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Maria Lusser

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Abstract

The report provides proceedings of the "Workshop on public-private partnerships in plant breeding" which was organised by JRC-IPTS in September 2013. It contains a summary and evaluation of the presentations and discussions from the workshop. Additionally short papers submitted by the presenters are annexed.

PPPs are regarded as a possible approach to address market failure in the field of technology innovation when the public and the private sector (alone) are not able to carry out the required R&D activities. PPPs in plant breeding are established at national, regional or transnational level. The examples of PPPs and other forms of public-private cooperation presented in the workshop show that these approaches may allow broader access to modern plant breeding techniques and germplasm and help to address (to some extent) the challenges of climate change and other breeding needs of the bioeconomy 2020. However, projects under PPPs are mainly focused on basic and pre-breeding. The duration of approximately three years is too short for the development of new varieties (applied plant breeding). PPPs are not used for the development of new varieties of minor crops. The public sector generally does not carry out an analysis of the social efficiency before the decision to provide funds for PPPs in plant breeding is taken.

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Contents

Abbreviations and Acronyms

BBSRC	Biotechnology and Biological Sciences Research Council
BIOVEGEN	Spanish Technology Platform for Plant Biotechnology
BMBF	Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung)
CAP	Common Agricultural Policy
CBSG	Centre for BioSystems Genomics
CIP	Competitiveness and Innovation Framework Programme
CIRC	Crop Improvement Research Club
CIMMYT	International Maize and Wheat Improvement Centre (Centro Internacional de Mejoramiento de Maíz y Trigo)
DG RTD	Directorate General for Research and Innovation
EC	European Commission
EIB	European Investment Bank
EIP	European Innovation Partnership
EIT	European Institute of Innovation and Technology
ERA-NET	European Research Area Net
EU	European Union
EU 12	Member States of the European Union admitted in 2004 (ten Member States) and 2007 (two Member States)
EU 15	Member States of the European Union prior to the accession of ten Candidate Countries on 1 May 2004
FP	Framework Programme
GABI	Genome Analysis in the Biological System Plant
GHG	Green House Gases
GIS BV	Group of Scientific Interest Plant Biotechnologies
GM	Genetically Modified
HAPI	Horticulture and potato initiative
IICT	Instituto de Investrigação Científica Tropical
IMF	International Monetary Fund
INRA	Institut National de la Recherche Agronomique (National Institute for Agricultural Research)
IPR	Intellectual Property Rights
IPTS	Institute for Prospective Technological Studies
JRC	Joint Research Centre
JTI	Joint Technology Initiative
KBBE	Knowledge-Based Bioeconomy
NAM	Nested Association Mapping
NCM–FJLS	Nordic Council of Ministers for Fisheries and Aquaculture, Agriculture, Food and Forestry
NordGen	Nordic Public-Private Partnership for Pre-breeding
OECD	Organisation for Economic Co-operation and Development
PLANT-KBBE	Transnational Plant Alliance for Novel Technologies - towards implementing the Knowledge-Based Bio-Economy in Europe
PPP	Public-Private Partnership
PVP	Plant Variety Protection
QTLs	Quantitative Trait Loci
R&D	Research and Development
SME	Small and Medium Enterprises
WPI	Wirtschaftsverbund Pflanzen Innovation

Executive summary

Introduction

- During the last decades developments in plant breeding globally showed a significant shift of activities from the public to the private sector. Crops with a small market share are of less interest for private breeding companies. Therefore, concerns are raised that important crops and traits could be neglected because of lack of interest of the private sector.

- Public-private partnerships (PPPs) are regarded as a possible approach to address market failure in the field of technology innovation when the public and the private sector (alone) are not able to carry out the required R&D activities. In recent years many PPPs in plant breeding have been established. However, hardly any publications on the functioning, benefits and constraints of PPPs in plant breeding are available.

The workshop

- A workshop was organised by the Institute for Prospective Technological Studies of the European Commission's Joint Research Centre in September 2013 which brought together experts from the European Commission and the public and private sectors in EU Member States. The workshop was structured into three sessions:

  Session 1: Overview of PPPs in plant breeding

  Session 2: Issues relevant for establishing PPPs

  Session 3: Examples of PPPs in plant breeding and other forms of co-operation

Definition of PPP

- The term "public-private partnerships" is used for different forms of cooperation between the public and private sectors in plant breeding such as collaborative projects, programmes, platforms and clusters. However, the question arises if all these approaches constitute PPPs.

- In order to clarify this issue, the definitions used by international organisations were studied. Most of them refer to PPPs which provide, manage and maintain infrastructure or public services such as transport and health care and welfare programmes.

- In the field of technology innovation definitions are very vague or missing. In order to cover all interesting approaches it was finally decided to broaden the scope of the workshop to "PPPs and other forms of cooperation".

PPPs in plant breeding at national and international level

- Partnerships in plant breeding take place between two or a larger number of public or private institutes and companies on national or international level. There are different approaches in funding, sharing risks and benefits and property rights of produced varieties or intermediate material.

- Most of the European PPPs in plant breeding are established at national level. However, they try to capture additional funds from international programmes or attract international partners. During the workshop PPPs and other forms of cooperation in plant breeding established in the Netherlands, United Kingdom, Germany, Spain and France were presented.

- Funding structures for breeding projects also have been established at regional and transnational level. The Nordic PPP in pre-breeding covers five Nordic Countries. PLANT-KBBE is a funding initiative for plant breeding research which started as a trilateral activity of France, Spain and Germany in 2003 and was gradually expanded with funding partners from Portugal and Canada.

- European countries participate also in global co-operations in breeding R&D such as the International Wheat Initiative and the Wheat Yield Network.

Research topics and strategy

- Projects under European PPPs mainly focus on strategic crops (i.e. relevant for the market) and on strategic traits (relevant e.g. for climate change adaptation, food security and use for biofuels).

- PPPs provide a valuable basis for crop breeding through development of technologies and pre-breeding. However,

strategies for translating results into new varieties are generally missing. Additionally, PPPs are not yet being used for the development of minor crops (crops which are not widely grown).

Modern plant breeding technologies

- Advanced breeding technologies have created unprecedented opportunities for advances in biological performance of crops. However, some of the key technologies are not affordable for many (especially smaller) public and private institutes and companies. Hence PPPs are needed to increase accessibility of modern technologies.

- The following technologies are examples of tools with good prospects for successful use in PPPs: transgenesis, mass clonal propagation, hybrid creation, DNA marker assisted breeding, genomics and mutagenesis in combination with TILLING.

Climate change adaptation

- The changing climatic situation in Europe could have major impact on agriculture during the next decades. On average, crop productivity and the areas suitable for crop production will be reduced because of increased heat stress, frequency of drought and biotic stresses. Therefore, breeding of new crop species for adaptation to climate change is required.

- Co-operation in plant breeding addressing the challenge of climate change exists or is in development, e.g. Nordgen in the Nordic countries, co-operation between VCU (value for cultivation or use) researchers from several EU Member States and possible co-operation of Southern MS for developing tools for improved water efficiency and for tree breeding respectively.

Intellectual property rights (IPR) and open access to germplasm

- PPPs may be a valid approach to increase accessibility of technologies which are protected by IPR and of germplasm. Some of the PPPs provide specific services in this context. However, IPR issues are sensitive and one of the experts stressed that that it is essential that they are agreed upon before starting up a potential project.

Time horizon of plant breeding

- Projects under PPPs established at national or international level usually last for approximately three years. Developing new varieties takes much longer. Approaches used in other fields (e.g. in the infrastructure sector) where PPPs are established for some thirty years are not (yet) used in plant breeding.

The economics of PPPs in plant breeding research

- PPPs are common in other fields (especially in the infrastructure sector) where cost-benefit analysis is carried out. Usually no economic studies are carried out by the public sector before deciding to establish PPPs in plant breeding. Private companies decide to participate in PPPs or not on the basis of cost-benefit considerations.

Intensive and transparent communication

- Expectations of public and private partners in projects are very different. Transparent communication and mutual respect are therefore crucial for successful partnerships.

1. Introducction

During the last decades developments in plant breeding globally showed a significant shift of activities from the public to the private sector[1] [2]. Within the private sector, a concentration of activities in a decreasing number of companies was observed. In 2009, the top nine seed companies reached together a market share of 43.8% in terms of net sales[3]. The private breeding sector mainly focuses on crops and traits which promise high revenues. Crops with a small market share are of less interest for private breeding companies. Therefore, concerns are raised that crops and traits which are important for the bioeconomy and agriculture are neglected because of lack of interest of the private sector[4] [5]. The bioeconomy covers the exploitation of the full range of natural and renewable biological resources, biodiversity and biological materials for bio-based products for uses as food and feed, as energy source and in the industry.

Public-private partnerships (PPPs) are regarded as a possible approach to address market failure in the field of technology innovation when the public and the private sector (alone) are not able to carry out the required research and development (R&D) activities. In recent years many PPPs in plant breeding have been established. However, hardly any publications on the functioning, benefits and constraints of PPPs in plant breeding are available.

Therefore, it was decided to organise a workshop on PPPs in plant breeding with the following targets:

- Map the PPPs on plant breeding currently established in the European Union (EU).
- Provide an overview on existing literature on PPPs in plant breeding (and agricultural research in general).
- Present examples of PPPs and other forms of cooperation in plant breeding.
- Discuss possible approaches for PPPs in plant breeding.
- Highlight specific issues which are decisive for breeding for the bioeconomy and potentially could be solved by PPPs such as access to modern plant breeding techniques, economics of PPPs, climate change and intellectual property rights (IPR).
- Discuss to what extent PPPs are able to address these issues.

In 2012 Arcadia International carried out a study on "Plant-breeding for an EU bio-based economy: The potential of public sector and public/private partnerships"[6]. As a follow-up to this study it was decided to organise a workshop in order to study the issue of PPPs in plant breeding. This report provides a summary of the presentations and discussions from this workshop.

Chapter 2 of this report provides information on the policy background and research context. Chapter 3 summarises the information from the three workshop sessions. Session 1 started with a discussion of the definition of PPPs. Additionally, the session comprised overview presentations on PPPs in plant breeding from the point of view of public institutes, the private breeding sector and research under the

1 D. Murphy, "Plant Breeding and Biotechnology: societal Context and Future of Agriculture", Cambridge University Press (2007), ISBN 978-0-521-82389-0

2 M. Morris et al. (2006), "The global need for plant breeding capacity: what roles for public and private sectors". Hort. Science 41, 30-39.

3 P. Schenkelaars et al., "Drivers of consolidation in the Seed Industry and its Consequences for Innovation", COGEM report: http://www.google.at/search?hl=de&source=hp&q=%22Drivers+of+consolidation+in+the+Seed+Industry+and+its+Consequences+for+Innovation%22&btnG=Google-Suche&aq=f&aqi=&aql=&oq=

4 P.W. Heisey et al., "Public Sector Plant Breeding in a Privatizing world", U.S. Department of Agriculture, Agriculture Information Bulletin No. 772.

5 P.W. Heisey, "Privatization of Plant Breeding in Industrialized \countries: Causes, Consequences and the Public Sector Response", in D. Byerlee et al. "Agricultural research Policy in an era of privatization", CABI (2002).

6 Van Elsen et al. (2013) Plant breeding for an EU bio-based economy. The potential of public sector and public/private partnerships. Arcadia International, Brussels.

EU Framework Programmes and Horizon 2020. Session 2 included presentations on specific issues which are important for breeding for the Bioeconomy 2020 such as modern plant breeding techniques, economics of PPPs and climate change.

In session 3 examples of PPPs in plant breeding and other forms of co-operation were presented.

The Annexes of the report include the list of participants, the agenda and short papers provided by the speakers.

2. Background information

2.1. Policy background

The future standard of living and social and economic security in the EU depend on its ability to drive innovation. Therefore, innovation is a main focus of the Europe 2020 strategy[7].

The Europe 2020 strategy was further developed in specific policy sectors. In the field of bioeconomy the European strategy and action plan "A Bioeconomy for Europe: Innovating for Sustainability"[8] was developed by the Directorate General for Research and Innovation (DG RTD) of the European Commission (EC). Bioeconomy covers the exploitation of the full range of natural and renewable biological resources, biodiversity and biological materials for bio-based products for uses as food and feed, as energy source and in the industry. The European strategy and action plan aims at addressing a set of challenges such as the expected impacts of climate change, the predicted peaking in the use of fossil-based resources and the projected global demographic growth with an increased demand of food. In this context, breeding of new plant varieties should contribute to the improvement of productivity, sustainability and the suitability of crops for non-food utilization, to the increase of the nutritional value of food crops and to the mitigation of the consequences of climate change. The European strategy and action plan identifies actions to be taken by the Commission with specific relevance for agriculture and plant breeding.

In the field of agriculture, the Commission Communication "The Common Agricultural Policy (CAP) towards 2020"[9] addresses the challenges of food security and climate change. The Communication specifies that reforms of the CAP are necessary to deal with the consequences of climatic changes for the agricultural production conditions. Also the need of farmers to increase the sustainability of their activities to meet environmental targets such as the reduction of greenhouse gas (GHG) emission, to play an active role in climate change mitigation and to provide renewable resources and energy has to be addressed.

The White Paper "Adapting to climate change"[10] establishes a European framework for action to improve Europe's resilience to climate change. It emphases the need of adaptation in all key European policies and the need to enhance co-operation at all levels of governance. The following adaptive solutions identified in the White Paper are of special relevance in the context of plant breeding:

- Choosing crops and varieties better adapted to the length of the growing season and water availability, and more resistant to new conditions of temperature and humidity.
- Adapting crops with the help of existing genetic diversity and new possibilities offered by biotechnology.
- Support to agricultural research and to experimental production aiming at crop selection and development of varieties best suited to new conditions.

2.2. Research context

New plant varieties provide important technical solutions for the challenges faced by the bioeconomy sectors and for adaptation to climate change. A study on plant breeding performed in the USA[11] concludes that 50% or more of the achieved yield gains in agriculture could be attributed

7 Communication from the Commission to the European Parliament, the Council and the Committee of the Regions: Europe 2020 Flagship Initiative Innovation Union, SEC(2010) 1161.
http://ec.europa.eu/research/innovation-union/pdf/innovation-union-communication_en.pdf

8 "Bio-based economy for Europe: state of play and future potential", web link: http://ec.europa.eu/research/consultations/bioeconomy/consultation_en.htm

9 Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: "The CAP towards 2020: Meeting the food, natural resources and territorial challenges of the future", COM(2010) 672.
http://ec.europa.eu/agriculture/cap-post-2013/communication/com2010-672_en.pdf

10 Commission staff working document "Adapting to climate change: Towards a European Framework for action", COM(2009) 147.
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2009:0147:FIN:EN:PDF

11 J. Fernandez-Cornejo, "The Seed Industry in U.S. Agriculture: An Exploration of Data and Information on Crop Seed markets, Regulation, Industry Structure, and Research Development", U.S. Department of Agriculture (USDA), Agriculture information bulletin, no.786.

to genetic improvements of plant varieties. Fertilizers, pesticides, machinery and labour are the other contributing factors.

Many studies are available discussing the consolidation in the seed industry[12], the development of public and private activities over time[13] or mapping the public and private breeding sector[14] [15]. They apply different methodologies such as case studies and interviews, evaluation of field trial data and research and development (R&D) pipeline data on genetically modified (GM) varieties[16] and the analysis of patent and plant variety protection (PVP) grants[17]. However, quantitative information is limited, especially for the public breeding sector. In terms of geographical coverage most of publications deal with non EU countries or only single or a few EU Member States.

In recent years PPPs have been established in many fields including plant breeding. However, only few publications on the topic of PPPs in plant breeding exist[18]. Papers focus rather on developing countries[19] and information provided is very limited. Economic studies and especially cost-benefit-analysis are still missing.

In 2012 Arcadia International carried out a study on "Plant-breeding for an EU bio-based economy: The potential of public sector and public/private partnerships"[20]. Overall, the report of the study concludes that "it is hard to envisage the public conventional plant breeding sector delivering new varieties, including traits required for fulfilling the needs of the bioeconomy strategy 2020 where private plant breeding is not currently investing enough." Concerning PPPs, the report concludes: "Public-private partnerships are more developed in the EU 15 MS[21] rather than in the EU 12 MS[22] in which public conventional plant breeders play the role of transferring technology to the market together with a commercial partner. The majority of these PPPs are dedicated to the development of upstream activities."

PPPs are regarded as a possible approach to address market failure in the field of technology innovation when the public and the private sector (alone) are not able to carry out the required R&D activities. Although giving preliminary information on existing PPPs in plant breeding, the study carried out by Arcadia does not give a conclusive answer on the potential of PPPs to fulfil the needs of the bioeconomy strategy 2020 which are currently not sufficiently addressed by the public or by the private sector alone (see table on "Breeding needs per agro food supply chain business sector" in Annex 3). Additionally, the study focused on applied plant breeding, whereas PPPs (currently) mainly deal with pre-breeding activities.

12 P. Schenkelaars et al., "Drivers of consolidation in the Seed Industry and its Consequences for Innovation", COGEM report: http://www.google.at/search?hl=de&source=hp&q=%22Drivers+of+consolidation+in+the+Seed+Industry+and+its+Consequences+for+Innovation%22&btnG=Google-Suche&aq=f&aqi=&aql=&oq=

13 D. Murphy, "Plant Breeding and Biotechnology: societal Context and Future of Agriculture", Cambridge University Press (2007), ISBN 978-0-521-82389-0

14 Kenneth J. Frey, 1996: "National Plant Breeding Study-I: Human and Financial Resources Devoted to Plant Breeding Research and Development in the United States in 1994.", Special Report, Iowa State University

15 J. Fernandez-Cornejo, "The Seed Industry in U.S. Agriculture: An Exploration of Data and Information on Crop Seed markets, Regulation, Industry Structure, and Research Development", U.S. Department of Agriculture (USDA), Agriculture information bulletin, no.786.

16 A. Arundel, D. Sawaya, "Biotechnologies in Agriculture and Related natural Resources to 2015", OECD Journal: General Papers - Volume 2009/3.

17 N. Louwaars et al., "Breeding Business: The future of plant breeding in the light of developments in patent rights and plant breeder's rights" Centre of Genetic Resources, the Netherlands (CGN), CGN Report 2009-14(EN)

18 M. Morris et al.(2006) "The Global Need for Plant Breeding Capacity: What Roles for the Public and private Sector?", Horticultural Science, 41, p.30-39.

