UPOV

SYMPOSIUM ON PLANT BREEDING FOR THE FUTURE

October 21, 2011
Geneva, Switzerland

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Chair: Mr. Peter Button, Vice Secretary-General, UPOV

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Welcome address

Mr. Francis Gurry,
Secretary-General, UPOV

A very good morning to you all. It is my great pleasure to extend a very warm welcome to you all today for this Symposium on Plant Breeding for the Future, which is being organized to coincide with the Fiftieth Anniversary of the UPOV Convention.

As you are all very well aware, the founders of the UPOV Convention recognized that an effective system for plant variety protection would be a driver for much needed investment in plant breeding and for innovation in agriculture through the development of new varieties of plants.

Some 50 years later, when we are celebrating the signing of that Convention in Paris, in 1961, a conjunction of circumstances is occurring that emphasizes, more than ever, the need for innovation in agriculture. We have, of course, an increase in world population, which currently stands at around 7 billion people, and is expected to rise to 9 billion by the year 2050. That increasing population and its need for food, combined with the need for renewable sources of energy, has placed a great deal of pressure on arable land and has meant that there is scarcity of such land. At the same time, we have the phenomenon of climate change, producing a number of different impacts on productivity in agriculture. So, in consequence, the need for innovation through, in particular, new plant varieties, is more relevant than ever.

At the same time, innovation, especially in agriculture, is a source of economic growth, economic development for the rural sector, and also a major source of new employment. A dynamic and sustainable agriculture depends on scientific progress and the application of science to crop development through plant breeding. This is, in particular, the subject of today's Symposium where we will look at what the future holds for us in these fields. What is the science of today telling us about the possibilities of tomorrow in the field of plant breeding ?

Let me extend a very warm thanks to all of our speakers and the experts who will be enlightening us throughout the proceedings today and it is now my great pleasure to introduce

Mr. Jean-Marc Bournigal
Principal Private Secretary of the Ministry of Agriculture, Food, Fisheries, Rural Development and Territorial Planning (MAAPRAT)
France

Her Excellency Ms. Ilse Aigner
German Federal Minister for Food, Agriculture and Consumer Protection
Germany

His Excellency Mr. H. Bleker
State Secretary
Ministry of Economic Affairs, Agriculture and Innovation
Netherlands

Lord Taylor of Holbeach
Parliamentary Undersecretary
Department for Environment, Food and Rural Affairs (DEFRA)
United Kingdom

Message from the Host of the 1961 Diplomatic Conference

Mr. Jean-Marc Bournigal,
Principal Private Secretary of the Ministry of Agriculture, Food, Fisheries, Rural Development and Territorial Planning (MAAPRAT), France

Mr. Chairman, Mr. Secretary-General,
Mr. Vice Secretary-General,

Ladies and Gentlemen, representatives of members and observers of the International Union for the Protection of New Varieties of Plants (UPOV),

Fifty years ago, at the suggestion of France, the delegations of six countries met in Paris in order to build an unprecedented intellectual property protection model for plants, based on a fair balance between the protection of owners and users' interests. Thus, the International Convention for the Protection of New Varieties of Plants (UPOV Convention), subsequently amended in 1972, 1978 and 1991, was born.

WHAT WAS AT STAKE ?

At the time, the aim was to ensure the continuity of efforts in terms of agronomic research, as, without such work, agricultural productivity cannot be improved, a fact yet again recalled by France at the recent G20 meeting on agriculture held in June in Paris. We will be unable to meet the global demand for food unless there is a sustainable increase in agricultural production, something we cannot achieve without the support provided by agronomic research. What was true at the time of the establishment of the UPOV Convention in 1961 remains entirely relevant today and the challenge facing us in the years to come seems to be even greater.

The Convention provides breeders with a breeder's right for new varieties, while making them accessible to third parties for research purposes, including the breeding of new varieties. The Convention thus guarantees that research work of benefit to our farmers may be carried out without any hindrance whatsoever at a time when the number of challenges linked to climate and health is increasing across the globe. From this point of view, we must abandon the practice of weighing the interests of breeders against those of farmers. The goal of a strong agricultural sector cannot be achieved without a robust research environment. I wish to recall that, during the twentieth century, half of the increases made with regard to agricultural productivity were the result of progress in terms of research in the field of genetics. We need research in order to develop varieties that are more resistant to changes in terms of climate and health and that require less water. I believe that we can all agree in this regard.

It should also be pointed out that there can be no sustainable agriculture without innovation in the field of agronomics. If we are to balance productivity with respect for the environment then we cannot simply adapt the classic methods; we need to adopt a new model and it is innovation that will allow us to make the necessary qualitative leap by creating varieties which do not require fertilizers or pesticides.

Finally, there can be no competitive agriculture without high-quality and, therefore, fairly-paid, research work. The fathers of the Convention, the fiftieth anniversary of which we are celebrating today, understood this situation very well indeed. Looking at this equation, the extent to which the intellectual property protection model put forward by UPOV is in harmony with the needs and expectations of our agricultural sector becomes clear. Consequently, we should not be surprised at its success. In 1961, six States defined the outline of the Convention; today, 70 members have come together to support its underlying philosophy, including, I am pleased to note, many developing countries.

Casting an eye back over the path travelled since the beginning, the number of species and varieties protected has continued to increase, with producers being offered greater genetic diversity. Progress has been made in terms of the quantities produced, even though it was recalled at the G20 meeting that now, more than ever, it is vital to continue with our efforts.

This achievement belongs to you, to UPOV. The up-to-date and modern nature of this Convention owes much to your commitment and work. Ladies and Gentlemen, more than ever, France firmly supports the model offered by UPOV. At a time when we must re-invest wholeheartedly in global agriculture, the Convention constitutes a fair balance between the individual and the collective interest, and between the private and the general interest. Research is the future of agriculture, be it in terms of productivity, food quality or protection of the environment. This model allows us to provide the research sector with the means to take up the challenges posed by the future. I wish to thank all of you for having participated in this project and hope, of course, that this day will also be a celebration of 50 years of work in support of the Convention.

Thank you.

Messages from the Founding Members of the Union

Her Excellency Ms Ilse Aigner, German Federal Minister for Food, Agriculture and Consumer Protection, Germany

President Choi,
Director General Gurry,

Ladies and Gentlemen,

Fifty years of UPOV means half a century of international cooperation for the protection of plant varieties.

It is a special honor and pleasure for me to send you my best wishes on the occasion of this anniversary.

With the signing of the UPOV Convention, December 2, 1961 marked a milestone in the promotion of modern plant breeding.

Germany is one of the UPOV founding members.
And as a representative of the German Federal Government, I am extremely pleased to see all of the positive developments in UPOV over the past 50 years.

In the meanwhile, some 70 States plus the EU have elected to join UPOV to benefit from the strong protection for plant varieties.

A growing number of Member States are thus offering IP protection for plant varieties, as required by the WTO TRIPS Agreement, by means of plant variety protection.

Moreover, there has been a steady increase in the number of titles of protection granted by UPOV for new plant varieties which have been developed.

The majority of States with plant breeding activities have chosen UPOV's system for the protection of plant varieties.

It enables plant breeders to recoup the high costs of developing a new variety of plant.

Plant variety protection thus helps promote vital progress in terms of plant breeding. At the same time, it ensures a fair balance between the interests of plant breeders and farmers. These were the main reasons why the Federal Republic of Germany opted early on for plant variety protection through the UPOV Convention. This was and is in the interests of both small and medium-sized plant breeders and rural agriculture.

Unlike more restrictive patent rights, the UPOV general principles promote the transfer of innovation: Through the so-called "plant breeder's exemption", all protected plant varieties are available to anyone for further plant breeding. Third parties also enjoy unrestricted access, for research and plant breeding purposes, to the genetic resources used in plant varieties.

This has been a decisive factor driving innovation in the plant breeding field, and is especially important as I see it.

Consequently, I would like to take a clear stand in favor of plant variety protection and against patents for plant varieties.

Ladies and Gentlemen,

As you are aware, in the course of this year the G20 Agriculture Ministers met in Paris, to take up a vital future issue:

How can we guarantee the human right to food ?

And how can we feed a growing world population ?

We all agree: The most important thing is to strengthen agriculture.

Governments worldwide are under pressure, in the face of present and future global challenges, to ensure sustainable food security and economic development.

Naturally, this includes high-yielding, robust and locally adapted plant varieties.

The G20 Agriculture Ministers therefore undertook, in their final declaration, to strengthen plant breeding above all through the internationally agreed legal instruments for the protection of plant varieties.

The key to feeding the world is the responsible utilization of genetic resources.
This must become a stronger focus of our activities, to help us solve the problems of the future.

We must also improve yields for arable crops with the help of modern plant breeding technology.
Here, smart breeding is one example.

Only in this way can we achieve long-term productivity increases in agriculture.

Ladies and gentlemen,

UPOV enjoys a strong reputation at the international level.
The presence of many international representatives from WTO, FAO, CBD, ISF and other international organizations, who have gathered here today to celebrate this event with the UPOV family, reflects UPOV's high international esteem.

I wish UPOV continued success in future decades with the further development of plant variety protection.

Tackling mankind's future problems is especially important in my view. This is the only means of guaranteeing that a growing world population will have access to food, raw materials and energy in the future.

I look forward to the outcome of the technical symposium, and wish all participants and guests have interesting and productive discussions.

His Excellency Mr. H. Bleker

State Secretary, Ministry of Economic Affairs, Agriculture and Innovation, Netherlands

First, please allow me to congratulate you on the fiftieth anniversary of the Convention of the International Union for the Protection of New Varieties of Plants (UPOV).

The Netherlands and a number of other countries were involved at the start of this wonderful initiative. It has now developed into a global system in which 69 countries participate in order to promote the development of plant varieties and to provide the necessary framework.

The UPOV system also provides incentives to innovate and to breed plant varieties so that farmers and horticulturists in all parts of the world can make the best use of those varieties. It is now more than ever of vital importance in the interests of food security to promote the development of varieties that can help us to achieve good productivity while at the same time needing less inputs, being more resilient and better adapted, to the effects of climate change.

Although it is a big challenge, I see very good potential for farmers in developing countries to make further progress by using the UPOV system of plant variety protection.

Time does not stand still and we need to be adapting to changing circumstances. For instance we must consider carefully how to keep the effectiveness of plant breeders' rights in relation to patents on plant related inventions. We must find a new balance between both systems.

One thing is certain: even after 50 years of UPOV, there is still much work to be done and it would be good for UPOV that more countries joined in order to broaden its membership.

So, again, many congratulations on your 50th anniversary. I am fully confident that the reasons for the continuing efforts of UPOV are as strong as ever and that your enthusiasm will carry you through the next fifty years !

Lord Taylor of Holbeach

Parliamentary Undersecretary, Department for Environment, Food and Rural Affairs (DEFRA), United Kingdom

The UPOV Convention is a cornerstone of the global plant breeding industry. The United Kingdom is proud to be one of the first signatories of the original UPOV Convention and continues to recognize the importance of UPOV in supporting and stimulating the plant breeding industry.

The benefits of the UPOV Convention and plant breeders' rights legislation have been huge. The ability of plant breeders to collect royalties on their varieties stimulated the rapid development of plant breeding, leading to great increases in yield, quality and choice. An example of the importance of plant breeding has been evidenced by recent studies that show than more than 90% of yield gain in the United Kingdom's main agricultural crops since 1982 is due to the breeding of new varieties. The work being done by UPOV and the plant breeding industry to encourage the development of sustainable new varieties benefits the global community in mitigating the growing challenge of food security in the face of population growth and climate change.

My Department is working with the whole food chain to stimulate the green economy and to encourage the agriculture and food sector to increase productivity in a sustainable way with due regard to reducing greenhouse gas emissions and protecting the natural environment. New plant varieties and a system of plant variety protection, underpinned by UPOV, are essential to these aims.

The Second World Seed Conference emphasized that Governments need to develop and maintain an enabling environment to encourage innovation in plant breeding and seed production. The United Kingdom shares this view and has recently increased its investment in breeding research, as well as consulting on proposals for possible tax incentives for companies engaged in innovation. The UPOV system of plant variety protection is a key enabler for investment in the development of new plant varieties, essential to strengthen sustainability in food production around the world. Membership of UPOV is an important indicator of support by Governments for their plant breeding industries, providing them with the confidence they require to invest and introduce their new varieties. New plant varieties will play a central part in helping combat the challenge of food security for the benefit of the global community during the next decade and beyond.

UPOV, a truly international organization, with members in all continents in the world, is uniquely placed to encourage the continued development of such new plant varieties. The UPOV story is one of substantial success in its first 50 years. The organization remains relevant and will, I am sure, consolidate and build on that success during the next 50 years.

The Development of Plant Breeding and Plant Variety Protection

Mr. Bernard Le Buanec

1 - The Neolithic Revolution and the domestication of crops.

Some ten thousand years ago started what we call today the Neolithic Revolution, which was probably more a lengthy evolution than a revolution. At that time, human behavior changed from a hunting and gathering culture to an agriculture-based culture. How did this happen ? It happened with domestication and, in the scope of this presentation we will focus only on plants. Among the many species that were utilized by the gatherers, only a few have been domesticated. It is estimated that there are two hundred and fifty thousand described higher plant species, of which thirty thousand are known to be edible and of which seven thousand have been used for food on regular basis[1]. Of these, only around three hundred have been domesticated and used in agriculture[2].

In fact, domestication lead to a huge decrease of crop diversity, as humans only chose species that were able to meet their needs. For example, for cereals, the most important crops in many civilizations, the so-called domestication syndrome, was characterized by loss of spontaneous shattering, greater uniformity of seed ripening and germination, increased size of reproductive organs, change in biomass allocation and shorter lifespan[3]. Most often those changes were dependent on only a few major genes.

2 - Continuous selection of improved cultivars by the farmers after domestication.

The differentiation between domestication and selection, whilst practical, is somewhat artificial as, at least during the first phase of development of agriculture, domestication and selection of improved cultivars were certainly overlapping. That selection was farmers picking the best plants from each generation for sowing the following year. Those best plants were the results of natural mutations and spontaneous hybridization with neighbor crops or wild relatives. Some cases of hybridization facilitated by the farmers have been reported. However, even if the progress has been obvious, it was extremely slow as there was no knowledge on how to accelerate and fix the genetic gain. The agricultural revolution, which took place during the eighteenth century, when European agriculture underwent major changes, did not bring the expected yield increase, mainly due to the lack of variety improvement[4]. In fact, the notion of genetic was not known. We can say that during a very long period, farmers did not create genetic diversity but, at best, maintained the diversity resulting from natural evolution. We can also say that the selection of varieties, also known as landraces, was a byproduct of agricultural activities, and that the reward for the “selector” was a good and possibly better crop the following year.

3 - The emergence of plant breeding and professional plant breeders.

To simplify, we can say that the emergence of plant breeding came from two main discoveries: the existence of gender in plants allowing controlled crosses and the genetic laws allowing the understanding of heredity, choosing the parents for a cross according to the expected results and fixing the results of the crossing. Those discoveries, with, as usual, their share of controversies and skepticism, took place between the middle of the eighteenth century and the end of the nineteenth century, i.e. roughly during one hundred and fifty years. In the early stages, crosses were mainly made by amateurs on ornamentals and fruits crops. However, the first significant seed companies with real breeding programs were established in the middle of the nineteenth century.

1 Kingsbury N, p 408.
2 Holden, Peacock and Williams, in Kingsbury N.
3 Harlan 1992
4 Kingsbury, p 253.

Another essential step was made with the development of biometrics in the first part of the twentieth century, allowing the elimination of the results obtained by chance in an experiment[5].

The First International Conference on Hybridization and Cross-Breeding took place in London in 1899, followed by the second one in New-York in 1902 and a third one, where the word "genetics" was coined, in 1906 in London again. According to a speaker, the four issues the breeders were focusing on at that time were: disease resistance, cold hardiness, resistance to drought and alkali soils and greater productivity (quite similar, in fact, to the present day issues). The first association of plant breeders, The American Breeders Association, was established in 1903[6].

Breeders had decided to become a profession and, from that period onwards, as in any other profession, to defend their interests. Among those was the protection of their intellectual property. Indeed, in contrast with the previous situation whereby the new landraces were a byproduct of farming activities and, consequently, not necessarily needing any financial compensation, the only source of income of private professional plant breeders for their livelihood and continued investment is the sales of the propagating material of the varieties they have developed.

In 1938 the International Association of Professional Plant Breeders for the Protection of Intellectual Property, known as ASSINSEL, was established. Its main objective was clearly indicated in its name[7].

4 - The protection of plant breeder's right and the 1961 UPOV Convention[8].

During the first part of the twentieth century, several attempts were made at national and international levels to put in place an effective system of protection of intellectual property for plant breeders. With a few exceptions, such as the Plant Patent Act passed in 1930 in the USA for vegetatively reproduced crops (except tubers), the global result was rather meager. In the 1950s, the discussions resumed, with ASSINSEL playing an instrumental role that has been twofold: firstly ASSINSEL obtained a unanimous motion of its members during its annual congress in 1956 requesting for the organization of an International Conference to study the question of the protection of intellectual property in plant breeding; secondly the French members of ASSINSEL succeeded in convincing the French Government to convene such an International Conference. The first session of the Diplomatic Conference took place in 1957 and the second one in 1961, ending with the adoption of the 1961 UPOV Convention.

In its preamble, the Convention says that the contracting parties "are convinced of the importance attaching to the protection of varieties of plants not only for the development of agriculture in their territories[9] but also for the safeguarding of the interests of breeders". The convention establishes the conditions for obtaining protection and, in its article 5, the scope of the protection. One essential feature of the Convention is the breeder's exception, made necessary by the fact that progress in plant breeding is incremental and that access to plant genetic resources for research and breeding is necessary as shown, as an example, by figure 1.

5 Fisher, 1925, Statistical Method for Research Workers.
6 Kinsbury, p 159.
7 The word "professional" was dropped after some years and, in 2002, ASSINSEL merged with the International Seed Trade Association FIS to form the International Seed Federation ISF.
8 For more details see Heitz, 1987.
9 Emphasis by the author

Figure 1a presents the complexity of the pedigree of the variety Sonalika, released in 1964. Figure 1b gives some readable details.

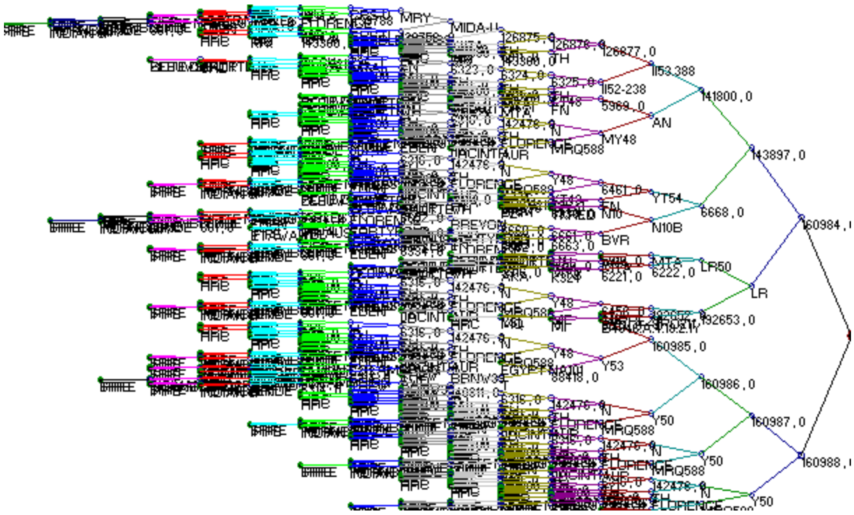

Figure 1a, pedigree of the wheat variety Sonalika, source CYMMIT.

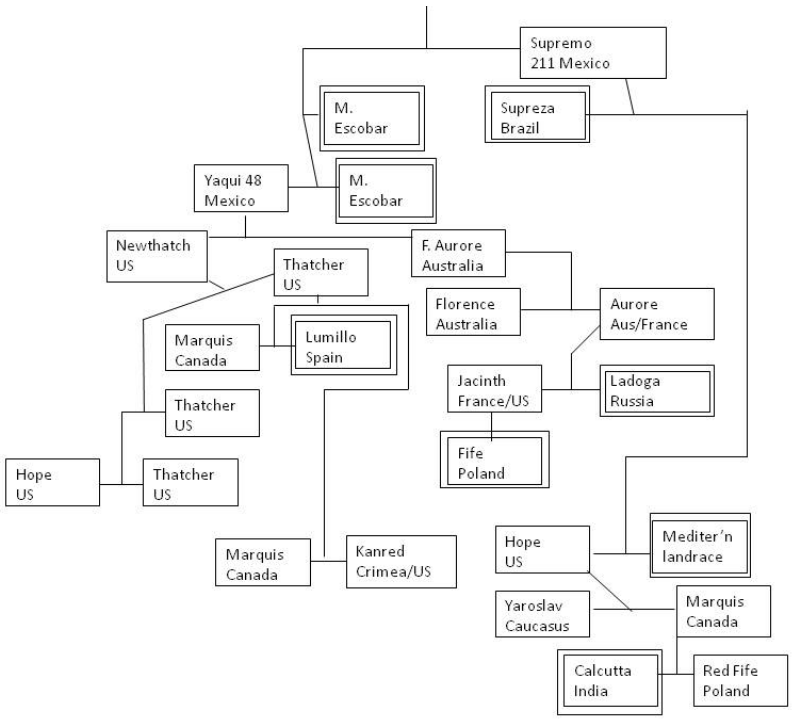

Figure 1b: A small segment of the bread wheat (cv. Sonalika) pedigree, source CYMMIT

5 - Some achievements of plant breeding.

5.1 - Yield improvement.

A linear view of agriculture evolution and wheat yield improvement in France[10] gives a good perspective of the yield improvement aspect from plant breeding.

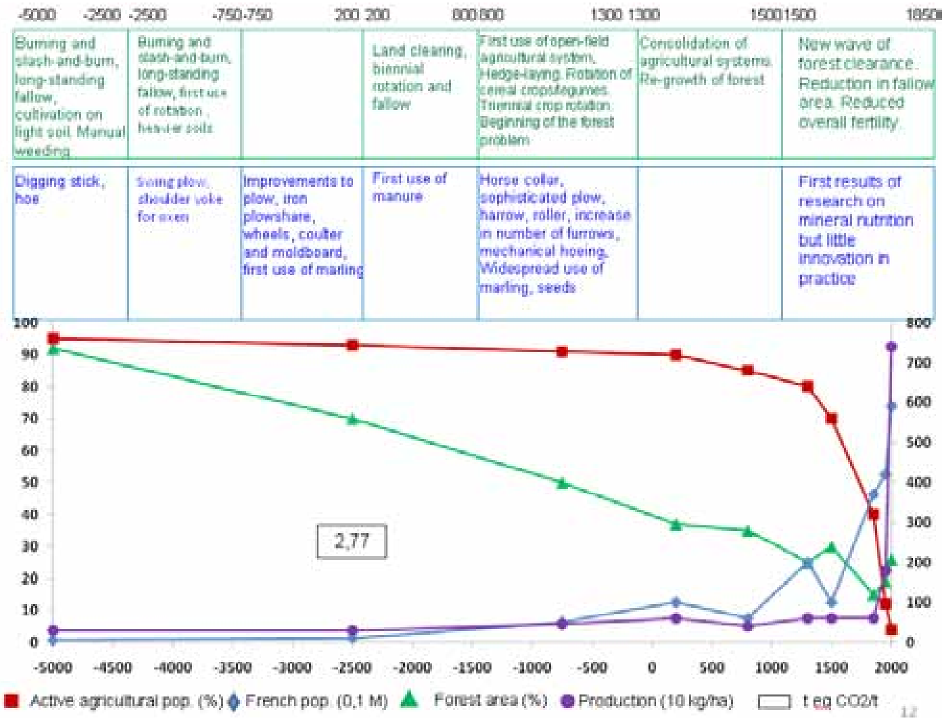

Fig 2a : Evolution of France Agriculture and wheat yield -5000 BC to 2000

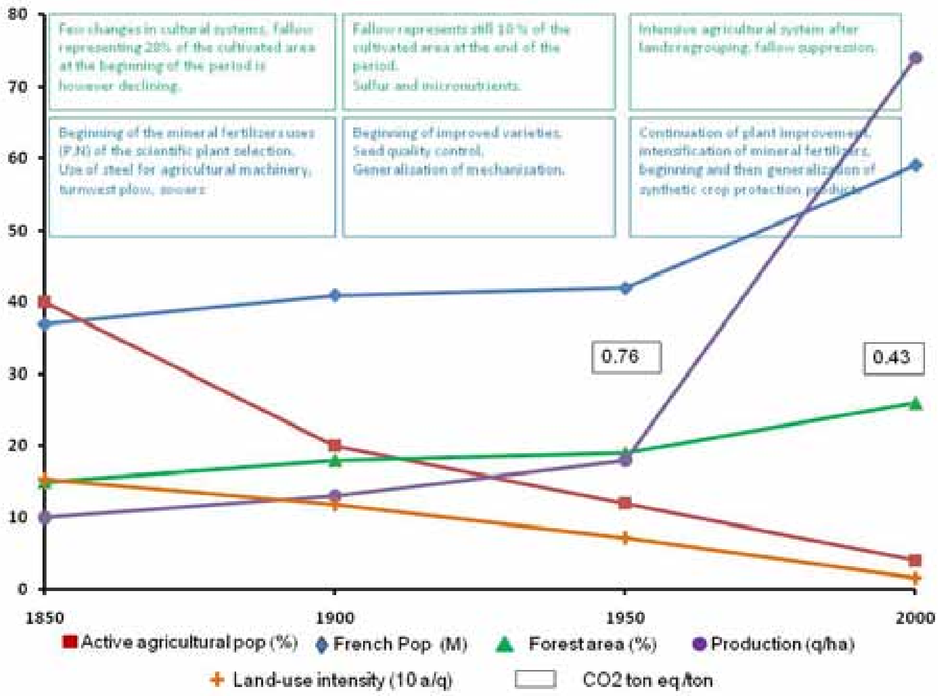

Fig 2b: Details of 2a, 1850-2000

10 Compiled from Gille B.,1978, Boulaine J, 1996 and G. Duby and A. Wallon, 1977.

Figures 2a and 2b (details of the last 150 years of 2a) show various parameters: the French total and agricultural populations, the forest acreage and the wheat yield per hectare. It appears that the wheat yield has increased extremely slowly from 3 to 10 quintals per hectare between the year - 5000 to the year 1850. Almost the only way to increase the national production to feed an increasing and more and more urbanized population was to increase the area of the cultivated land and, consequently, to clear forests and reclaim wet lands. From 1850 to 1950, the yield increased a little more rapidly from 10 to 16 q/ha, but still at a low pace, despite the agricultural revolution (*cf supra*). It is generally considered that the slowness of the progress was due to the lack of productivity of the wheat varieties. With the generalization of High Yielding Varieties, the yield per hectare increased drastically from 16 q/ha to 74 q/ha between 1950 and the year 2000. The genetic gain represents 50% of that increase[11]. In addition to the improvement of the land-use intensity (area needed for a unit of production), with an increase of the forest area, the CO2 ton equivalent by ton of wheat produced has decreased from 0, 76 in 1950 to 0, 43 in 2000[12]. Examples of similar evolutions exist for various crops and various countries[13].

It is interesting to note that yield improvement was not made to the detriment to hardiness, disease resistance and technical quality[14]. The example of upland rice in Africa is particularly interesting as, in this continent, the interest of HYVs compared to landraces is often disputed. In West Africa, local varieties and improved lines were compared under farmers' conditions, at different levels of productivity. Interpretable results were obtained in 198 farmers' fields, in 16 different environments as shown in figure 3[15].

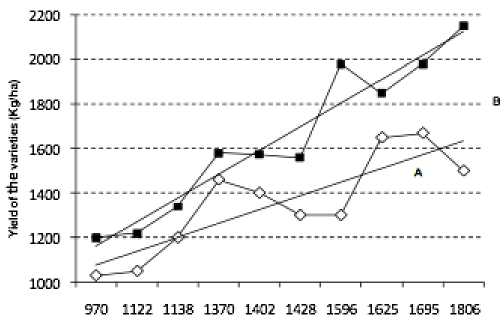

Figure 3 Yield performance of the local variety (A) and the improved line (B) according to the environmental potential measured by the average yield of the trial in each location

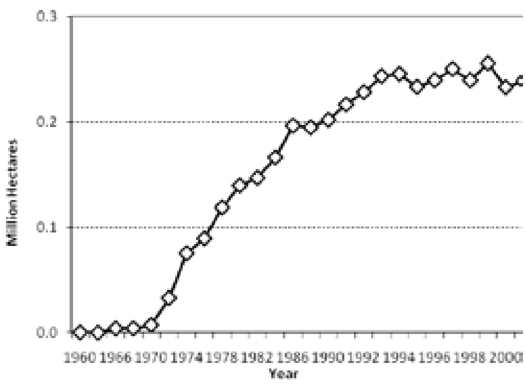

Figure 4 Increase of maize acreage in the Netherlands (Dutch Recommended List 2022)

In the range of tested environments, the improved line B is always better than the best local variety chosen by the farmer, even in low potential environments. In addition, the improved line responds much better than the local variety in environments with good potential.

