the fossil energy used and waste currently generated in producing them. Examples include plants developed to produce biopolymers, such as biodegradable plastics.

Develop more efficient biofuels
This ambitious goal can be reached by increasing the variety of plants that contribute to the renewable resource base, improving the conversion process for plants that are currently used as biofuels, and developing new plant types that produce oils which can be used efficiently as an energy source and could also be used in food packaging.

Chapter 4: The way forward

As this document has highlighted, the potential of plant genomics and biotechnology to deliver major advances in our lifestyles and prosperity is enormous. It can also maintain and enhance the competitiveness of EU farmers and food producers. In order for this bright future to materialise, the EU and its Member States need to take action now. Towards this end, we recommend the creation of a new technology platform to take the first steps towards building a consensus on the way forward. It will also help to set and coordinate the EU research agenda in the field. To get the ball rolling, we propose that the **Plants for the Future** platform be constructed on the following basis.

Strategic priorities

Europe's main short, medium and long-term plant genomics and biotechnological research objectives, as laid out in this document could constitute part of **Plants for the Future's** priorities – the others to be set in debates with the various stakeholders. The platform should focus on improving the safe exploitation of the genetic diversity in plants to:

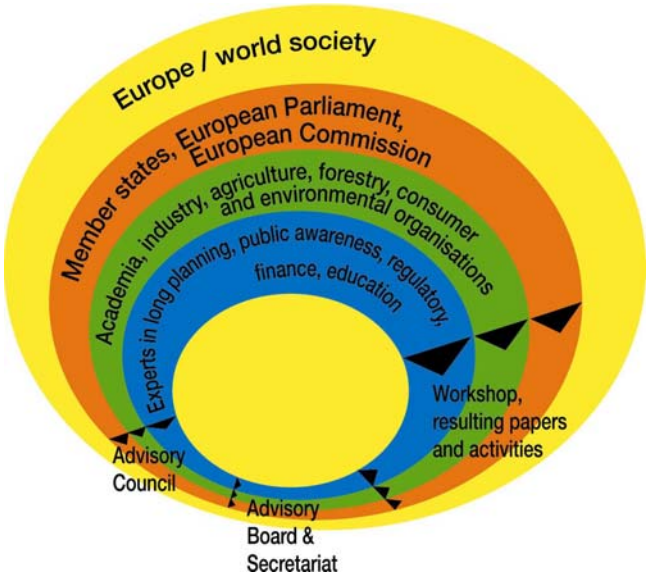
- Produce better quality, healthy, affordable, diverse food offering consumers in and beyond Europe real options to improve their quality of life.
- Bring about environmental and agricultural sustainability, including biomaterials, bioenergy and renewable resources
- Enhance the competitiveness of European agriculture, industry and forestry

Main activities

To meet its strategic priorities, **Plants for the Future** should focus on:

- Developing and implementing a pertinent long-term research agenda based on the identification of the priorities of the sector and of European citizens. We estimate that public and private funding – at EU, national and regional level – will have to exceed €45 billion over the next ten years if Europe is to remain competitive
- Enhancing the transparency of the R&D effort at the regional, national and European levels
- Promoting a coherent policy and supportive regulatory environment
- Addressing public concerns and developing societal consensus based on a mutual understanding among all stakeholders.

Management structure



The **Plants for the Future** technology platform will be managed by the Advisory Council, which will be set up to turn the current patchwork of plant genomics and biotechnological research into a coordinated, well-supported research network. To do so, it will define the contents of the Strategic Research Agenda and attract the necessary funding to implement it.

The Advisory Council should actively link the platform with all stakeholders, pooling ideas and fostering support for it. The Advisory Council must, therefore, be a broad representation of all the parties which have a stake in this crucial sector, including scientists, industry, consumer and farmers groups, environmental organisations, regulatory bodies, as well as political decision- and policy-makers at the EU, national and regional levels. These partners need to co-operate pragmatically to identify priorities.

Road map and milestones

The **Plants for the Future** platform should promote basic research in the field of plant genomics and biotechnology. It should focus on EU-grown crops, develop applied research programmes in the agro-food domain, and launch novel product-oriented R&D projects. We recommend the following research milestones on the road map to improving the sector.