19 X. Dellany, et al. (2012). "Fostering molecular breeding in developing countries". Molecular Breeding, 298, p. 857-873.

20 Van Elsen et al. (2013) Plant breeding for an EU bio-based economy. The potential of public sector and public/private partnerships. Arcadia International, Brussels.

21 EU 15 MS: The EU was established in 1993 with 12 Member States. Three additional MS joined in 1995. EU 15 MS are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom.

22 EU 12 MS: Ten Member States joined in 2004 and two in 2007. EU 12 MS are Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, Slovenia.

3. Workshop report

A workshop was organised by JRC-IPTS (Institute for Prospective Technological Studies of the Joint Research Centre) in Seville on 19 to 20 September 2013 that brought together experts from the EC and the public and private sectors in EU Member States. The rational for choosing experts from PPPs was the geographical distribution in order to cover the different climatic regions where PPPs are established. (No PPPs currently exist in Eastern Europe.) Two representatives were invited each from the PPPs NordGen (Nordic Public-Private Partnership for Pre-breeding), BBSRC (Biotechnology and Biological Sciences Research Council, UK) and PLANT2030 (Germany). As far as available one representative from public and one from private sector were invited. Additionally the coordinators from Biovegen (Spanish Technology Platform for Plant Biotechnology) and GIS BV (Group of Scientific Interest Plant Biotechnologies, France), one representative of the European Seed Association (ESA) and experts for climate change, economics and modern plant breeding techniques participated in the workshop. The EC was represented by one staff from DG RTD and several staff from JRC-IPTS. The names and affiliations of all participants are listed in Annex 1 of this report and the agenda of the workshop is included in Annex 2.

The workshop was structured into three sessions:

- Session 1: Overview of PPPs in plant breeding
- Session 2: Issues relevant for establishing PPPs
- Session 3: Examples of PPPs in plant breeding and other forms of co-operation

Many presentations and especially the discussion rounds provided information relevant also for other sessions. In order to provide a concise and structured summary of the relevant issues, the following paragraphs only roughly follow the order of the workshop and only include key information from presentations and a summary of the discussions.

The experts participating in the workshop provided short papers on the contents of their presentations. These short papers are included in Annex 4 of this report and provide a more detailed discussion of relevant topics, valuable background information and more detailed descriptions of specific PPPs or projects carried out under PPPs.

3.1. Overview of PPPs in plant breeding

3.1.1. Presentations

Public-Private Partnerships - Definition	M. LUSSER JRC-IPTS, Seville, Spain
Involvement of public plant breeding institutes in PPPs	M. LUSSER JRC-IPTS, Seville, Spain
ESA Members and PPPs	J.P. JUDSON European Seed Association, Belgium
Projects on plant breeding under the EU Framework Programmes and Horizon 2020	G. DUBOIS Directorate General for Research and Innovation, Belgium

3.1.2. Definition of PPPs

The term “public-private partnerships” is used for different forms of cooperation between the public and private sectors in plant breeding. One of the participants in the workshop listed the following possible approaches:

- Collaborative projects: with a mix of public and private partners
- Programmes: with joint funding from public and private partners
- Platforms: with joint participation from public and private partners
- Organisations: with loose or formal structures
- Clusters: with political weight

However, the question arises if all these approaches constitute PPPs. It is getting increasingly difficult to differentiate “public” from “private” plant breeding institutes. Only few plant breeding institutes in the EU are operating

on a completely public basis. There are institutes which although publicly owned are operated in a competitive way or which receive no public funds at all.

Additionally, there are many different forms of cooperation between the public and private breeding entities. Most public and private institutes use the possibility of sourcing in and out of certain breeding activities to other breeding institutes. Cooperation takes place between two or a larger number of institutes and companies on national or international level and there are different approaches in funding, sharing risks and benefits and property rights of produced varieties or intermediate material.

In order to clarify the issue of PPP definitions before organising the workshop, the definitions used by international organisations and institutes such as World Bank, Organisation for Economic Co-operation and Development (OECD), International Monetary Fund (IMF), and the European Investment Bank (EIB) were studied. The majority of publications deal with PPPs which provide, manage and maintain infrastructure or public services such as transport (e.g. highways, tunnels and bridges), water (supply and waste water treatment systems) and health care and welfare programmes. Consequently, also definitions used by organisations or in publications usually refer to this kind of PPPs.

The World Bank defines PPP as "A long-term contract between a private party and a government agency, for providing a public asset or service, in which the private party bears significant risk and management responsibility."[23] Although deviating in details, the definitions of other organisations and institutes have in common that they deal with all or most of the following aspects: supply of infrastructure assets and services, source of funding and expertise (usually private) and risk transfer from public to private sector.

In the field of technology innovation definitions are very vague or missing. In this context, the OECD[24] defines PPP as "any innovation-based relationship whereby public and private actors jointly contribute financial, research, human and infrastructure resources, either directly or in kind. As such, partnerships are more than simply a contract research mechanism for subsidising industrial R&D. Partnerships can be formal or informal arrangements governing general or specific objectives in research or commercialisation and involve two or more actors (e.g. consortia). ..."

Finally it was decided to broaden the scope of the workshop to "PPPs and other forms of cooperation". The discussions showed that there is great interest in the different forms of cooperation and therefore including them in the workshop appears as justified. However, for analysing the social and economic benefits and costs of a specific PPP (or other form of cooperation) an exact definition is indispensable. The section on economics of PPPs therefore uses a "narrow" definition (see below).

3.1.3. Overview of involvement of public institutes in PPPs

The study on "Plant breeding for an EU bio-based economy 2020" carried out by Arcadia International, Brussels provides some information on the involvement of public institutes in PPPs and other forms of public-private cooperation. The results are preliminary. However, in the absence of other studies on this topic, it was decided to present them in the workshop.

Some EUR 800,000 per year (approximately 5% of the expenditure of public breeding institutes in the EU) is used for contracting in services. Whereas services in molecular breeding are mainly contracted in from other public institutes, other services related to breeding are mainly provided by private institutes.

Half of the public breeding institutes focusing on developing new varieties and participating in the surveys carried out in the Arcadia study are involved in PPPs. Currently no PPPs in plant breeding exist in Eastern Europe. The related activities concern pre-breeding, resistance breeding and providing pre-breeding material or varieties to private companies. All representatives of public institutes focusing on research and pre-breeding activities participating in the study stated that they have projects under PPPs. Many of the projects are carried out under national or EU programmes and they are related to activities such as molecular breeding, genome sequencing, field evaluation, developing breeding and selection tools and breeding for resistance, efficiency of nitrogen uptake, photosynthetic efficiency and climate change adaptation.

3.1.4. Overview of involvement of private companies in PPPs

The conditions for R&D in the field of breeding are very specific. In comparison to other sectors in Europe, breeding companies invest heavily (up to 20% of their annual turnover[25]) in research to meet the requests from farmers. Additionally, the seed legislation[26] promotes innovation by setting out specific criteria that varieties need to meet in order to be marketed in the EU.

Also interdependency between plant breeders is higher than in other fields, especially concerning access to genetic

23 Public-Private Partnerships Reference Guide (2012), The World Bank, Washington, Unites States. http://ec.europa.eu/internal_market/publicprocurement/partnerships/public-private/index_en.htm

24 OECD, Science Technology Industry, Review No. 23, Special Issue on "Public/Private partnerships in Science and Technology".

25 ESA Seed Facts (Factsheet of the European Seed Association): http://www.euroseeds.org/publications/factsheets/ESA13.0319%20seedfact%20-%20Diverse%20-%20Innovative-lr.pdf

26 http://ec.europa.eu/food/plant/plant_propagation_material/index_en.htm

resources and key technologies. Innovations in the plant breeding sector are not protected in the same way as in other sectors. In plant breeding, the PVP rights which constitute a specific IPR system that allows access to protected varieties for further research and breeding applies. This means that companies may depend on each other's innovations to bring their own new products to the market. This applies specifically to the situation in Europe, whereas in other countries such as in the USA, access to germplasm is more restricted. For the use of biotechnology or other new technologies IP rights apply and this may effectively block the use of these technologies.

No overview study providing data on the involvement of private companies in PPPs in Europe has been carried out so far. The presentation provided during the workshop therefore focused on incentives and hurdles for establishing PPPs and on specific PPPs. This information is presented in chapters 3.2 and 3.3 respectively.

3.1.5. Projects on plant breeding under the EU Framework Programmes and Horizon 2020

DG RTD manages the budget for EU-funded research in the form of multiannual Framework Programmes (FPs). FP 7 (2007-2013) provided under the Knowledge-Based Bioeconomy (KBBE) Programme funds of more than EUR 100 million in total for almost 40 projects in plant breeding and related subjects. These projects were related to breeding tools (e.g. genetic and genomic) and processes (e.g. molecular breeding), specific traits (relevant for biotic and abiotic stress tolerance) and integrated approaches (e.g. breeding for organic and low-input systems).

The EU FP for the years 2014-2020 (Horizon 2020) will provide research funds of EUR 80 billion of which EUR 4.5 billion are foreseen for research related to food security and bio-based economy. For the first time, it will bring together three previously separate programmes: the Research FP, innovation aspects of Competitiveness and Innovation FP (CIP) and the EU contribution to the European Institute of Innovation and Technology (EIT). This approach will integrate the different forms of research and innovation and also lead to a simplification of rules and procedures for participation.

Horizon 2020 will promote different forms of partnering. Joint Technology Initiatives (JTI; e.g. JTI on Bio-based Industries) constitute PPPs. The European Research Area Net (ERA-NET) instrument is designed to support PPPs in their preparation, establishment of networking structures, design, implementation and coordination of joint activities as well as topping up of single joint calls. The aim of the European Innovation Partnerships (EIP) is to provide working interfaces between different actors, e.g. between agriculture, bio-economy, science, advisors, and other stakeholders in the case of the EIP on "Agricultural Productivity and Sustainability". They do not provide additional funding.

The presentation on "Projects on plant breeding under the EU FPs and Horizon 2020" was followed by an extensive discussion round. Many of the contributions were not related only to FP projects but also to public-private co-operations in plant breeding in general. This information is therefore included in chapter 3.2.

3.2. Issues relevant for establishing PPPs

3.2.1. Presentations

Modern plant breeding technologies and PPPs	D. MURPHY University of South Wales, United Kingdom
Breeding field crops for climate change	M. KOPPEL Estonian Crop Research Institute
The economics of public-private partnerships in plant breeding research	F.J. AREAL University of Reading, United Kingdom

Diverse issues are relevant for the establishment of PPPs. In the workshop, specific presentations were dedicated to the following three topics:

3.2.2. Modern plant breeding technologies

Advanced breeding technologies have created unprecedented opportunities for advances in biological performance of crops. However, some of the key technologies are not affordable for many (especially smaller) public and private institutes and companies. Hence PPPs are needed to increase accessibility of these technologies.

According to the presentation given in the workshop the following technologies are regarded as key tools for modern plant breeding activities with good prospects for successful use in PPPs:

- **Transgenesis** is mainly used for a few traits in a few major crops. Broader application is hindered by IPR restrictions, high regulatory costs and consumer concerns in some countries (e.g. the EU). PPPs could help to extend the scope and utility of this technique in long term.

- **Mass clonal propagation** is highly effective for certain crops although there may be problems with abnormalities and disease transmission. Good results already have been achieved through public-private collaboration e.g. for plantation crops.

- **Hybrid creation** is highly effective for a wide range of crops. It has benefited from new developments in tissue culture and haploid technologies. It has been used successfully by the public and private sector and in public-private collaboration e.g. for rice and maize breeding.

- **DNA marker assisted selection** significantly accelerates breeding programs and is best used in combination with other technologies. High upfront costs are required to provide the necessary expertise and infrastructure. PPPs could further the application of the technology on newer crops.

- **Genomics** is a technology currently mainly used in pre-breeding sector. It requires high upfront costs for infrastructure and expertise. The big amount of data which has to be analyzed results in a challenge for informatics. The technology is under development and therefore suitable for innovative PPPs.

- **Mutagenesis in combination with TILLING** has a great scope also for the use in PPPs although IPR may be an issue.

The list presented during the workshop is not exhaustive. Further techniques of importance are new breeding techniques, phenotyping, bioinformatics, etc.

3.2.3. Climate change

The average annual temperature in Europe is likely to increase more than in the rest of the world; the largest increase is expected in Northern Europe during the winter period and in the Mediterranean area during the summer period. The frequency of extreme climatic events (heat waves, heavy rain falls, storms etc.) is expected to increase in whole Europe. Annual precipitation is going to increase in Northern Europe and decrease in the Mediterranean area.

The changed climatic situation could have major impact on agriculture. On average, crop productivity and the areas suitable for crop production will be reduced because of increased heat stress, frequency of drought and biotic stresses. Therefore, breeding of new crop species for adaptation to climate change is required.

The main breeding needs in this context are:

- For Southern countries breeding for traits related to drought and heat stress tolerance (e.g. breeding for bigger and deeper root system and enhanced water uptake capacity, shifting flowering time towards the period when temperature is lower, prolonged grain filling period, etc.).

- Breeding for pest and disease resistance to address challenges of the evolution of new pathotypes and the moving of pathogens into currently pest free areas and higher uncertainty of the need of pest control because of higher climate variability.

- Breeding for a multitude of agricultural crops including crops of minor use and emerging future crops to cope with climate change.

- For Nordic countries breeding for changed overwintering conditions.

In the discussions during the workshop experts agreed that an EU-wide cooperation in breeding for climate change adaptation would not be practical. Institutes have to find partners based in regions which encounter the same problems. E.g. Nordic countries cannot address the higher temperatures by using varieties from their Southern neighbours. New varieties need to be developed which are suitable for a photo period of up to 24 hours per day.

Co-operations in plant breeding addressing the challenge of climate change exist or are in development, e.g. Nordgen in the Nordic countries (see chapter 3.3).

3.2.4. The economics of PPPs in plant breeding research

From an economic perspective public intervention (public funding) may be needed when there is a failure in the market that impedes to achieve a social optimum level in the provision of goods and services. In the case of plant breeding research public intervention can be justified on the following grounds:

- When plant breeding research has associated spill-over benefits (i.e. positive externalities) which are the flows of knowledge and the scientific and technical advances obtained by the research that are shared with society, the productivity improvements of other firms and the reduction of costs.

- When the generation of knowledge obtained from plant breeding research has characteristics of a public good. A public good is a good or service that has the features of non-rivalry and non-excludability and as a result would not be efficiently provided by the market.

However, a market failure is a necessary but not sufficient rationale for any public intervention. If the cost associated with the public intervention is higher than the benefits associated with the internalisation of the externality a public intervention would not be adequate from an economic point of view. Therefore, a cost-benefit analysis should be carried out whether there is a significant benefit before public funding to conduct plant breeding research is spent.

In order to evaluate the performance of PPPs all costs and benefits should be taken into account in assessing efficiency. Production costs (e.g. costs associated with the production of plant breeding research such as labour costs, materials used, renting of buildings) are only part of total costs of organising the supply of a good or service. Transaction costs should also be included. These are costs associated with making, executing, monitoring, bargaining and renegotiating

contracts among the entities engaged in the production process.

If the public sector decided to provide goods and services associated to plant breeding research it would need to find institutional arrangements that minimise the total costs of supply including making, executing and monitoring contracts. Also it would need to introduce ex-ante competition at the bidding stage (tendering process) to induce low costs.

The suggested approach would be analogue to the approaches used for providing infrastructure which has proved to be cost efficient in many cases. The presentations and discussions in the workshop showed that existing PPPs in plant breeding deviate considerably from these considerations:

- The public sector generally does not carry out an analysis of the social efficiency before the decision to provide funds for PPPs in plant breeding is taken. Private companies on the other hand decide on a cost-benefit basis if they participate in a specific PPP and project.

- PPPs are not established to provide "public services" only. Depending on negotiations and agreements the public or the private sector or both are able to exploit the results achieved by PPPs on plant breeding.

- The establishment of PPPs in plant breeding does not involve tendering processes in order to reach low costs but is rather based on a system providing grants or subsidies to participating institutes.

- Funds for the PPPs are provided by both the public and private sector. In some PPPs a fixed ratio for public to private funding (e.g. 50:50 or 90:10) applies (independent of the nature of the specific project and of its risks and benefits for the partners).

3.2.5. Further relevant topics

Many further relevant issues for the establishment of PPPs were developed in the workshop presentations and discussion rounds. The following paragraphs provide a short summary.

Risk

Experts noted that the participation in PPPs constitutes considerable economic risks. Sudden cuts of budget may lead to the collapse of PPPs. There is also the danger that partners are lost because of a shift of priorities for public institutes or bankruptcy in the case of small private companies.

Administrative burden

The management of PPPs means considerable administrative burden. The participation of small and medium enterprises (SMEs) in consortia is foreseen and may be also a requirement (e.g. in many FP calls). One expert stated that there is frequently a lack of interest as the administrative burden for participating in projects for these companies is too high. Workshop participants agreed that administration procedures should be simplified as far as possible.

Time horizon of plant breeding

Developing new varieties takes many years and therefore breeding requires long-term projects. Participants criticized especially that FP projects usually have duration of only three years. It was stated that there are also some five years projects, that some continuity is allowed between programmes and that the EIPs will provide links between different funds.

Also projects under PPPs established at national or regional level last only for a few years (see chapter 4.3). It is noted that approaches as chosen in the infrastructure sector where PPPs last for some 30 years are not (yet) used in the field of plant breeding.

Research topics and strategy

Experts agreed that the involvement of PPPs in basic research and pre-breeding (such as development of new technologies, genotyping and phenotyping) is important. Some of them were of the opinion that there should be a balance with projects for applied breeding. It is generally very difficult to receive funds for applied plant breeding. Experts criticized that programmes were technology driven but not market driven and that there was a lack of strategic direction especially in international programmes. Farmers' interests should be taken into account for planning. There was agreement that PPPs in plant breeding generally should not work with model plants as the extrapolation of results achieved for model plants to crop plants is questionable.

The examples of projects presented in the workshop (see chapter 3.3) show that they focus on strategic crops (i.e. relevant for the market) and on strategic traits (relevant e.g. for climate change adaptation, food security and use for biofuels). It is noted however that most of the targeted crops are major crops at a global level or in the respective country or region. PPPs provide a valuable basis for crop breeding through development of technologies and pre-breeding. However, strategies for translating results into new varieties are generally missing. Additionally, PPPs are not yet being used for the development of minor crops (crops which are not widely grown).