5.2 - Adaptation to new environments

People moving around the globe have progressively adapted crops to new environments, but, in general, that adaptation has taken a very long time. For example, it has taken many centuries to adapt rice to northern areas in Japan[16]. Given climatic variations and the quick move of species around the world, it is very likely that adaptation of crops to new environments will be necessary in the future. Thanks to plant breeding, this will be possible much faster than in the past. Three examples may illustrate that evolution.

11 M. Brancourt-Hulmel and al, 2003.
12 A. Riedacker, 2008.
13 B. Le Buanec, 2009 and ISF, 2002
14 M. Brancourt-Hulmel and al, 2003, ISF, 2002.
15 Jones M.P., Diallo R., 1995.
16 Kinsbury N., 2009, p 51.

5.2.1 - Adaptation of maize to northern Europe

Maize was introduced in Europe at the end of the fifteenth century, after the discovery of the Americas by the Europeans. However, growing of maize remained limited to areas south of the 45^{th} parallel, with warm and rather wet summers, until the 1960s. The development of hybrids with improved earliness and early vigor (crosses between European flint lines and early dent North American lines), associated with good seed quality, with a quick and regular field emergence, has enabled moving the crop North. The situation in the Netherlands illustrates that evolution. (Fig 4)

5.2.2 - Adaptation of rapeseed to Australia[17]

In Australia, the first commercial crop of rape seed took place in 1969, but, in 1972, the black leg disease devastated the fledgling rapeseed oil industry. That source of oil being considered as important for the country, breeding programs started in 1970 in Victoria and in 1973 in New South Wales and Western Australia. In addition, rapeseed had a weeding problem in Australia, due to the specific weed spectrum, especially with *Brassica* weeds such as wild radish.

Resistance to black leg was sourced mainly from Japanese Spring material and French Winter material. The triazine tolerance was sourced from Canada, where it had been introduced, with the help of embryo rescue, into *Brassica napus* from a wild population of *Brassica rapa*. The first black leg resistant varieties were put on the market in the 1980s and the first triazine tolerant variety in 1993. In about twenty years the problems linked to a specific environment, high level of black leg occurrence and specific weed spectrum were solved, allowing a spectacular increase in rape seed cultivation. (see fig 5). The Australian oilseed production has more than trebled from 1993 to 1999, predominantly due to rape seed and, in 1999, Australia had become one of the major oilseed exporters.

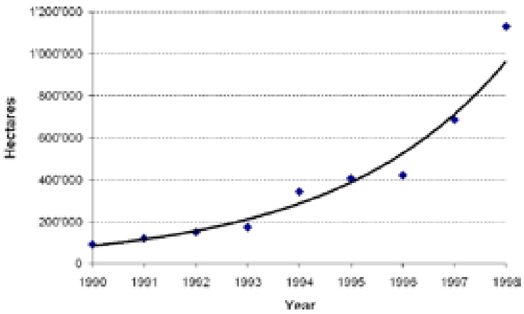

Fig 5 Evolution of Rape Seed Acreage in Australia

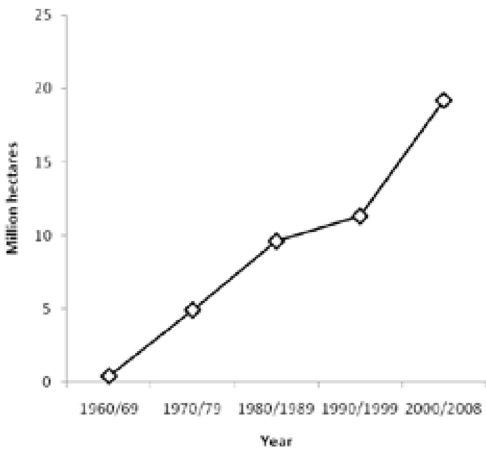

Fig 6: Evolution of soybean acreage in Brazil

17 Salisbury P., 1999 and personal communication, 2011.

5.2.3 - Adaptation of soybean to equatorial Brazil[18]

In the 1960s, soybean was a minor crop in Brazil, mainly grown in the state of Rio Grande do Sul at around 30° of latitude south. The varieties were coming from the south of the USA at around 30° of latitude North, with the same daylight conditions. In the 1970s, soybean became more important and started moving North, particularly in the State of Parana, due to the coffee decline, especially after the 1975 frost. From then on, the crop continued to move northward and it is now possible to grow soybean at 0° latitude with the same efficiency as 30° latitude.

The determining character that has been modified to allow that adaptation to a new environment was the photoperiodism of the crop. The adaptation work began in the 1970s in Campinas and Londrina, with the development of populations by crossing US varieties with genotypes having a long juvenile period that had been identified in the already existing varieties. Subsequently spontaneous mutations, expressing various degrees of juvenility, were identified, selected and then used as parents in crosses for the development of varieties for low latitude environments. However, greater efficiency was obtained when the breeding program was moved to the state of Maranhao, region of adaptation of the germplasm. In the mid-1980s, several adapted varieties had been obtained. Various characteristics were also improved during that period including, in particular, varieties with different seed coats to withstand high temperatures. The dramatic increase of soybean growing in Brazil is shown in figure 6.

5.2.4 - Conclusion

Those three examples show that in the space of 10 to 20 years, modern plant breeding has allowed the adaptation of crops to different physical or biological environments.

5.3 - Development of a new species, Triticale[19]

Some natural hybrids, between wheat and rye, mostly sterile, had been described at the end of the nineteenth century. The sterility resulted from accidents at the mitotic stage, due to the odd number of chromosomes of the hybrid. The will to combine the quality of wheat with the hardiness and the cold resistance of rye pushed the breeders to try and solve the problem of sterility. This was made possible by the development of two techniques: polyploïdization using colchicine to double the number of chromosomes, discovered in 1937, and cytogenetic, significantly improved in the 1950s, to select the progenies with a correct number of chromosomes. For instance, in France, a breeding program started in 1958; the first variety was put on the market in 1979. The modern varieties of Triticale have a yield potential as good as wheat and hardiness close to that of rye. It is also appreciated for the length of its straw. Triticale represents a gain in biodiversity.

Triticale is cultivated in several countries and the world acreage has increased regularly since 1980. (See figure 7)

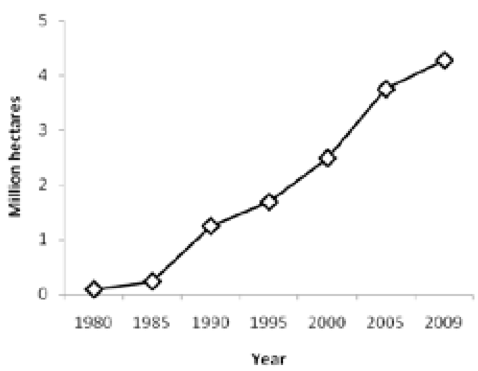

Fig 7: Evolution of Triticale acreage at the world level

18 Dall'Agnol A. and Sendin P., personal communications 2011.
19 Bastergue et al, 2006.

5.4 - Improvement of quality

The product quality, both technical and nutritional, has been improved in many crops. Rapeseed illustrates well work done in that domain[20].

There are three species that are grown under the name of rapeseed or canola: *Brassica rapa*, *Brassica napus* and *Brassica juncea*. Rapeseed has been grown as early as the 20th century B.C. in India and was then introduced in China and Japan at about the time of Christ. Rapeseed was grown in Europe as early as the 13th century and the oil was used for both cooking and lighting. After the development of steam power, rapeseed oil was used as a lubricant when it was found that it clung to water- or steam-washed metal surfaces better than other lubricants. Rapeseed was introduced to Canada for that use, the peak period being the Second World War. After that period, use as a lubricant declined sharply and Canadian farmers began to look for other uses for the plant and its products, mainly as edible oil and feed meal.

However, for those usages, rapeseed oil had two main weaknesses: a high level in erucic acid considered as early as 1956 as health damaging and a high level of glucosinolates in the meal that led to palatability and nutritional problems when fed to livestock and poultry. Canadian breeders were pioneers in trying to solve those two problems. Whilst screening the available gerplasm, in 1960 they found a spontaneous mutant forage crop cultivar with low level in erucic acid. By crossing that cultivar with oil varieties and then backcrossing, they rapidly developed a variety that was released in 1968. In order to speed up the process, they developed an original method allowing the seed to be cut in two parts so that one part could be tested for its oil composition by gas chromatography and the other part, after selection, could still germinate.

In 1967, another natural mutant was found to be low in glucosinolates and the same process used for low erucic acid was implemented. The first variety with low erucic acid and low glucosinolates was released in 1974. That kind of variety is known as double 0 rapeseed or double low rapeseed.

Those important changes, that have been followed by many other countries, primarily based on the germplasm developed in Canada, has allowed a large increase in the rapeseed production at world level and rapeseed oil is now the third oil in terms of volume for human consumption.

More recently other changes have been made in the fatty acids composition of the rape seed using several techniques: low linolenic and high oleic acids content by mutation breeding using ethylmethane sulfonate (EMS) and molecular markers assisted selection, high lauric acid by genetic engineering. High erucic canola has also been developed in Canada by the screening of existing gerplasm and then crossing and backcrossing.

In less than 50 years, using several techniques from screening natural mutations and then crossing and backcrossing to induced mutation, genetic engineering and molecular markers assisted selection, a crop has been deeply modified for various human, animal and industrial uses, and now that crop is grown on 31 million hectares in the world.

20 Canola Council of Canada, 2011; Lespinasse Y. and al, 2011.

5.5 - Conclusions

Those few examples, among many others that could have been developed, clearly show the interest of plant breeding for facing the challenges met by humankind, by improving yields, adapting crops to new physical and biological environments, creating new species and improving quality. This is in line with the preamble of the 1961 Act of the UPOV Convention stating that the Contracting Parties were "convinced of the importance attaching to the protection of new varieties of plants [...] *for the development of agriculture in their territory*[21] ".

Evolution of plant breeding after 1961 and the need for a revision of the Convention

During the 1970s and 1980s, plant biotechnology made considerable progresses that has been described in many publications and will not be detailed in this presentation[22]. In particular, new techniques were allowing a rapid increase in development of new varieties - the creation of converted lines by genetic engineering, the use of any part of a plant as reproductive material - all those techniques presenting a risk to jeopardize the right of an initial breeder.

Those concerns were raised as early as 1980 by ASSINSEL which, during its Congress in Cannes (France), had a lively discussion on sister lines, converted lines, distinctness and novelty and decided to have in-depth discussions on that topic on the occasion of its 1981 Congress in Acapulco. After the Acapulco Congress, ASSINSEL requested UPOV "to take all necessary measures to prevent converted lines from infringing and pirating breeder's genetic material". In 1982, ASSINSEL sent a letter to its members stating that "the ASSINSEL Council, conscious of the new developments in the area of plant breeding, particularly in respect of the applications and issues raised by Genetic Engineering, believes that the time has come to again study the question of important characteristics."

At that time, the Administrative and Legal Committee of UPOV, when consulted, considered during its meeting of April 28, 1983, that "amendment to the Convention was not advisable for the time being."

However, the general evolution in plant breeding, the ongoing discussions on the protection of biotechnological inventions at national and international levels, a motion was adopted by the vegetable seed section of FIS in 1986 that was noted by the Council of UPOV, lead the Council, during its session of December 1986, to instruct the Administrative and Legal Committee to study the possibilities of improving the UPOV Convention[23].

During its twenty-third session, the Administrative and Legal Committee[24] considered that the more specific aims of the revision would be:

- to strengthen the right of the breeder;
- to extend the practical scope of application of the plant variety protection system;
- to clarify, on the basis of experience, a number of provisions, [...], and to adapt them to the recent and prospective[25] developments.

After 4 years of intensive work of the Members of the Union, with the participation of International Governmental and Nongovernmental Organizations, a Diplomatic Conference was convened in March 1991 and a new Act of the Convention was adopted on March 19 of that year.

21 Emphasis by the author
22 Interested readers may refer to a recent publication of June 2011 : Biotechnologies végétales, environnement, alimentation, santé, ISBN Vuibert 978-2-311-00360-4
23 Document C/XX/13, December 2 1986
24 Document CAJ/XXIII/2, July 13, 1988
25 Emphasis by the author

Among the main changes, we may note a more detailed definition of a variety, the extension of the protection to all plant genera and species, the extension of the scope of protection including, under certain conditions, the protection of harvested material of the protected variety, the clarification of the use of farm saved seed, the introduction of the concept of essential derivation and dependency from the initial variety. Those changes, taking into account the technological and scientific developments since 1961, strengthened the plant breeder's right. They encourage plant breeders to continue to invest in research for plant innovation on an increasing number of species. The private research budget in plant innovation may be estimated at 4.5 billion US dollars in 2011. The number of species with protected varieties has increased dramatically from 80 in 1981[26], 350 in 1988[27] to 3045 in 2011[28]. The dramatic increase from 1988 to 2011 is due to the generalisation of the protection to all genera and species and the increase of UPOV membership[29] from 17 to 70.

6 - Conclusion

Selection of landraces and the subsequent breeding of new varieties have evolved continually with the development of agricultural practices and scientific discoveries. In order to encourage plant breeding, the protection of plant varieties has been introduced and then adapted during the twentieth century to accompany that evolution. Since, as we have seen, plant breeding is an important tool to help society to face the many challenges for humankind, it will be essential in order to continue encouraging investments in that area, to make sure that the protection of intellectual property will continue to be adapted when necessary, to remain strong and effective, whilst allowing access to genetic variability for the vital germplasm improvement.

26 Mast H., 1981
27 Doc UPOV C/XXII/8
28 GENIE Database, 2011.
29 Those figures include agricultural and horticultural species.

SESSION 1: Plant Science and the Future for Plant Breeding

The Role of Genomics in Crop Improvement

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For many years crop breeding, through the phenotypic selection of desired traits, has made outstanding contributions to maintaining steady increases in yield, nutrient use and to combating pathogens. The introgression of alien chromosomes and selection of specific chromosomal segments has been used to introduce specific traits from more genetically distant sources, but in general crossing genetically and phenotypically diverse lines has not been practical due to the large amount of unwanted phenotypic variation and unexpected variation. As a consequence, the production of new crop varieties can take many years and can have uncertain outcomes. Considering the inexorable rise in the human population and changing dietary habits, we need to produce food at an unprecedented high rate. Furthermore, this challenge has to be met while reducing inputs such as fertilizers and combating new disease epidemics, and maintaining high yields in an uncertain climate.

To meet these challenges plant scientists are developing new approaches to crop improvement, including transgenesis and genomics. The impact of genetic engineering since its commercial introduction in 1995 has been substantial, as measured by broad acres of planted crops. Genomics is a relatively new technology for crop improvement, and in my lecture I will describe its potential for changing plant breeding irreversibly. If successfully utilized in what is termed molecular breeding, the scope of breeding will be expanded so that previously under-exploited germplasm can be used, and the process speeded up. This technological change also goes hand in hand with an ever-depending increase in knowledge of plant biology. It is this deeper understanding that may eventually lead to predictive plant breeding, where specific sets of traits can be assembled on a computer and relayed to geneticists to make crosses and select progeny.

Bioengineering

Mr. Konstantain
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Over 70% of Russian territory is situated in the area of high-risk agriculture. The plant growing season in the major part of Russia is 2-3 months per year, compared to8-9 months in Europe and the United States of America. The maximal difference between summer and winter temperatures in Russia is 116.6 °C, representing the largest difference worldwide. At the same time Russia possess 10% of the cultivable soils of the world. So the creation of new crop varieties that are resistant to weeds, pests, viruses and other biotic and abiotic stress factors is the most relevant challenge for Russian agriculture [1].

During the development of new, improved varieties we try to use all available up-to-date techniques including bioengineering and genomic approaches. The order of priority for the crop plants involved in this process follows from their significance in agricultural economics and the specific conditions and requirements in their cultivation. For example, for wheat (total yield almost 62 million tons, 2009) the main new traits are drought and herbicide resistances [2]. For potato (total yield almost 31 million tons, 2009). it is resistance to pests and bacterial infections, and for sugar beet (25 million tons total yield, 2009), it is viral infections.

The application of plant bioengineering is the cutting-edge way to develop new plant varieties with the desired properties. During last 15 years, using this approach, a number of new varieties was created in Russia. That includes: potato lines, resistant to PVX virus, phytophthora and Colorado beetle; cabbage and sunflower lines resistant to herbicide phosphinotricine; sugar beet lines resistant to herbicide phosphinotricine and to BYV and BNYVV viruses [3, 4, 5]. According to preliminary data, the application of the MF3 gene (peptidyl-prolyl cis-trans isomerase from Pseudomonas fluorescence) for the creation of biotech sugar beet and potato plants resistant to the wide range of fungal and bacterial pathogens (Puccinia graminis, Septoria nodorum, Erwinia carotovora, etc) is the very promising.

The practical application of biotech plants is based on the principle of state registration of all new agricultural plants. According to the current Russian legislation, which is internationally harmonized, including with the International Union for the Protection of New Varieties of Plants (UPOV), the governmental body responsible for the registration process is the State Variety Commission of Ministry of Agriculture. The registration of new biotech plants is under a specific regulation because one of the principal precautionary arguments against the development and practical implementation of genetically modified organisms (GMOs) is the risk of disturbance of the genetic structure of recipient plant DNA in the sites of foreign DNA insertion [6]. However, today this problem can be solved.

For example, our participation in the international Potato Genome Sequencing Consortium project [7] made it possible to perform an accurate analysis of the genomic flanking regions of the transgenic inserts. It was shown that, in the Russian biotech potato lines, 'Elizaveta Plus' and 'Lugovskoi Plus', the transgenic inserts were situated in transcriptionally non-active regions. It was concluded that the possibility of the adverse effects of bioengineering intervention in both cases was minimal.

UPOV's 50th anniversary of the International Convention for the Protection of New Varieties of Plants undoubtedly coincides with revolutionary achievements in the bioengineering of new plant varieties.

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Heteorisis in Rye

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Heterosis is the genetic mechanism that makes it possible to realize the productivity potential of agricultural plants and animals.

The phenomenon of "hybrid power" was noticed in XIX century. First it was described by Ch. Darwin. The term "heterosis" was introduced by Shull. To date, heterosis using F1 hybrids has been developed for almost all agricultural plants. Moreover, as a rule, open-pollinated crops including rye are characterized by a higher level of heterosis. Perhaps this is conditioned in open-pollinated crops by the large reserve of genetic variability.

Research on genetics and breeding of heterosis in rye hybrids is concentrated mostly in Europe, because Europe accounts forapproximately 87% of the global rye area. Most of the results have been obtained in Germany. At present, hybrid varieties occupy about 60% of the total area of area in Germany. Several German F1 rye hybrids have been registered in Belarus: 'Picasso'; 'Askari', 'Fugato', 'Amato'.

Work has also been done on hybrid rye in Poland: F1 rye hybrids with high heterosis level were developed over several decades. Nevertheless, hybrid rye occupies no more then 5-7% on Poland.

Research on heterosis in rye is also carried out in Belarus, the Russian Federation, Sweden and Ukraine.

Outside of Europe scientists at University of Sydney in Australia have conducted research.

The success of development and introduction into agricultural production of hybrid rye varieties has been achieved thanks to the resolution of some formidable problems with self-incompatability in cross-pollinated species.

The main goals for breeding F1 hybrids of a winter rye are the following:

- Development of inbred-line collections with high combining ability (GCA and SCA) and with weak inbred depression in generations;
- Identification of sterility maintainers (non-restorers) and restorers;
- Development of cytoplasmic male sterility system - CMS - (sterility maintainer + male sterile analogue of a sterility maintainer /♀/, restorer /♂/);
- Development of an effective technique for hybrid variety production from the female (MS) and male components;
- Development of an economically viable scheme of production of hybrid seed and system of seedgrowing of hybrid varieties (Hardzei, 2002).

From the genetic point of view, the greatest interest is represented by first three problems. The last two problems are methodical and organizational tasks.

Development of inbred-lines

Many researchers of winter rye tried to use self-pollinated lines for the purpose of F1 hybrid development. It was possible to overcome inbred depression, by use of sources self-fertility, which were found in rye populations. On the basis of such sources, collections of lines with a high level of self-compatibility and a low level of inbred depression were developed. At the Institute of Genetics and Cytology (Minsk) a source of self-compatibility was also found, which is controlled by a small number of genes.

At present a number of self-compatibility genes is already localized: Sf1 (1R); Sf2 (2R); Sf3 (4R); Sf5 (5R); Sf4 (6R). Three mutations defining self-compatibility in loci S, Z and S5 were mapped on chromosomes 1R; 2R and 5R respectively. One protein- and three DNA- markers for these loci were defined. Undoubtedly, such research facilitates the process of inbred-line development.

CMS using in rye

The practical use of heterosis in rye started after the discovery of cytoplasmic male sterility (CMS). The first male sterile plants were described by Putt in 1954. Later, different types of male sterility with different cytoplasmic and nuclear control were described. According to research of Kobylyanskij: male sterility is controlled by one recessive ‘rf’ gene, by the homozygous (rf rf) state; and fertility by the heterozygous (Rfrf) or dominant homozygous (RfRf) state. This type was named R-type because it was studied on the Russian rye population ‘Wiatka’.

P-type CMS (“Pampa”) which was found in Germany among plants of the Argentina rye variety ‘Pampa’, is the most studied from a genetic point of view. Analysis of P-type CMS was carried out by L.Madej. He has established that this type of male sterility is the result of interaction of sterile cytoplasm and two nuclear genes. A more complex model was presented by Rubenbauer in 1984. He established that this CMS type is controlled by sterile cytoplasm and by at least four nuclear genes of male sterility, which are designated: ms1; ms2; ms3; ms4. In the dominant state, these genes restore fertility. According to results of molecular research, P-type CMS is controlled by two of the basic nuclear ‘ms’ genes, localized on chromosomes 1R and 4R, and also three ‘ms’ genes with a smaller effect, localized on chromosomes 3R, 5R and 6R. There are no data concerning correlation between ‘ms’ genes and the aforementioned ‘rf’ genes. Probably, this difference only exists in the name.

Along with the genetic and breeding research based on CMS R - and P-types, work with CMS G-type has also been carried out. It was begun by Adolf and Winkel in 1985 on the variety ‘Schlagler’. The results of this research provide a basis to conclude that practically all lines of rye are capable of restoring fertility. However, it can lead to an uncontrollable loss of sterility. For G-type CMS, the nuclear gene of fertility restoration ms1 (rf) on a chromosome 4RL is localized, genes-modifiers on chromosomes 3R (ms2), 6R (ms3) are also described. It has also been established, that the gene located on chromosome 5R (dw6), is not connected with an ms1 gene.

CMS types A; C; S; and V, have also been found, in populations from different ecological groups. Comparative studies of various CMS types have shown, that only the P-type is characterized by easy sterility maintenance and by a low frequency of fertility restoration genes . For other known CMS types - R, G, A, C, S, V - it is difficult to find non-restorers, and with restorers problems do not exist. The wide use in research of P-type CMS is because of the high frequency in populations of sterility maintenance genes, since there is no risk to lose in generations sterile forms. Currently, almost all commercial hybrid varieties of winter rye are developed on the basis of P-type CMS.

An exception is G-type CMS. In 2000 in Germany, a first line-population F1 hybrid of rye ‘Novus’, developed on the genetic basis of G-CMS (□ ms-line ’Gülzower-1’) and population variety ’Valet’” □ [9] was registered (Melz Gi., et al., 2001) Later, several hybrid rye varieties on the basis of G-CMS were registered in Germany: ‘Hellvus’, ‘Helltop’ (unpublished data – “Dieckmann Seeds”).

Due to high frequency of restorer genes in populations, any variety can be used as a restorer, irrespective of the female genotype.

The results of studying German F1 hybrids in Belarus, on the basis of G-ЦМС have shown weak winter hardiness (fig.1).

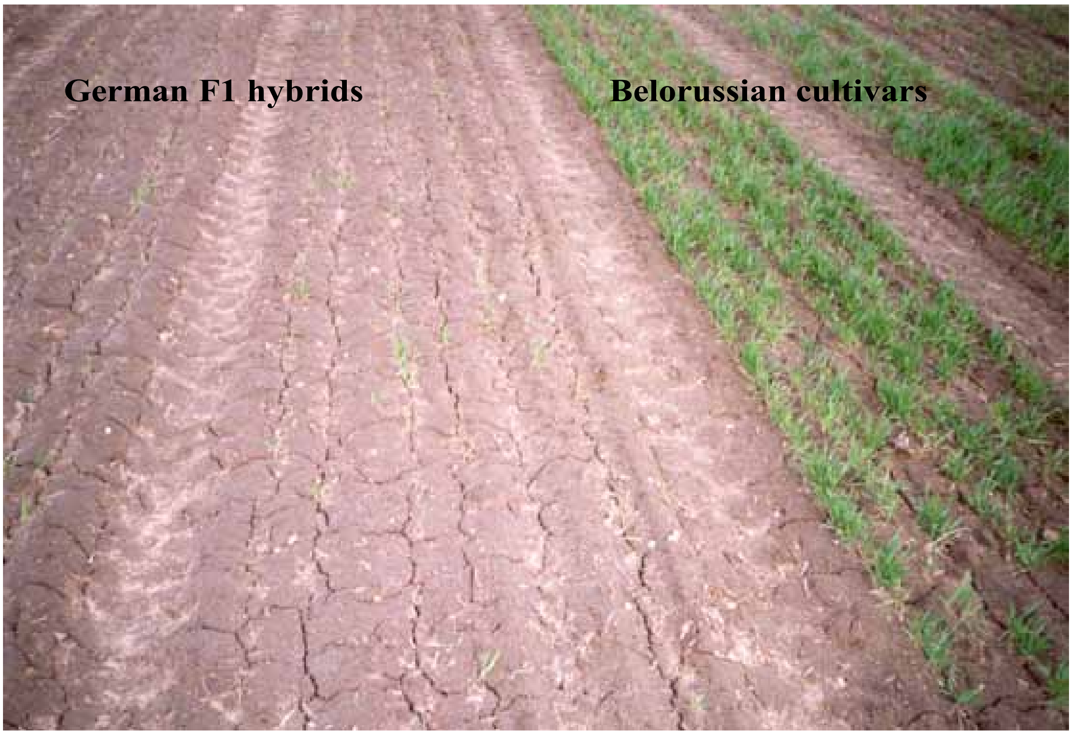

Figure 1. Winter hardiness of German and Belorussian rye varieties (Zhodino, 10.04.2003)
Analysis of pollen fertility has shown that all hybrids were characterized by a high restoration index: 89,8 - 100 %.

It has been established that the basic barrier for rye hybrids based on G-ЦМС development is the low frequency of sterility maintenance genes in rye populations. Crossing of Ms-testers of G-type with 350 inbred-lines of Belorussian collection revealed only two sterility maintainers. Other lines were restorers with a restoration index of 72,5% - 100%. Thus, during the reproduction of male sterile components, there is a risk of losing ms-forms.

Genetic control of CMS
Molecular-genetic methods of research have revealed distinctions in mitochondrial DNA (m-DNA) of male sterile plants and normal plants. It has been established that CMS in rye is connected with reorganisation of the mitochondrial genome, leading to the formation of "chimerical" genes (or new polycistron transcripts), which are found in practically all studied cms-forms. In some cases it was even possible to establish the origin of all fragments of chimerical genes; however, more often the source of some sequences is unknown. It has also been established that mutant mitochondrial genes are corrected by nuclear Ms (Rf) genes –fertility restorers. This correction can occur at different stages: from DNA replication until interaction with CMS-proteins (Danilenko N.G., Dawydenko O.G., 2003). Thus far it is not clear what mechanisms underlie the interaction between the mutant mitochondrial genome and the nuclear ms (rf) genes, and also as a whole genetic CMS-system and self-fertility system.

Methods of hybrid rye variety development
Firstly, an assessment is made of the combining ability of the initial material (inbred-line, populations). After the selection of forms with high GCA and SCA, pair isolation of female and male components with ms-testers is carryied out. Inbred-lines from these crossings, depending on the pollen fertility of the F1 progeny, are divided into restorers and non-restorers (maintainer).