Short and medium-term (to 2015)

- Establish coherent basic plant genomics research programmes for the major EU-grown crops: cereals, grain legumes, solanaceous species, major oil producing plants, and fruit and wood-producing trees
- Develop research programmes aimed at exploiting the knowledge from plant genomics and biotechnology to improve the sustainability of production, co-existence, yield, harvestability, storability and processability of the major EU-grown crops
- Develop research programmes focused on the nutritional contents of food and feed crops
- Establish public/private partnerships to explore the development of novel agricultural, food, energy and biomaterials products

In the medium and long-term (to 2025)

- Develop a comprehensive genomics knowledge base for all economically and strategically important crops grown in the EU and their related genetic resources
- Develop enhanced phenotyping tools for mining the genetic diversity of important EU crops
- Establish public/private partnerships to develop superior crop varieties which meet the requirements for sustainable production in an environmentally friendly manner, while satisfying consumer preference for healthy and safe food
- Establish collaborative programmes with developing countries on crop genomics to promote self-sufficiency, greater sustainability and competitiveness there

The **Plants for the Future** platform's goal should be to involve all stakeholders in the accompanying activities and, in particular, to translate the strategic priorities defined above into a coherent and dynamic research agenda. The Advisory Council will be managed in a way that will encourage initiatives in a bottom-up and realistic way. We plan to create the Advisory Council by mid-2004 which will then formulate a strategic agenda by early-2005.

Plants for the Future should make use of available EU instruments, and promote the networking and coordination of national programs as exemplified by the ERA-NET initiative. For the first time, this ERA-PG (for plant genomics) brings together research programme-makers and managers from across Europe to improve the coordination of national and regional plant genomics research programmes. It will also identify and support actions of specific importance at the regional level and complement these activities with private-public partnerships.

To be successful in the long-term, this initiative needs to be transparent and forge a reasonable consensus at the level of the Advisory Council. It should include the critical evaluation of novel developments, regardless of whether they are positive or appear questionable. It will also be crucial to create the legal framework necessary to exploit the results of the research programme. This platform will help Europe reap the rewards of an invigorated agro-industry sector delivering a large diversity of safe and healthy food and bio-products.

Annex: Selected glossary

Agri-food sector: the sector of the economy that produces agricultural and food products
Agribusiness: agriculture-related industries
Agro-food industry: agriculture and food related industries
Bio-based economy: the sector of the economy that produces products derived from living organisms
Biofuels: fuels derived from living organisms, as opposed to fossil fuels
Biomaterials: materials derived from living organisms, as opposed to synthetic materials
Biotechnology: technologies for cultivating, modifying or deriving products from living organisms
Co-existence: the cultivating of conventional, organic and genetically modified crops in the same area without them affecting one another
Genetics: science and technology of hereditary factors
Genetic modification: scientific technique for altering the genetic make up of living organisms which results in genetically modified organisms (GMOs)
Forestry: the cultivation of trees and the management of forests and woodland. Related sectors include paper and pulp industry.
Plant genomics: the science and technology of the genetic make up of plants

Genval Group

The Genval Group – which was set up by the European Association for Bioindustries (EuropaBio) and the European Plant Science Organisation (EPSO), in co-operation with the Commission in 2003 to draft this document – is made up of:

Simon Barber (EuropaBio)
Simon Bright (Syngenta, UK)
Bernard Convent (Bayer, BE)
Hans Kast (BASF, DE)
Waldemar Kütt (European Commission)
Chris Lamb (JIC, UK)
Karin Metzlaff (EPSO)
Christian Patermann (European Commission)
Christophe Roturier (ARVALIS, FR)
Ralf-Michael Schmidt (BASF)
Frank Wolter (ESA, DE)
Indridi Benediktsson (European Commission)
Michel Caboche (INRA, FR)
Dick Flavell (Ceres, US)
Beate Kettlitz (BEUC)
Markwart Kunz (Südzucker, DE)
Etienne Magnien (European Commission)
Jim Murray (BEUC)
Vincent Pétiard (Nestle, FR/CIAA)
Joachim Schiemann (Federal Biological Research Centre, DE)
Lothar Willmitzer (MPIMP, DE)
Marc Zabeau (VIB, BE)