As mentioned above, for most of the programmes fixed ratios of public to private funding apply. Experts noted that the higher the contributions from the private companies the closer projects have to be to applied breeding (approximately 10% private contribution in the case of basic research and 30-50% in the case of applied research and development) in order to be attractive.

Important traits

In addition to those traits discussed under climate change, also traits relevant for sustainability (nitrogen use and water use efficiency) and yield are major drivers to establish PPPs. Further traits are mentioned as objectives of specific PPPs in chapter 3.3.

Experts reported about co-operations between VCU (value for cultivation or use) researchers concerning sustainability criteria from several EU Member States and possible co-operations of Southern MS for developing tools for improved water efficiency and for tree breeding respectively.

Making results of projects available for use

Projects often produce a very large amount of data (e.g. in the case of genotyping). Experts mentioned that frequently resources are missing to process all produced data and to make them available to other researchers. Results which are not used can quickly lose their value. One expert suggested that such data could be made available to academic researchers for exploitation.

IPR and open access to germplasm

As mentioned in chapter 3.1.4, PVP rights in Europe allow access to protected varieties for further research and breeding. This allows rather open access to germplasm which is not the case in other countries (e.g. in the USA). For the use of biotechnology or other new technologies IPR apply and this may effectively block the use of these technologies. Some experts stated that they noted a shift to open access but others criticised that there is no long term strategy in place regarding germplasm access. One of the experts noted that a database linked to patents might be useful for breeders.

PPPs may be a valid approach to increase accessibility of technologies which are protected by IPR and of germplasm and some of them provide specific services in this context (e.g. Intellectual Property and Licensing Committee of GIS BV). However, IPR issues are sensitive and one of the experts stressed that that it is essential that all IPR issues are agreed upon before starting up a potential project.

Intensive and transparent communication

Expectations of public and private partners in projects are very different. Transparent communication and mutual respect are therefore crucial for successful partnerships.

3.3. Examples of PPPs in plant breeding and other forms of co-operation

3.3.1. Presentations

NORDGEN	
Public-Private Partnership for Pre-breeding – a Nordic model	M. RASMUSSEN NordGen - Nordic Genetic Resource Center, Sweden
Pre-breeding: a forgotten and underutilized tool	A. JAHOOR Nordic Seed, Denmark
GIS BV	
GIS BV – Group of Scientific Interest “Plant Biotechnologies”	R. PIOVAN GIS Biotechnologies Vertes, France
BBSRC	
BBSRC: Breeding Collaboration	J. PHILIPS BBSRC, United Kingdom
PPP and innovation	D. THOMPSON Syngenta Seeds Ltd, United Kingdom
BIOVEGEN	
Biovegen Spanish plant biotech sector: an overview	G. RUIZ DE GAUNA Biovegen, Spain
BIOVEGEN	
PPP in PLANT2030: The case of the PRE-BREEDYIELD Project	A. ABBADI Norddeutsche Pflanzenzucht, Germany
Tree for Joules Improving eucalypt and poplar wood properties for bioenergy	J. PINTO PAIVA Instituto de Investigação Científica Tropical (IICT), Portugal

3.3.2. National PPPs and other forms of cooperation

Most of the European PPPs and other forms of cooperation in plant breeding are established at national level. However, they usually try to capture additional funds from international programmes (e.g. from the FP) or attract international partners.

The list of PPPs and other cooperation presented on the following pages is not exhaustive, but includes only those which were presented in the workshop. The examples show the high level of heterogeneity of approaches in the EU such as programmes, clusters, organisations and platforms or combinations thereof.

CBSG: Centre for BioSystems Genomics (the Netherlands)

CBSG was established in 2002 with a research budget of EUR 110 million for 10 years (50:50 funding by public and private sector). It brings together universities, research institutes and private companies. CBSG's management structure consists of the Steering Committee, the management team and executive committee, cluster and project committees, all of which constitute representatives from the public and private partners.

Projects under CBGS deploy genomics to improve breeding programmes. They concentrate on pre-competitive breeding activities and are targeted towards two genetically close crops: potato and tomato.

The rational for establishing the partnership was building up capacity for infrastructure and to capture further funding (e.g. from the EU). In order to achieve critical mass CBSG tries to attract international investment and partnerships (e.g. with Canada and India). Four spin-offs have been created. The benefits for industry include time and cost reduction for basic research and for the breeding process.

BBSRC: The Biotechnology and Biological Sciences Research Council (United Kingdom)

BBSRC is the leading public funder of non-clinical bioscience research and innovation in the UK with the aim to address major economic challenges including food security and the need for renewable low-carbon sources of energy, transport fuels and chemicals. BBSRC uses a variety of funding models to support fundamental research aligned to industrial need. The most relevant in the context of plant breeding are the following:

- **Crop Improvement Research Club (CIRC)**

  CIRC operates through the Research Technology Club model that has been applied by BBSRC to a variety of sectors and which establishes joint funding pots to support pre-competitive research while encouraging closer links between academia and industry through regular networking events. CIRC was established in 2011 as a five year partnership between BBSRC, a consortium of 14 companies, and the Scottish Government. It supports 15 research projects worth EUR 8.5 million. The projects involve 12 breeding centres throughout the UK and overall 100 experts. They focus on improving the productivity and quality of wheat, barley and oil seed rape for use in food. Key areas of research are grain processability and utilisation (e.g. wheat lacking B-type starch granules, improved processability of malting barley), pest and disease resistance (fungal resistance in cereals, pest and virus resistance in oil seed rape), root function (e.g. phenotyping of root function) and yield improvement (e.g. manipulation of photosynthetic carbon metabolism in wheat to improve yield).

- **Horticulture and potato initiative (HAPI)**

  HAPI is an example of a collaborative funding activity that addresses a strategically important area of research. BBSRC will invest up to EUR 8.5 million through two calls and the Scottish Government will contribute EUR 0.7 million. Participating private companies provide 10% of the project costs. The following six key areas will be addressed: pests and pathogens, seed quality and vigour, resource use efficiency, changing seasons, crop maturity and spoilage and soil.

GABI – Genome analysis in the biological system plant (Germany)

GABI was established as joint programme on plant genomics research and lasted from 1999 to 2010. It was supported by the BMBF (Bundesministerium für Bildung und Forschung, Federal Ministry for Education and Research) and Wirtschaftsverbund Pflanzen Innovation (WPI) an industry platform. Some seventy research institutions and companies participated and 350 scientists were involved. Its main objective was the analysis of the structure and function of the genomes of the most important cultivated plants.

PLANT2030 (Germany)

PLANT2030, which is supported by the BMBF and private companies, has been designed to strengthen PPPs in plant breeding and biotechnology (crop research). It comprises two modules for funding:

Module A - PRODUCTS supports industry-driven consortia and the focus is strictly on applied research. The private partner(s) have to contribute at least 30% of the total costs, considering the entire network. Overall, EUR 19.3 million is contributed by public funding and EUR 9.5 million by the private sector.

Module B – TRANSFER supports application-oriented consortia. It is focused on local and economically important plants. Model plants and basic research at reference systems should only be employed in exceptional cases. (Contributions: EUR 39.4 million of public funding and EUR 12.3 million contributed by the private sector).

Target crops are barley (4 projects), wheat (3), sugar beet (2), oilseed rape (2), maize (2), sunflower (1), grapevine (1) and rye (1).

Projects are grouped into three thematic fields:

- The thematic field „HARVEST" focuses on enhancement and stabilization of yield, improved resistance against pathogens and advanced tolerance against abiotic stresses.

- The thematic field „QUALITY" targets elevated levels of valuable (health-improving) ingredients, reduced levels

of undesirable ingredients (e.g. allergens), the adjustment of working properties for the production of food, feed, energy and commodities and the optimization of plant architecture.

- The thematic field „SUSTAINIBILITY“ focuses on the improvement of water- and nutrient use efficiency, sustained application of plant protective agents (e.g. minimization of application rates) and the preservation of biological diversity of the agronomically employed ecosystem.

Precision breeding for yield gain in oilseed rape

In the workshop a project on pre-breeding for yield gain in oilseed rape (*B. napus*) was presented which is carried out under PLANT2030. The project involves seven private companies and seven academic institutes. The duration of the project is three years and the total value is EUR 5.8 million. The targets are yield and yield stability, nitrogen-use efficiency and drought tolerance.

Two large Nested Association Mapping (NAM) populations have been developed, which incorporate novel genetic diversity, as a resource for *B. napus*. The NAM populations were developed by crossing a pre-breeding collection of 50 rapeseed genotypes selected specifically with regard to yield gain, nitrogen use efficiency and drought tolerance to a common elite line. Founder genotypes of the pre-breeding collection are subjected to deep phenotyping studies as well as genome re-sequencing. All genotypes and additional experimental crosses are being phenotyped and genotyped.

BIOVEGEN, the Spanish Technology Platform for Plant Biotechnology (Spain)

BIOVEGEN was created in late 2005 as plant biotechnology platform bringing together 24 private companies (nowadays 26) and eight academic centers active in different fields: plant breeding, bioenergy, forestry, fertilizers, ornamentals, fruit trees, plant additives and nutrition. Objectives are the generating of public-private R&D projects, increasing knowledge and technology transfer, contributing to the designing of R&D strategies adapted to the agriculture sector and encouraging increased public and private investment in R&D.

Various activities are carried out in order to achieve these goals:

- Support for R&D projects (connection of supply and demand of technology, advice, coordination, search for funding, etc.),
- Development of a Strategic Research Agenda,
- Partnering events,
- Reports and publications of interest to the sector and databases,
- The Bulletin of Technological Offer/Demand was created as a tool to connect common technological interests between researchers and enterprises for the development of collaborations: R & D projects, exchange of personnel, licenses, contracts, etc.

The structure of BIOVEGEN consists of the assembly (all members), the executive Board (nine members) and the technical secretariat. 44% of the funding is provided by the private sector and 56% by national grants.

In the workshop CITRUSEQ, a PPP in Spain established with the support of BIOVEGEN was presented. CITRUSEQ started in 2009 as collaboration between six private companies and three research organisations and was co-funded by the Ministry of Science and Innovation (total budget of EUR 4 million of which EUR 2.3 million have been provided by the companies). Research activities include sequencing, genotyping and development of genomic tools for the improvement of citrus (sweeter varieties, seedless, more resilient, more flavorful, with different ripening times, etc.).

GIS BV: Group of Scientific Interest Plant Biotechnologies (France)

GIS BV was created following the “Genoplante” network which was established in 1999 and fostered for more than ten years the development of collaborations between French public and private partners.

The convention agreement of the GIS “Plant Biotechnologies” was signed in 2011, for the duration of ten years. The management structure consists of Scientific Advisory Board, Governing Council, Managing Board, Intellectual Property and Licensing Committee and the Committee of Sustainable Development.

The aim of the GIS BV is to encourage public-private collaborations with a larger number of partners and research topics, in order to reinforce the competitiveness of the French agriculture and the seed and plant breeding industry. The strategic objectives are adaptation to climate change, optimization of water and mineral use efficiency, the improvement of crop yield and quality in the frame of sustainability intensification and new uses of plant products.

GIS BV follows more than 60 ongoing collaborative research projects. It manages five working groups and organises three to four workshops per year and represents the interest of its members at national and European level.

Examples of research projects with duration of eight to nine years are the following:

- Developing new maize varieties for abiotic stress.

- Breeding of wheat varieties for yield, quality and tolerance to stress (focus on high throughput genotyping and phenotyping).

- Developing new varieties and cultivation systems for miscanthus and sorghum with improved lignocellulosic biomass yield and low environmental impact for industrial applications and second generation biofuels.

- Optimizing the oil content and yield in rape grown under nitrogen stress.

- Improve sunflower genetic resources for the stability of oil production under water stress.

3.3.3. Regional and transnational PPPs

In addition to PPPs which operate primarily at a national level, funding structures have been established at regional and transnational level. The following PPPs were presented during the workshop:

NordGen: Public Private Partnership in Pre-breeding (Finland, Denmark, Sweden, Norway and Iceland)

The Nordic Public-Private Partnership for Pre-breeding was initiated by the Nordic Council of Ministers for Fisheries and Aquaculture, Agriculture, Food and Forestry (NCM–JLS) in 2011. It covers the Nordic region with some cooperation with Baltic States. Stakeholders are NCM–FJLS, NordGen (secretariat), the five Nordic Agricultural Ministries, private plant breeding companies (12 out of 13 plant breeding entities currently active in the Nordic countries) and public institutes and universities involved in plant breeding and plant breeding research.

The PPP started with a pilot phase of three years with a budget of approximately EUR 1 million. Funding is 50:50 by the ministries and the participating plant breeding entities. The pilot phase of the programme is currently evaluated by an international panel. A proposal to continue the PPP-collaboration and to increase the budget to a total of ca. EUR 6 million over the next years has been presented to the five Nordic ministers.

NordGen focuses on pre-breeding activities which according to their understanding covers (i) broadening of the genetic base in a given crop by wide hybridization and introduction of a new and wider genetic variation into the breeding pool of a crop, (ii) introduction of specific traits of importance for a crop into an adapted genetic background (iii) development/adaptation of tools and methods. The projects under the pilot phase target apple, barley and ryegrass.

Pilot-project on pre-breeding in barley

One of the pilot–projects dealing with pre-breeding in barley was presented during the workshop. The project lasts from January 2012 to December 2014 and comprises seven participants, five private companies and two universities.

The main goal is to provide the basis for effective cereal breeding for disease resistance and harvest stability under changing climatic conditions capable to meet current and future challenges in the Nordic region. This will be achieved by developing knowledge, tools and germplasm suitable for this purpose. The project uses 180 barley lines collected from the participants in the project and includes the following work packages:

- **Database development and association mapping**

  A database will be established by collecting available and creating new data on molecular markers and genetic resources and made available to the project partners.

- **Disease resistance:**

  The project will focus on some "existing diseases" such as Scald (*Rhynchosporium secalis*) and Net blotch (*Drechlera teres*) and some "new and emerging diseases" such as Ramularia leaf spot (*Ramularia collo-cygni*), Spot blotch (*Bipolaris sorokiniana*) and Fusarium head blight (*Fusarium spp*).

- **Climate change:**

Field trials in two locations (Denmark and Iceland) in two years are evaluated for lodging, earliness, plant height, straw and ear breaking and alleles of the *Denso* dwarfing genes.

- **Preparing for the future:**

The project will be continued in a second phase with stronger emphasis on long term goals.

PLANT-KBBE - Transnational Plant Alliance for Novel Technologies – towards implementing the Knowledge-Based Bio-Economy in Europe (France, Spain, Germany, Portugal and Canada)

PLANT-KBBE is a funding initiative for plant breeding research which started as a trilateral activity of France, Spain and Germany in 2003 and was gradually expanded with funding partners from Portugal and Canada. Initially PLANT-KBBE funded only public research institutes. Consortia applying to more recent calls have to consist of public and private entities.

Project for improving eucalyptus and poplar properties for bioenergy

In the workshop a project on eucalyptus and poplar species was presented. The duration of the project is three years. It involves four private and nine public partners in four countries and funds of EUR 2.2 million.

The main challenge for efficient use of eucalyptus and poplar for biofuels is the recalcitrance of cell walls to breakdown and the main goal of the project is to address this issue. The following tasks are carried out under this project:

- Identification and functional characterization of candidate genes (responsible for transcriptional and post-transcriptional regulation of wood formation).
- Develop high-throughput phenotyping for key wood and cell wall constituents.
- Compare the structural and functional architecture of wood quality in eucalyptus and poplar by improving the resolution of available genetic maps using high-throughput genotyping methods and common markers; locating precisely and assessing quantitative trait loci (QTLs) for wood properties relevant to bioenergy; and dissecting a major lignin QTL.

3.3.4. Global PPPs

The workshop did not focus on global co-operation in breeding R&D. However for completeness it should be mentioned that such co-operation exists and European countries participate. Two prominent examples are:

International Wheat Initiative

It was launched in September 2011 and coordinates worldwide research efforts in the fields of wheat genetics, genomics, physiology, breeding and agronomy.

Wheat Yield Network (WYN)

The initiative was launched in 2012 and aims at increasing wheat's genetic yield potential by 50 percent in the next 20 years. It originates from the CIMMYT Wheat Yield Consortium (Centro Internacional de Mejoramiento de Maíz y Trigo; International Maize and Wheat Improvement Center*).*

4. Conclusions

Partnerships in plant breeding take place between two or a larger number of public or private institutes and companies on national or international level. The term "public-private partnerships" is used for different forms of cooperation between the public and private sectors in plant breeding such as collaborative projects, programmes, platforms and clusters.

PPPs are common in other fields (especially in the infrastructure sector) where cost-benefit analysis is carried out. Usually no economic studies are carried out by the public sector before deciding to establish PPPs in plant breeding. Private companies decide to participate in PPPs or not on the basis of cost-benefit considerations.

Projects under European PPPs mainly focus on strategic crops (i.e. relevant for the market) and on strategic traits (relevant e.g. for climate change adaptation, food security and use for biofuels). PPPs provide a valuable basis for crop breeding through development of technologies and pre-breeding. However, strategies for translating results into new varieties are generally missing. Additionally, PPPs are not yet being used for the development of minor crops (crops which are not widely grown).

Projects under PPPs established at national or international level usually last for approximately three years. Developing new varieties takes much longer. Approaches used in other fields (e.g. in the infrastructure sector) where PPPs are established for some thirty years are not (yet) used in plant breeding.

Advanced breeding technologies have created unprecedented opportunities for advances in biological performance of crops. However, some of the key technologies are not affordable for many (especially smaller) public and private institutes and companies. Hence PPPs are needed to increase accessibility of modern technologies.

The changing climatic situation in Europe could have major impact on agriculture during the next decades. Co-operation in plant breeding addressing the challenge of climate change exists or is in development.

PPPs may be a valid approach to increase accessibility of technologies which are protected by IPR and of germplasm. Some of the PPPs provide specific services in this context.