The most simplified and clear schemes were developed by H.H.Geiger and T.Miedaner (Geiger H.H., Miedaner T. 1999; Geiger H.H.,2007) (Fig. 2; 3)

For development of asterile analogue of a non-restorer at least 4 crosses are made with the Ms-tester. Simultaneously, the restorer is multiplied. F1 hybrid seeds can be produced by two methods: 1) top-cross, where female and male components are located separately in the field; or 2) mixture of seeds, by mixing seeds of a female ms-component with the male fertile parent before sowing in a proportion of 95%: 5%, respectively (fig.3); economically this method is more favorable.

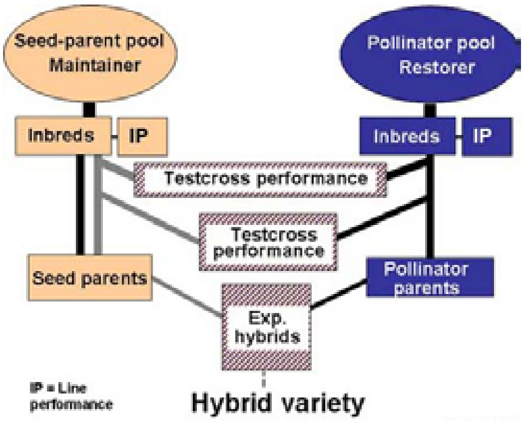

Figure 2. Scheme of winter rye F1 heterosis hybrid development (Geiger, 2007)

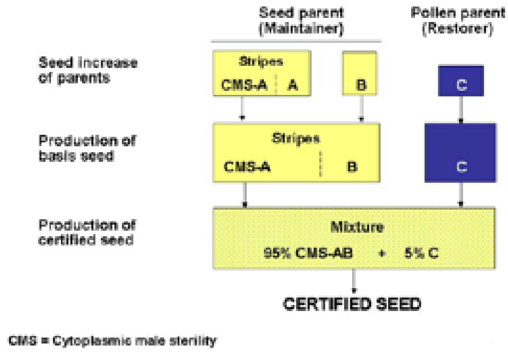

Figure. 3. Scheme of rye hybrid seed production (Geiger, Miedaner, 1999).

The efficiency of hybrid breeding is increased by using double and triple interlinear hybrids. At present, breeders develop hybrid varieties where male sterile interlinear F1 hybrids are used as the female component, and a synthetic restorer, which consists as a rule of several inbred-lines, is used as the male parent - . Such a hybrid formula provides a stable, high level of heterosis. Furthermore, the flowering phase of synthetics is longer in comparison with lines, thereby providing synchronous flowering of female and male components.

Genetic diversity of parental components of F1 hybrids

It is known that the level heterosis of F1 hybrids is, to a great extent, determined by the degree of genetic diversity of the crossing components. Long-term observation has shown that, as a rule, a small degree of genetic diversity of crossing components renders the effect of heterosis, insignificant, and the use of genetically strongly divergent components can lead to intermediate inheritance. In this regard, there is a necessity to define the optimum genetic distance of components of crossings for the "management" of heterosis, with the application of effective methods. The development of molecular marker technology allows the possibility to define precisely the genetic distance between crossed forms, which might allow the selection of parental components of F1 hybrids without testing of the progeny.

Melchinger A. E., on the basis of his data and the results of some research of other authors, tried to establish a connection between genetic distance (based on DNA-markers) and heterosis level (Melchinger, A. E., 1999). He established however, that it is not possible to predict the heterosis level precisely on the basis of genetic distance between the crossing forms, based on DNA-markers. A problem is that the definition of markers for concrete quantitative traits is necessary, but not for a whole genetic diversity. Testing of progeny is still the most exact method of assessing combining ability. Hence, the influence of the degree of genetic diversity on the heterosis level and, in particular, determining the optimum genetic distance between components, remains open.

Fertility restoration in F1 hybrids of rye

The important element in hybrid rye breeding with the use of P-CMS is the full restoration of pollen fertility of F1 hybrids. Here there are a number of difficulties: the frequency of fertility restoration genes in rye populations is small; and the fertility of F1 rye hybrids depends equally on the female and male components (tab. 1). However, the genetic reasons underlying the interaction between the Ms-form and restorer are not precisely defined.

Table 1. Restoration level of pollen fertility (%) at F1 rye hybrids

MS-line, ♀	Restorer, ♂				Average
	4-1	25-1	17-3	'Kalinka'	
MC-7	97,0±1,2	96,3±1,3	81,5±2,5	91,0±1,8	91,5
MC-2	90,2±1,8	87,5±2,3	75,7±3,5	30,6±2,5	71,0
MC-13	76,2±2,7	65,5±2,8	62,6±4,4	68,6±2,7	68,2
MC-24	69,7±3,0	60,7±2,6	63,7±3,5	57,5±2,4	62,9
MC-5	22,4±2,8	24,3±2,3	18,6±2,7	1,5±0,5	16,7
Average	71,1	66,9	60,4	49,8	62,1

It is also necessary to note that, as a rule, for the development of hybrid varieties researchers use lines characterized by high productivity more than for high restoring ability (P-CMS). As result, hybrid varieties possess an insufficient level of pollen fertility, andin rainy weather during flowering, this leads to susceptibility of hybrids to ergot. To solve this problem, it is necessary to add about 10% seeds of a population variety to hybrid seed (fig 4).

Figure 4. Hybrid variety with 10% of population variety

There are different data concerning the structure of heterosis. Geiger and Miedaner have established, that heterosis is mostly conditioned by higher grain number and weight per spike and by 1000 kernel weight, while the stem density shows small or even negative heterosis. The research of V.D.Kobyljansky demonstrated that, in most cases, heterosis was conditioned by number of productive stems on 1 m2 (54 %) and to a lesser degree by grain number per spike (24 %) and 1000 grain weight (22 %). More likely, that authors used material of different ecological groups, different CMS types (P and R respectively), which have different genetic control. Hence, the heterosis structure could differ.

Practical results of hybrid rye development.

As a result of joint research between SPCAF (Belarus) and KWS LOCHOW (Germany), first F1 hybrids of winter rye were developed: LoBel-103, LoBel -203, LoBel -303, which have exceeded the standard on 8,0-14,4 T/ha (tab. 2).

Table 2. Characteristics of heterosis F1 hybrids of rye (Zhodino, 2004-2005)

Traits	'Radzima – st.'	'LoBel-103'	'LoBel -203'	'LoBel -303'
Yield, T/ha	67,8	80,8	75,8	82,2
Height, m.	1,35	1,19	1,17	1,18
Lodging resistance, scale (1-9)	7,0	8,0	8,0	8,0
Stem density, stems/m2	445	575	589	554
Grain weight per spike, g	1,56	1,43	1,39	1,53
Seed-set, %	75	82	84	79
Winter hardiness, %	96,0	90,5	90,3	94,0

The results of State study of F1 hybrids also have shown higher yields compared to standard variety (tab. 3)

Table 3. Yield of F1 hybrids in different places of State study, 2004-2005 г.

Place of study	Yield, T/ha						
		'LoBel-103'		'LoBel -203'		'LoBel -303'	
	'Radzima – st.'	T/ha	± to st, T/ha	T/ha	± to st, T/ha	ц/га	± to st, T/ha
'Kobrin'	76,0	84,6	+8,5	86,1	+10,1	85,8	+9,8
'Oktyabr'	62,8	70,0	+7,2	69,9	+7,1	73,0	+10,2
'Zhirovichi'	69,3	76,1	+6,8	75,9	+6,6	75,0	+5,7
'Molodechno'	83,8	107,8	+24,0	106,2	+22,5	104,4	+20,6
'Gorki'	66,5	79,9	+13,0	78,7	+12,2	75,0	+8,5

The F1 hybrid 'LoBel-103' since 2006 is included in the State registry of varieties and is used as the standard for hybrid rye. Since 2007, F1 hybrid 'LoBel -203' was also included in the State registry as 'Halinka'.

The first Belorussian F1 hybrid of rye named 'Plisa' was developed in 2007. During three years of State study this variety has shown a higher yield compared to the standard 'LoBel-103' (tab.4)
'Plisa' is a line-population hybrid variety. It was developed with the use of an ms-line of G-type ♀ (breeding № - MS-2) and population hybrid ♂ ('Valdai' x 'Kaupo') as restorer (fig.5). As wrote above, any rye population for G-CMS is characterized by a high restoration index; therefore, this variety is not sensitive to ergot even without the addition of 10% of another population variety.

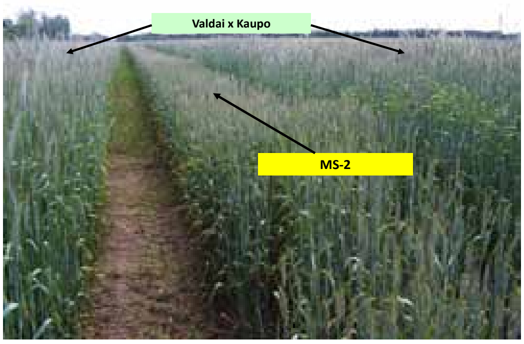

Figure 5. Hybrid seeds production of hybrid variety 'Plisa' '

Table 4. Yield of F1 hybrid 'Plisa' in different locations in State study, 2007-2009)

Place of study	Yield, T/ha		
		'Plisa	
	'LoBel-103 – st. '	T/ha	± to st, T/ha
'Kamenets'	79,6	78,5	-1,1
'Lepel'	86,5	92,0	+ 5,5
'Oktyabr'	50,4	53,5	+ 3,1
'Molodechno'	90,9	94,8	+ 3,9
'Gorki'	88,1	88,3	+ 0,2

Hybrid rye in agricultural production.
It is known, that the basic and most important advantage of hybrid varieties of rye is the higher grain yield compared to population varieties. However, it is necessary to take into consideration some restrictions at use of hybrid rye in agricultural production.

Firstly, hybrid varieties demand more fertile soils and accurate cultivation technology. On poor sandy soils, hybrids are not able to display heterosis: hybrid rye varieties must display at least 10% heterosis to cover of the more expensive seed of F1 hybrids compared to population varieties. Farmers or other agricultural organizations must buy seed of F1 hybrids every year. Cultivation of F2 progeny is not effective because of the reduction of heterosis level.

In Belarus, on average, 44.5% (about 2 million hectares) of croplands are light sandy and sandy loam soils with sandy sublayer, which are characterized by low natural fertility, extremely unstable water regime and increased acidity. These soils are unsuitable for the cultivation of crops, such as wheat, triticale, and hybrid rye. On such soils, diploid population varieties of rye should be cultivated. It was calculated that acreage of hybrid rye in Belarus in near future cannot be more than 10-14% of the total wimter rye acreage.

There are no official data about the acreage of the four German hybrid varieties (‘Picasso’; ‘Askari’, ‘Fugato’, ‘Amato’) registered in Belarus,.

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Breeding for Virus Resistance in Cereals

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Introduction

Cereals, especially wheat and barley, are of prime importance for feeding the earth´s growing population. Besides fungal diseases and insects, viruses cause severe yield losses in cereals all over the world. These are soil-borne viruses such as Barley yellow mosaic virus (BaYMV) and Barley mild mosaic virus (BaMMV), with respect to barley or Soil-borne cereal mosaic virus (SBCMV) and Wheat spindle streak mosaic virus (WSSMV) in wheat, which are all transmitted by the plasmodiophorid Polymyxa graminis. Furthermore, insect-transmitted viruses like the aphid transmitted Barley yellow dwarf virus (BYDV) and Cereal yellow dwarf virus (CYDV), the leaf hopper transmitted Wheat dwarf virus (WDV), or the mite transmitted Wheat streak mosaic virus (WSMV) are important pathogens of cereals (for review cf. Ordon et al. 2009). Because of global warming resulting in longer periods of higher temperature in autumn and winter in many regions of the world and in an expanded flight activity and overwintering of insect vectors, insect-transmitted viruses are predicted to become even more important in the future.

Due to transmission by the plasmodiophorid Polymyxa graminis, which is known to be infectious up to a soil depth of about 70 cm, cultural practices as well as the application of chemicals to avoid high yield losses, which maybe up to 50% in barley for BaMMV/BaYMV, are not effective against soil borne viruses. With respect to insect transmitted viruses, yield losses may be reduced by spraying insecticides which, however, causes additional costs, is often not effective, e.g. against leaf hoppers, and should be avoided in environmental-friendly and consumer-protecting plant production systems. Therefore, breeding for virus-resistant varieties is the only possibility to ensure wheat and barley cultivation on the growing area infested with soil-borne viruses and to reduce insecticide sprayings with respect to insect-transmitted viruses.

A brief overview on the achievements and future prospects for breeding for virus resistance in cereals is illustrated by resistance of barley to BaMMV/BaYMV and BYDV.

Barley yellow mosaic virus complex

Due to a constant spread of the area infested and yield losses up to 50%, barley yellow mosaic disease caused by different strains of BaMMV and BaYMV, is recognized as one of the most important diseases of winter barley in Europe today. Based on data in 2010, the potential economic losses caused by BaMMV/BaYMV in Germany can be calculated as follows: the acreage of winter barley in Germany in 2010 was 1,303,000 Ha and the average yield was 6.66T, resulting in production of 8,677,980T of barley. In 2010, the price for 1T of barley was about 150€, resulting in an economic value of 1,301,697,000€. According to Huth (1988) 50% of the barley growing area in Germany has to be considered as potentially infested with BaMMV/BaYMV, i.e. 651,500 Ha. Taking into account only a moderate yield loss of 25%, this corresponds to a loss of 1,074,975T equivalent to 161,246,250€. Resistant varieties were detected within the set of released varieties in Germany soon after the first discovery of this disease in Europe in 1978. By genetic analysis, it was discovered that resistance in these varieties is due to a single recessive gene, which was called rym4 and assigned to chromosome 3HL of barley. However, at that time (1980´s) resistant varieties were in general considerably lower yielding than susceptible varieties (Table 1). Today barley breeding has achieved a combination of resistance to BaMMV/BaYMV and high yields, and most of the released varieties are resistant and out-yielding susceptible varieties.

Table 1: Development of yield of BaMMV/BaYMV resistant and susceptible varieties in Germany from 1986-2011 (Anonymous 1986, 1995, 2005, 2011)

	No. varieties		Yield	
Year	Resistant	Susceptible	Resistant	susceptible
1986	6	37	4.3*	5.6
1995	24	41	6.5	6.3
2005	52	23	6.7	6.1
2011	55	9	6.9	6.4

*1=minimum, 9=maximum

Because of this very narrow base of resistance, extensive screening programs for resistance in the primary and secondary gene pool of barley were conducted. Based on these results, followed by genetic analyses and development of molecular markers, at least 8 different loci conferring resistance to the different strains of BaMMV and BaYMV have been mapped within the barley genome (Fig. 1, Friedt & Ordon 2007).

Closely linked molecular markers represent an efficient tool in breeding for resistance against BaMMV/BaYMV, since they facilitate the selection of resistant plants without phenotypic analysis, which for BaMYV/BaYMV-2 relies to a large extent on the climatic conditions during winter and spring. In practice, the availability of appropriate molecular markers allows doubled haploid populations (DHs) to be screened in vitro and only those plantlets that carry the resistance encoding allele need to be transferred to the greenhouse.

Moreover, backcrossing procedures required to incorporate these resistance genes derived in general from low yielding exotic germplasms into adapted high yielding varieties can be considerably abridged by molecular markers, resulting in an enhanced use of virus resistance present in genetic resources (for overview cf. Palloix & Ordon 2011).

Furthermore, these markers facilitate efficient pyramiding of resistance genes, i.e. the combination of different resistance genes against the same pathogen in a single genotype (Werner et al. 2005). Pyramiding may become of special importance in the future because many of the known recessive resistance genes are not effective against all strains of the barley yellow mosaic virus complex. By this approach the usability of partly-overcome resistance genes can be extended.

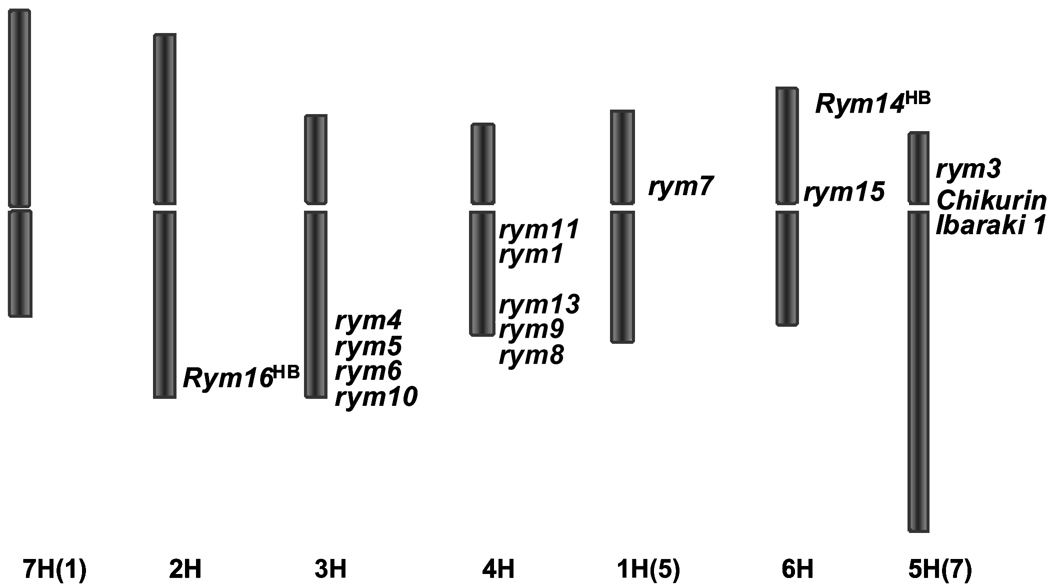

Fig. 1. Localisation of resistance genes against BaMMV/BaYMV

However, respective markers are based in general on polymorphisms around the locus of interest, meaning that recombination may lead to false selections. Therefore, isolation of such resistance genes is of special interest, on the one hand to get information on the structure and function of virus resistance genes and on the other hand to facilitate directed allele-based selection procedures. In this respect the Rym4/Rym5 locus, located on chromosome 3H, has been isolated by applying a map-based cloning approach (Pellio et al. 2005) and it turned out that this locus comprises the translation initiation factor 4[e] (Hv-eIF4E, Stein et al. 2005). Knowledge of such resistance genes facilitates screening of large gene bank collections for new, maybe more efficient, alleles and opens the way to a directed assessment of genetic diversity with respect to resistance to BaMMV/BaYMV (Stracke et al. 2007, Hofinger et al. 2011).

As the plant translation machinery adjacent to Hv-eIF4E comprises different genes, which turned out to be involved in potyvirus resistance (LeGall et al. 2011), these are valuable candidate genes for different loci-encoding resistance to the barley yellow mosaic virus complex. Mapping of these candidate genes is in progress but, up to now, no candidate gene has been mapped in the vicinity of a BaMMV/BaYMV resistance locus.

Barley yellow dwarf

On the world-wide level, barley yellow dwarf caused by different strains of the aphid transmitted Barley yellow dwarf virus (BYDV) and Cereal yellow dwarf virus (CYDV), is the most important virus disease of cereals. In barley, different genes conferring tolerance have been identified, i.e. Ryd2 located on chromosome 3H, Ryd3 located on chromosome 6H, and besides others a QTL on the long arm of chromosome 2H (cf. Ordon et al. 2009). Breeding for resistance to these viruses by phenotypic selection is quite difficult because reliable selection requires artificial inoculation procedures based on rearing virus bearing aphids. Therefore, the development of molecular markers for these resistance genes is of special interest for facilitating efficient selection of tolerant genotypes. Respective markers are available for the mentioned genes and QTL and offer – besides marker based selection procedures – the opportunity for pyramiding these genes in order to enhance the level of tolerance. Based on respective markers and DH-lines, Ryd2, Ryd3 and the QTL on chromosome 2H were combined and respective DH-lines carrying all possible allele combinations were tested in field trials after artificial inoculation with BYDV. In these studies, it was found that a combination of Ryd2 and Ryd3 does not only lead to enhanced tolerance but also to a reduction in the virus titre (Fig. 2), i.e. quantitative resistance (Riedel et al. 2011).

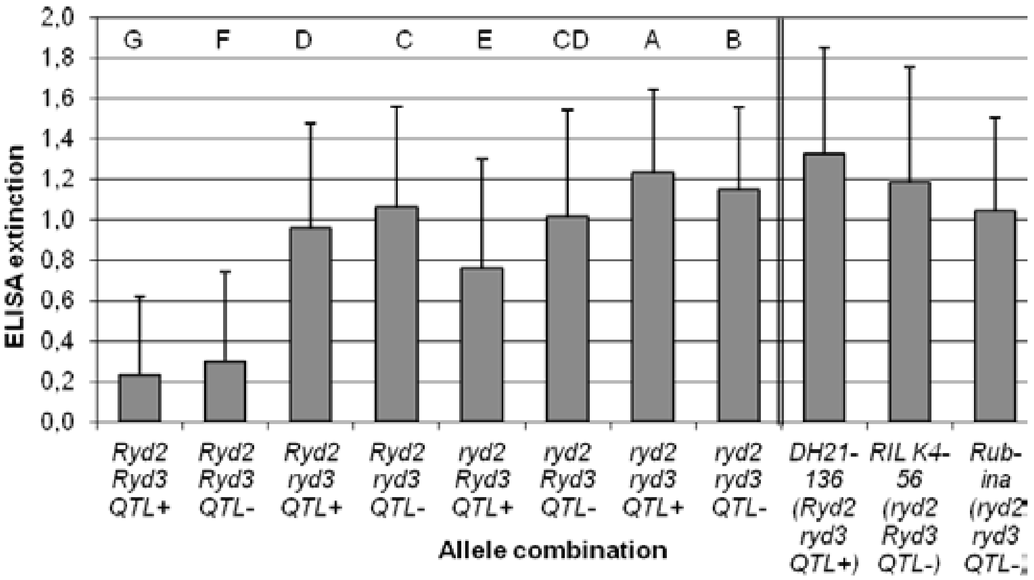

Fig. 2: Average ELISA extinction (405nm) and standard deviation in DH-lines of a DH-population carrying different allele combinations at the Ryd2, Ryd3 locus and the QTL on chromosome 2H. Different letters indicate significant differences. Data of parental lines and the susceptible standard are shown for comparison (Riedel et al. 2011).

Conclusions and future prospects

Breeding for virus resistance has achieved considerable success in the past e.g. with respect to BaMMV/BaYMV. Today, molecular markers already facilitate efficient breeding for virus resistance/tolerance in barley and also in wheat, where respective markers e.g. for SBCMV, but also for BYDV are available (Ordon et al. 2009). Recently, the genomic sequence of monocotyledon species like Brachypodium and Sorghum has become available, in addition to the rice genome, and efficient tools for exploiting the synteny between these species (Mayer et al. 2011) have been developed, which together with the constantly rising sequence information in cereals itself, especially barley and wheat, will lead to enhanced isolation of virus resistance genes. The isolation of genes involved in virus resistance will transfer breeding for virus resistance in cereals to the allele level, facilitating the identification of novel alleles and their directed use in molecular breeding strategies in order to enhance virus resistance. The use of these alleles mainly derived from exotic germplasm can be fostered by marker assisted backcrossing for the gene of interest simultaneously with the enhanced elimination of the donor background by genotyping using high throughput SNP technologies, e.g. the 9k iSelect chip in barley. However, respective alleles may also be transferred directly to high yielding varieties using new advances in gene technology, such as zinc-finger-nucleases (Shukla et al. 2009). Gene technology not only offers the opportunity for an enhanced use of the allelic diversity present with respect to virus resistance genes within the respective gene pool (allele replacement) but also creates new virus resistance, e.g. using small interfering RNAs (Prins et al. 2008).

In summary, all the advances in biotechnology will improve breeding for resistance to viruses in cereals and will enable plant breeding to react in a directed and rapid manner to the challenges arising from new virus diseases and virus strains, thereby contributing to a reduction of yield losses caused by cereal viruses, which is important for feeding the earth´s growing population.

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Stress Resistance in Maize

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Over the next 40 years, the world will need to increase crop production by 70%. This will have to happen in spite of climate change and the increasing scarcity or costs of natural resources such as land, water, fertilizer, and energy. If we fail to meet these challenges, the world will face escalating food prices, extensive social unrest, accelerated migration, further encroachment of agriculture into valuable ecosystems and reduced opportunities for climate change adaptation or mitigation. For the major food crops-maize, rice, and wheat-annual productivity gains in farmers' fields have to increase from the present rate of 1.2% to 1.7% for maize, from 0.8% to 1.2% for rice, and from 1.1% to 1.6% for wheat. Wheat will be the food crop most affected by climate change, with the greatest impact occurring in South Asia. The region is home to one-seventh of the world's populace and by 2050 is likely to account for one of every four human beings. South Asia is currently self-sufficient in wheat production, but demand for the crop there will expand at least 40% over current levels by mid-century and wheat farmers are expected to harvest 20-30% less due to climate change, all else being equal. The food security challenges this implies will be unprecedented. In sub-Saharan Africa, production of the region's main staple food, maize, may drop 10-15% or more over the same period, due to the combined effects of drought and heat.

To satisfy increased demand under increasingly challenging conditions—climate change, greater weather variation (drought, flooding, heat shocks), natural resource scarcities—farmers will need crops that can tolerate stress while transforming water, nutrients, and solar energy more effectively into grain and other useful products. This is a huge order, but modern plant science provides ways to meet the challenges. Plant breeding has greatly benefited from rapid advances in bioinformatics, precision phenotyping, and genomics. For example, for the price of developing and deploying a single transgenic crop variety we can now genotype a significant portion of the entire native genetic diversity for major food crops (maize, rice, wheat), allowing us to understand that diversity and use it to develop, say, heat tolerant wheat for South Asia. Precision phenotyping has greatly contributed to developing drought tolerant maize for Africa. Biotech tools are allowing further improvement of that trait and its transfer to maize varieties for Asia and Central America; regions where droughts will occur more often and sorely affect resource-poor farmers. Transgenic approaches have opened opportunities to protect major crops from insects and weeds or to improve their grain or feed quality. Plants respond in genetically complex ways to abiotic stresses; as a result we are only just learning how to use transgenics for drought tolerance or to create crops that use nutrients or energy more efficiently under farm field conditions.

New technologies can offer solutions, but need to be deployed. There is a large gap between farmers' yields and those on experiment stations in many low- and middle-income countries. This suggests that the agricultural production on this planet could well be doubled without strong area expansion. Seed and plant variety legislation are at the core of bringing stress-tolerant crops to farmers' fields, yet even on the 50th anniversary of UPOV many countries are struggling to facilitate ready access by farmers to recent breeding gains. Millions of farmers in Africa, Asia, and Latin America grow outdated varieties and lack information about newer ones. Markets in these areas often do not support the development of a competitive seed sector, able to foster fast and cheap access to varieties that incorporate the latest progress in breeding. Doubling global crop production is not the responsibility of science and technology alone: regulatory agencies and decision makers need to examine critically whether or not policies are implemented in ways that achieve their intended purposes. This is even more urgent for transgenic crops, where complexity and controversy have contributed to monopolizing their development and deployment.

Looking ahead, leaders can be sure that food insecurity and related issues will command increasing attention and impact all parts of society. Whether for the development of stress-tolerant crops, of competitive markets in disadvantaged regions, or of policies that speed the responsible, cost-effective, and equitable deployment of new technologies, agricultural R&D timeframes require that investments and policy decisions be made *now*, to ensure affordable food and sustainable agricultural production on an increasingly populous planet well into coming decades.

Molecular Virus-Plant Interactions and Pathogen Defense in Tuber Crop Plants

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1. Introduction

Virus-resistant varieties are needed to prevent the heavy quantitative and qualitative yield losses caused by viruses. True resistance prevents virus infection, spread of the virus in the plant and/or reduces accumulation of the virus in infected cells and tissues. It is different from *tolerance* that lacks any of the aforementioned features but refers to virus-plant interactions in which the systemically infected plant displays no apparent symptoms (Cooper & Jones 1983).

Resistance of plants to viruses can be studied from two directions. The obvious direction is to focus the studies on resistant individuals in the plant population and, by comparison to the susceptible individuals, determine which host factors (genes) are required for resistance. On the other hand, studies may aim to identify the host factors needed for infection by the virus and, subsequently, utilize the mutated, incompatible forms of them as resistance factors. These two approaches have the same objective, i.e., virus resistant plant varieties, and will be demonstrated with a few examples, the main emphasis being on root and tuber crops. However, first, the importance of virus resistance in crop plants is discussed because it is the main means by which virus diseases can be controlled in the field.

2. Resistance is needed for the control of spread of viruses

Viruses are transmitted to new crops either in infected seeds and planting materials (*vertical transmission*) or by vectors, contacts between leaves and roots of the adjacent plants, or contamination from tools and equipment (*horizontal transmission*). These two means of virus transmission together result in a cumulative increase of virus incidence in the crop over the subsequent growing seasons. Because all kinds of viruses are transmitted vertically in vegetatively (clonally) propagated crops and can also be transmitted horizontally, depending on circumstances of the cultivation environment, they are most severely affected by virus diseases. For the same reason, viruses transmitted in true seed (seed-borne viruses) can cause severe losses.

2.1. Control of vertical transmission of viruses

In vertical transmission, the virus is carried to the next crop directly in the propagules obtained from the previous, infected crop. All viruses are transmitted vertically during clonal propagation of crops, but, in contrast, most viruses are not transmitted in true seed. This is because most plant viruses fail to enter the embryo or persist therein. Consequently, the plants may be infected in the field during the growing season but their seeds will produce healthy plants. This is surprising because, other than the embryo, the tissues in the seed are typically infected, similar to other parts of the plant (Rajamäki & Valkonen 2004). Because only a few viruses are successful in overcoming the mechanism that excludes viruses from the embryo, the lack of seed transmission seems to represent a type of virus resistance that is very important but not well-characterized.

The highest yield losses are experienced when plants are grown from virus-infected seeds, seed potatoes, or other infected planting materials. Therefore, it is of outmost importance to use virus-free seed, seed tubers, bulbs, cuttings etc. for planting the crop. To meet the phytosanitary requirements, seed production is located in areas where the infection pressure of viruses is low. Factors playing a role in the infection pressure include the abundance of virus vectors and the wild plants, weeds, volunteer plants of the previous crop and plants of the neighboring crops, which may function as virus reservoirs.

Production of healthy seed and planting materials from virus-susceptible varieties will be difficult if the sources of virus cannot be eliminated from the seed production area, because there are only very limited means, other than variety resistance, to control viruses in the field. The virus vectors, such as aphids and whiteflies, may be killed with insecticides, or their landing and feeding on plants may be inhibited by the application of mulches or mineral oil sprays. However, the efficiency of these practices is highly variable and, with some exceptions, insignificant. It is therefore apparent that production of virus-free seed and planting materials is easier when varieties express any level of meaningful resistance to the prevailing viruses.

Three of the seven most important food crops, namely potato, sweet potato and cassava, are vegetatively propagated, as are also many vegetable crops, fruit trees and berry plants. In planting material of vegetatively propagated crops, viruses are transmitted to new crops with high efficiency because the mechanism that excludes transmission via the true seeds is not in effect. It is typical that vegetatively propagated crops harbor many viruses whose co-infections and synergistic interactions cause heavy yield losses, making viruses the most damaging pathogens of these crops (Ross 1986; Karyeija et al. 2000). It is crucial to replace the infected material periodically and restart production from healthy plants of the varieties maintained in tissue culture collections in the laboratory. Long-term storage of vegetatively propagated plant germplasm uses organ tissues, such as shoot tips, rather than cell and callus cultures, to avoid somaclonal variation and other problems related to genetic instability. For obtaining virus-free shoot tips from infected plants, various techniques of meristem tip culture are available. Cryotherapy has been described as a method in which virus elimination and genetically stable long-term preservation of varieties can be achieved simultaneously (Wang et al. 2009; Wang & Valkonen 2009).

Besides economical sustainability and profitability of plant production, virus-free plants are needed in plant breeding. Infected plants are not likely to exhibit their true phenotype, and they may produce lower yields and suffer from impaired seed or pollen germination. Eventually, freedom from viruses is needed for the release of the new variety.

2.2. Control of horizontal virus transmission

Horizontal transmission increases virus incidence in the crop during the growing season. The most important vectors of plant viruses in the field are insects with sucking mouthparts, such as aphids, leafhoppers and whiteflies, and also some species of thrips and eriophyoid mites. Control of virus transmission by killing the vectors with insecticides often has limited success because transmission may take only a few seconds and occurs while the vector probes the leaf. Some viruses are transmitted by nematodes in the root system, also resulting in infection of the aboveground parts of the plant. These nematode-born polyhedral (nepo) viruses are particularly challenging to control because they can also be transmitted via seed and pollen. While seed-transmission of viruses is considered to be vertical, transmission via pollen can result in both vertical (self-pollination) and horizontal (cross-pollination) transmission.

A few genera of root-infecting microbes classified as protists transmit viruses in the zoospores which they release from infected roots and resting spores (sporangia). The resting spores may remain viable in soil and retain infectious virus particles for over a decade. The viruliferous resting spores and the virus-carrying living nematodes (species transmitting viruses do not form cysts) constitute a virus reservoir in soil, hence the term 'soil-borne viruses'. Since treatment of soil with chemicals that could kill protists or nematodes is potentially very harmful to the beneficial soil organisms and environment, it is not allowed in many countries. Hence resistance of varieties remains as the only option for control of the soil-borne viruses (Lennefors et al. 2008; Ordon et al., 2009; Santala et al. 2010).

3. Mechanisms of virus resistance in plants

3.1. Dominant resistance conferred by R genes

Initially, following infection, plant cells recognize pathogen-associated molecular patterns (PAMPs) and elicit basal-defense by production of pathogenesis-related proteins (PR-proteins) that are pathogen non-specific (Almagro et al. 2009). Many PR genes are induced upon virus infection, however, little is known about their effect on viruses. As a counter-defense, pathogens suppress basal-defense using specific virulence proteins called effectors (Jones & Dangl 2006). The effectors are recognized by specific receptors, known as R proteins, on a "gene-for-gene" basis (Flor 1946), which elicits a quicker and a more powerful defense response. The R genes occur in gene clusters that constitute highly similar genes. Different genes in the cluster may recognize widely different pathogens (Gebhardt & Valkonen 2001).

The best characterized example of virus resistance functioning on the gene-for-gene basis is controlled by the protein N, which is an R protein that recognizes Tobacco mosaic virus (TMV, tobamovirus) in tobacco plants using the C-proximal leucine-rich repeat (LRR) domain. More precisely, N recognizes the TMV replicase protein (p50), which is an effector that suppresses basal antiviral defense (RNA silencing) in plants (Caplan et al. 2008). However, the LRR domain cannot recognize TMV unless the TIR domain at the opposite end of the N protein interacts with another host protein (NRIP1). Hence, recognition of pathogens by R genes involves several host genes (proteins) (Caplan et al. 2008). Similarly, experimental evidence indicates that an R protein acts as a "guard", recognizing a specific complex of proteins formed by the pathogen effector protein and its target host protein (Collier & Moffett 2009). In the case of TMV p50 replicase, the target host protein of this effector and the protein complex recognized by protein N are not yet known.

The specific recognition of a pathogen by an R protein induces a signalling cascade, which in turn activates a wide range of genes and defense responses, collectively called a hypersensitive resistance response (HR). HR prevents virus loading to the phloem and translocation to other parts of the plant by an as yet unknown mechanism, but virus replication and cell-to-cell movement in the initially infected leaf are not affected. However, some R genes inhibit virus replication, which is called extreme resistance (Valkonen et al. 1996). For example, wild and cultivated potato species contain genes that confer HR or extreme resistance to *Potato virus Y* (PVY), which is the most important virus infecting potato crops worldwide (Valkonen 2007), or to Potato virus X (PVX) (Cockerham 1970). Studies on the gene Rx conferring extreme resistance to PVX in potato show that, besides extreme resistance, Rx can also induce a HR-like response if the system is manipulated to allow unusually high accumulation of PVX in the infected cells (Bendahmane et al. 1999). Variability in the additional genes involved in recognition or the genes required in downstream signalling for defense responses may also cause genotype-dependent phenotypic changes in the resistance response induced by an R gene (Valkonen et al. 1998).

Besides the gene Rx (Bendahmane et al. 1999), no other virus resistance gene has been isolated and characterized from potato. However, gene Y-1, which recognizes PVY and induces cell death but confers no resistance (Vidal et al. 2002), and *G-Ry*, which seems to be a homolog of Y-1 (Lee et al. 2010), have been isolated and described. Y-1, which is derived from *Solanum tuberosum* ssp. *andigena*, is structurally most similar to N and resides in potato chromosome XI, in a cluster of R genes that also contains the gene Na for HR to Potato virus A and the gene Ry_{adg} that confers extreme resistance to PVY (Hämäläinen et al. 1997; 1998). The viral proteins recognized by Ry_{adg} and Na are not known, but recent results show that the potato gene *Ny*, conferring HR to PVY, recognizes the HCpro protein of PVY (Moury et al. 2011; Tian and Valkonen, unpublished). HCpro is a powerful effector able to suppress RNA silencing (Brigneti et al. 1998).

The potato R genes, which confer extreme resistance to PVY (*Ry*) and PVX (*Rx*), inhibit virus replication efficiently and seem to recognize most, if not all, strains of the virus. By contrast, the genes for HR are virus strain-specific and limit virus spread rather than replication (Valkonen et al. 1996). Indeed, genes for HR are more readily overcome by new variants of the virus. Amino acid substitutions in the viral protein that is recognized by the R protein may allow virus variants to overcome recognition. Therefore, the genes for extreme resistance are preferred in potato breeding. Gene-specific PCR markers are available for marker-assisted selection (MAS) of resistance to many potato viruses (Gebhardt et al. 2006; Witek et al. 2006; Valkonen et al. 2008).

3.2. Mutated host susceptibility factors as virus resistance genes

Breeding for recessive resistance is a well-adopted concept, especially in control of potyviruses (Robaglia & Caranta 2006) that belong to the family *Potyviridae* and which constitute the largest group of plant-infecting RNA viruses (Adams et al. 2011). In this family, PVY is the type member of genus *Potyvirus*, and PVA also belongs to the genus.

Wittman et al. (1997) were interested in host factors required by potyviruses for infection of the host plants. They found that the viral protein VPg, linked to the RNA genome of potyviruses, interacts with the cellular translation initiation factor 4E (or its isoform eIF(iso)4E). This finding was extended to other members of family Potyviridae and their host plants in subsequent studies by other laboratories. Importantly, disruption of the interaction by mutations introduced to the VPg protein was found to be detrimental to virus infection. A breakthrough was experienced in breeding for resistance to potyviruses when it was realized that many recessive resistance genes which had been used in breeding programs for decades actually encode mutated forms eIF4Es (Robaglia and Caranta 2006). Indeed, disruption of the 4E-VPg interaction by mutations in 4E seems to make plants resistant to potyviruses.

However, the mechanism by which mutations in eIF4E confer resistance has remained elusive, despite many studies on eIF4-VPg interactions (Robaglia & Caranta 2006). Phenotypically, the resistance can take many forms, including inhibited virus replication in the initially infected cell, or restricted cell-to-cell, or long-distance (vascular) movement in the plant (Vuorinen et al. 2011). This case-by-case variability has been difficult to explain. Recently, we also found that that the potyviral protein HCpro interacts with eIF(iso)4E and eIF4E (Ala-Poikela et al. 2011). Importantly, analysis of the HCpro proteins in a large number of potyviruses showed that they all contain a specific, conserved 4E-bind motif, similar to the motif of the cellular scaffold protein eIF4G, which binds eIF4E, to initiate cap-dependent translation of cellular messenger RNAs. When the conserved amino acids in the 4E-binding motif of HCpro were mutated in Potato virus A, the virus almost lost its infectivity: only very low titers of the virus accumulated in only a few inoculated plants (Ala-Poikela et al. 2011). These findings and further studies are expected to advance understanding of the mechanism by which potyviruses control host functions for their own benefit. The data should also help to predict and test which mutations in eIF4E could confer broad-spectrum resistance to many potyviruses simultaneously.

Our results have also shown that the VPg is able to suppress RNA-silencing: . VPg is translocated into the nucleus and accumulates in the nucleolus, where it interferes with RNA-silencing and antiviral defence (Rajamäki & Valkonen 2009). In general, little is known about involvement of nucleolus in RNA-silencing and about the functions of proteins of plant RNA viruses in the nucleus or nucleolus. Therefore, this novel function discovered with VPg indicates, first of all, that nucleolus controls some important functions in RNA-silencing and antiviral defense. The results also imply that some host proteins residing in nucleolus are targets of the viral effector VPg, and mutated forms of those host factors might confer resistance to potyviruses.

Studies on molecular virus-host interactions have the potential to reveal novel functions for organelles and genes of plants and to reveal their importance in viral infection or antiviral defense. It is important to identify the host genes involved in antiviral defense systems in plants in order to utilize them in resistance breeding. It is also important to identify the host genes used by viruses for controlling infection and movement in the plant, because their mutated forms a likely to confer resistance to viruses.

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SESSION 2: Applying the Science: Challenges and Opportunities

Plant Variety Protection and Technology Transfer

Mr. Peter Button,
Vice Secretary-General, UPOV

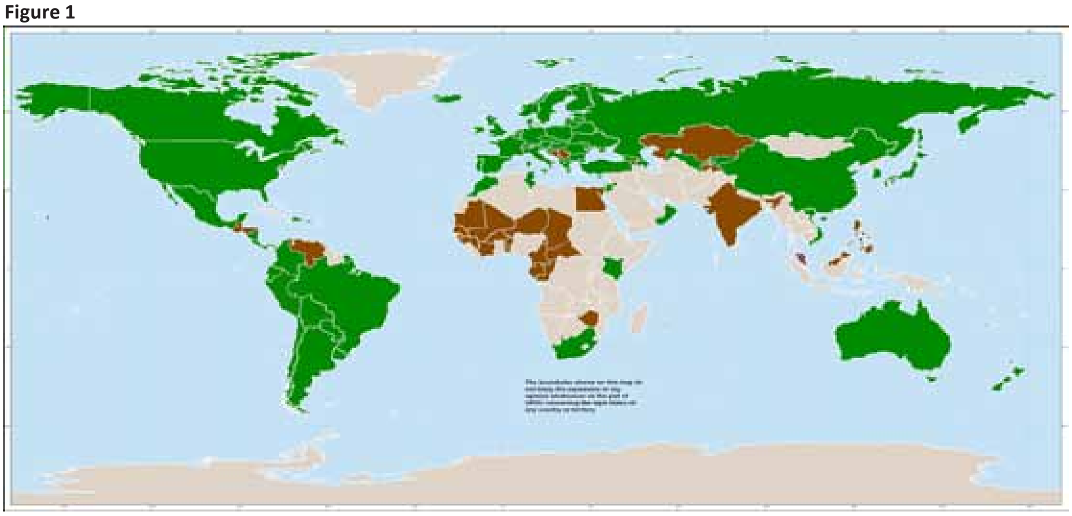
The aim of this Symposium is to provide a global view of latest findings in plant science and to consider how that science can be applied to plant breeding in the future. The focus of this presentation is to show how plant variety protection supports plant breeding and the crucial role it has to play in ensuring that plant breeding achievements – new plant varieties – are delivered to farmers and growers: a key form of "technology transfer" in agriculture.

The basis of the presentation is the findings of the recent UPOV seminar "Plant Variety Protection and Technology Transfer: the Benefits of Public-Private Partnership", held in Geneva on April 11 and 12, 2011 (see *www.upov.int/meetings/en/details.jsp ?meeting_id=22163*). However, before I report on those findings I would like to summarize the framework that the International Union for the Protection of New Varieties of Plants (UPOV) provides for plant variety protection.

The UPOV System

This Symposium has been organized to coincide with the Fiftieth Anniversary of the International Convention for the Protection of New Varieties of Plants, by which UPOV was established, in 1961. As of October, 2011, UPOV had 70 members; 69 States and one international intergovernmental organization, the European Union. The map in Figure 1 shows the territories covered by UPOV, colored in green, and the States and Organizations which have initiated the procedure to become a member of UPOV, colored in brown. Table 1 provides a summary of the status of members of the Union, States and intergovernmental organizations which have initiated the procedure for acceding to the UPOV Convention and States and intergovernmental organizations which have been in contact with the Office of the Union for assistance in the development of laws based on the UPOV Convention.

Figure 1



The mission of UPOV is: "To provide and promote an effective system of plant variety protection with the aim of encouraging the development of new varieties of plants for the benefit of society". New varieties are a crucial means of delivering new technologies to farmers and growers and, ultimately, of course, delivering benefits through to consumers. However, these new varieties will not exist without the work of breeders, as several speakers have already explained.

The importance of new plant varieties

It is virtually impossible to list all the benefits that new plant varieties offer to famers, but they can include: higher yield; resistance to pests and diseases; tolerance to stresses (e.g. drought, heat); greater efficiency in the use of inputs; improved harvestability and crop quality. New plant varieties also offer diversity of choice to farmers that can improve their access to national and international markets (see Figure 2).

Figure 2: Benefits of New Plant Varieties for Farmers and Growers

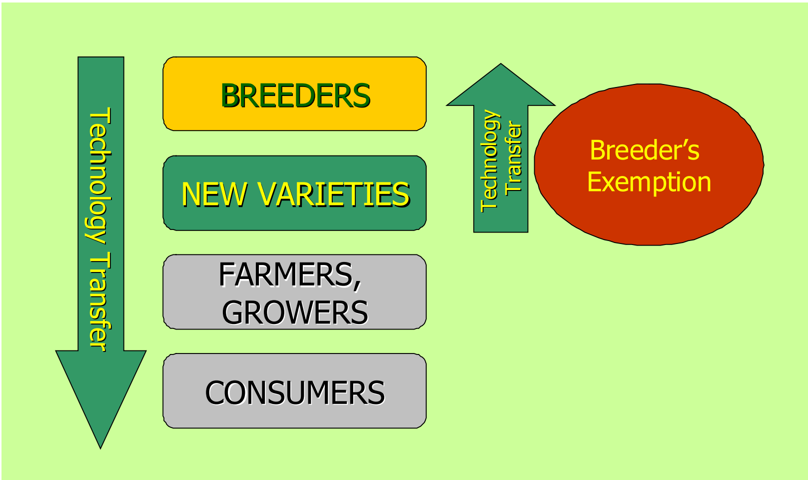
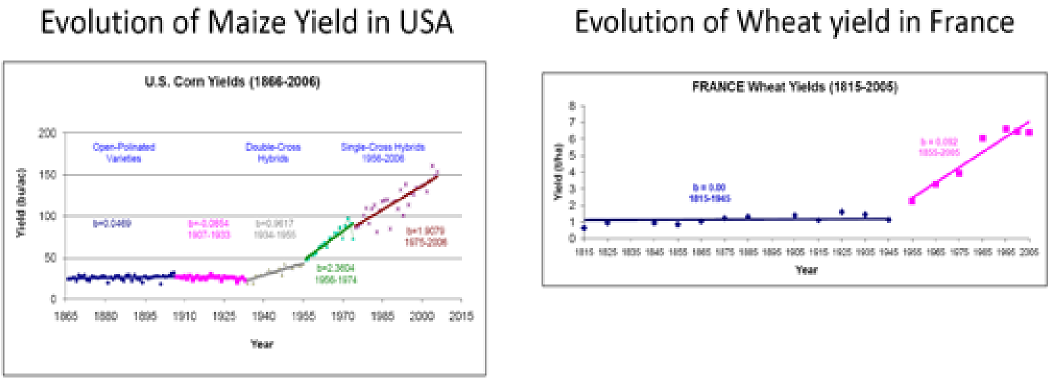


Figure 3 illustrates, for example, the evolution of yields in wheat (France) and maize (United States of America) since the advent of modern plant breeding, at least 50% of which has been attributed to new varieties.

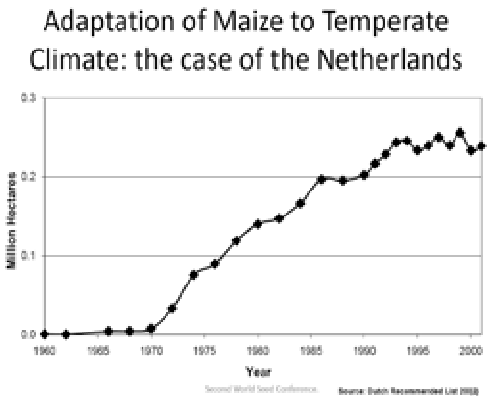
Figure 3



Bernard Le Buanec, Second World Seed Conference (Rome, September 2009) (see *www.worldseedconference.org/en/worldseedconference/home.html*)

It is also important to look at the broader benefits of new varieties. With regard to climate change, there are already impressive examples to indicate how breeding is able to respond to differing environments. The maize crop, for example, up until 1970 was not adapted to cultivation in the Netherlands (see Figure 4). It was only by the efforts of breeders that farmers are able to have new maize varieties that grow well in the Netherlands, having been adapted to their specific climatic conditions.

Figure 4: Climate adaptation in Maize



Bernard Le Buanec, Second World Seed Conference (Rome, September 2009) (see *www.worldseedconference.org/en/worldseedconference/home.html*)

The effects of breeding mentioned above are quite broad in their scope and it is also important to be aware of the diversity of breeding objectives. Many people will be aware of breeding objectives such as improved yield, disease and pest resistance etc. (see Figure 5).

Figure 5: Disease resistance in Hot Pepper

Phytophthora blight (Fungal disease):

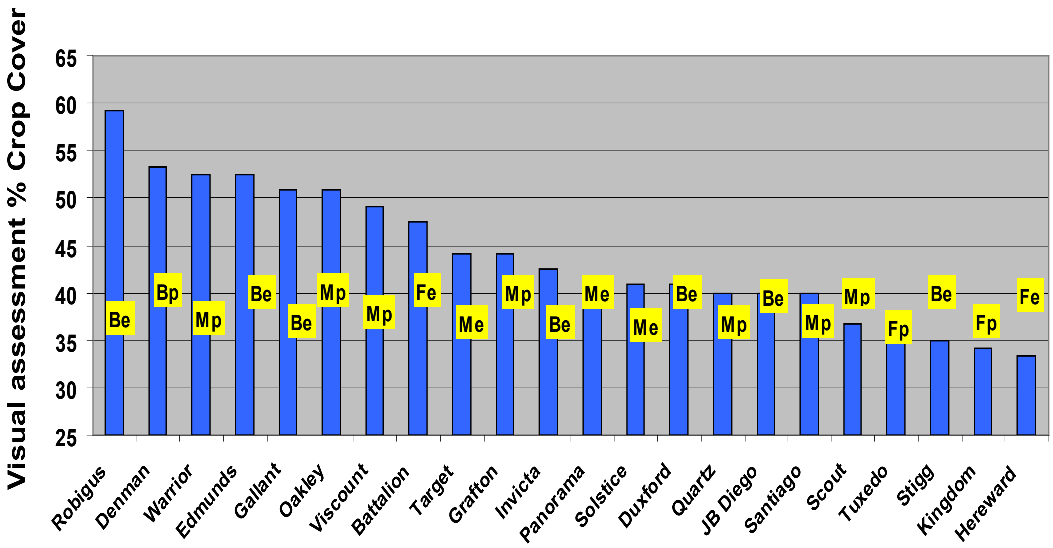
Above
Resistant variety
(Dok-Ya-Cheong-Cheong)

Below
Susceptible variety

Chang Hyun Kim, Second World Seed Conference (Rome, September 2009) (see *www.worldseedconference.org/en/worldseedconference/home.html*)

However, there are many other advantages that new varieties can bring. Figure 6 demonstrates the range of variation in the competition ability of different varieties of winter wheat with Blackgrass, which is of particular importance for weed control. This is just an example to illustrate the wide scope of traits that varieties can confer, some of which are of great importance to farmers, but may not be obvious to the public.

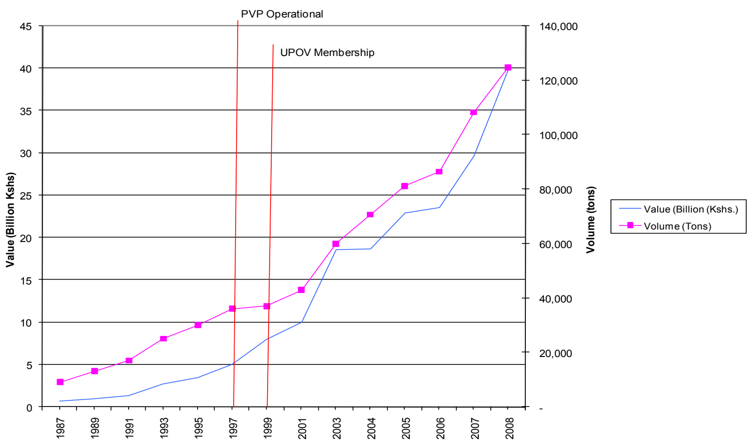
Figure 6: Winter Wheat – Crop competition by variety



Barry Barker: Seminar on Plant Variety Protection and Technology Transfer: the Benefits of Public-Private Partnership (Geneva, 2011) (see *www.upov.int/meetings/en/details.jsp ?meeting_id=22163*)

The export of cut flowers provides the Kenyan economy with an important source of foreign exchange earnings, and a source of income for the development of the rural economy. Figure 7 provides information on the export of ornamental plants from Kenya, which increased rapidly between 1987 and 2008. That increase coincided with the increased number of applications for protection of varieties in Kenya, most of which concerned varieties of foreign origin. The introduction of foreign varieties contributed to the increased competitiveness of the Kenyan flower industry in the European market. After the introduction of PVP in Kenya in 1997, the volume of exports increased from approximately 40,000 tons to 120,000 tons – a three-fold increase. However, the value of those exports increased eight-fold, from approximately 5 billion Kenyan Shillings to 40 billion Kenyan Shillings. This increase in export earnings provides a demonstration of the importance of having the right variety for success in the market place and the importance of plant variety protection and UPOV membership to improve access to such new varieties.

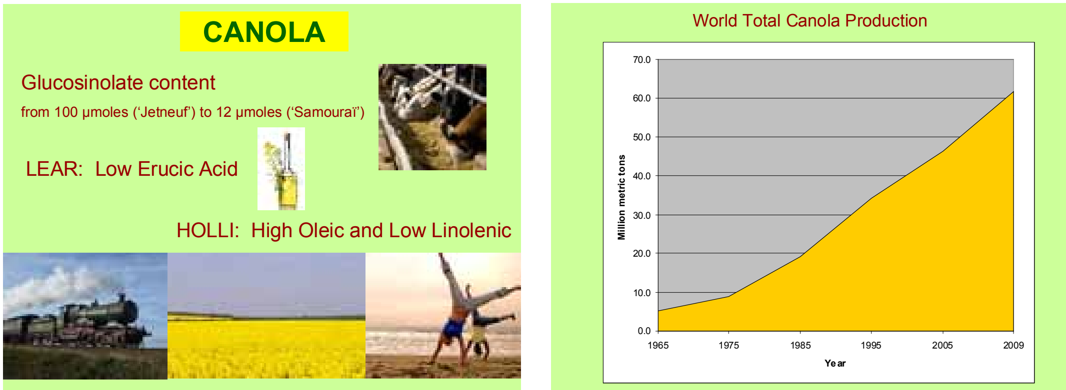
Figure 7: Export of Kenyan Cut Flowers



Evans Sikinyi, Second World Seed Conference (Rome, September 2009) (see *www.worldseedconference.org/en/world-seedconference/home.html*)

The importance and scale of the contribution of plant breeding can be further illustrated by the example of Canola (Rapeseed) (see Figure 8). Originally, only the oil component of canola provided a useful product, as a lubricant for steam engines. It was only when breeders started to work on the crop that it attained major importance for agriculture. Firstly, breeders reduced the glucosinolate content so that the meal could be used for feeding animals. As a next step, breeding was employed to reduce the erucic acid content so that the seed could be used as a source of edible oil for human consumption. More recently, efforts are continuing, and breeders are working to develop high oleic and low linoleic acid varieties with nutritional benefits for consumers. In this one crop alone the dramatic developments that breeding is able to produce are exemplified, even without reference to the yield and agronomic improvements that have been developed in parallel. The result in this case is a substantial increase in the production of rapeseed and, thereby, diversification of cropping systems.