ANNEX 1: List of participants to the workshop

Workshop on "Public-Private-Partnerships in Plant Breeding"

Date: 19th – 20th September 2013

Venue: Isla de la Cartuja, Edificio Expo, 1st floor, **Room A40**, c/ Inca Garcilaso 3, Seville, Spain

Organisers: JRC-IPTS

Final LIST OF PARTICIPANTS

EXTERNAL PARTICIPANTS	
Amine Abbadi	Norddeutsche Pflanzenzucht Hans-Georg Lembke KG, Germany
Francisco Areal	University of Reading, United Kingdom
Ahmed Jahoor	Nordic Seed, Denmark
Jean-Paul Judson	European Seed Association, Belgium
Mati Koppel	Estonian Crop Research Institute, Estonia
Denis J Murphy	University of South Wales, United Kingdom
James Phillips	BBSRC, United Kingdom
Jorge Pinto Paiva	Instituto de Investigação Científica Tropical (IICT), Portugal
Romain Piovan	GIS Biotechnologies Vertes, France
Morten Rasmussen	NordGen - Nordic Genetic Resource Center, Sweden
Laura Riesgo	Universidad Pablo de Olavide, Sevilla, Spain
Gonzaga Ruiz de Gauna	Biovegen, Spain
David Thompson	Syngenta Seeds Ltd, United Kingdom

EUROPEAN COMMISSION	
Jacques Delincé	Joint Research Centre (JRC-IPTS)
Gaetan Dubois	General Directorate for Research and Innovation (DG RTD)
Maria Lusser	Joint Research Centre (JRC-IPTS)
Stephen Langrell	Joint Research Centre (JRC-IPTS)
Ivelin Rizov	Joint Research Centre (JRC-IPTS)
Emilio Rodríguez Cerezo	Joint Research Centre (JRC-IPTS)

ANNEX 2: Agenda

Workshop on "Public-Private-Partnerships in Plant Breeding"

Date: 19th – 20th September 2013

Venue: Isla de la Cartuja, Edificio Expo, 1st floor, **Room A40**, c/ Inca Garcilaso 3, Seville, Spain

Organisers: JRC-IPTS

Chair: Maria Lusser, JRC-IPTS

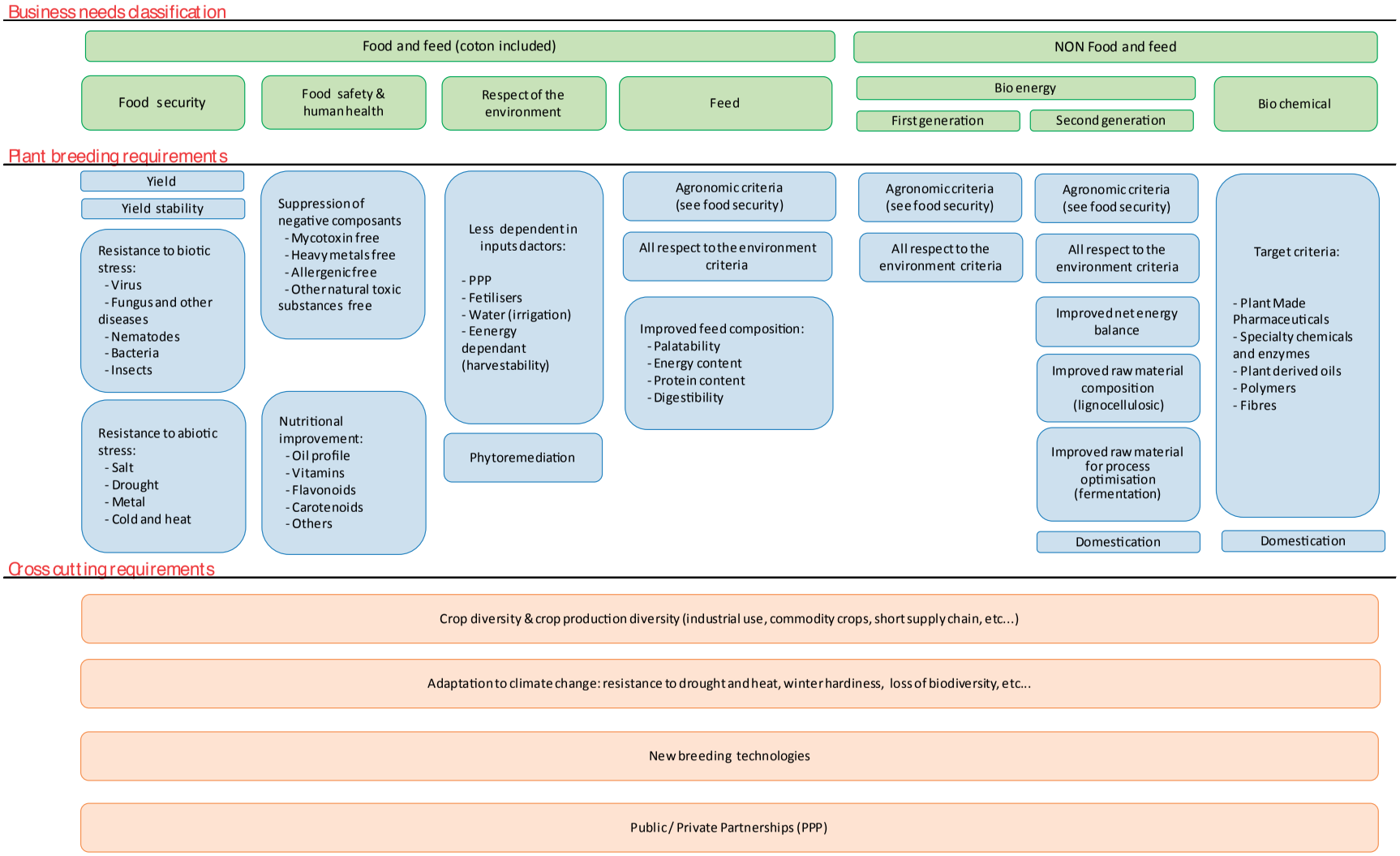
Final AGENDA

Day 1 – 19 September		
9:00-9:15	Welcome	**Jacques Delincé** Joint Research Centre (JRC-IPTS), Spain
9:15-9:30	Introduction to JRC-IPTS and AGRITECH research on plant breeding Objectives of the workshop	**Maria Lusser** Joint Research Centre (JRC-IPTS), Spain
Session 1	**Overview of PPPs in plant breeding**	
9:30-9:50	Definitions of PPPs Overview of involvement of public institutes in PPPs	**Maria Lusser** Joint Research Centre (JRC-IPTS), Spain
9:50-10:20	Private plant breeders and public private partnership	**Jean-Paul Judson** European Seed Association, Belgium
10:20-10:50	Coffee break	
10:50-11:20	Projects on plant breeding under the EU Framework Programmes and Horizon 2020	**Gaetan Dubois** General Directorate for Research and Innovation (DG RTD), Belgium
11:20-11:50	Discussion	
Day 1 – 19 September (continued)		
Session 2	**Issues relevant for establishing PPPs**	
11:50-12:50	Modern plant breeding technologies and PPPs	**Denis Murphy** University of South Wales, United Kingdom

12:50-13:20	Climate change	**Mati Koppel** Estonian Crop Research Institute
13:20-14:20	Lunch break	
14:20-14:50	The economics of public-private partnerships in plant breeding	**Francisco Areal (speaker)** University of Reading, United Kingdom **Laura Riesgo** Universidad Pablo de Olavide, Seville, Spain
14:50-15:20	Discussion	
15:20-15:50	Coffee break	
Session 3	**Examples of PPPs in plant breeding and other forms of co-operation (part 1)**	
15:50-16:50	NORDGEN Public-Private Partnership for pre-breeding – a Nordic model Pre-breeding: a forgotten and underutilized tool	**Morten Rasmussen** NordGen - Nordic Genetic Resource Center, Sweden **Ahmed Jahoor** Nordic Seed, Denmark
16:50-17:20	GIS Botechnologies Vertes	**Romain Piovan** GIS Botechnologies Vertes, France
17:20-17:50	Discussion	
21:00-23:00	Dinner	

Day 2 – 20 September		
Session 3	**Examples of PPPs in plant breeding and other forms of co-operation (part 2)**	
09:30-10:30	BBSRC CIRC BBSRC: Breeding Collaboration PPP and Innovation	**James Phillips** BBSRC, United Kingdom **David Thompson** Syngenta Seeds Ltd, United Kingdom
10:30-11:00	Biovegen	**Gonzaga Ruiz de Gauna,** Biovegen, Spain
11:00-11:30	Coffee break	
11:30-12:30	PLANT 2030 PPP in PLANT2030: The case of the PRE-BREEDYIELD Project TREEFORJOULES, a Plant KBBE project to improve eucalypt and poplar wood properties for bioenergy	**Gunhild Leckband**, **Amine Abbadi (speaker)** Norddeutsche Pflanzenzucht, Germany **Jorge Pinto Paiva (speaker)** Instituto de Investigação Científica Tropical (IICT), Portugal **Authors: Grima-Pettenati J., Leplé J.C., Gion J.M., Harvengt L., Fladung M., Schmitt U., Meier D., Kamm B., Leal L., Pinto Paiva J., Rodrigues J., Ruiz-Fernandez F., Canton F.R., Gallardo F., Allona I., Sixto H.**
12:30-13:00	Final discussion	

ANNEX 3: Table of breeding needs per agro food supply chain business sector



Source: Arcadia International

ANNEX 4: Papers

Definitions of PPPs

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The majority of publications on public-private partnerships (PPPs) deals with PPPs which provide, manage and maintain infrastructure or public services, i.e. PPPs as a form of public procurement. Examples are transport (e.g. highways, tunnels and bridges), water (supply and waste water treatment systems), health care and welfare programmes. Consequently, also definitions used by organisations or in publications usually refer to this kind of PPPs. Also the European Commission has introduced PPPs as a public procurement approach (see below).

The World Bank defines PPP as "A long-term contract between a private party and a government agency, for providing a public asset or service, in which the private party bears significant risk and management responsibility"[27]. In a publication from 2008[28] the OECD provided a summary of definitions of PPPs concerning public services or infrastructure which are listed in the Box 1. All these definitions show common features: They describe relationships between the government (public body) and the private sector with the aim to provide, manage and maintain infrastructure and services which traditionally were provided by the public sector. The approach of PPPs is chosen in order to use public funds more efficiently, share risk, and to make best use of available knowledge and assets. The OECD has also established principles for public governance of public-private partnerships[29].

On the other hand, in the field of technology innovation, the term PPPs is less clearly defined. The OECD has produced a review on "Public/Private Partnerships in Science and Technology" which provides a definition (see BOX 2). The publication explicitly excludes "contract research mechanism for subsidising industrial R&D" from the definition of PPPs. Apart from that all kinds of joint activities between public and private sector with a broad range of possible goals appear to fall under the definition (see BOX 2).

The European Commission promotes "Partnering in Research and Innovation" as a tool to overcome the economic and financial crisis[30]. This term includes public-public partnerships (P2Ps) and public-private partnerships (PPPs). In the framework of the EU Single Market policies a new proposal for ta directive on concessions (EU rules on setting up public-private entities) has been submitted in 2011[31]. Under the Seventh Framework Programme for Research (FP7)[32], the Competiveness and Innovation Programme (CIP)[33] and the European Research Area (ERA) and the Innovation Union policy framework, different forms of partnering have been developed and piloted. This policy is continued under Horizon 2020. Also in this context, the European Commission does not define the term PPPs. However, the European Commission defined criteria which have to be met by PPPs in order to be accepted for participation in Horizon 2020[34]. The summary of these rules as provided in a brochure of DG RTD are included in BOX 3.

27 Public-Private Partnerships Reference Guide (2012), The World Bank, Washington, Unites States. http://ec.europa.eu/internal_market/publicprocurement/partnerships/public-private/index_en.htm

28 Public-Private Partnerships - In Pursuit of Risk Sharing and Value for Money, OECD.

29 OECD Principles for Public Governance of Public-Private Partnerships http://www.oecd.org/governance/oecdprinciplesforpublicgovernanceofpublic-privatepartnerships.htm

30 Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Partnering in Research and Innovation. COM(2011) 572 final.

31 http://ec.europa.eu/internal_market/publicprocurement/partnerships/public-private/index_en.htm.

32 Decision no 1982/2006/EC of the European Parliament and of the Council of 18 December 2006 concerning the Seventh Framework Programme of the European Community for research, technological development and demonstration activities (2007-2013)

33 Decision no 1639/2006/EC of the European Parliament and of the Council of 24 October 2006 establishing a Competitiveness and Innovation Framework Programme (2007 to 2013)

34 Council of the European Union, Conclusions on partnering in research and innovation, 3133rd Council meeting Competitiveness (Internal Market, Industry, Research and Space), Council meeting, Brussels, 6 December 2011

BOX 1:Definitions of public-private partnerships (public services or infrastructure)

In this book ("Public-Private Partnerships - In Pursuit of Risk Sharing and Value for Money", OECD, 2008), the OECD, defines a public-private partnership as an agreement between the government and one or more private partners (which may include the operators and the financers) according to which the private partners deliver the service in such a manner that the service delivery objectives of the government are aligned with the profit objectives of the private partners and where the effectiveness of the alignment depends on a sufficient transfer of risk to the private partners.

According to the International Monetary Fund, public-private partnerships (PPPs) refer to arrangements where the private sector supplies infrastructure assets and services that traditionally have been provided by the government. In addition to private execution and financing of public investment, PPPs have two other important characteristics: there is an emphasis on service provision, as well investment, by the private sector; and significant risk is transferred from the government to the private sector. PPPs are involved in a wide range of social and economic infrastructure projects, but they are mainly used to build and operate hospitals, schools, prisons, roads, bridges and tunnels, light rail networks, air traffic control systems, and water and sanitation plants.

For the European Commission[30], the term "public-private partnership" is not defined at Community level. In general, the term refers to forms of co-operation between public authorities and the world of business which aim to ensure the funding, construction, renovation, management and maintenance of an infrastructure of the provision of a service[31].

Standard and Poor's[32] definition of a PPP is any medium- to long-term relationship between the public and private sectors, involving the sharing of risks and rewards of multi-sector skills, expertises and finance to deliver desired policy outcomes.

For the European Investment Bank[33], "public-private partnership" is a generic term for the relationship formed between the private and public bodies often with the aim of introducing private sector resources and/or expertise in order to help provide and deliver public sector assets and services. The term PPP is thus used to describe a wide variety of working arrangements from loose, informal and strategic partnerships, to design-build-finance-and–operate (DBFO) type services and formal joint venture companies.

35 Green Paper on Public-Private Partnerships and Community Law and Public Contracts, COM(2004)237 Final, European Commission, Brussels.

36 The EC has published more recent documents on PPPs. However the statement on the use of PPPs by the EC described by the OECD publication still applies.

37 Public Private Partnerships: Global Credit Survey (2005), Standard and Poor's, New York, United Sates.

38 The EIB's Role in Public-Private Partnerships (PPPs), European Investment Bank, Luxembourg, http://www.eib.org/attachments/thematic/eib_ppp_en.pdf

BOX 2: Definitions of public-private partnerships (technology innovation) [39]

In the area of technology policy, the term "public-private partnership" can be defined as any innovation-based relationship whereby public and private actors jointly contribute financial, research, human and infrastructure resources, either directly or in kind. As such, partnerships are more than simply a contract research mechanism for subsidising industrial R&D. Partnerships can be formal or informal arrangements governing general or specific objectives in research or commercialisation and involve two or more actors (e.g. consortia). While informal arrangements exceed formal partnerships, such arrangements become more structured when costs and benefits are directly accountable (either in kind or direct). ...

... At a general level, public/private partnerships can be classified according to the types and characteristics of actors involved, including: i) university-industry partnerships; ii) government (including laboratories)-industry partnerships; iii) research institute-industry partnerships; and iv) a combination of the above, such as partnerships linking multiple government research institutes to one another and to industry. ...

... Public-private partnerships can also be classified according to the functional objectives and goals of governments, such as support for strategic research and technology development; improving the mechanism of commercialisation and technology diffusion; generating spinoffs and technology-based firms. In addition, providing access to innovation financing and training, and stimulating networking among innovation actors have become more explicit objectives of partnerships. ...

BOX 3: Criteria for PPPs for receiving funds under Horizon 2020[40]

... For any PPPs to be supported as part of Horizon 2020, they will need to meet all the required criteria. In the European Commission's proposal, these include: demonstrating that they provide added value at EU level; a scale of impact on industrial competiveness, sustainable growth, and socio-economic issues which is demonstrably greater than what would be achieved without using the PPP model; organisation founded on the principles of transparency and openness; clear long-term commitment from all partners based on shared vision and clearly defined objectives; a scale of resources deployed that leverages additional investments in research and innovation; clear definition of roles for each of the partners; and, agreed key performance indicators.

39 OECD, Science Technology Industry, Review No. 23, Special Issue on "Public/Private partnerships in Science and Technology".

40 New public-private partnerships for research in the manufacturing, construction and automative sectors, European PPP research support recovery Progress Report: July 2012: http://ec.europa.eu/research/industrial_technologies/pdf/ppp-in-manufacturing-construction-automotive-sectors_en.pdf

Overview of involvement of public institutes in PPPs

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In 2012, JRC-IPTS managed an outsourced study on "Plant breeding for an EU bio-based economy 2020"[41]. The study was carried out by Arcadia International, Brussels. This study provides preliminary information on the involvement of public institutes in PPPs and other forms of public-private cooperation.

The study focused on breeding activities leading to the release of new cultivars and carried out by public breeding institutes. This included molecular breeding activities in support to germplasm characterisation and to variety development. However, other pre-breeding activities and research were excluded. The main objectives of the study were to review of the main breeding needs for the EU bioeconomy 2020, to evaluate the breeding needs which are currently not or insufficiently covered by the private sector and to map the current status, capacity and potential of the public plant breeding sector including public-private cooperation.

The study also provided preliminary information on contracting in and out of services and the involvement of public institutes in public-private partnerships and other forms of cooperation. The following paragraphs present results from the study (from the study report and from the raw data).

The table below shows that some 5% of the expenditure is used for contracting in services. Whereas services in molecular breeding are mainly contracted in from other public institutes, other services related to breeding are mainly provided by private institutes. Contracting out, mainly to private companies, achieves income of approximately EUR 1 million per year.

The questionnaire of the "general survey" carried out in the study (directed to public institutes involved in breeding activities leading to the release of new cultivars) asked about the involvement in public-private partnerships and its nature. Approximately half of the participating institutes are involved in PPPs. Only one of these institutes is based in the EU 12. The PPPs concern activities such pre-breeding, resistance breeding and providing pre-breeding material or varieties to private companies.

Complementary to the "general survey", a "specific survey" was directed at public breeding institutes not involved in breeding activities leading to the release of new cultivars. Ten questionnaires completed by representatives of public institutes only state that they have projects under PPPs. Many of the projects were carried out under national or EU programmes and they related to activities such as molecular breeding, genome sequencing, field evaluation, developing breeding and selection tools and breeding for resistance, efficiency of nitrogen uptake, photosynthetic efficiency and climate change adaptation.