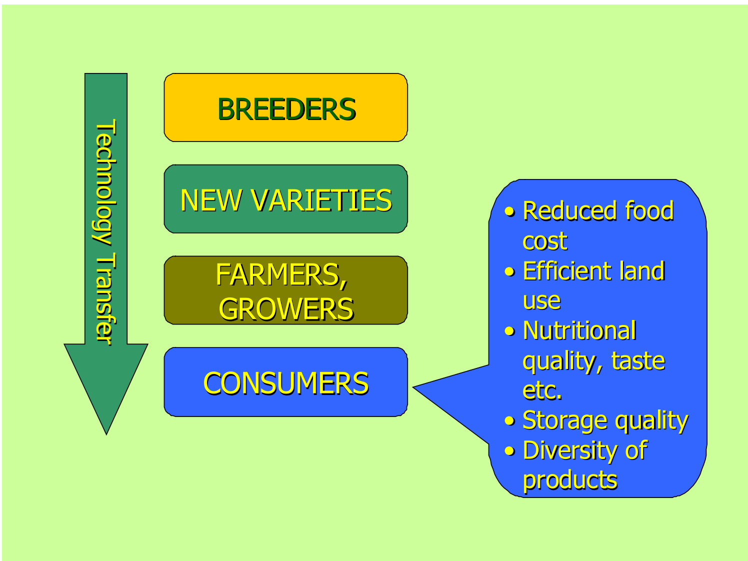
Figure 8: Canola breeding developments



Yves Lespinasse, Seminar on Plant Variety Protection and Technology Transfer: the Benefits of Public-Private Partnership (Geneva, 2011) (see *www.upov.int/meetings/en/details.jsp ?meeting_id=22163*)

Plant breeding provides benefits to farmers in the form of new, improved varieties, which then deliver benefits to consumers and society as a whole. We can see examples of those benefits in terms of reduced cost of high quality food, efficient land use, diversity of plant-derived products etc. (see Figure 9). In short, breeders are delivering benefits and adding value through the agricultural chain of production.

Figure 9: Benefits of New Plant Varieties for Society

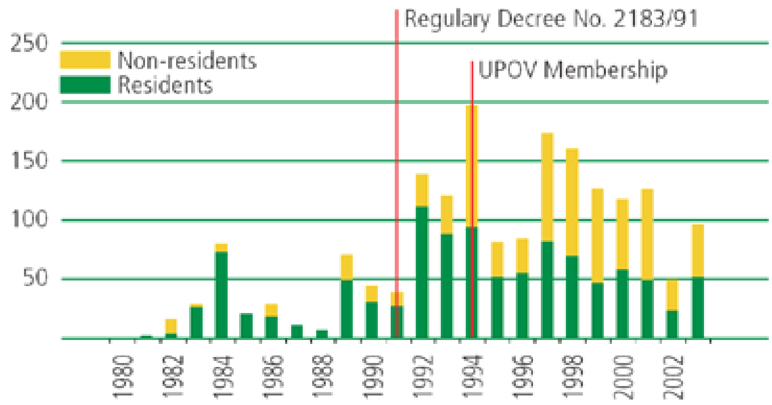


The Benefits of Plant Variety Protection and UPOV Membership

Plant breeding is a long and expensive process. However, at the end of that process, new plant varieties can be very easily and quickly reproduced. Therefore, a system of protection is needed in order to allow breeders to recover their investment. One of the important aspects of the UPOV Report on the Impact of Plant Variety Protection (Impact Study) (see *www.upov.int*) was to look at how plant variety protection encourages breeders and breeding. That study illustrated the impact in terms of increasing diversity of breeders, particularly in the private sector, but also with regard to the public sector, where researchers were encouraged to focus their research towards more adapted varieties. In general, the Impact Study observed an overall increase in breeding activity as a result of the introduction of the UPOV system of plant variety protection.

Figure 10 provides information on the developments in Argentina with regard to providing an effective system of plant variety protection and UPOV membership. In 1991, the National Institute of Seeds *(Instituto Nacional de Semillas)* (INASE) institute was created and the PVP system was amended to be in conformity with the 1978 Act of the UPOV Convention, except for certain aspects concerning foreign applications. Those developments were accompanied by a substantial increase in the number of titles granted to domestic breeders. In 1994, the PVP system in Argentina became fully compatible with the 1978 Act of the UPOV Convention and Argentina acceded to the UPOV Convention. The number of titles granted to non-residents increased in conjunction with those developments.

Figure 10: Argentina: number of titles granted



Source: Impact Study

Figures 11 to 16 provide information from China and the Republic of Korea on how the UPOV system and membership of UPOV encourages breeding and the availability of new varieties from the public and private sector. There is information that government breeding is incentivized, with additional income being made available through plant variety protection: there is growth not just in the private sector but also in the public sector breeding.

Figure 11: Republic of Korea: breeding investment in Chinese Cabbage

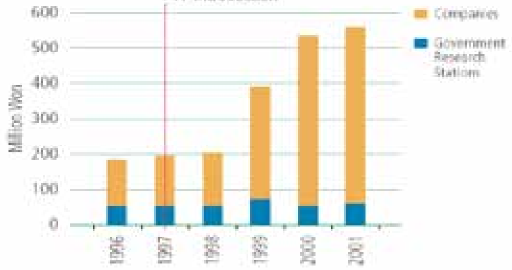


Figure 12: China: Number of Applications by Categories of Applications (Agriculture)

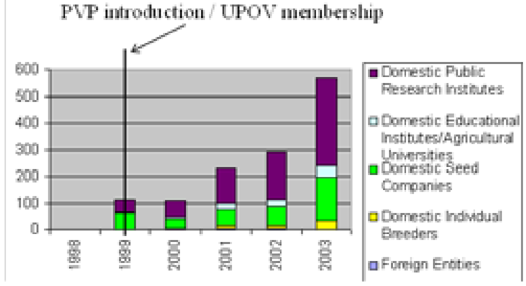


Figure 13: China: Number of Breeders in Henan Province (Maize)

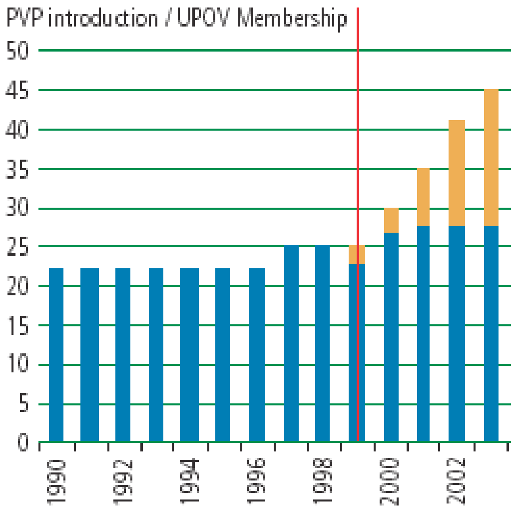


Figure 14: China: Number of Breeders in Henan Province (Wheat)

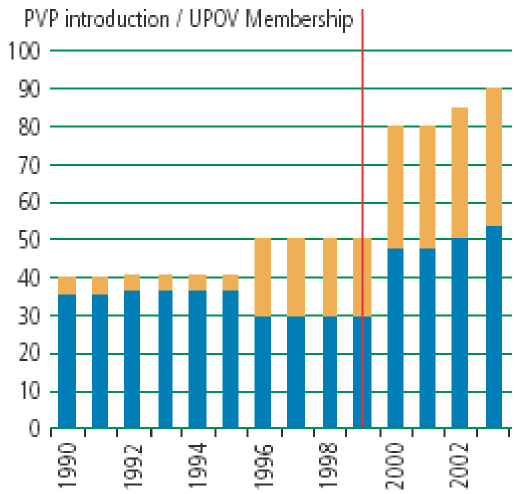


Figure 15: Republic of Korea: Number of Rose Breeders

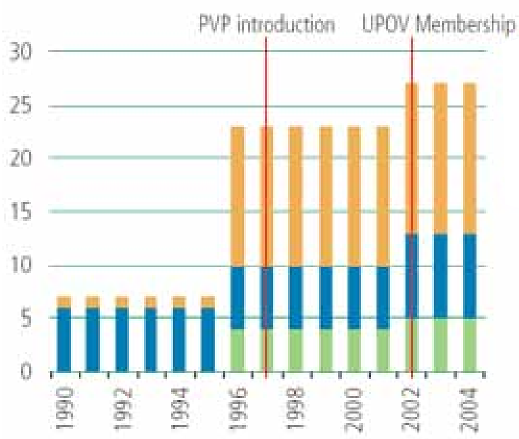
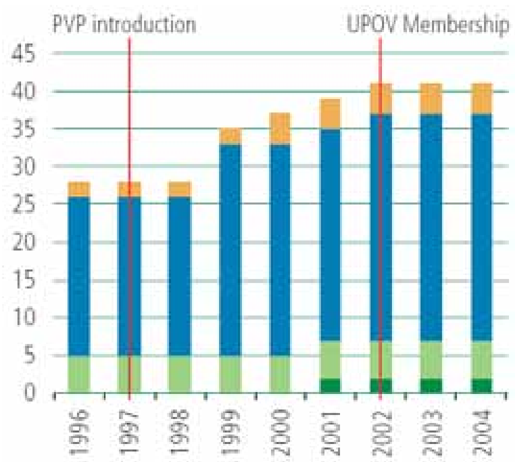


Figure 16: Republic of Korea: Number of Rice Breeders

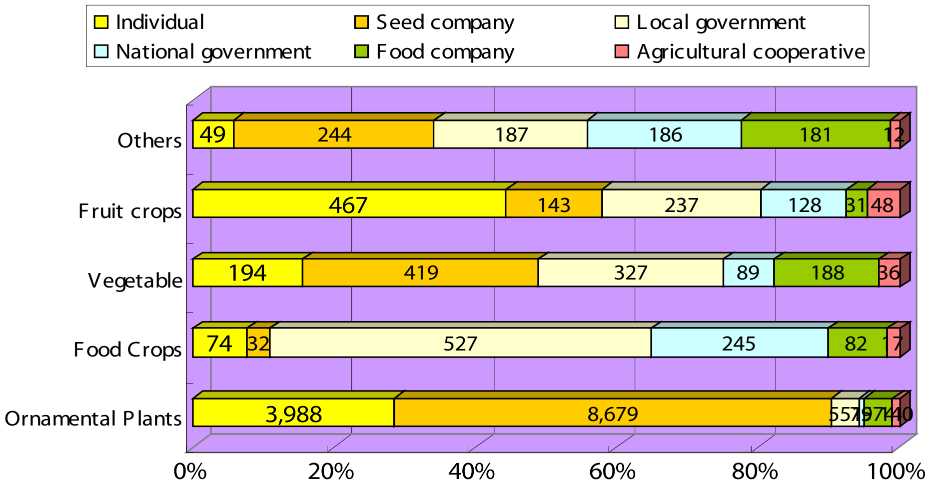


- Companies
- Government Research Stations
- Individuals
- University Researchers

Source: Impact Study

The analysis in Japan (Figure 17) demonstrates the diversity in types of breeders that develop new varieties where the UPOV system of plant variety protection is in place. This indicates the relevance of PVP for different types of breeders in the private sector, the public sector and also for public-private partnerships.

Figure 17: Japan: number and proportion of varieties protected by types of breeders



It may be useful to recall some of the key aspects of the UPOV Convention and to explain how they are applicable to different types of breeders, particularly with regard to the breeder's right and exceptions. The breeder's right in the 1991 Act of the UPOV Convention (see Figure 18) sets out the rights which a breeder has on propagating material of a protected variety. It is the choice of the breeder to decide who is authorized to grow the variety and on what terms. This is an important aspect to be considered by public sector or private sector breeders.

Figure 18:

1991 Act of the UPOV Convention
Article 14
Scope of the Breeder's Right

(1) [Acts in respect of the propagating material] (a) Subject to Articles 15 and 16, the following acts in respect of the propagating material of the protected variety shall require the authorization of the breeder:

(i) production or reproduction (multiplication),
(ii) conditioning for the purpose of propagation,
(iii) offering for sale,
(iv) selling or other marketing,
(v) exporting,
(vi) importing,
(vii) stocking for any of the purposes mentioned in (i) to (vi), above.

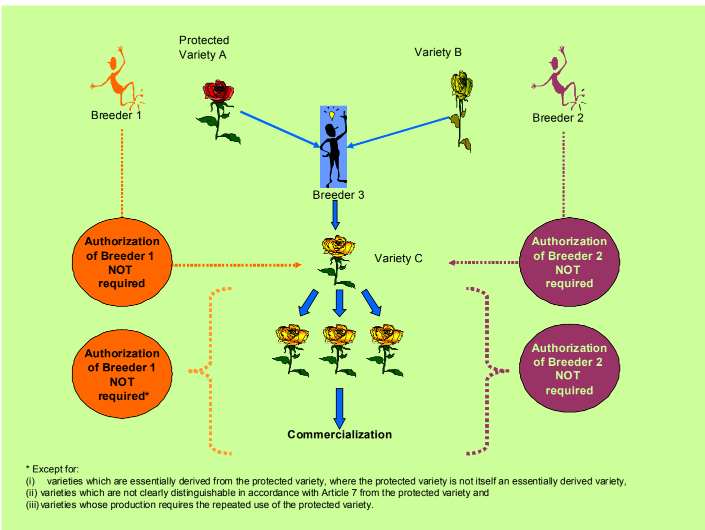
(b) The breeder may make his authorization subject to conditions and limitations.

It is also relevant to recall that there are exceptions to the breeder's right in the UPOV Convention. Certain exceptions are compulsory, and there is also an optional exception (see Figure 19).

Figure 19: Summary of exceptions to the Breeder's Right under the 1991 Act of the UPOV Convention

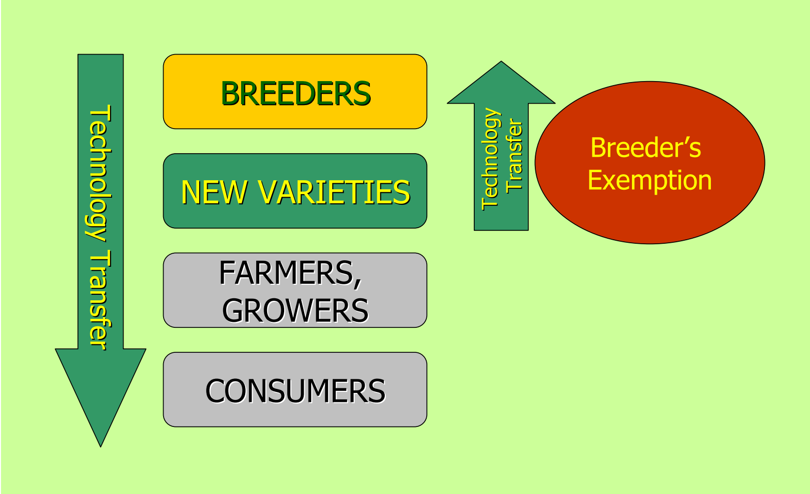
Firstly, with regard to the exceptions, a key feature of the UPOV system is the "breeders' exemption", which is a compulsory exception (see Figure 20). The exception under Article 15(1)(iii) of the 1991 Act states that the breeder's right shall not extend to "acts done for the purpose of breeding other varieties, and, except where the provisions of Article 14(5) apply, acts referred to in Article 14(1) to (4) in respect of such other varieties.". This is a fundamental element of the UPOV system of plant variety protection known as the "breeder's exemption", whereby there are no restrictions on the use of protected varieties for the purpose of breeding new plant varieties. The second part of Article 15(1)(iii) "and, except where the provisions of Article 14(5) apply, acts referred to in Article 14(1) to (4) in respect of such other varieties." clarifies that, except for the varieties included in Article 14(5) (i.e., essentially derived varieties; varieties which are not clearly distinguishable of the protected variety and varieties whose production requires the repeated use of the protected variety), the commercialization of the new varieties obtained does not require the authorization of the title holder of any protected variety used in the breeding of those new varieties.

Figure 20 Illustration of the Breeder's Exemption



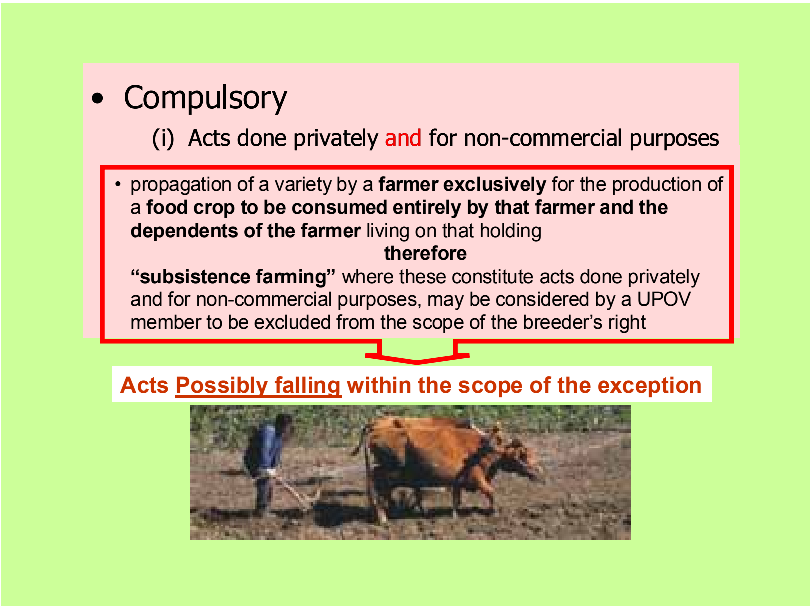
The summary chart in Figure 21 symbolizes how new varieties are a means of transferring technology down the chain of production and how the breeder's exemption provides technology transfer back up the chain, by allowing new varieties to be used by other breeders.

Figure 21: Breeder's exemption facilitates technology transfer to breeders



The aim of the UPOV system is to encourage the development of new varieties of plants, of which farmers and growers are the primary beneficiaries. The UPOV Convention also provides certain exceptions for farmers and growers. Under the 1991 Act of the UPOV Convention, acts done privately and for non-commercial purposes fall outside the scope of the breeder's right. Thus, where "subsistence farming" refers to the propagation of a variety by a farmer exclusively for the production of a food crop to be consumed entirely by that farmer and the dependents of the farmer living on that holding, such farming may be considered by a UPOV member to be excluded from the scope of the breeder's right (see Figure 22).

Figure 22: Exceptions to the Breeder's Right



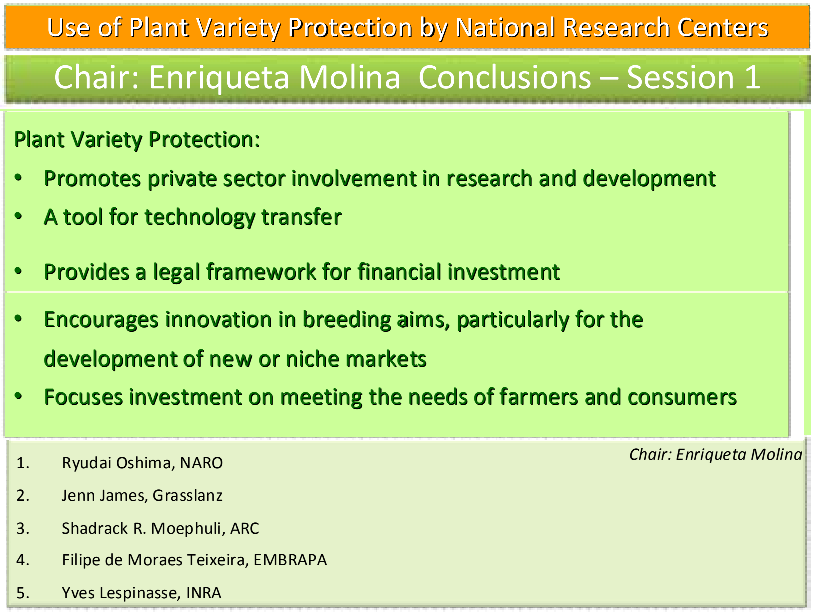
With regard to the optional exception in relation to farm-saved seed, the 1991 Act of the UPOV Convention provides that UPOV members may permit farmers to use for propagating purposes on their own holdings the product of the harvest obtained on their own holdings from the protected variety, within reasonable limits and subject to safeguarding legitimate interests of the breeder. The inclusion of the optional exception in the 1991 Act of the UPOV Convention recognizes that, for some crops, there has been a common practice of farmers saving the product of the harvest for propagating purposes, and this provision allows each member of the Union to take account of this practice and the issues involved on a crop-by-crop basis, when providing plant variety protection. The use of the words "within reasonable limits and subject to the safeguarding of the legitimate interests of the breeder" is consistent with an approach whereby, if the optional exception is implemented, it is done in a way which does not undermine the incentives provided by the UPOV Convention for breeders to develop new varieties, because that would also undermine the benefit to farmers, growers and society as a whole.

Disseminating new plant varieties to farmers and growers

With regard to technology transfer it is important to realize that considerable resources are required in order to disseminate varieties to farmers, growers and consumers. The findings of the recent UPOV seminar "Plant Variety Protection and Technology Transfer: the Benefits of Public-Private Partnership" (UPOV Seminar) (see *www.upov.int*) highlighted a number of aspects in that regard.

In the first session, presentations were made by national research centers on their use of plant variety protection. One of the key conclusions was that plant variety protection is a tool for technology transfer, which promotes private sector involvement in research and development. In other words, it promotes private sector involvement in the early stages of variety development and helps to ensure that research and variety development is focused on the needs of farmers and consumers. An important basis for that result is the legal framework for financial investment provided by plant variety protection (see Figure 23).

Figure 23: Use of Plant Variety Protection by National Research Centers



Seminar on Plant Variety Protection and Technology Transfer: the Benefits of Public-Private Partnership (Geneva, 2011) (see *www.upov.int/meetings/en/details.jsp ?meeting_id=22163*)

Figures 24 and 25 contain data provided by Mr. Felipe de Moraes Teixeira, Brazilian Agricultural Research Corporation (EMBRAPA), Brazil, illustrating the value that plant variety protection offers in its research. Every US Dollar invested in EMBRAPA research generates an average return of six and a half US Dollars for Brazilian society.

Figure 24: Returns on Research Investment from PVP (EMBRAPA)

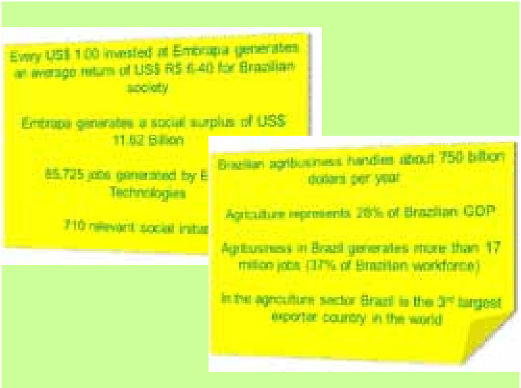
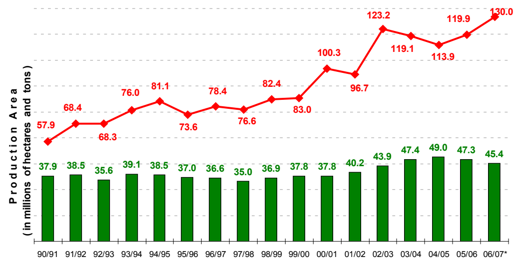


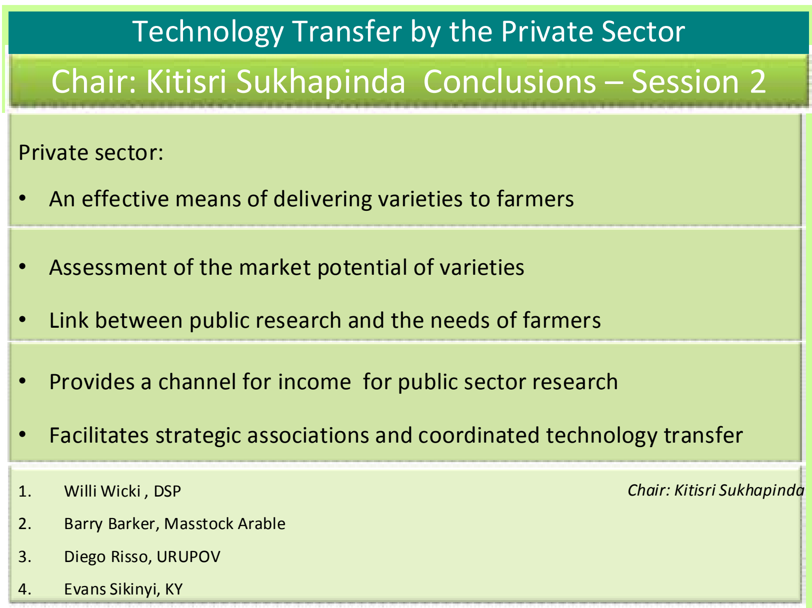
Figure 25: PVP and increasing productivity in Brazil



Mr. Felipe de Moraes Teixeira, Brazilian Agricultural Research Corporation (EMBRAPA), Brazil: Seminar on Plant Variety Protection and Technology Transfer: the Benefits of Public-Private Partnership (Geneva, 2011) (see *www.upov.int/meetings/en/details.jsp ?meeting_id=22163*)

An important session of the UPOV Seminar concerned the role of the private sector in its relationships with the public sector. A clear conclusion was that the private sector provides an effective means of delivering varieties to farmers. In that regard, the private sector can be a very important partner for public sector breeders in delivering seed to farmers. In addition, the private sector also provides feedback from farmers to breeders. It was concluded that the private sector provides a key role in assessing the market potential of varieties and making the connection from the farmers to the public sector researchers. The plant variety protection system was identified as an important means of facilitating strategic associations and coordinated technology transfer in the context of public-private partnerships (see Figure 26).

Figure 26: Role of the private sector in technology transfer



Seminar on Plant Variety Protection and Technology Transfer: the Benefits of Public-Private Partnership (Geneva, 2011) (see *www.upov.int/meetings/en/details.jsp ?meeting_id=22163*)

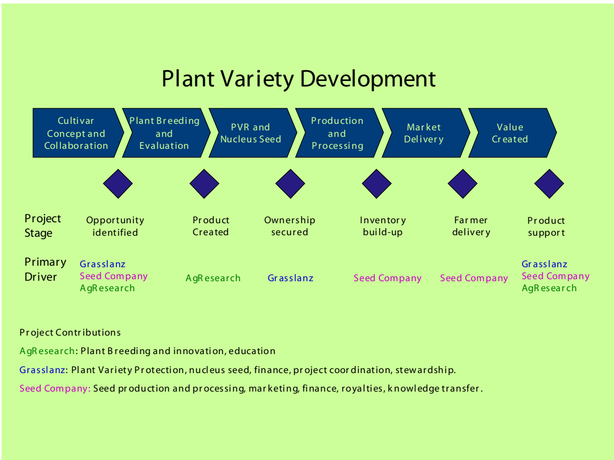
Figure 27 provides a summary of information presented at the Seminar by Mr. Wicki, DSP SA (Switzerland), who identified three stages in wheat variety development and delivery of seed to farmers: firstly, development of new varieties, (breeding); secondly, variety evaluation; and, thirdly, seed production and supply to farmers. In Switzerland, under the DSP arrangement with Agroscope, the public sector is involved in developing new varieties and to some extent in final evaluation of those varieties. However, it relies on the commercial, private company – DSP – to help to evaluate varieties and to deliver high quality seed to farmers.

Figure 27: Public and private funding of the Swiss wheat breeding program

Mr. Wicki, DSP SA (Switzerland) Seminar on Plant Variety Protection and Technology Transfer: the Benefits of Public-Private Partnership (Geneva, 2011) (see *www.upov.int/meetings/en/details.jsp ?meeting_id=22163*)

Figure 28 illustrates a similar situation with regard to grass development in New Zealand, presented by Ms. Jenn James Grasslanz Technology, again identifying the different stages from variety (cultivar) concept through plant breeding, evaluation, market delivery and value created. From the beginning of the process, there is involvement of the public and private partners. Plant breeding, in this case, was undertaken by the public sector AgResearch; the varieties were then transferred to Grasslanz Technology and to seed companies to bulk up those varieties and to deliver high quality seed to farmers.

Figure 28: Plant Variety Development (Grasslanz)



Ms. Jenn James, Grasslanz Technology (New Zealand) Seminar on Plant Variety Protection and Technology Transfer: the Benefits of Public-Private Partnership (Geneva, 2011) (see *www.upov.int/meetings/en/details.jsp ?meeting_id=22163*)

In the UPOV Seminar, the presentations from national public research centers explained why plant variety protection is important for them and how they use the private sector to support their activities. The third session of the UPOV Seminar provided a view of the international research centers on intellectual property protection. Mr. Lloyd Le Page, Chief Executive Officer, Consultative Group on International Agricultural Research (CGIAR) Consortium, explained that variety protection provided a mechanism to facilitate dissemination of varieties to farmers and noted that open access does not ensure widespread dissemination or use. One of the conclusions from the session was that plant variety protection often provided an incentive for small and medium sized local enterprises to become seed distributers and, thereby, to benefit from intellectual property rights. It was also recalled that the breeder's exemption provided a mechanism to facilitate access to germplasm for further breeding. Finally, it was noted that the use of plant variety protection was consistent with the International Treaty on Plant Genetic Resources for Food and Agriculture and its Standard Material Transfer Agreement (SMTA) (see Figure 29).

Figure 29: International Research Centers and PVP

Seminar on Plant Variety Protection and Technology Transfer: the Benefits of Public-Private Partnership (Geneva, 2011) (see *www.upov.int/meetings/en/details.jsp ?meeting_id=22163*)

Overall Conclusion

In summary, the conclusions of the Seminar demonstrated the value of plant variety protection for encouraging the development of new varieties of plants that respond to the needs of farmers, growers and consumers and for encouraging investment in the delivery of those varieties to farmers and growers. It was seen that the UPOV system of plant variety protection played an important role for the private sector, public sector and for public-private partnerships.

International Union for the Protection of New Varieties of Plants (UPOV) as of October 21, 2011

I. Members of UPOV

Albania3	Chile2	France2	Latvia3	Poland3	Switzerland3
Argentina2	China2	Georgia3	Lithuania3	Portugal2	The former Yugoslav
Australia3	Colombia2	Germany3	Mexico2	Republic of Korea3	Republic of Macedonia3
Austria3	Costa Rica3	Hungary3	Morocco3	Republic of Moldova3	Trinidad and Tobago2
Azerbaijan3	Croatia3	Iceland3	Netherlands3	Romania3	Tunisia3
Belarus3	Czech Republic3	Ireland2	New Zealand2	Russian Federation3	Turkey3
Belgium1	Denmark3	Israel3	Nicaragua2	Singapore3	Ukraine3
Bolivia	Dominican Republic3	Italy2	Norway2	Slovakia3	United Kingdom3
(Plurinational State of)2	Ecuador2	Japan3	Oman3	Slovenia3	United States of America3
Brazil2	Estonia3	Jordan3	Panama2	South Africa2	Uruguay2
Bulgaria3	European Union3,4	Kenya2	Paraguay2	Spain3	Uzbekistan3
Canada2	Finland3	Kyrgyzstan3	Peru3	Sweden3	Viet Nam3
					(Total 70)

1 1961 Convention as amended by the Additional Act of 1972 is the latest Act by which one State is bound.

2 1978 Act is the latest Act by which 22 States are bound.

3 1991 Act is the latest Act by which 46 States and one organization are bound.

4 Operates a (supranational) Community plant variety rights system which covers the territory of its 27 members.

II. States and intergovernmental organizations which have initiated the procedure for acceding to the UPOV Convention

States (15):
Armenia, Bosnia and Herzegovina, Egypt, Guatemala, Honduras, India, Kazakhstan, Malaysia, Mauritius, Montenegro, Philippines, Serbia, Tajikistan, Venezuela and Zimbabwe.

Organization (1):
African Intellectual Property Organization (OAPI)
(member States of OAPI (16): Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Congo, Côte d'Ivoire, Equatorial Guinea, Gabon, Guinea, Guinea-Bissau, Mali, Mauritania, Niger, Senegal, Togo).

III. States and intergovernmental organizations which have been in contact with the Office of the Union for assistance in the development of laws based on the UPOV Convention

States (21):
Algeria, Bahrain, Barbados, Cambodia, Cuba, Cyprus, El Salvador, Ghana, Indonesia, Iraq, Islamic Republic of Iran, Lao People's Democratic Republic, Libya, Pakistan, Saudi Arabia, Sudan, Thailand, Tonga, Turkmenistan, United Republic of Tanzania and Zambia.

Organizations (2):
African Regional Intellectual Property Organization (ARIPO)
(member States of ARIPO (18): Botswana, Gambia, Ghana, Kenya, Lesotho, Liberia, Malawi, Mozambique, Namibia, Rwanda, Sierra Leone, Somalia, Sudan, Swaziland, Uganda, United Republic of Tanzania, Zambia, Zimbabwe)

Southern African Development Community (SADC)
(member States of SADC (15): Angola, Botswana, Democratic Republic of the Congo, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, United Republic of Tanzania, Zambia, Zimbabwe).

Variety Traits for the Future

Mr. David Nevill,
Head of Cereals R&D, Syngenta International AG

The world faces daunting and unprecedented challenges, ranging from climate change to growing populations. Better use of resources, new tools and modern technologies are needed more than ever to improve the ability of our farmers to produce food, feed, fiber and fuel demands while protecting precious natural resources (Figure 1).

Companies like Syngenta invest in research and development to bring forward new innovations that drive long-term agricultural productivity, rural development and environmental sustainability. We believe that such innovation needs to be encouraged, supported and protected. We also believe in sharing the knowledge we create to foster new innovation.

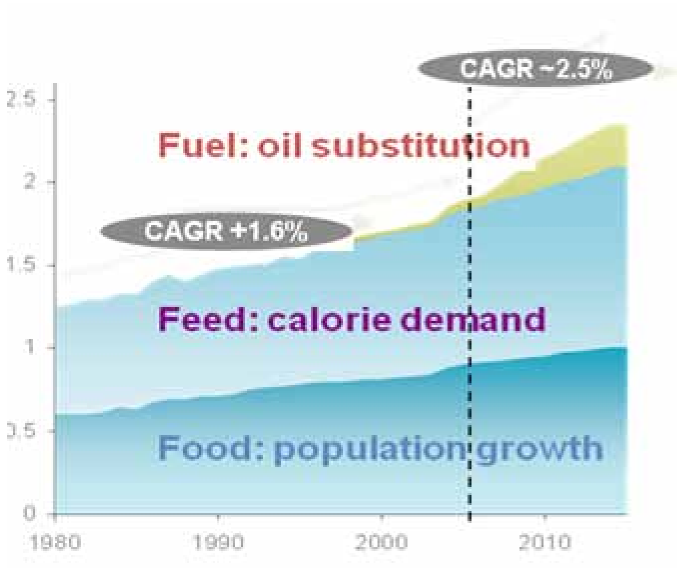


Figure 1. Agricultural demand in metric tTonnes of grain

To date, progress in improving varietal performance has been made through a combination of factors including:

- Plant breeders' excellent agronomic knowledge of how to select parents and progeny that are suited to major grower and consumer needs
- Understanding of key limits to yield at the level of plant architecture and of stress resistance (especially disease and insect resistance)
- Understanding of varietal adaptation in agro-climatic zones to drive germplasm exchange and broaden the exploitation of genetic gain
- Development of heterotic systems in several crops to exploit the homogeneity, robustness and vigor of F1 hybrids
- Genetic modification (GM) approaches to deliver agronomic traits not directly available in the gene pool
- Practical application of tissue culture techniques to enable wider crosses and to accelerate line fixation
- Limited use of markers (at DNA and physiological levels) to try to go beyond phenotypic selection

But more is needed. Producing ”more with less” in order to address global production challenges requires a step-change to the traditional approach of gradual improvement of varieties, and heavy investment in modern plant biotechnology and advanced breeding techniques is needed. Plant breeding of the future will require new technology and knowledge-management approaches, including:’

- Genomics, DNA-sequencing, and related high throughput technologies, to enable a deeper understanding and manipulation of plant genetics
- A greater capability to measure phenotype and environment in precise, automated ways, plus the ability to integrate this data with the underpinning genetics
- New capabilities to work together in knowledge-networks to stimulate, integrate and develop new ideas into practical products.

These developments in technical understanding, data integration and open-idea networking, allow breeding to exploit both breadth and depth of germplasm potential in new ways in order to achieve greater genetic gain in yield and quality, as well as more robust adaptability.

As we look to the next twenty years, the traits of the future must deliver solutions to the following challenges:

- Adapted and durable resistances to biotic stress factors, such as diseases and insects. The ongoing evolutionary battle between pathogen and host will continue and deepen alongside the intensification of agricultural production. The combined tools of plant genetics, chemical crop protection and agronomy will be needed to maintain a balance in favor of efficient crop production.
- Abiotic stress, especially due to climate change, will become an increasing problem, not only as individual factors such as heat and drought stress, but also because of variability and unpredictability of conditions. This will be a very difficult target for plant breeders, which will require robustness of genotype x environment interaction
- Meeting societal and government expectations for bio-fuels – and in a way that does not compromise demand for food and feed
- Providing pleasure in the mega-cities of the growing world – for example, through flowers which bring color to the harsh urban environment as well as fruits and vegetables that bring taste and flavor despite long supply chains, or malting barleys that bring alcohol and aroma to beers and whiskies
- As the world human population grows, not only in numbers but also in wealth, then we must meet indirect demand though feed to supply increased amounts of animal-based protein in diets as well as direct food needs.

This qualitative change in food consumption means that a population of 9 billion in 2050 will demand levels of crop production similar to a population of 12 billion with today’s dietary habits (current world population about 7 billion). The capabilities of plant breeding will be stretched to the limit to meet these production demands, exacerbated through the factors mentioned above. Two dimensions of integration will be needed to solve these problems. Firstly, agronomic know-how must drive the optimization of genetics and chemical crop protection in practical grower-oriented systems. Secondly, we should develop and leverage a comprehensive and powerful crop- and grower-focused technical knowledge-base derived from the complementarity and synergy of private-public partnerships. Syngenta has a broad range of products and capabilities to participate in this collaboration space and we aspire to enable the delivery of sustainable solutions for agricultural production.

Vegetable and Field Crop Strategies in East Africa

Mr. Yashwant Bhargava,
Head of R&D, East African Seed Company Ltd

East Africa is the easterly region of the African continent and is used to specifically refer to the area now comprising of Kenya, the United Republic of Tanzania, Uganda, Rwanda and Burundi. The geography of this region is often stunning and scenic. Shaped by global plate tectonic forces that have created the great Rift Valley, East Africa is the site of Mount Kilimanjaro and Mount Kenya, the two tallest peaks in Africa. It also includes the world's second largest freshwater lake - Lake Victoria and the world's second deepest lake - Lake Tanganyika. The climate of East Africa is rather atypical of equatorial regions. Because of a combination of the region's generally high altitude and the rain shadow of the westerly monsoon winds created, East Africa is surprisingly cool and dry for its latitude. Rainfall in East Africa is influenced by El Nino events. Temperatures, except on the hot and generally humid coastal belt, are moderate with maxima of ~ 25°C and minima of 15°C.

East Africa is variably endowed with considerable inter-and intra-specific diversity of crops and is the centre of origin and diversity for important cereals and vegetable crop(s). Presently, approximately 15,000 accessions are being conserved by the different national gene banks in the sub-region. In the last two decades, attempts have been made to strengthen the plant genetic resources activities in the region and the Eastern African Plant Genetic Resources Network was established in 2003 with financial support from the Swedish International Development Cooperation Agency with the primary function to mobilize resources and strengthen national programs in the region to optimally conserve and use their plant genetic resources.

The Rockefeller and Melinda Gates (Foundation) have supported the development and release of more than 100 new crop varieties, dozens of which are already in use, including 11 new strains of rice called "New Rice for Africa" (NERICA), cultivated on 300,000 acres across the continent. The Foundation estimates that, over 10 years, 400 more improved crop varieties and work in 20 African countries can contribute to eliminating hunger for 30 million people and move 15 million out of poverty. Following the private-philanthropy-government-partnership, guided by a philanthropic-plan formula, the Foundation's current efforts in Africa are focused on scientific development of more productive crops and fertilizers, cultivation of local talent in plant science, farming, agricultural policy and business, strong commitment from national governments and public-private collaboration regarding infrastructure, water and irrigation, the environment, and building markets for the inputs and outputs of a revolutionized farm sector.

The key challenges in East African countries are: policy distortions (viz., exchange rate, subsidies, taxes, producer support); trade distortions (viz., trade share of developing countries – exporters gain and importers lose); risk factor (viz., weather index, contingent loans, price shocks, political disturbance); energy cost (viz., food-fuel-cash crop interactions are complex); and resource degradation. At the same time, there is a need to understand the value chain economics by building strong public-private partnerships in agri-business sector(s) to generate economic activity through provision of infra-structure to support rural diversification and encouraging a new generation of development program(s).

The prime economy activity in the East African countries is farming - the farming practices between different villages and regions differ as the parameters change from one location to another. Farmer(s) today are under pressure to produce more food, but are facing a host of difficulties and challenges (viz., market, diseases and drought). In times to come, they will need to double the productivity to meet the increased demand through active utilization of crop(s) with value added traits and biological productivity systems, all packed into a seed. Farmers not only have the technology options but, for a given product or service, they have a large number of brand options, all of which are promoted using multiple media. The level and extent to which this phenomenon has spread across the rural segment still remains an amorphous area to the planners and marketers in the absence of an organized and well-defined information base. There are clear differences between the practices under irrigated- and non-irrigated conditions. There are no reliable estimates on purchases of production inputs by smallholders for pesticides or fertilizers or even hybrid seeds in rural areas. It is even likely that organized sector databases on such products take into account only the sale at the wholesaler's end in the urban areas, with the distribution reach of such products in rural areas largely remaining unknown.

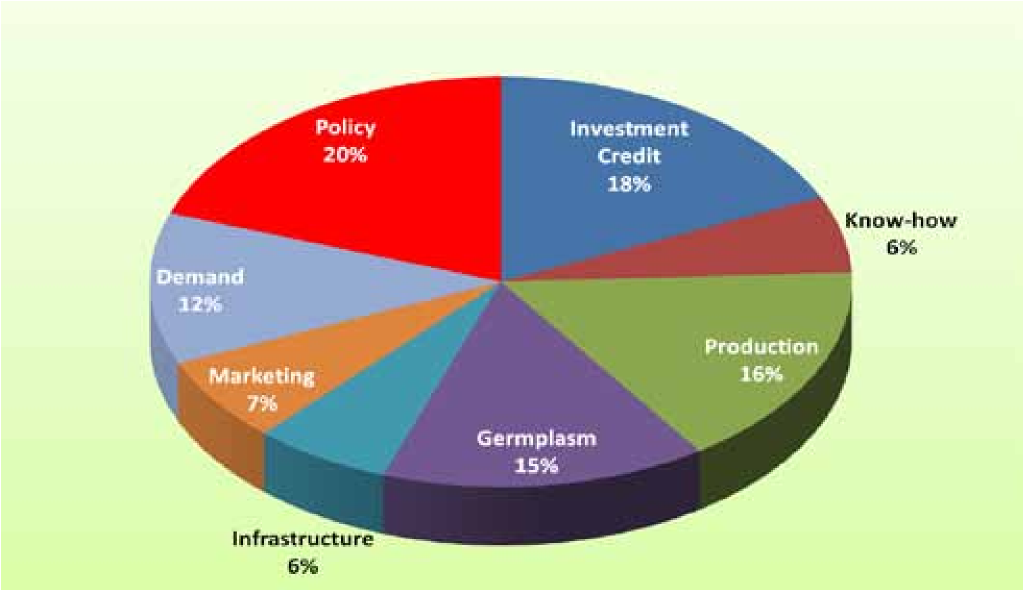


Figure – Factors affection seed supply in East African Countries

A range of factors including climatic, topographical, technological and innovation, habits, financial, marketing, trading, transportation, storage, production processes, legal framework on land tenure systems, international conventions, conflicts and others affect food security. Measures to address food security should be multi-dimensional and involve all stakeholders both within East African countries and the neighboring countries. East African countries need to take cognizance of these challenges to come up with measures, both short- and long-term, to achieve food security.

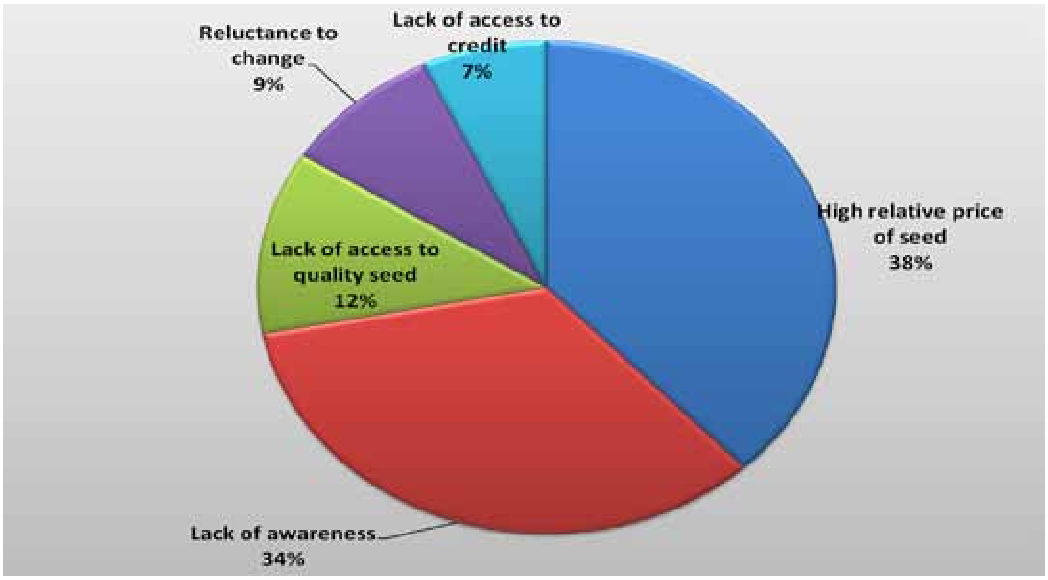


Figure – Factors affecting seed demand in East African Countries

Grow existing market share and make commitment for quantity and quality parameters, adequate seed supplies of adapted varieties in vegetable and field crop(s) could make the difference. Smallholder farmers need access to high quality seeds of adapted varieties at affordable prices – the local seed sector is the main source of supply. The World Vegetable Center (AVRDC) vBSS program aims to increase vegetable production, marketing and consumption to foster rural development, reduce poverty and improve the livelihood and nutrition of poor vertical expansion – present distribution network needs to be enhanced for better penetration. Pricing would be an extremely powerful driver for strategic consideration for both “marketing” and “finance” functions through transactional and value pricing.

Maize is of fundamental importance in East Africa as a staple food, as a tool for economic development, for political stability and is useful when it comes to the welfare of the poor. Maize accounts for ~ 60% of the expenditure of low-income households; hence when prices of this commodity are high, the poor are the most affected. The value of maize is very low in relation to transport within the East African countries, rendering intra-regional trade and exporting of this commodity, a bit difficult – leading to a large difference between import and export prices. The problems of maize marketing are made worse by other constraints, such as unreliable rainfall, low capitalization of small holder agriculture and stunted to declining production of the commodity: this has made East Africa a net importer of Maize.

Over the last year, the price of maize in East African countries has doubled. The price of maize has increased by 122% in Uganda, 104% in Rwanda and 89% in Kenya, according to the World Bank’s Food Price Watch report (August, 2011). Globally, maize (up 84%), sugar (up 62%), wheat (up 55%) and soybean oil (up 47%) contributed most to the increase in food prices. UN has declared drought in the eastern region of East Africa being the worst in last six decades and the refugee situation as the worst humanitarian crisis.

The vegetable crop(s) in East African countries are, in general, produced under open-field conditions in areas of high rainfall or irrigation and under protected culture in greenhouses. The introduction of field vegetables into prevailing farming systems is relatively straightforward, although husbandry and management requires a greater degree of expertise and discipline and the input costs may be 2-3 times higher than input costs for cereals. The key factor(s) in these successes include rigorous product differentiation and market segmentation, demand-driven- and export-oriented-strategies, favorable institutional and regulatory environments and skilled management along the entire supply chain.

Crops identified using the criteria set and the indicators of their importance:

Crop(s)	Countries	Indicators of importance
Maize	Kenya, United Republic of Tanzania, Uganda, Rwanda,	Maize is the principal food staple, dominating diets of rural and urban poor
Potato	Kenya, Uganda, Rwanda, Burundi	Potato is a short-season, high-value crop, grown for household consumption and as a cash crop mainly by small farmers
Sweet potato	Kenya, Uganda, Rwanda, Burundi	Sweet potato is a short-season crop which provides food on marginal and degraded soils - rich in carbohydrates, proteins and vitamins and provides high cash income per unit of land
Sorghum	Kenya, Uganda, United Republic of Tanzania, Rwanda, Burundi	Sorghum has the distinct advantage of being drought resistant, and subsistence farmers cultivate sorghum as a staple food crop. Sorghum is a multi-functional crop providing grain and stems as feedstock for sugar, alcohol, fuel and for poultry / livestock feeding
Finger Millet	Kenya, Uganda, Rwanda, Burundi	Important food crop in traditional low–input, cereal-based farming systems
Banana	Kenya, Uganda, United Republic of Tanzania, Rwanda, Burundi	Banana (African dessert / plantain / highland banana varieties) is a major staple food - source of income for over 20 million people
Cassava	Kenya, Uganda, Rwanda, Burundi	Cassava has the ability to grow on marginal lands where cereals and other crops do not grow well and can tolerate drought and can grow in low-nutrient soils. Roots are consumed freshly boiled, or raw, and leaves are used as a green vegetable, which provides protein and vitamins A and B. Cassava starch is used as a binding agent in the production of paper and textiles, and as monosodium glutamate – flavoring agent
Rice	Kenya, Uganda, United Republic of Tanzania, Rwanda, Burundi	Oryza punctata is indigenous and is a freely tillering annual, commonly found in rain-flooded depressions: the grains are boiled with water or milk and eaten as a staple. Other species is O. longestaminata

Crop(s)	Countries	Indicators of importance
Cowpea	Kenya, Uganda, Rwanda, Burundi	East Africa is a centre of domestication: high levels of diversity are found in cultivated and wild cowpeas. It is a broadly adapted and highly variable crop, cultivated around the world for seed and also as a vegetable - both as a leafy green and for green peas, cover crop and for fodder. Cowpea is an extremely resilient crop, and is cultivated under some of the most extreme agricultural conditions in the world
Pigeon-pea	Kenya, Uganda,	Popular crop in the warm semi-arid and sub-humid tropics of eastern Africa. Subsistence farmers grow pigeon pea - often on poor soils and with few or no inputs. It is a hardy, drought-tolerant crop. The crop is consumed both in fresh form and as dried grain, and also is used as fodder for livestock. Mostly of vegetable-type, with large pods/seeds, in contrast to the “Asian type” pigeon peas which are small seeded and used for making soup
Phaseolus	Kenya, United Republic of Tanzania, Uganda, Rwanda, Burundi	Second most important source of human dietary protein and the third most important source of calories for over one million people in rural and poor urban communities in the cool highlands of East Africa
Brassica sp.	Kenya, United Republic of Tanzania	Brassica carinata (Ethiopian mustard) and B. capitata are used as a leafy vegetable – salad
Yam	Kenya, Uganda, Rwanda	Dioscrorea bulbifera and D. minutiflora are native to East Africa.
Wheat	Kenya, United Republic of Tanzania, Uganda	Durum wheat strains have been found with resistance to rust, dwarfing, very early heading and very late maturity
Tomato	Kenya, United Republic of Tanzania, Uganda, Rwanda, Burundi	Popular vegetable, grown widely throughout the country. Tomato has made it an important source of Vitamins A & C in diets
Forage	Kenya, United Republic of Tanzania, Uganda	The Massai savannah and steppe are the center of origin and diversity for certain forage species
Pearl Millet	Kenya, Uganda	Food staple in the semi-arid areas - inadequate rainfall and poor soil conditions

It is likely that organized sector databases on such products take into account only the sale at the wholesaler’s end in the urban areas – the distribution reach of such products in rural areas largely remaining unknown. While the change in the cropping pattern occur depending upon the changes in the market and monsoon conditions, there is a steady but all pervading change process occurring in the case of farm practices with respect to inputs available and utilized by the rural farmers.

The combination of drought, conflict and soaring food prices has had a deadly effect on the region’s most vulnerable children and families. The availability of grains in East African countries is low and coupled with export restrictions has contributed to price rise in the region. Long term support is critical to build drought resilience and implement climate-smart farming. The World Bank has provided US $ 686 million to save lives, improve social protection and foster economic recovery and drought resilience for people in East African countries (World Bank Group’s Food Price Watch Press Release no. 2012/PREM/048 – August, 2011).

The creation of wealth in East African countries requires smallholder farmers to change from being subsistence farmers to being profitable business – a business that can be operated more productively and that provides marketable surpluses, infra-structure development, strength in numbers and capacity-building are the key areas of concern. The link between producers and post-harvest activities can be improved to increase the efficient use, and quality, of seed for planting and to secure the harvest. The respective country government(s) should gradually put in place ‘targeted safe nets’ and not trade restrictions and price controls. It is expected that East African countries would progress towards open borders and the reduction / removal of trade tariffs and creation of harmonized product quality standards besides the widespread application of modern innovative agricultural technologies, in order to develop an optimized roadmap for ensuring the availability of food and the reduction of poverty.

Commodity	Productivity in East African countries	Benchmark (Ref. FAO STAT 2010)
Maize (bags/acre)	9	Argentina – 31 / South Africa – 13
Tea (kg/acre)	4,507	Malawi – 3,523 / India – 2,774
Coffee (processed) (kg/acre)	214	Brazil – 345 / Colombia – 436
Sugarcane (tons/acre)	28 – 25	Malawi – 43 / Sudan – 42
Dairy (liters/cow per year)	1,371	Argentina – 4,773 / South Africa – 3,093

Figure – Agricultural Productivity in East African Countries

Addressing the enigmatic problems of lagging areas which hold potential for agricultural growth needs attention as agriculture in East African Countries is undergoing economic and physical change. The context includes: a) Income growth and demographic change; b) urbanization and transformation of markets; c) growing influence and leverage of the private sector; d) looming effects of climate change; e) rising energy and commodity prices; f) continued domestic and international price distortions'; g) under-investment in technology and infra-structure. Genetic improvement and achievement of better crop management practices seems to be a key to success through development of research strategies for yield improvement, capacity building on modern technologies and infra-structural investment to encourage adoption of newer technologies, thereby, directing migrants remittances to productive use in rural areas.

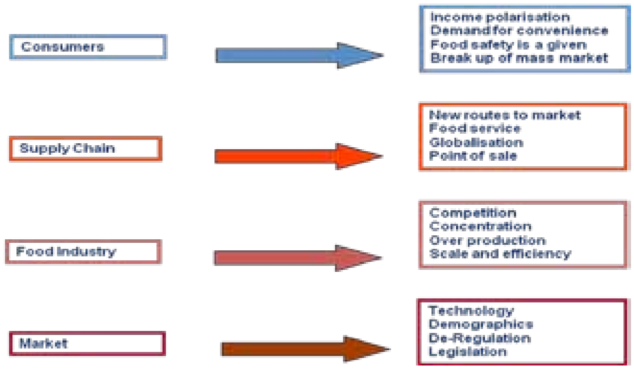


Figure – Keys forces in Value Chain

The development of a strategy document provides the framework for sustainable conservation of plant genetic resources leading to improved agricultural production and food security in eastern Africa with direct implications for addressing the Millennium Development Goals related to food security and reducing hunger. The beneficiaries are the crop improvement programs in the region through increased access to a wide range of crop genetic diversity to produce superior varieties, with a spill-over to neighboring regions. The efficient and effective utilization of eastern Africa's genetic resources to identify long-term support for upgrading and capacity building needs will need to have the broad buy-in and support from all the key stakeholders encouraging partnerships and sharing responsibilities and facilities, thereby linking with the relevant global crop strategies.

Achieving food security is a key policy challenge to East African countries – Kenya, the United Republic of Tanzania, Uganda, Rwanda and Burundi. A range of factors, including: climatic; topographical; technological and innovation; habits; financial; marketing; trading; transportation; storage; production processes; legal framework on land tenure systems; international conventions; conflicts; and others, affect food security. Measures to address food security should be multi-dimensional and involve all stakeholders, both within East African countries and the neighboring countries. East African countries have taken cognizance of these challenges and have come up with measures both short- and long- term, to achieve food security (EAC Food Security Action Plan: 2010-15, publ. in May, 2010).

Innovative new markets are emerging that can enable smallholders to benefit from conserving agro-biodiversity and adopting sustainable production practices for international carbon markets. The different project(s) are currently focusing on piloting new methodologies and developing incentive mechanisms. Results and ideas will be introduced to industry, policy makers, development partners and academic audiences to determine ways forward that benefit farmers, the environment and the goals of sustainability. There is also a critical need to establish and sustain institutional linkages to maximize the use of capacities and mandates to enable rationalization of public and private sector involvement in biotechnology research and development. This will ensure the focusing of available resources on priority programs for efficient delivery of selected technologies.

Breeding Prospects for Horticulture in Asia

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Introduction

Horticulture industry in Asia

Among the world's top 10 multinational seed companies, horticultural crops occupy a minor part of its total sales. The main companies in Asia engaging in horticultural crop seed production are Sakata and Takii Seed Companies, which account for less than 2% out of the total world's seed market. Syngenta have established branch research stations in China and the Republic of Korea, wherein vegetable seeds are mainly developed and produced. Both Sakata and Takii seed companies produced vegetable and flower seeds that are being distributed to the world market. Both companies' strength is in flower seed market all over the world. Suntory and Kirin seed companies, based in Japan, have developed flower breeding tools or techniques for some flower crops. For horticultural crops, Suntory has succeeded in developing genetically modified (GM) flowers for the world market. Newly developed varieties of rose and carnation have been released in some developed countries for exclusive production.