Table 1: Contracting in and contracting out activities by public plant breeding institutes in the EU 27 I 2010 (amounts in kEUR)

	Molecular Breeding	Germplasm Collection & Charact.	Variety Development	Variety Testing	Total
Contrating IN	**344**	**108**	**207**	**150**	**809**
Of which from public organisations (%)	80	10	25	10	
Of which from private organisations (%)	20	90	75	90	
Contracting OUT	**2**	**46**	**180**	**828**	**1,056**
Of which to public organisations (%)	0	3	0	2	
Of which to private organisations (%)	100	97	100	98	
Balance	**-342**	**-62**	**-27**	**678**	**247**

Source: Arcadia International

41 van Elsen et al. (2013) Plant breeding for an EU bio-based economy. The potential of public sector and public/private partnerships. Arcadia International, Belgium.

Private plant breeders and public-private partnership

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There are many interests at stake in the formation of a public private partnership: stimulating research and innovation, responding to societal challenges, leveraging private investment and developing networks and platforms that would otherwise not come about. There are also different types of objectives: fostering new collaborative approaches across sectors, tackling bottlenecks in a specific sector, encouraging multidisciplinary and cross-border partnerships or generating long-term strategic alliances. Finally, there are the specific objectives of the funding partners involved, both public and private. Looking at how the concept of public private partnership applies to the plant breeding sector, from the breeders' perspective, requires qualifying the sector, its practices and its challenges.

At the very start of the crop production value chain, plant breeding companies invest up to 20% of their annual turnover on further R&D. In comparison to other sectors in Europe, breeding companies invest heavily in research due to a market pull from farmers who request the best performing varieties. Also, the seed marketing legislation in Europe has created the conditions for a market push towards further innovation, by setting out specific criteria that varieties need to meet in order to be marketed in the EU.

Furthermore, innovations in the plant breeding sector are not protected in the same way as in other sectors. In plant breeding, a specific IPR system applies ("plant variety rights"), which essentially allows access to protected varieties for further research and breeding. So the basis for innovation in the sector is "open access" to genetic resources, which means that companies work in any case "in partnership" and depend on each other's innovations to bring their own new products to the market.

The presentation will look at four examples of public private partnership, in the Nordic countries (NordGen), in Germany (GABI), in the Netherlands (CBSG) and a transnational initiative (Plant-KBBE). It will aim to highlight what are the key drivers for public private partnership in plant breeding, and what are the key elements that companies are looking for. It will also reflect on what types of initiatives may be needed at European level to effectively complement national and private research spending.

Modern plant breeding technologies and PPPs

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The purpose of this paper is to review the availability of modern plant breeding technologies in the context of public-private partnerships (PPPs) and the utility of such PPPs for practical crop improvement. This includes topics such as access to relevant datasets, biotechnologies, molecular resources, germplasm pools plus availability of nearer market breeding/multiplication infrastructure such as large glasshouses and field sites and associated breeding expertise. It also encompasses access to more downstream activities required for successful commercialization such as regulatory methodologies, farmer/retailer/customer relations and other market interfaces. Any consideration of plant breeding PPPs should consider the entire spectrum of R&D activities ranging from basic research (pre-breeding) all the way to commercial application of crop varieties in agriculture.

In historical terms, the process of breeding improved plant varieties for agriculture has relied on PPPs ever since the beginnings of scientific breeding at the start of the 20th century. As a generalization, most of the underpinning basic research and theoretical work occurred in universities. Examples include development of quantitative breeding theory, induced mutagenesis, plant tissue culture and crop genetics. In most developed countries, public sector research institutes served to apply some aspects of these fundamental advances to specific crops of local interest as part of their mission to carry out strategic research. In some cases this included the development of new crop varieties that could be released to private sector seed companies for immediate multiplication and sale to farmers. In other cases, institutes released partially improved varieties that still required considerable downstream development (e.g. crossing into existing well-known elite lines) by private seed companies.

With the notable exception of the Pioneer Hi-Bred Corn Company and its hybrid maize in the USA, the more upstream plant breeding research activities were not a major focus for much of the private sector during the first two thirds of the 20th century. Although there were significant advances in the yields of many temperate commercial crops during this period, the majority of these improvements were due to non-biological inputs such as fertilizers, crop protection agents (pesticides, herbicides, fungicides etc), and mechanization. The most notable agricultural advance of the late 20th century, the Green Revolution of the 1960-70s, depended on a mixture of plant breeding (of semi-dwarf cereals) and the intensive application of inputs (especially fertilizers). The Green Revolution was largely a public sector innovation with private sector input restricted to near-market activities such as seed multiplication and distribution.

By the 1970-80s the yield benefits of non-biological inputs manufactured by the private sector were starting to plateau. This led some of the larger agrochemical companies to extend their R&D interests towards biological technologies, i.e. plant breeding, in order to both maintain yield improvements and to extend their market penetration. This period coincided with three significant developments, namely:

1. Greater commercial protection for new varieties via plant breeders' rights using UPOV

2. Invention of genetic engineering with the prospect of patentable varieties

3. Ideologically driven withdrawal of public sector funding for breeding research and privatization of many public institutes

By the 1990s these developments had created a 'perfect storm' for the public sector whereby both universities and research institutes withdrew from practical plant breeding and focused much more on basic plant science – a process referred to as the 'academisation' of the public sector. To a significant degree we still live with the legacy of this process whereby the public sector funding and career/prestige mechanisms remain based largely on academic credentials such as journal impact factors and citation rates. Unlike their predecessors in the 20th century, very few modern plant biologists have expertise in practical plant breeding in the field. During the 2000s, the research focus was on model plant species. In the 2010s, however, the advent of cheap DNA sequencing has started to generate huge amounts of potentially useful data from major crop genomes. One task of modern PPPs should be to leverage these genomic and other data-rich resources for practical breeding as well as for academic research.

In contrast, major multinational agbiotech private companies have tended to focus much of their breeding work on readily protectable technologies such as GM wherever possible. In some cases this includes new varieties developed by non-GM breeding where the newly developed varieties are crossed with GM lines as one of the final stages of the breeding process. This results in a new crop variety with a desirable non-GM trait (e.g. more nutritious oil composition) that is packaged into an existing GM trait (e.g. herbicide tolerance) to create commercial seeds that have full IPR protection. Since the inception of large scale commercial GM cultivation in 1996, this technology has spread throughout much of the world (with the notable exception of Europe) and now accounts for 12% of global cropland. Despite this, 1st generation GM technology is very restricted in the actual transgenic traits available and much of its success has been due to its favourable IPR status and farmer convenience.

The corporate agbiotech sector has launched numerous PPPs in developing countries with mixed success and some NGO charitable funders (e.g. Gates, Rockefeller) have supported such initiatives. The agbiotech sector faces several challenges in developing countries but reduction of public funding and decline of public sector activities such as seedbanks and extension services have created a vacuum into which private companies can move – often via PPPs partially funded by NGOs. The continuing lack of public sector expertise and capacity in near market plant breeding in many developed countries is a barrier to the creation of fully credible North-South PPPs that are directly focused on practical crop improvement. This is especially true for the many 'orphan' crops (e.g. sorghum, cassava, yams) that are dietary staples in developing countries but have not yet been subject to the many decades of intensive R&D and modern breeding devoted to commercial commodity crops such as wheat, maize, rice and potato.

In terms of technology improvement these are some of the major opportunities and challenges for the next decade.

- Modern biotechnologies are increasingly reliant on non-biological hardware (e.g. automated DNA sequencers, metabolite analysers, and non-invasive phenotyping systems or phenomics); and software (e.g. data analysis and information handling systems) systems

- Core technologies such as genomics, proteomics, and QTL analysis are greatly extending the range and precision of trait manipulation by breeders

- The extension of variation, or 'genome enhancement' can be achieved by a range of non-transgenic technologies such as TILLING and wide hybrids

- Transgenic technologies are being improved to minimize undesirable outcomes such as gene silencing and the transfer of unwanted DNA, to target transgenes to specific genomic locations, and to provide more precise forms of transgene regulation

- Marker assisted selection is increasingly being applied to improve efficiency and the range of traits that can be manipulated in crop breeding programs

- The collection, management, and distribution of plant germplasm resources on regional and global scales is an important aspect of crop improvement

In global terms, the challenges of population growth and economic progress mean that crop yields need to increase by as much as 50% in the coming decades. This target is made more difficult by climate change which is giving rise to uncertainties about weather patterns and possible new pest/disease threats. In much of the world where food insecurity is a major issue, many of the immediate solutions will involve existing low-tech approaches that will ideally be delivered via local PPPs. In the longer term, the high-tech modern plant breeding technologies that have already been developed will be vital, not only to improve yields of all crops, but also to do this in a sustainable manner that minimizes undesirable practices such as conversion of pristine land to farming or overuse of chemical inputs.

The current structure of public and private sector R&D is not suitable for the delivery of modern plant breeding advances to practical farming via PPPs. This is especially true for where the technologies are most needed, i.e. in developing countries.

In the past few years, there have been several important initiatives to address this challenge, which will be assessed in the presentation. While these initiatives are a good start, much more radical changes are required in order to enable the public and private sectors to come together in credible decadal-scale PPPs aimed directly at small and larger farmers rather than for short term initiatives or other box-ticking exercises as is so common at present.

The presentation will conclude with a survey of some possible ways forward for PPPs in the context of both European and global agriculture.

Breeding field crops for climate change

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According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, the following climatic changes are expected to occur in Europe by the end of the 21st century.

The average annual temperature in Europe is *likely* to increase more than in the rest of the world; the *largest warming* is expected in northern Europe in winter and in the Mediterranean area in summer period. Winters are presumably going to be shorter and milder with less frosty days and shorter snow season. Increase of maximum summer temperatures are *expected* in southern and central Europe accompanied with increased frequency, intensity and duration of heat waves. Temperature rise increases risk of summer drought in central Europe and especially in the Mediterranean area. Variability of interannual and daily temperatures is *likely* to increase in summer and decrease in winter. The frequency of extreme climatic events (heat waves, heavy rain falls, storms etc.) is expected to increase in whole Europe. The amount of precipitation in different regions of Europe is expected to change in opposite direction. Annual precipitation is *going* to increase in northern Europe and decrease in the Mediterranean area. Extremes of daily precipitation are *very likely* to increase in magnitude and frequency in northern Europe, especially in winter period. Precipitation is *likely* to increase in winter but decrease in summer in central Europe and decrease in the Mediterranean area.

Higher temperatures, decreasing precipitation and higher frequency of drought will decrease the area suitable for crop production and reduce the crop productivity in southern Europe. Additionally, increasing number of areas affected by soil salinity will reduce usable area for crop production. According to different climate change scenarios, the cropland area in EU is estimated to decrease by 28-47% whereas grassland area is expected to decrease by 12-18% by 2050. The area suitable for cultivation of crops adapted to more arid conditions (millets, soy bean, chickpea, sunflower) is expected to increase by 14-31% by the same time. At the same time increased precipitation and prolonged growth period will create more suitable conditions for crop production in northern Europe. Climate change will result in changes of borders of environmental zones and areas of crop cultivation. The Northern zones might see up to 35% of new crop species, when Mediterranean area could see up to 25% reduction in the number of crops. Therefore, breeding of new crop species for adaptation to local photoperiod, edaphic and climatic conditions, is required in both areas. New and more productive crops like grain maize are needed in northern areas to gain from more favourable conditions. The Mediterranean area, in the contrary, requires new drought and heat tolerant crops for maintaining the food production and continuity of farming practices.

Crop diversity in landscape and field level provides more tolerance against extreme climate events. Availability of wide range of crops and varieties with different demands for growing conditions and different growing patterns increases the flexibility and sustainability of agroecosystems and increases their tolerance to variable weather and extreme weather events. Therefore, breeding programs should focus not only on major crops but should deal with multitude of agricultural crops including crops of minor use and emerging future crops to cope with climate changes.

More focus should be put on breeding for traits related to drought and heat stress tolerance in currently cultivated crops. Cereals with bigger and deeper root system and enhanced water uptake capacity, prolonged flag leaf duration with increased ability to survive green at droughty conditions are important water stress avoidance traits that require more focus in breeding programs. Highest yield reduction is caused by prolonged high temperatures at flowering time. Therefore, breeding for changed plant phenology for shifting flowering time towards the period when probability of high temperatures is lower and compensating it with prolonged grain filling period could be a successful breeding strategy. In certain regions the replacement of winter crops with spring ones or vice versa could be a suitable possibility to avoid heat stress at critical periods of plant development.

In Nordic countries the traditional varieties of overwintering crops are bred for cold tolerance and long survival under the snow cover. Changing climate requires varieties with new type of winter hardiness. New varieties should tolerate repeated freezing and melting, temporary flooding and prolonged ice coverage.

Frequency of occurrence of biotic stresses caused by pest and diseases is expected to increase in all areas. Climate change will foster evolution of new pathotypes and cause new pests and diseases to move into currently pest free areas. As the higher climate variability increases uncertainty in the pest control, breeding for pest and disease resistance becomes more important than it is now. Higher temperatures suppress plant response reactions to certain pathogens, like cereal rusts and powdery mildew, therefore modified types of host resistance are required to incorporate into breeding programs for successful pest management.

In summary, breeding of diverse crops and varieties, adaptation of new crops, breeding for heat and drought tolerance, breeding for changed overwintering conditions and resistance to pests and diseases are important breeding tasks in breeding of field crops for maintaining food productivity and farming practices in changing climatic conditions.

The economics of Public Private Partnership in plant breeding

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(presenter)

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Public-private partnerships (PPPs) have become an increasingly popular way to deliver public projects and services by governments. Traditionally PPPs have been used to deliver public services that needed significant funding such as roads, bridges, schools and hospitals. Despite public and private financial funding has been devoted for plant breeding research in the EU the delivery of new varieties is considered insufficient to fulfil the needs of the EU bio-economy strategy 2020 (van Elsen et al., 2013). We identify and discuss the main aspects associated with funding plant breeding research using PPPs from an economic perspective.

Introduction

Plant breeding research activities have focus mainly on food and feed crops (mainly grains) with little attention being paid to non-food and non-feed crops. Private research has clearly focused on more profitable alternatives from a private point of view leaving some research areas unexplored. These under-researched areas may bring social benefits that could justify its public funding. In this respect PPPs[42] could be used to target research on under-researched areas that have associated social benefits while bringing the expertise from the private sector on creating/identifying demand for new products derived from research.

Plant breeding research can contribute to both the safety and quality of food products. For instance it can contribute to the reduction of toxic components in food (e.g. mycotoxins, pesticide residuals, toxic molecules such as glycoalkaloids, glucosinates). Also, the development of novel plant varieties aiming at stable yields and more environmentally friendly contributes to the sustainability of food production. Finally, plant breeding research may produce positive externalities. For instance plant breeding research conducted by one organisation may benefit other organisations in the plant breeding sector and in other related sectors.

Market Failures of Plant Breeding Research

From an economic perspective public funding may be needed (i.e. there is a need for public intervention) when there is a failure in the market that impedes to achieve a social optimum level in the provision of goods and services (i.e. failure to achieve social efficiency). Common market failures are the case of public goods, market power (e.g. natural monopolies), externalities and ignorance and uncertainty.

The case for consideration of government intervention on plant breeding research can be based on the following grounds. First, the generation of knowledge obtained from plant breeding research, and research in general, has characteristics of a public good. A public good is a good or service that has the features of non-rivalry[43] and non-excludability[44] and as a result would not be provided by the free market. For instance, scientific publications that result from research show these features.

Plant breeding research has associated spillover benefits (i.e. positive externalities) which are the flows of knowledge and the scientific and technical advances obtained by the research that are *shared* with society; the productivity improvements of other firms; rivals' R&D results are positively correlated with own research productivity (Cockburn and Henderson, 1994); and the reduction of costs (Levin and Reiss, 1984; Bernstein and Nadiri, 1989).

"When efficiency is the only relevant goal, the existence of a market failure is a necessary but not sufficient rationale for any public intervention" (Vining and Weimer, 1990). Therefore, before any government intervention (i.e. release public funding to conduct plant breeding research) we should ask whether there is a significant social value in conducting this type of research.

Benefit-Cost Analysis of PPPs

Benefit-Cost Analysis provides rules for deciding which candidate interventions would increase efficiency and which one, if any, should be chosen. Economic analyses find evidence that investment in agricultural research in general yields high returns. These returns include benefits not only to the farm sector but also to the food industry and consumers in the form of more abundant commodities at lower prices. Thus, Griliches (1958) estimated the realised social rate of return of 35-40% and 20% on public and private funds invested in hybrid corn and hybrid sorghum research respectively. Other analyses have found similar rates of

42 We understand public-private partnerships as a process which entails that a public organisation provides funding to private organisations to provide public goods and services.

43 Non-rivalry is present when the consumption of a good or service by one individual does not prevent others from doing the same.

44 Non-excludability occurs when a good or service cannot be provided to one individual without being available to others to enjoy.

return for research on different agriculture commodities (Peterson, 1967; Schmitz and Seckler, 1970; Bredahl and Peterson, 1976; Sundquist, Cheng and Norton, 1981; Huffman and Evenson, 1993). These relatively high social rates of return have been contested by more recent research (Fuglie et al., 1996) that estimates of returns of public agriculture research may be biased upward due to errors in estimates of the research lag (the time lag between research expenditure and eventual research benefits); failure to take into account spillovers from the private sector (i.e. failure to take into account the contribution of the private sector to technology development and diffusion); extra costs of funding research through taxes; costs of technology transfer are neglected or guessed; effects of farm programs that may lead to commodity surpluses; negative environmental, health and safety effects of new technology; and extra costs with resource dislocation and adjustment. Despite these errors Fuglie et al. (1996) reported a drop of the social rates of return to agricultural research between 1915 and 1985 from 60% to 35%, which is still high. To our knowledge no research has been specifically conducted on the social rates of returns to plant breeding research. Therefore we take the assumption that there is a positive correlation between the social rates of returns to plant breeding research and agricultural research. Under this assumption we have a case for government intervention based on social efficiency and social value grounds.

Public-private partnerships work in the following way: 1) Government or local authority decides the service it requires (e.g. conduct research on plant breeding related to non-food and non-feed crops); 2) Government seeks tenders from the private sector for designing, conducting, financing research projects to provide these social goods and services (e.g. knowledge); 3) Capital costs are borne by the private sector; 4) The provision of the service is not self-financing, the public sector pays the private firm for providing it; 5) The public sector is not an owner of assets not provider of services. It buys services from the private sector.

Structuring of PPPs is complex. There are many aims from different parties (investors, lenders, companies providing development and operational services, authorities creating and implementing policies, authorities procuring PPPs, general public).

Improving the efficiency with which public services are delivered should be the main reason to change the public provision of goods and services to another organisational form. In order to evaluate whether PPPs do improve efficiency all costs and benefits should be taken into account in assessing efficiency. Transaction costs theory (Coase, 1937) recognises that production costs (e.g. costs associated with the production of plant breeding research such as labour costs, materials used, renting of buildings) are only part of total costs of organising the supply of a good or service. Transaction costs should also be included. These are costs associated with making, executing, monitoring, bargaining and renegotiating contracts among the entities engaged in the production process. PPPs involve important transaction costs. If the country or region where plant breeding research is required has public research capabilities there would be costs associated with interorganisational rather than intraorganisational transactions (i.e. raise bargaining and monitoring costs). Also it is worth noting that conflicting goals between private and public sector partners may lead to an increase in contract complexity and asymmetric information problems. Ideally a public goal is the minimisation of costs although usually is reduced to seek re-election (i.e. minimising budget expenditures). In contrast the main private goal is to maximise profit. Bargaining and opportunism costs are transaction costs related to the degree of difficulty in specifying and monitoring the terms and conditions of a transaction. Thus, complex tasks involve uncertainty about the nature and costs of the production process itself. The greater the uncertainty the greater the bargaining costs during both contract negotiations and execution.

An important characteristic of PPPs is the treatment they are given in the public accounts. For traditional government-procured projects, the full investment cost of the projects is reported in the budget upfront whereas for off-balance sheet PPPs do not require such reporting. Regarding the annual charges, whereas traditional government capital projects often do not require project lifecycle costs (other than the initial capital investment) to be budgeted ex-ante (i.e. such costs typically need to be approved every year), PPP projects require budgeting annual payments to the nongovernment partner. This means that an off-balance sheet PPP results in a shift in commitments from a capital budget (today) to an operating budget (over the years to come) with investments having no impact on the deficit/surplus and will not have an impact on the debt which is particularly important for governments that have as a goal to keep budget and debt targets under control.

If the public sector decided to provide social goods and services associated to plant breeding research it would need to find institutional arrangements that minimise the total costs of supply including making, executing and monitoring contracts. Also it would need to introduce ex-ante competition at the bidding stage (tendering process) to induce low costs. If there are not enough competent bidders of consortium to ensure competition taxpayers may not get value for money. Another important point would be to create ways to ensure that private-sector expertise, innovation and the management of risk are included into the provision of public services.

Conclusions

A large part of agricultural research services are not public goods and can be provided by private producers. However, there are social returns to plant breeding research that may require public intervention if social efficiency is not achieved and there is a significant social value associated to it.

There is no single recipe for what way to fund neither agricultural research nor plant breeding research being PPPs a way in which public goods and services can be provided. Cost-Benefit analysis should be conducted for alternative funding options. At a country level the decision of using PPPs to provide goods and services related to plant breeding research depends on the country research capabilities. If there are countries with research capabilities there would be less rationale for using PPPs. PPPs could be used in cases where private efficiency is sufficient to overcome the extra financing costs of using private interest rates and transaction costs.

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Nordic Public-Private Partnership for Pre-Breeding Description of the program

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1) Background for establishing a Nordic Public-Private Partnership for Pre-Breeding (PPP) of cultivated plants

Plant breeding in the Nordic countries is rather diverse. The climatic and agro-ecological differences between countries and between regions within the countries are large. Also regional geo-physical differences and differences in the socio-economical history and status of agriculture have to be taken into account. Access to high quality seeds of adapted cultivars is a priority for all countries.

No other regions in the world produce food this far in the north, and as a consequence the Nordic region must provide for their own varieties; germplasm adapted to 16+ hours of light in summertime cannot be found in other parts of the world. For the most southern parts, plant breeding activities in neighbouring European countries can provide access to well adapted cultivars. However the ambitious environmental goals of the Nordic countries cause strong pressure to reduce the environmental footprint of agricultural production, set quite high demands on cultivar performance concerning disease resistance, nutrient use efficiency, and stable quality traits.

Plant breeding in the Northern countries has very long history. The initiatives were taken both by private seed companies and by public institutions and agricultural universities. Today the Nordic countries have 13 agricultural plant breeding entities, eight of these are private companies (predominantly owned by farmers), two are private with major public shareholders and three are public institutes or universities carrying out plant breeding and variety development for marginal areas. Most of the plant breeding entities are small or medium sized; however two are amongst the main plant breeders within their target crops on a global level. Plant breeding in the main crop species is predominantly funded by royalties based on plant variety rights while plant breeding in minor species mainly has a mixed funding from royalty income and different sources of public and/or private sector support. To develop a Nordic Public-Private Partnership it has been very important that all entities were treated equally having similar rights and obligations regardless of the source of funding for their activities.

The last couple of decades have shown a pronounced decrease in the number of crop species in active plant breeding programmes. Plant breeding activities have focused on the main agricultural crops, and many plant breeding programs on minor crops were phased out, sold to other regions or closed down. At the same time the dependency of farmers on adapted germplasm has increased because of climate change, the increasing need of a greener and more environmentally friendly agriculture, the need of sustainable intensification of food production and the need to meet new marked demands.

As research centre costs of labour intensive field scale trials has increased, less and less research of potential interest for plant breeding is performed outside the laboratory. Furthermore the low academic prestige of applied breeding does not motivate researchers to engage in this activity. An increasing, international competition on the seed markets has led the private plant breeding entities to focus on main crop species and on variety production and marketing new varieties. The long term breeding goals and especially pre-breeding activities have as a consequence been difficult to fund by both public and private investors.

2) Definition of pre-breeding: Filling the gap between science and variety production

The concept of pre-breeding is not a single, well established definition. In the Nordic discussions, the focus was set on filling the gap between science and variety production, for whatever reason this gap may have. To be able to address a wide range of crop types, representing the actual plant breeding activities in the Nordic region, it was important to operate with a wide definition of pre-breeding as follows:

- Base broadening: broadening of the genetic base in a given crop by wide hybridization and introduction of a new and wider genetic variation into the breeding pool of a crop.
- Gene introduction: introduction of specific traits of importance for a crop into an adapted genetic background allowing for plant breeding programs to apply these traits in further plant breeding and variety development.
- Development/adaptation of tools and methods in order to speed up the breeding process or in other ways providing a higher efficiency in the breeding program.

All three elements of the definition will contribute to improved access to adapted varieties for Nordic agriculture.

3) Initiation of Partnership and description of stakeholders and roles

Establishing the Nordic Public-Private Partnership for Pre-breeding was decided by the Nordic Council of Ministers (NCM) (http://www.norden.org/en/nordic-council-of-ministers) for Fisheries and Aquaculture, Agriculture, Food and Forestry (MR-FJLS) in February 2011. In this decision the structure of the partnership is defined (http://www.nordgen.org/ngdoc/

plants/ppp_sekr/PPP_Basic_Documents/Basic_documents/PPP_Proposal_Avtal.pdf):

MR-FJLS funds a secretariat held by NordGen, which has the task of setting up the partnership. The partnership is controlled by a steering committee with representatives from all ministries, the plant breeding entities and Nordic agricultural academies.

When setting up the partnership, the secretariat invited all 13 Nordic plant breeding entities dealing with plant breeding for food and agriculture for the Nordic countries to a joined meeting. The plant breeding entities were therefore well informed about the process. 12 of the plant breeding entities agreed to join the partnership.

The frame for the PPP-projects is also set by the MR-FJLS agreement. Projects must be initiated by the plant breeding entities in order to secure direct links to actual plant breeding activities and that initiated projects address core challenges for the individual crops. This criterion is however under debate. The projects must be pre-competitive, and must include a majority of the Nordic plant breeding entities in a given crop. Proposed projects must address concerns for Nordic agriculture. The project funding is 50% from the ministries and must be matched by 50% from the participating plant breeding entities. Contribution in kind is possible; currently the vast majority of the private participants contribute in kind. Finally it is important that all issues with regard to IPR are addressed by the participants before the project is initiated. This criterion has led to formation of consortia agreements between project partners in the individual projects.

The partnership is initiated by a pilot phase of three years. At the end of this phase an external evaluation of the partnership and the projects will be carried out. The budget for the projects in the pilot phase is approximately 8 million DKK per year, including public funding from the ministries and private co-funding from the plant breeding entities.

4) First call

The first call of the Nordic PPP was initiated in the autumn 2011. It targeted the crops barley, forage crops and fruits / berries (http://www.nordgen.org/ngdoc/plants/ppp_sekr/PPP_Basic_Documents/PPP_Calls/PPPFirstCall2011_final.pdf). The call resulted in three applications, one for each targeted crop group. The project proposals were evaluated by a dual procedure involving an external scientific evaluation and an evaluation for relevance carried out by the PPP-SC.

Two of the three proposals were approved initially. The third proposal could be approved after some adjustments had been carried out and clarifications were provided.

5) Ongoing Pre-Breeding projects

The first of the initiated PPP-projects is titled "NordApp – pre-breeding for Future Challenges in Nordic Apples" (http://www.nordgen.org/ngdoc/plants/ppp_sekr/PPP_SC_Approved_Projects/Apple/NordAppNov3.pdf). The project deals with breeding for resistance against apple canker and storage rot in Nordic apple cultivars, and has established a Nordic platform to carry out this work. Large-scale screening for suitable resistance genes has been carried out combined with DNA analyses and marker association. All three remaining Nordic apple breeders from Finland, Norway and Sweden participate.

The second ongoing PPP-project is titled "Combining Knowledge from Field and from Laboratory for Pre-Breeding in Barley" (http://www.nordgen.org/ngdoc/plants/ppp_sekr/PPP_SC_Approved_Projects/Barley/Proposal_Barley_PPP_final.pdf). The project concerns validation, testing and further developing molecular markers for disease resistance and adaptative traits in barley, and adapting these markers to Nordic plant breeding material. Comprehensive field screening has been carried out together with molecular analyses and association studies. The group works with a panel of advanced germplasm from all breeding programs, and has already identified markers useful for Nordic barley breeding. All Nordic barley breeding programs are involved in this project.

The third ongoing PPP-project has the title "PPP for pre-breeding in Perennial ryegrass (Lollium perenne L.)" (http://www.nordgen.org/ngdoc/plants/ppp_sekr/PPP_SC_Approved_Projects/RyeGrass/PPP_pre_breeding_Lolium-final.pdf). The project is a fine example of pre-breeding by base broadening. It targets climatic adaptation of perennial ryegrass to more northern conditions. It performs comprehensive screening of exotic germplasm to identify traits of importance for winter hardiness, persistence and productivity under long-day conditions using genotyping and phenotyping to establish a broad breeding population. All Nordic forage grass breeders participate and also a partner from Estonia is associated to the project.

6) Evaluation and audit

The terms of reference for evaluation were developed by the steering committee and the secretariat, and approved by the Nordic Council of Ministers. An international evaluation panel was appointed. They started working in January 2013, and delivered their report to the Council of Ministers in early June 2013. The evaluation of the program was very positive, and has provided solid conclusions and a number of useful recommendations for future development. The main recommendations were to secure long term engagement. The evaluations furthermore suggest expanding the collaboration to more crops including underutilized crops, where plant breeding is no longer undertaken in the region, by providing a higher level of public funding, and also to develop a stronger strategy to identify and prioritize crops and traits to be addressed in future collaboration.

Simultaneously to the evaluation procedure a mid-term audit was performed. This report has also been important for

the decisions regarding continuation and possible expansion of the collaboration.

A proposal to continue the PPP-collaboration and to increase the budget to the initially indicated level of 25+25 mill. DKK over the next few years has been presented to the five Nordic ministers. The second PPP call is expected to be an open call and to be announced in 2014.

In the pilot phase it was very important especially for the private partners that the immediate benefits of project work packages were clear to justify participation and investment. With growing trust between the plant breeding entities and the funding ministries such issues may become of less importance, but open and clear long-term engagement from the ministries will be decisive.

Four international seminars and workshops were held by NordGen in collaboration with others since 2009 with the aim of identifying crops and traits of relevance and developing regional prioritizations.

A concern has been expressed regarding the strict 50/50 funding scheme. The plant breeding entities being mostly SME's can only allow for a certain level of investment in long term R&D. A successful development of crops for the Nordic region will require additional support of pre-breeding work in Nordic crop by established research centers and the conventional funding structures.

The challenge how to adapt and improve minor/underutilized crops still needs to be addressed. Because of the 50/50 funding structure, private partners cannot engage in pre-breeding activities in such crops.

7) Developments on national and international level

Establishing a Nordic PPP has attracted some interest from the Baltic states and from the EU and information about the partnership and about priorities of crops and traits was provided in the form of a Concept Note. It is hoped that this information will influence the future development of Horizon 2020.

8) Important points when establishing partnerships

Create awareness. All stakeholders must understand the (global and local) challenges for agriculture and food production/food security, the impact of climate change and the urgency to respond to these challenges. They must recognize the importance of access to germplasm in active and successful plant breeding programs to perform efficient pre-breeding. All stakeholders must understand that the development required cannot be left to the market alone, and cannot be successful without involvement of variety breeding.

Keep high level of transparency. Building-up trust between stakeholders and potential project partners is very important, and an efficient and open communication is key in this process. Providing simple, efficient, transparent and easily reachable platforms for information exchange is necessary.

Define and prioritize the problems to be addressed. Pre-breeding can have a wide definition and many goals can be set. In order to be effective and efficient the challenges to be addressed and the types of crops and traits to be targeted by a partnership must be analyzed and identified.

Address regional challenges. Challenges in plant breeding are mostly related to agro-ecological zones and solutions will not be useful for larger regions. Collaboration on a regional level and specifically addressing the main challenges in a given crop is important in order to produce actual results and ensure real impact of the collaboration.

Identify stakeholders. Possible stakeholders must be identified, and their potential to contribute must be assessed. Communication between stakeholders reveals interests and priorities, and also willingness to participate; the capacity and competence they are willing to invest, as well as it is of importance to create an ownership to the process. Mapping potential stakeholders is valuable when setting up new projects.

National authorities must resume showing responsibility for the development of their local agriculture and food production and they must commit **to long term engagements** to do so.

Accept differences in agendas, understand limitations, and respect differences in skills. In partnerships, know the skills of your partner, respect his limitations and build on his strengths. Don't create expectations that cannot be met. This is probably the most common mistake in public-private collaborations.

Develop different strategies for major crops and crops with well-functioning market systems and for minor or underutilized crops. Major differences exist between commercial crops with substantial investments in plant breeding and access to advanced tools and methods and minor/underutilized crops, where investments in plant breeding is limited and access to modern tools and techniques as well as access to sequence information is limited or inexistent. In major crop species, partnering with (private) plant breeders may yield fast progress, even if the targeted region was not initially a market for the breeding program. In minor/underutilized crops other partners may be required to gain efficiency, and partnering with local breeders, farmer communities or minor seed companies, that can provide some market access, may be a way forward. The co-funding ability of such partnerships will differ from those active in large crops.

Keep focus on plant breeding. In projects, focus on the actual needs of the specific crop but not on the needs of a given research group or of an institution. If you solve the

farmers' problem, you probably will solve "bottlenecks" in the system.

Communicate results. It is very important - especially in long term engagements like pre-breeding projects - that clear, measurable and communicable objectives are defined, and results communicated to the funding structures. When embarking in activities that could take > 20 years it is even more important to keep track and provide a base for evaluation and assessment of the investment in order to secure continuity.

A global platform to facilitate establishment of public-private partnerships in pre-breeding should provide guidance and assistance for all above mentioned aspects, and should act as a meeting point for establishing partnerships. Possible tasks could be carrying out surveys for identifying and prioritizing target crops and traits, and for identifying potential stakeholders. The platform could assist in creating awareness on national, regional and global levels. It could provide communication infrastructure for partnerships to be established, and depending on the nature of the partnership even to manage project information and exchange. A global platform could develop strategies and roadmaps for major crops versus minor crops. And finally it could provide practical support through standards for various administrative tasks such as standards for consortium agreements, project contracts, partnership agreements and reporting forms.

Public Private Partnership in Pre-Breeding: Combining Knowledge from Field and from Laboratory for Pre-breeding in Barley

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Summary

The project "Combining Knowledge from Field and from Laboratory for Pre-breeding in Barley" is a pilot-project in the frame of public-private partnership. The main goal for this pre-project is to lay the foundation for effective cereal breeding for resistance and adaptation to changing climatic conditions capable to meet current and future challenges. The main objective of the proposal is to develop and use available molecular markers to screen current breeding material for important traits related to the most important diseases as well as traits linked to effects of climate changes, such as drought tolerance, earliness and lodging. For the verification of already published and available molecular markers, each company will test in total 96 lines. The information concerning the suitability of molecular markers will be shared among the participants. For identification of linked DNA markers, association mapping will be conducted. For this purpose, each breeder will provide 30 lines in order to get as much as possible genetic diversity. The combination of field data and data from high-throughput SNP genotyping will facilitate the identification of linked DNA markers. A work package is dealing with long term activities. Here, it is planned to develop segregating progenies not only for disease resistance but also for the traits underlying climate changes as well as nutrition use efficiency.

Project participants:

Participant	Country
Nordic Seed	Denmark
Lantmännen SW Seed	Sweden
Graminor Breeding AS	Norway
Sejet Planteforædling I/S	Denmark
Boreal Plant Breeding	Finland
Agricultural University of Iceland (LBHI)	Iceland
University of Copenhagen – Faculty of Life Science	Denmark

Time frame

1st of January 2012 to the 31st of December 2014.

Introduction

In all the Nordic countries the commercial breeding programs have a long term focus on the current main diseases of barley. Several research projects have been undertaken, some of them inter-Nordic, and in a few cases DNA markers have replaced disease tests in commercial breeding, but the potential is still underutilized. Therefore, there is a need for a deeper and more structured collaboration to prepare for the future. In addition, the consequences of the climate change, in combination with the goal to reduce fungicide use for sustainable agriculture and food safety, justifies further Nordic projects.