Japan

Japan is one of the top three horticultural producing countries in Asia, especially in terms of vegetables, fruits and flower production, as shown in Table 1. Horticultural production in Japan is relatively stable with a minor decrease in recent years. The horticultural crops with the highest level of production are: cabbage and Japanese radish for vegetables; "Unshu" mandarins and apples in fruit trees; and chrysanthemum and carnations, for flowers.

Table 1. Horticulture production in Japan

Vegetables ('000s T)	Japanese radish	Carrots	Chinese cabbage	Cabbage	Spinach	Welsh onions	Lettuce
2008	1603	657	921	1389	293	510	544
2009	1592	649	924	1385	286	508	550

Fruit tree ('000s T)	"Unshu" mandarin	Apple	Japanese pear	Pear	Persimmon	Loquat	Peach	Plum	Cherry
2008	906	911	328	33.5	267	71.0	157	26	17
2009	1003	846	318	33.6	258	67.0	151	21	17
2010	786	798	259	26.2	189	57.0	137	21	20

Flowers (millions of stem)	Chrysanthemum	Carnation	Rose	Tropical orchids	Gentian	Lily
2007	1,814	387	355	22.6	117.5	170.3
2008	1,792	388	347	22.0	111.4	170.8
2009	1,731	367	331	21.2	109.5	167.5

India

India is an agricultural country wherein 68% of its total population is still engaging in agriculture. Horticultural crops occupy 10% of the total cultivated area, producing 214.72 million tons, as shown in Table 2. India aims to double its horticulture production to 300 million tons by 2012 and bring more cultivated area for fruits, vegetables and flowers by utilizing and actively performing newly launched National Horticulture Mission. India is the second largest producer of fruits and vegetables next to China. The total estimated production of fruits is about 43 million tons from 3.78 million hectares (Ha.) of land. The vegetable production area is about 6.09 million Ha, producing 84.62 million tons, as illustrated in Fig. 1. India shares about 15 % of the world's total production of vegetables from about 2.8% of cultivated area in the country. Varying agro-climatic conditions in India make it possible to produce a wide variety of vegetables as many as 61 annual and 4 perennial vegetables all year round. India is the largest producer of mango, banana, sapota and acid lime. About 54.2% and 11.0% of the world's mango and banana production are cultivated and produced in India respectively.

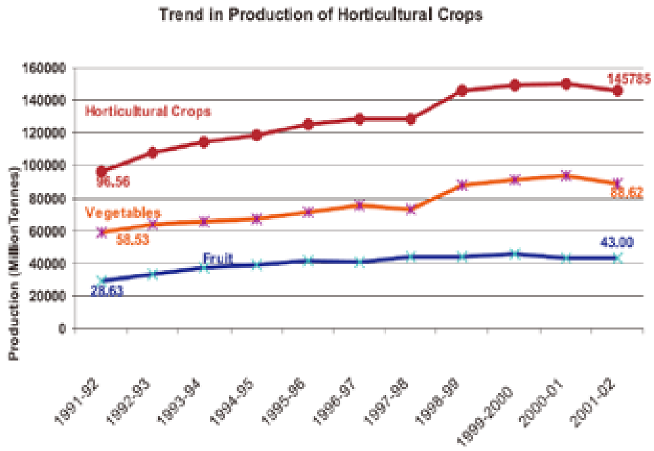

Fig. 1. Trend in production of horticultural crops in India
Data source: Department of Agriculture and Cooperation, Ministry of Agriculture, India

Table 2. Area and production of horticultural crops (unit: '000s Ha., '000s MT)

	2006-07		2007-08		2008-09	
Crops	Area	Production	Area	Production	Area	Production
Vegetables	7,581	114,993	7,848	128,449	7,981	129,077
Fruits	5,554	59,563	5,857	65,587	6,101	68,466
Plantation crops	3,207	12,007	3,190	11,300	3,217	11,336
Spices	2,448	3,953	2,617	4,357	2,629	4,145
Flowers	144	880	166	868	167	987
Aromatic & Medicinal plants	324	178	397	396	430	430
Almond & Walnuts	132	150	132	177	136	173
Mushroom	-	37	-	37	-	37
Honey	-	51	-	65	-	65
Total	19,389	191,813	20,207	211,234	20,661	214,716

*Flower production figures for loose flowers only
NOTE: Total may slightly differ due to rounding of of figures
Data source: Ministry of Agriculture and Co-operation

The Republic of Korea

The Republic of Korea is one of the biggest contributors in terms of agricultural products in Asia. Although agriculture only occupies 1.5% of the world's total agricultural land, the Republic of Korea has substantially developed its horticultural crop breeding and production industries since the 1980's. The Republic of Korea introduced a system of plant variety protection in 1998 and became a member of UPOV in 2002. In 2011, the Republic of Korea made the plant breeders' rights available for almost all economically important crops. Among the horticultural crops, more than 50% of the shares are from vegetables, as shown in Table 3. The major breeding activities in horticulture are based on public institutions, such as Rural Development Administration (RDA); aside from that, private institutions such as vegetable and flower seed companies are also active in breeding and seed production. The Republic of Korea has made substantial advancements in vegetable breeding since the 1980's, largely influenced by the contribution of Dr. Jang-Choon Woo in the early 1950's.

Table 3. The relative importance of horticultural crops in The Republic of Korean agriculture, 2006

Groups of crop	Area ('000's Ha)	Value of produce (US$ millions)		Seed trade (US$ millions)		Major breeding forces
Groups of crop	Area ('000 ha)	Amount	%	Import	Export	Major breeding forces
Food crop	1,178	9,738	46.5	-	-	Public
Vegetables	315	7,353	35.1	31.70	18.8	Private
Fruit trees	152	2,907	13.9	-	-	Public
Flowers	8	941	5.0	-	-	Public
Total	**1,653**	**20,939**	**100**			

Horticultural seed industry in Asian countries

The total seed market for the World's top 24 countries is US$ 28,200 million. Within that market, 7 major Asian countries share US$ 8,600 million, corresponding to about 30.5% of the total market share (Table 4). Within the last decade, the seed market of all Asian countries has been steadily increasing, especially in India and China, because of the rapid increase of their consumption. It only shows that horticulture accounts for more than half of the seed market in each country. Therefore, it is very important market for the international seed companies.

Table 4. Seed market in Asian countries.

Countries	Market size(million US$)
China	4,000
India	1,500
Japan	1,500
Russia	500
Australia	400
The Republic of Korea	400
Others	300
Total	**8,600**

Japan

Japan became a member of UPOV in 1982 bound by the 1978 Act of the UPOV Convention, and acceded to the 1991 Act in 1998. The number of Plant Variety Protection (PVP) applications and grants steadily increased from about 230 to about 1,300 in 20 years (Fig. 2) reported by Intellectual Property Division, Ministry of Agriculture, Forestry, and Fisheries (IPD, MAFF). The Japanese consumer is one of the important markets for seed companies. Therefore, many domestic and international seed companies filed PVP applications for their newly developed varieties in Japan.

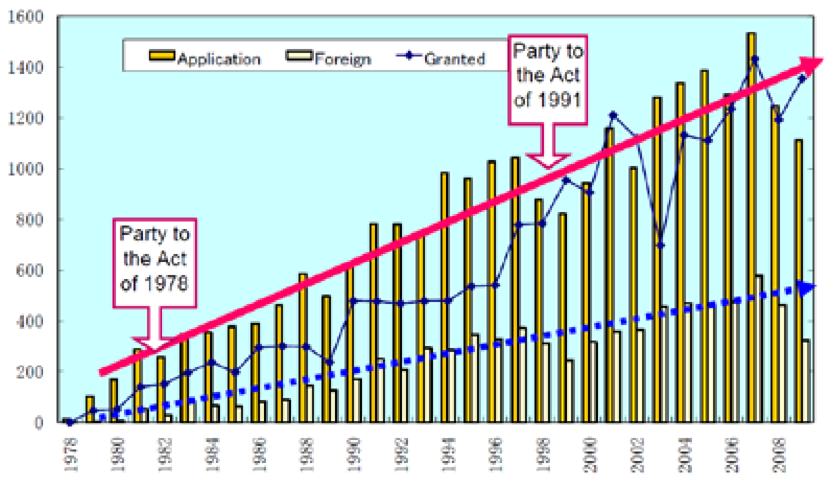

Fig. 2. Number of yearly application and grant of PBRs in Japan (J. Endo 2011, IPD, MAFF)

Both Japan and The Republic of Korea files a relatively large number of PVP applications for newly developed varieties of flowers compare to vegetables. It only shows that flower is one of the major horticultural crops applied for plant variety protection.

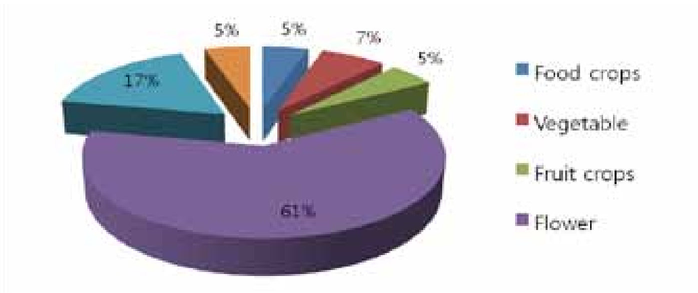

Fig. 3. Percent of granted variety by crops in Japan (from 1978-2010, total 20,779)

From a total of 20,779 grants, agricultural cooperatives account for 56%, followed by the local government, with 21%. Interestingly, food companies account for about 13% (Fig. 4). As domestic production of horticultural crops decreased recently, it is expected that the seed market will also gradually decrease by about 3% in the future. This trend is more or less the same as world's horticulture industry is concern. Specialist expects that the market size will reached almost half in 20 years.

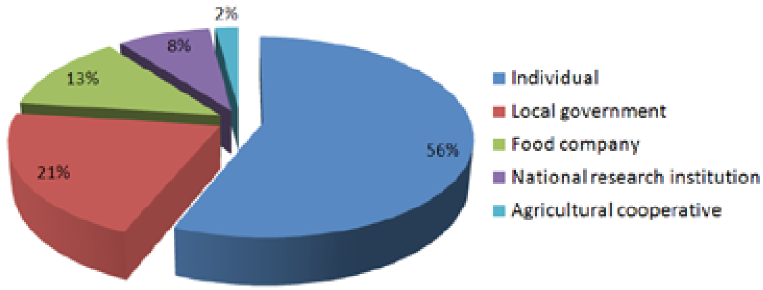

Fig. 4. Status of grant varieties by owner in Japan (from 1978-2010, total of 20,779)

India

Seed is the most important and primary agricultural input in India. Its quality has a direct impact on production. There are more than 200 private vegetable and flower seed companies in India. Today, the Indian seed market is one of the biggest in the world with annual sales of around US$ 920 million. Domestic consumption accounts for US$ 900 million while the sales in the global market accounts for the remaining US$ 20 million. Given the growth and development of the seed sector in recent years, India has the potential to become the key player in the seed export business in the developing world, with prospective markets in Asia, Africa and South America.

Like many agriculturally developed Asian countries, India has sizeable public and private sector seed businesses. The large public sector plays an important role in India that includes the National Seeds Corporation (NSC), the State Farms Corporation of India (SFCI) and the thirteen State Seed Corporations (SSCs). These corporations engage primarily in production and marketing of high yielding and hybrid seed varieties developed by the public sectors.

Although some private seed companies such as "Pocha Seeds Pvt. Ltd." and "Sutton and Sons Pvt. Ltd." have been established since the pre-independence era, accelerated growth of the private sector began only after the introduction of the new seed policy in 1988, which promoted a liberal business condition. Currently, there are over 200 private seed companies, together with a few multi-national companies, and these tends to focus on low volume, high value crops, with the principal effort being placed on creating hybrids for oilseeds, maize, cotton and vegetable crops. The private sectors account for about 70% of the market in terms of market turnover, whereas the public sectors have the greater share in terms of sales volume.

At present, vegetable research is carried out in four central institutes, one (1) national research centre and twenty six (26) State agricultural universities. The all India Coordinated Research Program of the Project Directorate of Vegetable Research provides facilities for multidisciplinary and area specific research on 23 vegetable crops, which provide a national grid for multi-location testing of technologies developed by various institutions. As a result, research on various aspects of major vegetable crops is being undertaken in order to improve existing varieties and standardize production techniques and methods.

The Republic of Korea

In 1997, International Monetary Fund of The Republic of Korea take over the Korean seed industry by which four major seed companies were bankrupt and merged to international seed companies. More than 65% of seed market was accounted for by international companies, but in 2009, it dropped dramatically to 43%.

The major seed companies in the Republic of Korea have their own breeding research institutes and a branch office in major Asian countries, where seed production is organized. Seed production is mainly (approximately 81%) organized in other Asian countries, as shown in Table 5. The major seed companies in the Republic of Korea have also established a branch office in China where almost all vegetables are produced. Some of the seed produced in China is exported to the Republic of Korea and the remaining seed produced are sold in China for local consumption. As shown in Table 5, Radish and Chinese cabbage are among the most important vegetables in the country, accounting for more than 60% of total quantity.

Table 5. Seed production of the major vegetables in the Republic of Korea, 2010 (unit: '000s kg, %)

Crop	Total (A+B)	Domestic (A)	Oversea (B)	Rate (B/A+B) (%)	Major countries where seed produced
Chinese cabbage	89.7	59.4	30.3	33.7	Italy, New Zealand, China
Korean melon	0.8	0.2	0.6	71.8	China, Thailand, Indonesia,
Onion	40.5	9.2	31.3	77.3	China, Italy, France
Pepper	35.9	1.5	34.4	95.8	China, Thailand, Indonesia
Radish	589.1	120.7	468.4	79.5	China, Italy, Australia
Cabbage	68.0	4.8	63.2	92.9	United States of America, Denmark, China,
Watermelon	13.1	0.4	12.7	96.8	China, Thailand, Indonesia,
Cucumber	15.5	0.8	14.7	94.9	China, Thailand, Indonesia
Squash	16.9	0.4	16.5	97.3	China,
Carrot	39.6	0.3	39.3	99.2	South Africa, Denmark, Italy
Spinach	176.6	10.1	166.5	94.3	United States of America, Denmark, Australia
Welsh onion	79.3	2.6	76.7	96.8	China, United States of America, Chile
Tomato	1.2	0.1	1.1	92.4	China, Thailand
Total	**1,166.2**	**210.5**	**955.7**	**81.9**	

Data Source: Korea Seed and Variety Service (KSVS)

In 2009, the total seed market size in the Republic of Korea was about US$ 581 million, which is almost 1.1% of the world's seed market. The horticultural seed market size was about US$ 400 million. Horticultural crops represent 51.6% of the total world seed market (Table 6).

Table. 6. Market size of the Republic of Korea seed industry by categories. Unit: million US$

Total	Vegetable	Flower	Rice	Industrial crops	Fruit trees	Mushroom	Potato/miscellaneous cereal	Feed crops
581	150 (25.8%)	110 (18.9%)	107 (18.4%)	60 (10.3%)	40 (6.9%)	40 (6.9%)	63 (10.8%)	11 (1.9%)

Source: Korean Seed Association

The Plant Variety Protection (PVP) system in the Republic of Korea was introduced in 1998 in order to protect plant breeders' rights (PBRs). The species and crops for which protection is available are designated on an annual basis. Varieties of 668 species/ crops were submitted for varietal protection in 2009, and almost all plants and crops are covered by protection by the Korea Seed and Variety Service (KSVS). Looking at the number of varieties protected in the Republic of Korea, flower varieties represent the highest number of horticultural crops, but vegetables are assumed to account for a larger market size (Table 7).

Table 7. Number of PBR grants in the Republic of Korea

Crops	'98~'04	2005	2006	2007	2008	2009	2010	Total
Vegetable	106	45	61	72	62	64	97	507
Fruit trees	52	14	20	12	13	18	20	149
Flowers	522	214	152	263	256	263	260	1,930

Table 8. Vegetable seed export and import in the Republic of Korea, 2006 ('000's US$)

Crops	Export	Import
Hot pepper	6,893	
Radish	5,243	626
Cabbage	2,785	-
Chinese Cabbage	1,418	-
Onion	-	1,169
Sweet pepper	-	835
Tomato	-	511
Spinach	-	439
Carrot	-	365
Others	2,424	808
Total	**18,763**	**4,753**

The value of seed exports and imports for the Republic of Korea is shown in Table 8. One of the distinctive indications is that crops are predominantly separated into those for export and those for import. Based on the 2007 report made by the National Institute of Horticultural and Herbal Science, Rural Development Administration (NIHHS,RDA),hot pepper is one of the most important vegetable crops in the Republic of Korea wherein seeds is also the main export item.

China

The Plant Variety Protection (PVP) system of China is managed by two organizations: the Ministry of Agriculture and the State Forestry Administration.

Vegetable genetic resources have been collected and preserved for a total of 30,736 accessions: 29,198 accessions of seed-propagated vegetables cover 21 families, 67 genera, and 132 species; and 1,538 of the accessions are vegetatively propagated vegetables. With the development of vegetable science and technology, a large number of new, improved varieties have been released and used for seed production. Conventional breeding is conducted in large scale by individual scientific research institutes around the country. Many varieties with various beneficial characteristics have been selected and released. Some of the varieties are grown over a large area and there is still a significant level of production.

Breeding for F1 hybrids started in China in the 1960s. Since then, a few institutions have started to study hybrid seed production technology. Shortly after that, some self-incompatible lines and male sterile AB lines were used to produce F1 hybrids for cabbage and Chinese cabbage. Later, F1 hybrids were produced in more crops such as cucumber, tomato and pepper. Breeding for disease resistance is one of the important vegetable breeding goals. Breeding techniques such as microspore culture, tissue culture and marker-assisted selection have been used to breed new varieties.

According to the cultivated area and the total value of vegetables, the seed market may be more than 1.4 billion US dollars (Table 9) (Mengyu and Zhang, 2006). With the development of vegetable production, a large number of vegetable seed producers and distributors have been established. They can be classified into four types: public seed companies, research institutes, international seed companies and local private seed companies. Private seed companies have rapidly been established in recent years. There are thousands of small seed companies in China, wherein most of them are engaged in small scale production. Some of them started to breed their own varieties and establish a marketing network. They are very active and play a main role in Chinese vegetable seed industry. Because of such a large seed market, about 60 foreign seed companies are now working in China. Many of them not only sell their vegetable seeds, but have also established breeding stations in China. The main international vegetable seed companies in China include Syngenta, Seminis, Bejo, Rijk Zwaan, Nongwoo Bio., and many others.

There has been a tremendous increase in both export and import of vegetable seeds in recent years. In 2005, China exported a total of 5835.3 tons of various vegetable seeds, valued at US$ 39.36 million, and imported a total of 7452.7 tons of seeds, valued at US$ 44.92 million (Table 10) (Sun 2009).

Table 9. Estimated vegetable seed market in China.(Sun 2009)

Species	Acreage ('000s Ha)	Seed needed (Tons)	Total value ('000s US$)
Chinese cabbage	15,000	60,000	300,000
Tomato	974	877	41,253
Cucumber	1,254	3,135	73,767
Radish	326	1,369	3,218
Beans	175	21,000	24,780
Lettuce	370	740	17,412
Eggplant	816	734	8,637
Pepper	553	830	24,885
Cabbage	242	242	4,271
Cauliflower	293	293	5,860
Celery	125	225	2,117
Chinese chive	105	399	2,817
Carrot	373	933	5,483
Spinach	590	3,186	3,759
Broccoli	95	86	2,012
Garlic	629	377,400	354,756
Onion and Chinese leek	790	2,844	16,723
Watermelon	1,806	5,418	541,800
Squash, Pumpkin, Gourd	244	732	3,448
Total	**25,516**	**479,711**	**1,434,550**

The Regulations on the Protection of New Varieties of Plants in China was enforced on October 1, 1997, and conformed to the 1978 Act of the UPOV Convention. China became a member of the International Union for the Protection of New Varieties of Plants (UPOV) on April 23, 1999. This means that breeders of new varieties of relevant botanical genera or species from UPOV member States can seek protection in China, and Chinese breeders and residents can seek protection in other UPOV members.

Table 10. Values of exported and imported vegetable seeds in China (000,000 US$).

	Export			Import		
	2003	2004	2005	2003	2004	2005
The Republic of Korea	64.68	56.73	63.62	37.12	31.96	45.15
Holland	43.82	53.44	65.92	40.81	31.15	58.24
Japan	28.91	28.20	25.89	90.93	119.81	120.55
Other	8.20	12.55	12.60	36.60	26.45	13.04
USA	74.82	95.66	105.77	45.51	45.57	39.77
France	11.62	24.43	32.90	6.05	12.82	12.27
Thailand	0	3.70	4.22	33.78	33.04	36.87
Italy	5.79	12.17	21.85			
India	10.50	14.27	18.82			
Israel		0	4.56	33.19	34.37	31.25
Australia				17.87	20.85	18.96
Denmark				15.27	17.31	20.95
Sub Total	**248.34**	**301.15**	**356.15**	**357.13**	**373.33**	**397.07**

Thailand

There are 85 private seed companies involved in the seed business in Thailand according to 2004-2006 report by Seed Association of Thailand (SAT). Among those companies, 20 of them focus mainly on seed imports, 37 focuses on seed export and 28 companies engage both import and export seed business. Only 30% of those seed companies have invested in the business of import and export at a value higher than 10 million baht or equivalent to 324453.44 US$ (1US$= 30.82 Thai baht), most of them being foreign seed companies.

During the past five years, the seed industry in Thailand has made considerable progress in the development of high performance hybrid varieties of many kinds of vegetable, field crop and flowers, wherein the seed production is increasing in terms of volume of exports to 53 countries and also in terms of market value. Although most of vegetable seeds can be produced under the environmental conditions in the country, there are some vegetables that need to be imported due to their environment-specific production requirements. Imported seeds are traded within the country and re-exported to other countries as well. The volume and value of imported and exported seed has increased year-by-year by more than 20% and 16% respectively as shown in Table 11. Detailed information can be found at *www.doa.go.th*.

Table 11. Amount (kgs.) of exported and imported vegetable seeds in Thailand.

Crops	2004		2005		2006	
Crops	Import	Export	Import	Export	Import	Export
Cauliflower	8,949	1,034	10,971	745	7,472	855
Cabbage	23,544	5,285	24,683	8,532	26,643	6,652
Chinese Kale	409,540	3,079	423,940	4,066	424,577	3,471
Cucumbers	4,624	54,589	5,140	45,287	6,030	58,663
Water melons	3,962	90,455	5,322	103,234	2,830	89,324
Broccoli	764	453	795	581	1,159	554
Chinese Cabbage	66,932	6,396	48,804	7,598	91,772	6,321
Chinese Radish	162,217	25,342	195,142	34,981	307,244	28,221
Green Mustard	57,376	4,042	50,567	4,554	68,066	8,455
Lettuces	49,751	14,565	21,431	19,809	11,096	18,403
Peppers	4,101	18,220	4,108	21,297	1,895	30,123
Tomatoes	1,888	22,328	1,361	32,561	966	31,133
Onion	10	5	130	-	3,486	-
Bitter Gourd	-	-	-	-	-	3,170
Total	**795,662**	**245,793**	**794,399**	**283,245**	**955,242**	**285,345**

Source: Office of Agricultural Regulation, Dept. of Agriculture (OAR, DOA)

I. Recent breeding achievements in horticultural crops in Asia

Strawberry

In Japan, strawberries are produced mainly in the northern regions, such as Hokkaido and Tohoku districts. These can be broadly classified into two areas: subject to very cold winters; and subject to relatively mild winters. As a result of these climatic differences, the varieties of strawberry grown in each of these regions vary. The dominant varieties of strawberry produced in northern Japan are the late June-bearing types with a relatively long dormant period, such as 'Morioka-16', 'Belle Rouge', 'Akitaberry', 'Kita-ekubo', 'Kitanokagayaki', 'Kentaro' and 'Otomegokoro' which are suitable for open field culture, semi-forcing culture, and late raising in the cold districts. The early June-bearing varieties such as 'Fukuharuka', 'Fukuayaka' and 'Mouikko' are grown in Miyagi and Fukushima prefectures (Table 12). In view of this economic potential, both public and private research institutes are actively working to breed year-round bearing strawberry varieties, in addition to June-bearing varieties. As a result of these efforts, a total of nine new varieties: 'HS-138', 'Kareinya', 'Kiminohitomi', 'Hohoemikazoku', 'Esupo', 'Natsuakari', 'Dekorujyu', 'Summer candy' and 'Natsujiro', have been released since 2000 (Table 12).

Until now, the breeding of strawberry varieties and development of cropping patterns in northern Japan have been pursued principally through public experimental stations that are directly connected with the production districts. However, given that the development of new varieties and cropping patternsis time consuming and costly, it is important to find a more cost-efficient way of doing this work, based on effective collaboration between interested research institutes, agricultural organizations, and private companies.

The Republic of Korea produces a large quantity of strawberries under plastic-covered greenhouses during the winter-spring season. Some of strawberry varieties originated from Japan long time ago. However, recently the Republic of Korea governmental breeding institutes have developed a series of varieties for the domestic market. As a result, domestic-bred varieties now account for around 61% of the total consumption in the Republic of Korea (Fig 5). The Republic of Korea's recent breeding activity is also very advanced in horticultural crops, such as rose, strawberry, lily and chrysanthemum.

Table 12. Strawberry varieties bred in Tohoku and Hokkaido, Northern Japan

Grant Year	Variety	Cropping type
Before 2000	**June-bearing** / 'Morioka-16' (1968), 'Belle Rouge' (1989), 'Akitaberry' (1992), 'Kitaekubo' (1995), 'Miyagi VS1' (1998)	Open field and/or Semi-forcing culture
Before 2000	**Ever-bearing** / 'Oishi-shikinari' (1970), 'Everberry' (1987), 'Pechika' (1995)	Summer-to-autumn culture
After 2000	**June-bearing** / 'Kitanokagayaki' (2000), 'Kentaro' (2006), 'Otomegokoro' (2006), 'Komachiberry' (2007), 'Kitanosachi' (2007) 'Fukuharuka' (2006), 'Fukuayaka' (2006), 'Moikko' (2007)	Open field and/or Semi-forcing culture Forcing culture
After 2000	**Ever-bearing** / 'HS-138' (2004), 'Kareinya' (2004), 'Kiminohitomi' (2005), 'Hohoemikazoku' (2006), 'Espo' (2007), 'Natsuakari' (2007), 'Dekorujyu' (2007), 'Summer candy' (2007), 'Natujiro' (2007)	Summer-to-autumn culture

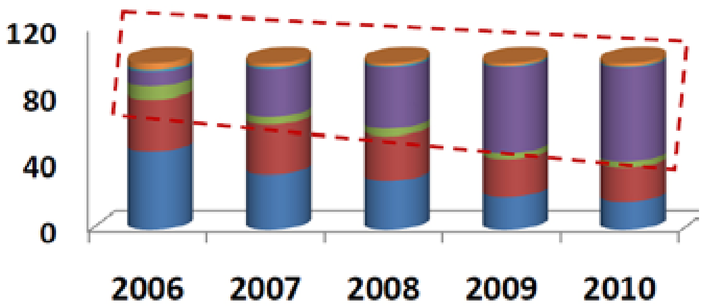

Fig. 5. Number of strawberry varieties registered in the Republic of Korea.
Dotted box indicates market share ratio by the Republic of Korean-bred varieties.
Legend: Korean varieties (violet), Japanese varieties(red and blue)

Kiwifruit

ZESPRI International Limited (Zespri), a company established in 1997 in New Zealand, that markets Kiwifruit and stocks with authorized production in more than 60 countries in the world and earns more than US$ 1.2 billion, accounting for more than 25% of the world's consumption. ZESPRI spent about 20% of marketing expenses from all the results of research and development of new variety breeding at Horticulture Institute, New Zealand. Breeding research is one of the top priorities in this company, because they believe that breeding new varieties is crucial for their marketing system. This company had been in cooperation with the Horticulture Institute, New Zealand. This institute is managing more than 50,000 lines in their experimental field, including the varieties such as Orange', 'Jumbo' 'Gold', 'Green', which are distributed all over the world.

ZESPRI collects royalty fees from all over the world. One of the largest kiwifruit production areas in Japan is Ehime prefecture. Zespri granted the Japanese farmers the right to produce their varieties in return for an agreed payment of royalty (Table 13). A total of 258 tons of 'Zespri Gold' were produced in Ehime prefecture in 2005, increasing by 5 times by 2008 and accounting for about 20% of the total kiwifruit production in Ehime prefecture. In the same period, the volume of production of other kiwifruit varieties remained almost static (Table 13).