The main goal for this pre-project is to lay the foundation for effective cereal breeding for disease resistance and harvest stability in changing climatic conditions capable to meet current and future challenges in the Nordic region. This will be done by developing physiological, genetic and molecular knowledge, tools and germplasm for the future and better adaptation to growing conditions. More specifically, the primary objective is to develop and use available molecular markers to screen current breeding material for traits related to the most important diseases, as well as important agronomic traits, such as earliness, lodging and straw/ear breaking.

For this purpose, 180 barley lines (30 from each participating breeding company) have been collected.

Work packages

M: Database development and association mapping

Work package M ("Data base development and association mapping") has the tasks to (a) collect publicly available information on molecular markers and genetic resources, (b) to make this information available to the project participants in the form of a database, (c) to convert valuable and commercially important molecular markers into PCR-based markers – where this is necessary and possible (d) to genotype the 30 breeding lines from each of the participating breeders with published markers linked to relevant traits, and send for detection and identification of high throughput Single Nucleotide Polymorphisms (SNPs) by a 9K Illumina Chip, (e) to analyse marker-trait association by linking phenotypic data and the SNPs data in an association analysis, (f) to develop easy-to-use PCR-based markers utilizing new genes identified by the association analysis.

D: Disease resistance

Some diseases have been investigated for a long time (e.g. net blotch and scald), while others are 'new' and evolving in the field (e.g. Ramularia, Bipolaris, Fusarium). Our goal is

to include diseases with severe impact on crop yields under current and future climate conditions. The project includes the following diseases:

1. **Scald** (*Rhynchosporium secalis*), 2. **Net blotch** (*Drechlera teres*), 3. **Ramularia leaf spot** (*Ramularia collo-cygni*), 4. **Spot blotch** or **Bipolaris** (*Bipolaris sorokiniana*), 5. **Fusarium head blight** (*Fusarium spp.*)

Each disease was evaluated at two locations and for two years.

Thus, the combinations listed in the table "Proposed combinations of disease and site" were specified.

The nematode resistance phenotyping was outsourced through the Public partner.

Crossing with material tested in the common pool can be made two years after the end of this project phase. Important issues for future are taken care of in 'Future WP'.

C: Climatic changes

Characterization has been done on the following characters; lodging, earliness, height, straw breaking and alleles of the *Denso* gene. The field trials were evaluated over two years (2012 and 2013) in two locations (Denmark and Iceland).

D: Preparing for the future

The initial project period of two years is too short for long term pre-breeding activities. The parties of the project are agreeing to continue the work in a second phase with stronger emphasis on long term goals. Examples of future perspectives that have been raised are an increased focus on new and emerging diseases, climatic change and increased nutrient use efficiency in barley. To prepare for the next stage of PPP, new sources of resistance will be sought in the literature and crosses will be initiated and segregating progenies will be developed. The main emphasis is on the diseases, which have an increased importance under Nordic conditions such as Spot blotch (*Bipolaris sorokiniana*) and Ramularia leaf spot caused by *Ramularia collo-cygni*. Additionally, a long term goal for the plant breeding is to develop stable varieties with plasticity, which can stand extreme growing conditions such as prolonged spring drought, water logging and nutrient use efficiency.

Table: Proposed combinations of disease and site

Net blotch	Ramularia	Bipolaris	Scald	Fusarium	
	X		z	X	Graminor
			X	X	NOS
	X		X		SW
					Sejet
X		X			Boreal

Presentation of GIS BV

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The plants for tomorrow will have to meet the needs of a productive, competitive and sustainable agriculture, for the food and feed industry and for the sector of renewable carbon sources.

The Group of Interest "Plant Biotechnologies" (GIS BV) aims at developing technologies and skills, in order to produce the knowledge necessary to create innovative crop varieties. It is built on a large public-private partnership community (http://gisbiotechnologiesvertes.com/en/presentation-du-gis-bv/8-presentation/3-membres.html), – 29 members - which gathers public research institutes, seed companies, technical institutes, sector representatives, and competitive clusters.

The GIS BV labels research projects from its members, for scientific topics that fall into the field of the GIS BV. All the labeled projects form together the "Biotechnologies Vertes" program. It is articulated around 4 strategic objectives:

- Adaptation to global change
- Optimization of water and mineral use efficiency
- Improvement of crop yield and quality in the frame of sustainable intensification
- New uses for plant products

History and ambitions

The GIS "Plant Biotechnologies" was created following the "Genoplante" network.

The Génoplante network was created in 1999. For more than ten years, it fostered the development of successful collaborations between French public and private partners, and brought the French plant science research to its highest level in France and in Europe. The ambition of the GIS "Plant Biotechnologies" is to further support the development of large-scale research programs, while measuring up to the current international initiatives in plant biotechnologies. The aim of the GIS BV is to encourage public-private collaborations with a larger number of partners and research topics, in order to reinforce the competitiveness of the French agriculture and the seed and plant breeding industry.

The convention agreement of the GIS "Plant Biotechnologies" was signed in February 2011, for the duration of ten years.

Chair of the Governing Council: François Houllier, President of the French National Institute for Agricultural Research (INRA)

Vice-Chair of the Governing Council: Daniel Chéron, CEO for Limagrain Holding.

Labelled projects

Based on recommendation of the Managing Board and the Governing Council of the GIS BV, The GIS BV labels projects relevant to plant biotechnologies and representative of the strategic research interest of the members. The projects are followed in order to:

- Identify research results from precompetitive projects, and facilitate their visibility
- Provide support for IPR management
- Favor exchange of information and transversality, in particular between plant species

Labeled projects: http://www.gisbiotechnologiesvertes.com/en/projets-labellises.html

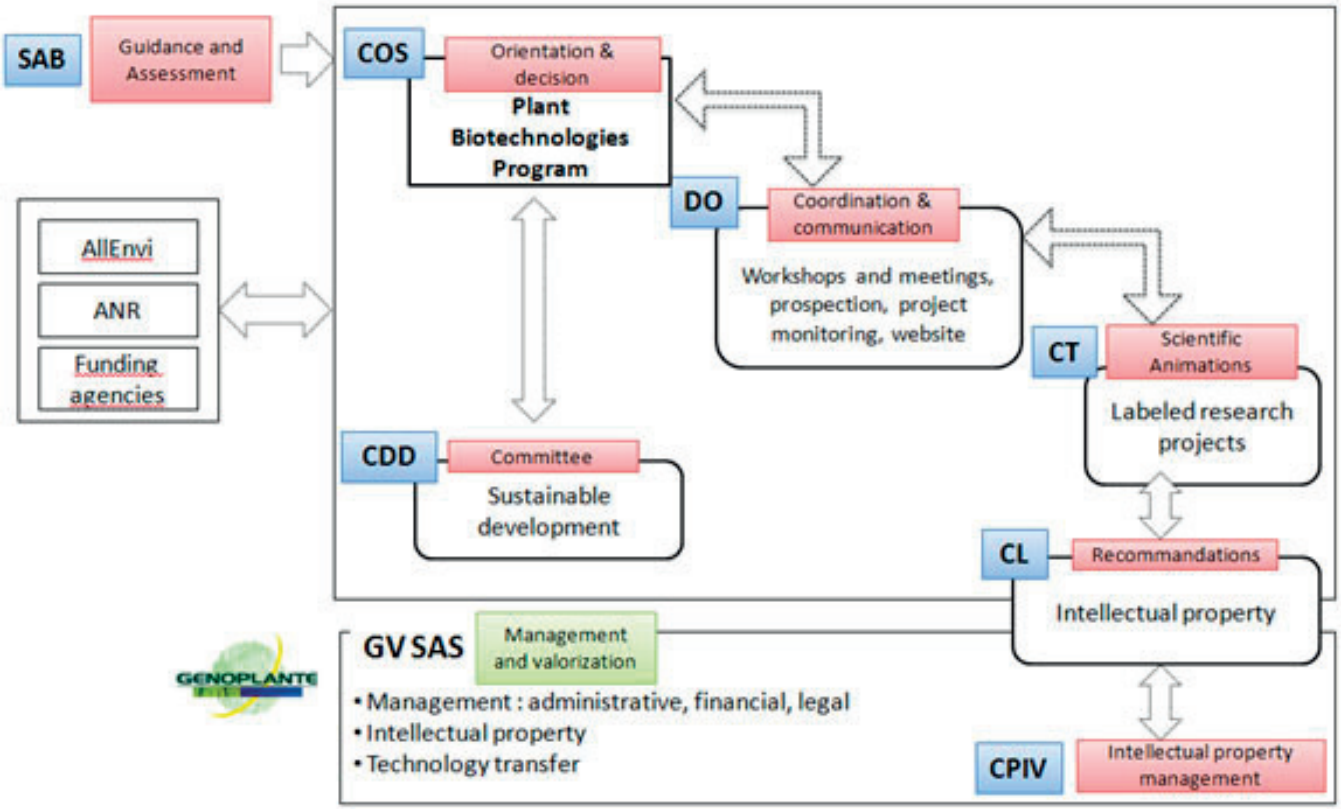
Workshop and Thematic Committees

The GIS "Plant Biotechnologies" organizes events, in collaboration with its members and with funding and programming bodies (AllEnvi Alliance, French National Research Agency):

- **Scientific workshops** open to all private and public members of the GIS BV. The aim of these workshops is (1) to present a **global vision of the state-of-the-art research** being carried out on a specific research topic, from fundamental to applied research programs, in France and at the international level and (2) to promote the exchange of ideas and positions, to evaluate potential technology transfer applications, and to encourage common research projects. These workshops set the basis for the redaction of **position papers**, summarizing the position of the research community, and making recommendations on research strategies and potential areas to support in national calls for proposals (http://www.gisbiotechnologiesvertes.com/en/publications.html).
- **Thematic Committee (CT) meetings:** the aim of these annual meetings is to discuss methodologies and to analyze scientific progress in the ongoing projects labeled by the GIS BV. These meetings allow the creation of connections within the scientific network of labeled projects, and aim at facilitating synergies and exchange of information between projects, as well as between private and public members of the GIS BV.
- **Large conferences** organized in collaboration with the French National Research Agency.

Organisation

To find out more : http://www.gisbiotechnologiesvertes.com/en/



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BBSRC: Breeding Collaboration

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The Biotechnology and Biological Sciences Research Council (BBSRC) is one of the seven organisations that form Research Councils UK, and invests in world-class bioscience research and training on behalf of the UK public. BBSRC supports around 1600 scientists and 2000 research students in universities and institutes across the UK. BBSRC science contributes to overcoming challenges in areas such as Food Security, Bioenergy and Industrial Biotechnology, and Basic Bioscience Underpinning Health.

BBSRC funding was identified in the UK Government strategy for agricultural technologies as the largest source of UK public spending on research and development in agriculture and food[45]. The strategy also states that, in the UK:

"the entire agri-food supply chain, from agriculture to final retailing and catering, is estimated to contribute £96 billion or 7% of GVA. The UK exported £18 billion of food, feed and drink in 2012 and is one of the top 12 food and drink exporters. There are 3.8 million people employed in the food supply chain including agriculture and fishing."

BBSRC aims to underpin the needs of UK industry by supporting a vibrant bioscience research community and uses a variety of funding models to support fundamental research aligned to industrial need:

- **Advanced Training Partnerships (ATP)**

http://www.bbsrc.ac.uk/business/training/advanced-training-partnerships.aspx

ATPs offer postgraduate level training to employees working in UK agri-food industries. Four partnerships worth approximately £13M have been funded (from 2011 to 2016) and will begin to deliver courses to staff from a range of companies from 2012. Each partnership operates under the leadership of an academic institution and focuses on a particular research area, covering the full range of food production from farm to fork. Industry is engaged in the development of the courses in order to facilitate their continuation after 2016.

- **BBSRC stand-alone LINK**

http://www.bbsrc.ac.uk/business/collaborative-research/stand-alone-link.aspx

This mechanism supports collaborative research with at least one company and one science-base partner where at least 50% of the full economic cost (FEC) of the project comes from industry. Applications should be for pre-competitive research that would not be undertaken without LINK support. Applications are assessed by BBSRC's Research Committees, alongside standard applications, using the same criteria. LINK projects are normally funded in preference to standard grants of equivalent scientific merit due to the significant user interest.

- **Crop Improvement Research Club (CIRC)**

http://bbsrc.ac.uk/circ

CIRC was established in 2011 to advance plant breeding and will support 15 research projects worth £7M to improve the productivity and quality of wheat, barley and oil seed rape for use in food. CIRC is a five year partnership between BBSRC, a consortium of 14 companies, and the Scottish Government. CIRC operates through the Research Technology Club model that has been applied by BBSRC to a variety of sectors and which establishes joint funding pots to support academic research while encouraging closer links between academia and industry through regular networking events.

- **Horticulture and potato initiative (HAPI)**

http://www.bbsrc.ac.uk/business/collaborative-research/programmes/horticulture-potato/horticulture-potato-index.aspx

BBSRC is able to flexibly develop the Research Technology Club model for industrial sectors where a standard Club is not suitable. HAPI is an example of a collaborative funding activity that addresses a strategically important area of research. Up to £7.5M has been committed in order to support research for sustainable increases in productivity and quality in potato and edible horticulture crop production systems.

- **Knowledge Transfer Partnerships (KTP)**

http://www.bbsrc.ac.uk/business/people-information/knowledge-transfer-partnerships.aspx

KTPs enable the transfer of knowledge and development of graduate and postgraduate personnel for industrial careers. A KTP lasts between 1 and 3 years and employs one or more graduates or postgraduates as KTP Associates, to work on an innovative project within industry. Associates are jointly

45 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/227259/9643-BIS-UK_Agri_Tech_Strategy_Accessible.pdf

supervised by the participating industrial and academic partners. Support is delivered through a public-funded grant to the academic partner, in addition to a contribution from the participating company that fully covers a University's cost of participation.

- **Industrial CASE studentships**

http://www.bbsrc.ac.uk/business/people-information/knowledge-transfer-partnerships.aspx

BBSRC is able to fund individual PhD studentships with industry in order to provide PhD students with a first-rate research training experience within a mutually beneficial research collaboration between academic and partner organisations. The students are primarily based at the academic partner, with a mandatory placement at the non-academic partner for a minimum of 3 months and up to 18 months. Student placement expenses must be met by the non-academic partner. Partner organisations with a successful track record of apply for individual studentships are invited to apply for blocks of industrial case studentship funding, which they are then able to use with multiple academic partners.

- **Industrial Partnership awards (IPAs)**

http://www.bbsrc.ac.uk/business/collaborative-research/industrial-partnership-awards.aspx

IPAs enable BBSRC to fund industrially aligned research through a 'responsive mode' mechanism which usually supports fundamental research. An industrial partner contributes in cash at least 10% of the full economic cost of a project in a UK research organisation. In-kind contributions from industry are also accepted but are not counted against the industry contribution. Applications assessed by BBSRC's Research Committees, alongside standard applications, using the same criteria. IPA projects are normally funded in preference to standard grants of equivalent scientific merit due to the significant user interest.

- **Technology Strategy Board (TSB)**

https://www.innovateuk.org/funding-support

The TSB provides funding for industrial innovation in the UK through a variety of schemes. BBSRC is also to provide co-funding for TSB collaborative research programmes in order to support the costs of academics carrying out BBSRC relevant research. Applications are made through the TSB and must be business-led and collaborative.

BBSRC is able to fund collaboration between the public and private sector through a varied portfolio of support mechanisms. Delivering flexibility to industry around timescales, contributions, and research priorities has enabled BBSRC to engage with multiple sectors that make use of the biosciences.

biovegen
spanish technology platform
for plant biotechnology

BIOVEGEN Intervention Spanish plant biotech sector: an overview

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The agriculture sector in Spain has an important weight at European level and with respect to the Spanish economy. Agricultural products produced in Spain represent 12% of EU production. The influence of Spanish agriculture on Spanish economy is greater than the European average, and it makes a good contribution to the Spanish trade balance.

Spain is a leader in horticulture, citrus, vineyards, olive groves and cereal. It has the peculiarity of being highly fragmented, with many small businesses, due to geographical and climatic differences between regions.

Spanish agricultural sector faces the challenge of increasing agricultural production, combining it with a better quality product, respect for the environment and resource efficiency. In addition, there are other business challenges: the shift of production to other countries, global trade and the costs this represents (with its corresponding problems regarding distances, storage and post-harvest food safety), the need to launch new and better products to market (the cost of obtaining a new range is estimated between 1 and 1.5 million €, with development times of between 5 and 15 years), rapid changes in consumer trends and declining cycles of the profitability of a variety (5-6 years).

For its part, Biotechnology and Plant Biology are experiencing phenomenal growth, with the emergence of revolutionary new technologies. In addition, the cost of access to these technologies is falling dramatically.

In Spain, the scientific situation in Plant Science is good. From 2003 to 2009, Spain was ranked 10th globally and 4th place at European level in terms of scientific production in the field of Biotechnology, indicators measuring both quantity and quality.

In addition, during the period 2000-2010, one third of biotechnology research generated in Spain was focused on food industry applications.

Spanish Research performs well in concepts related to Plant Biotechnology ("molecular biology", "plant science", "agricultural science"), analyzed from the point of view of quantity (number of citations) and the quality (citations per paper).

Regarding technology transfer issues, Spain has only 2.3% of vegetable varieties requests registered in CPVO between 1994 and 2013, occupying the 8th position. There are approximately 60 biotechnology companies (15% of all biotech companies), companies engaged in bridging the gap between Science and Business.

In Spain there is a deficit of Technology Transfer and collaboration between Science and Industry, which does not correspond to the size and importance of the business nor scientific sector. However, companies are looking for innovation, and incorporating it (usually buying it abroad, where public-private partnership and therefore the applicable technology offer are more developed). Moreover, globally there is a growing demand and the public sector is a good source of technology.

Therefore, in Spain we need to establish channels of communication between Science and Industry, as well as public-private cooperation mechanisms to facilitate companies' access to innovation.

One of these tools is BIOVEGEN, the Spanish Technology Platform for Plant Biotechnology. BIOVEGEN is a scientific and technological forum that brings together companies and research organizations. It aims to improve the technological potential of Spanish agroindustry by approaching technological offer and demand, establishing science-business collaborations. This Platform, which was created in late 2005, connects the Research and Industry to generate new business opportunities in plant production, by linking offer and demand of technology, and it is a useful tool to enhance collaboration between generators (Academy) and users (companies) of technology.

BIOVEGEN accounts now for 26 private entities and 8 public research organisations in different fields: plant breeding, both intensive and extensive crops, bioenergy, forestry breeders, R&D managing companies, fertilizers, ornamental breeders, fruit trees breeders, plant additives and nutrition.

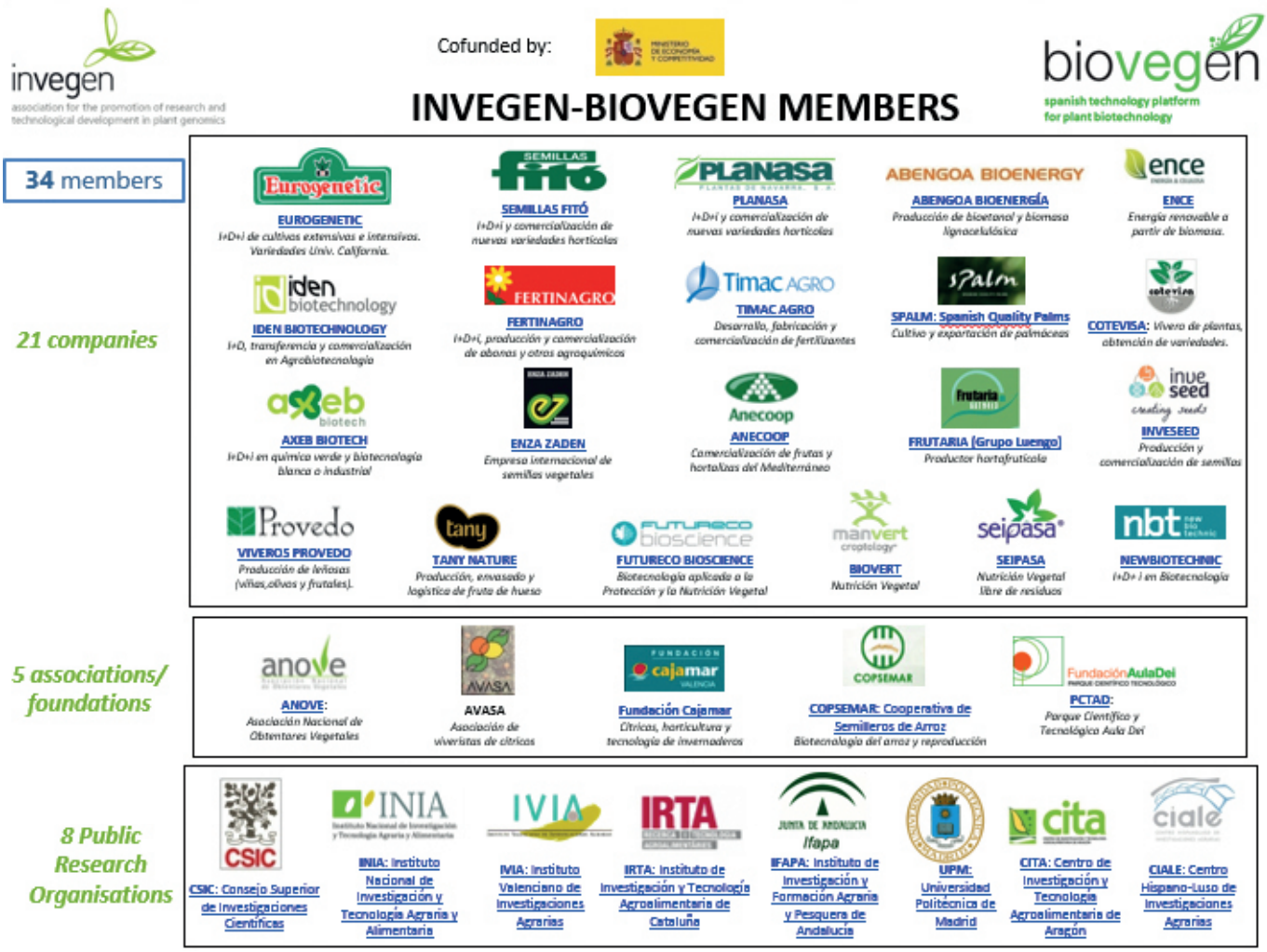
BIOVEGEN connects the Research and the Industry to generate new business opportunities in plant production, by linking offer and demand of technology, and it is a useful tool to enhance collaboration between generators (Academy) and users (companies) of technology.

BIOVEGEN develops various activities in order to achieve its goals: R&D projects (connection of supply and demand of technology, advice, coordination, search for funding...), development of a Strategic Research Agenda, partnering events, reports and publications of interest to the sector, collaboration with the Administration, databases, etc.

BIOVEGEN also created and is now managing the Bulletin of Technological Offer/Demand, a unique tool that connects common technological interests between researchers and enterprises for the development of collaborations: R & D projects, exchange of personnel, licenses, contracts, etc. BIOVEGEN delivers two types of Bulletins: Technological Offer of Researchers, that we distribute between the companies of our database (more than 900), and Technological Demand of companies, that we distribute among our researchers (43 centers, more than 400 research lines). Since the launching of this tool in September 2012, BIOVEGEN have mobilised 91 technological offers that have generated more than 100 expressions of interest of companies and 34 research groups interested. Also, with 25 demands of the industry mobilised, more than 150 expressions of interest of research groups have been generated.

Another emblematic example of public-private partnership in Spain (and in which BIOVEGEN has been heavily involved) is CITRUSEQ consortium: it is a series of projects aimed at sequencing, genotyping and development of genomic tools for the improvement of citrus. This project, which began in late 2009 and was cofunded by the Ministry of Science and Innovation (now Ministry of Economy and Competitiveness), is the result of a collaboration between 6 companies and 3 research organisations. It has a budget of € 4 million (of which € 2.3 M have been provided by the companies) and will allow the development of tools to produce sweeter citrus varieties, seedless, more resilient, more flavorful, with different ripening times, with better post-harvest treatment and better marketing. This project is a milestone in agricultural research in Spain, as it is the first time that you get the private sector involved in this measure for the development of a molecular breeding project.

In summary, in Spain we need to commit to the connection between producers (Science) and users (Company) of technologies, and promote public-private partnership if we want to maintain and improve the position of our agroindustry sector. And in BIOVEGEN we believe we are a useful tool to achieve this goal.



BIOVEGEN Members (January 2014).

PLANT2030 - PPP in Plant Breeding:
The case of the Pre-BreedYield Project
Precision Breeding for Yield Gain in Oilseed Rape
A. ABBADI

(presenter)

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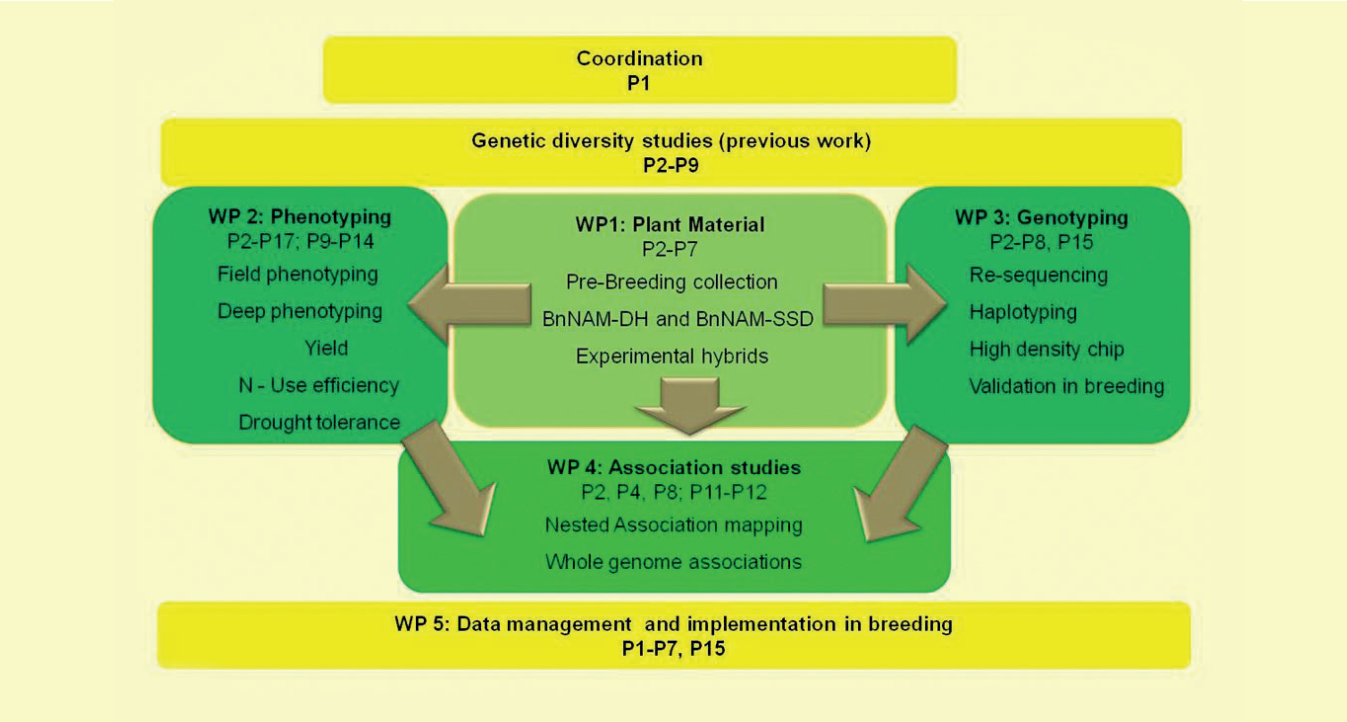
Rapeseed (*Brassica napus*) is one of the most recently domesticated major crop species, and due to intensive breeding has become the most important oilseed crop in Europe. Today around 6 M t of seed are produced annually on 1.5 M ha in Germany. Yield per hectare varies in different countries, reflecting different input levels and production efficiency. This highlights the scope for crop improvement, and yield will continue to be the primary focus of many rapeseed improvement programs. Modern varieties are based on a relative small subset of the available genetic diversity, because breeding progress suffers from low genetic diversity caused by severe selection bottlenecks in recent decades. Rapeseed is thus likely to respond strongly to programs aimed at selectively enhancing genetic variation for key economic input and output traits. To overcome this problem, **the public-private consortium "PreBreed-Yield"** is generating an "omics" pre-breeding platform that aims at the development of *B. napus* genetic resources and their implementation into innovative breeding material and prediction tools for yield in commercial breeding practice. The consortium including 7 commercial breeding companies and 7 scientific institutes is developing and implementing a diverse set of plant materials as well as genomics, genetics, phenotyping/phenomics, bioinformatics and statistics of complex trait and breeding to be used to enhance rapeseed pre-breeding, subsequent breeding and development of new elite commercial varieties.

Through the selection of excellent complementary partners, we established a strong pre-breeding consortium in rapeseed and generated considerable amounts of new data and knowledge. The implementation of the project results and the translation of these resources into innovative breeding material and prediction tools for yield in commercial breeding practice is the long term aim of this new pre-breeding platform.

Pre-BreedYield is combining advanced new quantitative genetics techniques in *B. napus* with deep phenotyping and emerging genomics technologies to generate new plant materials and tools for breeding. To translate these considerations into a research program we have organised the project into different work packages (WPs) that study different aspects of yield and yield stability in rapeseed. All these WPs are implemented in a tightly designed network between the partners according to their respective expertise. All partners are interacting with each other accordingly within and between these work packages.



Research organization and inter-dependence of WPs and partners of Pre-BreedYield

Two large *B. napus* Nested Association Mapping (BnNAM) populations (N=2500) have been developed, which incorporate novel genetic diversity, as a resource for *B. napus*. The BnNAM populations were developed by crossing a pre-breeding collection of 50 rapeseed genotypes (20 adapted and 30 exotics) selected specifically with regard to yield gain, nitrogen use efficiency and drought tolerance to a common elite line. The 20 adapted F1 combinations were used to produce 20 double haploid populations (BnNAM-DH, N=50-100 each), whereas the 30 exotic combinations were first back-crossed to the elite line and subsequently used to produce 1500 single-seed descent inbred lines (BnNAM-SSD). All BnNAMs genotypes are being phenotyped in field trials at 6 locations and subjected to genotyping using the 60kSNP Infinium Brassica consortium array for genome wide association studies. In addition 1000 experimental hybrids deriving crosses between selected BnNAMs and one male sterile line are being developed to study yield performance under field conditions. In parallel, the 51 founder genotypes of the pre-breeding collection are subjected to deep phenotyping studies as well as genome re-sequencing.

All these comprehensive data are integrated in a data management system, specially developed for implementation in molecular breeding processes. The material generated within this project in combination with Nested Association Mapping (NAM) will provide a powerful resource for association genetics, genomic selection and predictive breeding during the coming decades.

List of Partners

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Partner 3: Deutsche Saatveredelung AG, Lippstadt, Dr. Dieter Stelling

Partner 4: KWS SAAT AG (KWS), Einbeck, Dr. Frank Breuer

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Partner 6: Syngenta Seeds GmbH, Bad Salzuflen, Dr. Annika Spies

Partner 7: Raps GbR Saatzucht, Lundsgaard, Dr. Peter Duchscherer

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TREEFORJOULES, a Plant KBBE project to improve eucalypt and poplar wood properties for bioenergy

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Introduction:

Recently, interest in sustainably produced bio-energy and bio-based products has skyrocketed due to efforts to reduce reliance on nonrenewable fossil fuels, decrease environmental degradation, mitigate climate change, and develop robust knowledge-based bio-economies. Concomitantly, there has been an increased interest in the utilization of lignocellulosic biomass from forest plantations for second-generation renewable bio-energy feedstocks as they are non-food crops and offer the potential for generating a lower carbon footprint than annually produced crops. Fast-growing tree species such as poplar and eucalypts grown as short-rotation coppice (SRC) represent one of the most appealing sources of renewable biomass feedstock for Northern/ Western and Southern Europe as they are easy to establish, produce high yields of lignocellulosic biomass, and offer secondary benefits such as a low nutrient input. Since the chemical and structural composition of lignified secondary cell walls render woody feedstocks particularly recalcitrant to degradation, improved genetic material is needed to use these SRC as energy crops in an efficient manner.

The overall goal of the TREEFORJOULES project is to identify the major genetic factors underpinning the physicochemical properties of cell walls, the recalcitrance of which remains a key scientific challenge for establishing highly efficient, sustainably produced, second-generation biofuels.

This knowledge will be invaluable for future association studies and marker-assisted breeding of elite trees for improved downstream processing and efficient degradation thereby contributing to the KBBE goal of securing a sustainable energy supply.

The research group includes scientists from public and private organisations who are at the forefront of their fields, the active participation of Forest, Pulp and Paper, and Energy companies from France, Spain, and Portugal, as well as a German SME working to develop sustainable, ecological biorefinery concepts, systems, processes, and products.

TREEFORJOULES is funded by the PlantKBBE ANR(FR)-10-KBBE-0007; BMBF (DE)-0315914A, FCT (PT) AGR-GPL/0001:2010; Ministerio de Economia y Competitividad (SP) – PIM2010PKB-0702.

Project organization:

The project is organized in 4 working packages:

- **WP1** - transcriptional and post-transcriptional regulation of wood formation in eucalypts and poplar, through in silico integration of global transcriptomics to select candidate genes (CG) i.e. transcription factors (TF) and miRNAs differentially expressed in contrasted wood samples. These GCs will be mapped in WP3 and up to 25 will be functionally validated in transgenic wood sectors. The effects of nutrition and biotic stresses on biomass CGs expression, production and wood properties in different eucalyptus and poplar genotypes will also be assessed.

- **WP2** - to develop high-throughput NIR spectroscopic methods for wood property measurements including all key cell wall constituents with impact on the saccharification potential of biomass polysaccharides for bio-ethanol production and bio-oil production from lignin.

- **WP3** - to compare the structural and functional architecture of wood quality in *Eucalyptus* and *Populus* by (i) improving the resolution of available genetic maps using high-throughput genotyping methods and common makers (ii) locating precisely and assessing QTLs for wood properties relevant to bioenergy, and (iii) dissecting a major lignin QTL.

- **WP4** is devoted to project management, coordination through a website and common bioinformatic network to store, mine, and integrate the high-throughput genomic, genetic, and phenotypic data, as well as transfer of tools and technologies to industry and dissemination of results.

Added value of PPP international collaboration

TREEFORJOULES is a multidisciplinary and multisectorial proposal, bringing together scientists from academic organisations at the forefront of their area and leading industrial [(Altri Florestal SA (PT), FCBA (FR), ENCE (SP)] and public partners [CIRAD (FR), INRA (FR), THÜNEN (DE)] directly involved in tree breeding, and as well as a German company BIOPOS involved in research and development of the sustainable ecological biorefinery concept, systems, processes and products, and IBET involved in translation of scientific knowledge to industrial applications. TREEFORJOULES relies on collective translational expertise in cutting edge and emerging technologies: functional genomics, bioinformatics, high throughput phenotypic and genetic data linkage analysis (available populations for linkage mapping and QTLs detection) and advanced methods to assess wood traits relevant to bioenergy (both bio-ethanol and bio-oil). It is clear that no country or institution on its own can carry independently such a multidisciplinary project. Indeed, the efforts are balanced and complementary and as a matter of fact, the project objectives will be realized thanks to the combination of the know-how, laboratory facilities including large equipment, available plant material and analytical techniques geared by each partner. These complementarities will be enhanced thanks to training and transfer of knowledge scheduled for bioinformatics, new genetic transformation methods, and methods for analysis of energy-related wood properties. While it is consensual that new breakthrough in tree breeding will come from genomics, such studies are long term, riddle with complexity and risk and require a considerable amount of time and wide expertise. Advances in wood genomics need to be built upon precompetitive collaborative platforms including basic research, methodologies developers and end-users and this is what TREEFORJOULES hopes to achieve. By the combining efforts and materials from the four different countries, we will be able to construct a network that will hopefully lead to the development of new genomic tools and eventually will be invaluable in discovering important genes (and allelic forms) – to eventually develop new breeding solutions. Three bioinformatic platforms will merge their efforts to build a common network which will allow to share and centralise disperse databases to facilitate access and management of genetic/genomic data. In conclusion, the consortium has the critical size, collective translational appropriate range of expertise, and vision to ensure its ambitious aims. TREEFORJOULES will help strengthening the public-private partnership research on tree genomics and breeding in Western Europe.

European Commission
EUR 26634 EN – Joint Research Centre – Institute for Prospective Technological Studies

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Author: Maria Lusser

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