The farmers of the Republic of Korea also have an agreement with ZESPRI about the royalty fees for the production of 'Zespri Gold'. The amount of royalty is about 15% of total production, 3% is true royalty and other 10% is the fee for marketing in the Republic of Korea and other countries. For example, it is assumed that only 30% of total of 4,300 tons of 'Zespri Gold' produced in Jeju is sold for domestic consumption and the remaining 70% is exported to South East Asian countries (Table 14).

Table 13. Case study of overseas variety that has successful introduced in Japanese market.

		2005(Ehime)/2007(Jeju)	2008(Ehime/Jeju)
Ehime Prefecture, Japan	Zespri Gold	Production: 258 tons Sales: more than 1.4M US$ Share in the prefecture: 3.1%(weight) Unit price: 5 US$/kg	Production: 1,300 tons Sales: more than 6.8M US$ Share in the prefecture: 14%(weight), 20%(sales) Unit price: 5 US$/kg
Ehime Prefecture, Japan	Kiwifruit in total	Production: 8,300 tons Sales: 28M US$ Unit price: 3.4 US$kg	Production: 9,600 tons Sales: 34M US$ Unit price: 3.5 US$/kg
Jeju Island, Republic of Korea	Zespri Gold	Production: 1500 tones Market share: 8.5%(weight) Unit price: 8 US$/kg	Production: 2800 tones Market share: ca. 16% (weight) Unit price: 7 US$/kg
Jeju island, Korea	Kiwifruit in total	Production: 17,700 tons Unit price: 2.5 US$/kg	Production: 17,400 tons Unit price: 3.5 US$/kg

Gentiana

Ashiro Rindo is a successful case of a breeding-oriented development by a farming community in Japan. "Ashiro" is a small mountainous area in northern Japan that engaged in the breeding of rindo (gentians = *Gentiana* L.) to compete with other producers. Licenses for production of these varieties are only given only to farmers in Ashiro prefecture, in order to maintain high quality and to protect the brand. Ashiro is successfully exporting cut flowers to the European Union throughout the year with "Ashiro" as its brand name. The protection of the series of "Ashiro" gentians by plant breeders' rights in each country is essential to protect their varieties. Now, "Ashiro" is expanding its market by using production in Chile of provide cut flowers for the United States of America. As shown in Fig 6, cut flowers produced in New Zealand and Chile is exported to the European Union and the United States of America in order to achieve year-round supply (Endo, 2011).

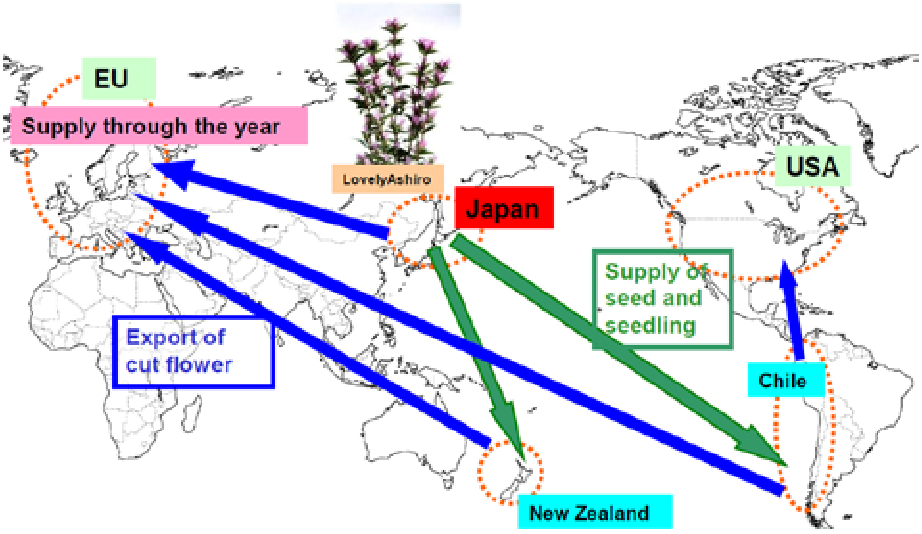

Fig 6. Ashiro Rindo is a successful case of breeding by local Prefecture farmers to facilitate worldwide distribution as "Ashiro" brand. (Data reported by J. Endo, the symposium on Plant Variety Protection, 2011, the Republic of Korea)

II. Recent breeding activities for horticultural crops in Asia

General breeding tools in creating new varieties

The table below shows the overview of breeding techniques used for vegetables and flowers by seed companies in Japan.

Table 14. Overview of breeding techniques and propagation for vegetables and flowers in private company in Japan.

Groups	Methods	Crops
F1 breeding/ Vegetables	SI	Chinese cabbage, Broccoli, Cauliflower, Brassica, Dikon radish
F1 breeding/ Vegetables	MS	Carrot, Onion, Bunching onion
F1 breeding/ Vegetables	Pollination by hand/ insect	Tomato, Egg plant, Pepper, Melon, Squash, Pumpkin, Water melon
F1 breeding/ Flowers	SI	Ornamental cabbage, Ornamental Kale
F1 breeding/ Flowers	MS	Helianthus
F1 breeding/ Flowers	Pollination by hand/ insect	Pansy, Primula, Petunia, Lisianthus, Gerbera
Vegetative propagation		Petunia, F1 *Limonium*

Mutation breeding

Mutagenesis has been used for a long time in plant breeding wherein a shortage of germplasm such as germplasm for drought tolerance, disease resistance and other morphological characteristics like plant height exists in natural or breeding population. In the early era, chemical mutagenesis was used, but people realized that the chemical methods were not only harmful to environment and human but also less effective compared to radioactive methods such as gamma ray and ion beam. Table 15 and Figure 7 provide an overview of mutation breeding achievements by irradiation breeding up to 2009.

Ion beams are produced by particle accelerators. Since 1986, Radioactive Isotope Beam Facility (RIBF) has the biggest facilities capable of accelerating heavy ions worldwide. It is well established that high-Linear Energy Transfer (LET) ion beams have higher biological effects than low-LET radiation, such as gamma and X-rays (Abe et al., 2007). Plant scientists started to use RIKEN Nishina Center's facility in plant breeding in 1993. Scientists found that the ion beam is highly effective for inducing mutagenesis of tobacco embryos during fertilization, without damage to other plant tissue. Normally, ion beam irradiation is known to produce double-strand breaks. Many types of mutants were isolated in tobacco including albino, periclonal chimera, sectorial chimera, herbicide-tolerant and salt-tolerant phenotypes (Abe et al., 2000). RIKEN has introduced 6 new flower varieties to the market since 2002. It took only three years to create the new varieties (Table 16). The sterile *Verbena* mutants, 'Emari Bright Pink' was released on the market after being developed using the ion beam in 2002. New color varieties, such as Petunia "Urfinia Rose Veined" (2003) and the new color *Torenia* "Ummer Wave Pink" (2007), were also produced. Thus, it seems that the ion beam is an excellent tool for mutation breeding to improve horticultural and agricultural crops with high efficiency.

Table 15. Variety development by irradiation breeding methods by countries in 2009

Crops	China	India	Japan	Russia	Republic of Korea	Netherlands	Germany	USA
Major cereals	366(55.9)	58(21.4)	82(35.2)	41(19.4)	8 (42.1)	1 (0.6)	72(41.6)	39(31.2)
Soybean	56 (8.5)	39 (14.1)	25 (10.7)	28 (13.3)	2 (10.5	-	10 (5.8)	26 (20.8)
Minor cereals	70 (10.7)	9 (3.3)	4 (1.7)	62 (29.4)	-	-	-	12 (9.6)
Industrial crops	23 (3.5)	29 (10.5)	9 (7.5)	10 (4.7)	-	-	-	3 (2.4)
Oil	41 (6.3)	16 (5.8)	1 (0.8)	3 (1.4)	6(31.6)	-	-	1(0.8)
Flowers	60 (9.2)	95 (34.4)	81(34.8)	40(19.0)	2 (8.0)	173(98.3)	80(46.2)	23(18.4)
Fruit tree	20 (3.1)	2 (0.7)	6 (2.6)	7 (3.3)	-	-	-	2 (1.6)
Vegetables	17 (2.6)	14 (5.1)	14 (6.0)	10 (4.7)	-	2 (1.1)	1 (0.6)	3 (2.4)
Others	2(0.3)	14 (5.1)	11 (4.7)	10 (4.7)	-		10 (5.8)	16(12.8)
Total	**655(100%)**	**276(100%)**	**233(100%)**	**214(100%)**	**19(100%)**	**176(100%)**	**173(100%)**	**125(100%)**

Data source: Food and Agriculture Organization, International atomic Energy Agency, Mutant Varieties Database (FAO-IAEA MVD, 2009)

Table 16. Mutant lines developed in various crops using RIBF

Mutant phenotype	Plant material	Ion/Dose (Gy)	Survival/ Mutation (%)	Developer
Sterile				
Verbena	Stem	N/10	842.8	Suntory Flowers Ltd
Cyclamen	Tuber	C/12	50/13	Hokko Chem,Ind. co Ltd
Flower color and shape				
Dahlia	Shoot	N/5	NE/20.3	Hiroshima City Agri Forest Prom, Cen.
Rose	Dormant scion	Ne/15	70/51.7	Kanagawa
		N/30	90/43.1	Pref Agri Cent
Chrysanthemum	Stem	C/10	94/14	Plt Btech. Inst. Ibaraki Agri, Cen.
Torenia	Leaf/stem	N/50	NE/1.9	
		Ne/20	NE/1.6	
Variegation				
Petunia	Stem	N/5	ND	Suntory Flowers Ltd
Semi-dwarf				
Barley	Dry seed	N/50	ND/2.6	Natl. Agr. Res. Cen. Min.
	Imbibed seed	N/5	ND/0.9	Agr. Forest. Fish
Sweet pepper	Dry seed	Ne/10	80/1.3	Natl. Inst. Veget. and Tea Sci.
Buckwheat	Dry seed	C/40	NE/0.9	Natl. Inst. Agr. Sci
		Ar/20	NE/1.0	
		Fe/30	70/4.0	
Salt-tolerance				
Rice	Imbibed seed	C/40	40/1.1	Tohoku Univ.
Waxy				
Rice	Dry seed	N/200	NE/2.2	Chiba Pref. Agri. Res. Cen.

ND: no data, NE: no effect

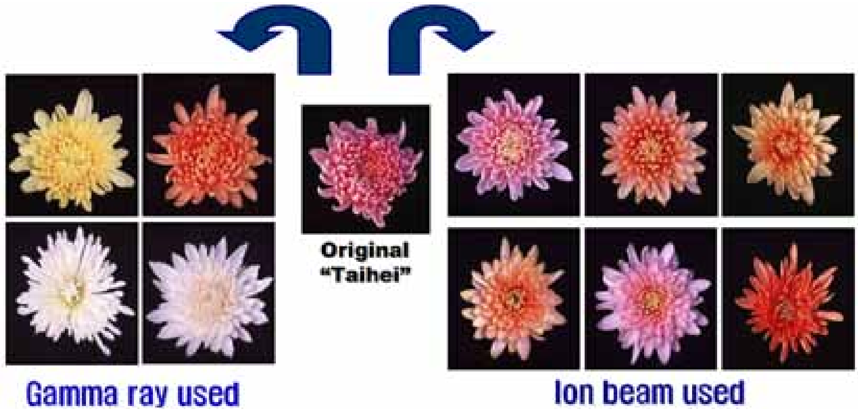

Fig. 7. Samples of mutation breeding conducted in Japan. Flower color modificationin chrysanthemum often showed by irradiation of gamma ray and ion beam. Ion beam irradiation showed higher frequency in flower color changes.

Mutation breeding in the Republic of Korea has recently been advanced by the Korea Atomic Energy Research Institute (KAERI) and Rural Development Administration (RDA), the Republic of Korea. The products are rice, some other cereals and mostly flowers. The examples in Figure 8 show green-yellow vein leaves of *Dendrobium moniliforme*. *'In vitro' Dendrobium moniliforme* seedlings were treated with low range of gamma irradiation. KAERI applied diverse dose methods with low range of phytotron and higher range of irradiation.

Fig. 8. Leaf variegation in "Dendrobium moniliforme" induced by gamma ray irradiation in the Republic of Korea.

There are four different organizations handling the mutation breeding researches in Japan namely RIKEN Nishina Center, Japan Atomic Energy Research Institute (JAERI) Takasaki, National Institute of Radiological Sciences (NIRS), and Institute of Radiation Breeding (IRB). RIKEN Nishina Center for Accelerator-Based Science is one of the leading institutions in the development of biotechnology for plant breeding. This institute is making substantial investment in technologies such as molecular biology, molecular breeding, molecular biochemistry and also atomic energy.

Fig. 9. Left; A fruit of "Norin No 15" Right; Seed capsule traveled to the space, onboard the spaceship "Progress" in 2008.

The Korea Atomic Energy Research Institute (KAERI) is one of the organizations engaged in radiation breeding in the Republic of Korea. In 2013, KAERI is planning to establish a branch institute for radiation breeding in Jeongup, the Republic of Korea. This institute will carry out plant breeding using mainly irradiation method.

The Institute of Atomic Energy for Agriculture, Chinese Academy of Agricultural Science (CAAS) is the main institute for mutation breeding in China, and more than 30 universities and key laboratories in the provincial agricultural research institutes are also engaged in mutation breeding. China is active not only in low LET, but also high LET irradiation methods, such as space breeding (Fig. 9). Radioactive irradiation breeding is also useful for fruit tree breeding by point mutation of the cells, and is effective for fruit disease resistance. Radiation breeding methods in woody crops, including fruit trees and forest trees, are studied in IRB, and many physiological and morphological mutants have been obtained. A mutant resistant to black spot disease was discovered in a gamma field from a tree of the Japanese pear variety 'Nijisseiki', which is susceptible to the disease. The mutant called 'Gold Nijisseiki' was registered as 'Norin No. 15' by Ministry of Agriculture, Forestry and Fisheries (MAFF), Japan, and is being rapidly adopted in pear producing areas (Fig. 9). A simple selection technique using leaf disk and toxin has been established and has remarkably improved the selection efficiency of resistant mutants (News letter of Institutional Review Board (IRB).

Interspecific hybridization

Interspecific hybridization was used for the first time by U in 1935 for the production of amphidiploids (allotetraploid) by crossing three different Brassica species, *B. campestris* (n=10), *B. oleracea* (n=9), and *B. nigra* (n=8), respectively. He made crossing among three Brassica species independently and produced interspecific hybrids that possess two different genomes in a cell derived from parents. The genetic relationship theory of Brassica species in "U's triangle" had been derived by confirmation of cytogenetic analysis of the interspecific hybrids (U, 1935). The products of amphidiploid, *B. napus* (n=19), *B. carinata* (n=17) and *B. juncea* (n=18) are widely used for the production of canola oil, leafy vegetables and other purposes (Fig. 10). Nowadays, interspecific hybridization method is widely used for breeding flower crops such as *Lilium*, *Tulipa*, *Alstroemeria*, and many other flower crops. Recently, this method was also used for introgression breeding in many vegetables crops. One of the examples is the Oriental melon in The Republic of Korea, which is cultivated as one of the major crops. The normal variety bred by F1 intraspecific hybridization method has been cultivated for long time until 1985, however, a new variety using interspecific hybridization method between traditional breeding line and one of the Russian melons. This melon hybrid developed from interspecific hybridization dominates the market and outshine the traditional melon varieties in the country. The new variety bred by interspecific hybridization has become the most popular Oriental melon within few years. Most of current Oriental melons originated and developed from the same breeding method are still preferred by Korean consumers.

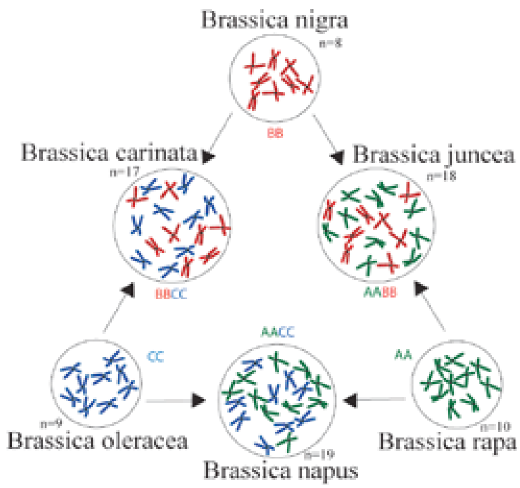

Fig. 10. Diagram of U's triangle to demonstrate the genetic inter-relationship of Brassica species. U, 1935

Lilium formosanum can easily propagate by seeds and has the ability to flower within one year after sowing. Mr. Nishimura, in Nagano, started to cross *L. formosanum* with *L. longiflorum* in 1928 that developed the *L. x formolongi* which combines the characteristics of flowering within one year after sowing the seeds with the presence of broad leaves like in *L. longiflorum*. To obtain the configuration of *L. longiflorum*, *L. x formolongi* has been backcrossed to *L. longiflorum* in the recent varieties. As *L. x formolongi* is propagated by seeds, viral infection does not occur. The other advantage is that cut flowers of *L. x formolongi* can be produced from July to November but the cut flowers of *L. longiflorum* are difficult to produce during these months. It has been estimated that about 15 million cut flowers of *L. x formolongi* are being produced. This method is now being applied for other *Lilium* crossing between *L. formolongi* and other *Lilium* species which belongs to other section such as Oriental hybrids or backcrossed to *L. longiflorum* as well. Recently interspecific hybridization is major breeding tool for new variety generation in *Lilium* which shares almost 40% of all grant varieties.

Genetic engineering

Breeding a blue rose has been the ‘‘Holy Grail’’ of rose breeding for centuries, but roses have proven a particularly difficult candidate to turn it into blue. This is now already changed with the joint venture between the Australian based Florigene and the Japanese Suntory company, successfully using Commonwealth Scientific and Industrial Research Organization (CSIRO)’s gene silencing technology to help create the world’s first blue rose. Roses are famous for their beautiful majestic colors including red, pink, orange, yellow and even white. These colors have been developed through traditional breeding but never has a blue rose successfully been bred.

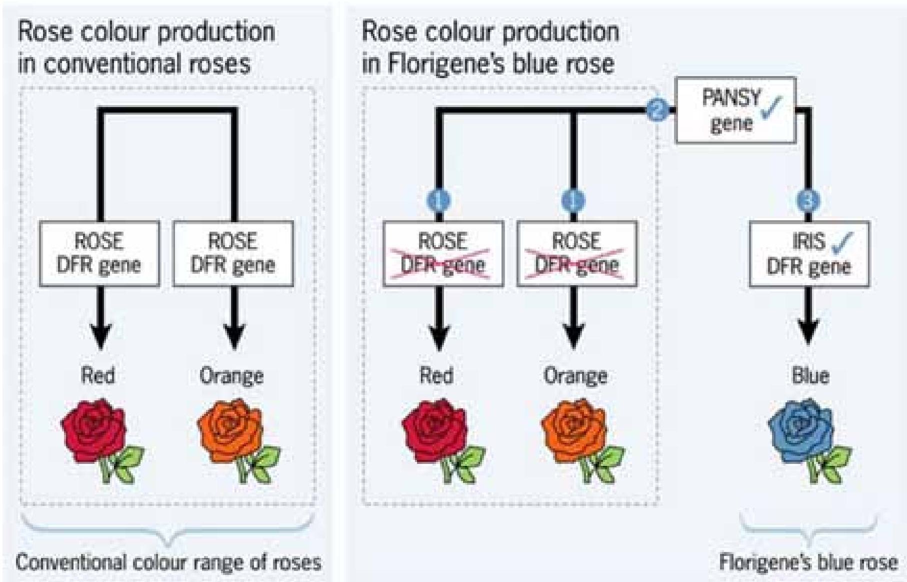

Fig. 11. Process of noble blue roses originated by plant biotechnology techniques by silencing red pigments “Dihydroflavorol Reductase (DFR)” genes(figure originated from CSIRO).

Inserting genes from the common Pansy and Iris into Rose DNA and at the same time switching off a Rose gene that prevented the production of the blue pigment known as “delphinidin” (Fig. 11) will possibly develop a blue colored rose. The legendary flower of love will be able to synthesize and express a full range of hues from palest baby blue to deep navy. Japanese drink manufacturer Suntory Ltd. and Florigene Ltd. first cracked the code for creating blue roses in 2004. It is now sold as variety name “Applause” in many developed countries (CSIRO, 2005).

Researchers from Suntory group are also developing other crops such as carnations, torenia, chrysanthemum and many other kinds of flowers. Regulation of genes related to the production color pigments such as "apigenidin", "cyanidin", "pelargonidin" and "delphinidin", affect the final color generation in higher plants (Fig. 12; Katsumoto et al. 2007). The production of Anthocyanidins including "apigenidin", "cyanidin", "pelargonidin" and "delphinidin" are regulated by over expression or suppression of genes using genetically modified technology and finally controlled the flower color modification (Tanaka et al., 2008). Chandler and Tanaka (2007) published about the overview of genetic modification in floriculture where they reviewed all valuable researches mentioned.

Fig. 12. "Applause" a blue rose variety bred first time through plant biotechnology in Japan.

III. Future prospects of horticulture breeding in Asia

The future of horticultural crop breeding will rely on 4 major technologies: marker oriented breeding, mutation breeding, introgression breeding and GMO breeding.

The development of markers is rapidly growing yearly especially in Japan, The Republic of Korea, and China as well. In the vegetable crop breeding, major seed companies are investing huge amount of money for molecular breeding. There are two strategies, one is by Marker-Assisted Selection (MAS) and the other one is by developing the Genetically Modified Organisms (GMO) crops. Flower crops are relatively free against market reluctance which already proven by blue rose in Japan and USA. Although for vegetables, there are still many barriers in order to release the GM vegetables in the market even though most of the researches are conducted by the governmental institutes of many countries. It seems that commercialization of GM vegetables is still on-hold due to some issues on its effect to human body raised by the organic-based farming advocates. Like in corn and soybean, GMO rape seed for disease and herbicide resistance is already introduced in China and India. Modification of pigmentation by GM method will be continued after successful of blue rose and moon series of carnation (Fig. 13). They are now developing distinctive color change of petunia, lily, chrysanthemum and some other important flower crops. Mutation breeding techniques will be developed more quickly than so far done. Different researches were conducted to get more diversity on natural germplasm especially in flower crops. Drought tolerance and disease resistance in some fungal pathogens such as powdery mildew in vegetable are one of the main characteristics to consider in conducting breeding

Fig. 13. Flower and petal color comparison. The pink -flowered rose variety 'Lavande' (left) was transformed with pSPB919. The resultant transgenic plants produced violet-colored transgenic flowers (right) containing 98% delphinidin (Courtesy from Plant Cell Physiology).

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Flower Breeding for the Global Market

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1. Introduction

The world flower market is complex and divided into different segments like cut flowers, indoor plants, bedding plants, perennials, grasses, shrubs and trees. Floriculture is using different propagation technologies like seeds, cuttings, bulbs and in vitro material. The total number of species is huge and their usage is depending on climate, culture and the economical situation. For Europe Prof. Horn estimated that around 400 species out of 250 genera and 100 families have commercial relevance. 95% of the relevant species have their origin outside of Europe.

My personal experience in this market is based on my work for Selecta Klemm in breeding, sales and marketing of bedding and pot plants, perennials and cut flowers.

Selecta is until today a family owned company with roots going back to 1932 when they started as a vegetable company which developed later into a cut flower producer. In the 1960's the company shifted their business to young plant production and breeding of carnation. Until 1996 Selecta stayed highly specialized with only 4 species: carnation, pelargonium, poinsettia and New Guinea Impatiens. After this period Selecta diversified its breeding activities and with a team of 7 breeders and in cooperation with partners worldwide is today active in breeding of approximately 45 species. The larger portfolio allowed Selecta to build up a distribution network including representatives, agents, wholesalers, root and sell partners and licensees. Today Selecta varieties are available worldwide. Besides breeding Selecta has a strong focus on the extension of the production of unrooted cuttings in East Africa.

2. The global flower market

Different authors estimate that the global flower market amounts to a retail value of approximately $100 billion worldwide with the cut flower market ranging between $40 to 60 billion. The yearly growth of the global market is difficult to estimate and highly depending on segment and country. The cut flower market has been flat or even shrinking over the last years. The bedding plant market or even more generally the market for outdoor plants is considered to grow in Europe and North America. Growth rates are ranging between 2 and 4%.

On retail level the three main markets are North America, Europe and Japan. It is estimated that these markets account for up to 80% of the global market. Breeding companies have a strong focus on these three markets.
There is no information available about the value created by the different propagation methods. In cut flowers the most important species (roses, chrysanthemum, tulips, lilies, gerbera and carnation) are obviously all vegetatively propagated using cuttings, bulbs and in vitro material.

Breeders of vegetatively propagated varieties intensively use plant breeders' rights and plant patents to protect their intellectual property. The official CPVO statistic shows that a 58% of the titles granted by the CPVO since 1996 are dealing with ornamentals. More than 95% of these varieties are vegetatively propagated (CPVO, pers. communication).

The floriculture is going through a consolidation process which is obvious on the level of the breeders and young plant producers. The price pressure in the retail industry is driving the consolidation upstream through all levels of the value chain. Breeders and young plant producers reduced their production costs by relocating their mother stock, seed production and tissue culture to low cost countries. The breeding itself is still concentrated in North America, Europe and Japan.

Besides the global acting breeders, there are still a huge number of small breeding companies or private breeders. Around 80 German companies or private persons are holding a European PBR title. The diversity of ornamentals creates a lot of niches. But also in bigger crops we have seen many examples where spectacular novelties were bred by small companies or private breeders. I believe that in floriculture we will have also in the future focused and highly motivated private breeders and small companies coexisting with the global players.

The segmentation between the classical plant classes like bedding plants, perennials, shrubs and even vegetables is blurring. Plants from all these classes compete for the same space in a patio, a window box or in the garden.

Consumers in general like to have a nice balcony, patio or garden. In spite of the desire for nice plants traditional work in the garden becomes more and more an activity that is not preferred. "Do it my-self" is becoming "Do it for me" and decorating is taking over gardening. Consumers today expect solutions and the work of breeders do not stop anymore at the stage of creating a new variety. We have to create solutions together with the growers and the retailers. Bedding plant mixes ready for planting are very popular in Germany at the moment and form a good example how solutions can be provided to the consumer.

Innovative breeding has to be combined with a successful marketing concept. One of the most im-pressive examples is still the introduction of Surfinia in Europe. Surfinia in Europe is a synonym for trailing Petunia. In cut flowers one of the most impressive examples for a successful combination of breeding and marketing was the introduction of Million Stars, a new Gypsophila variety.

Today the release of nearly any novelty is supported by intensive marketing approaches. In the past the young plant companies were focusing on their costumer, the grower. Today the retail is more and more approached directly by the breeder offering a package of genetics and marketing. Breeding and marketing cannot be seen independently anymore, a successful introduction of novelties combines innovate breeding with a unique marketing.

3. Developments in conventional breeding approaches

a. Bedding plants

The bedding plant market is heavily influenced by the introduction of new products taking market share from commodities. New species and genera have been developed to a commercial level and gained a high market share within a few years. A very good example is Calibrachoa. The first varieties were introduced in 1996 by Suntory. Today Calibrachoa is already the second biggest vegetatively propagated bedding plant in North America. At least 8 breeding companies are working intensively on Calibrachoa worldwide and year after year we can see stronger improvements.

Innovation in bedding plants is in many cases based on the successful creation of new interspecific or intergeneric hybrids. We can find a number of commercially successful examples in Osteospermum, Lobelia, Impariens, Nemesia, Calibrachoa and Petunia. Differently to the breeding of agricultural crops and vegetables wild species are not only the source for specific genes but the tool to create a completely new plant. The hybrid plant itself is in many cases already the commercial variety. Back-crossing to commercial varieties sometimes gives no improvements and can be difficult because of the sterile character of the hybrids.

The intensive use of interspecific hybridisation has created in many ornamental genera complex gene pools which are characterized by different ploidy levels. For example in pot carnation we can find di-, tri- and tetraploid commercial varieties which have been developed out of a range of species including Dianthus caryophyllus, D. deltoids, D. chinensis, D. allwoodii.

The breeding of new interspecific and intergeneric hybrids will continue and will also have a major impact on the development of the bedding plant market in the future.

b. Cut flowers

Cut flower production has been moved over the last decades from Europe and North America to South America and East Africa. The main reasons for this development have been the lower production costs and the influence of the climate on the quality. The shipping ability and shipping costs are the decisive factor to which extent the production of a species is moved to the South. A relatively new trend is that air freight is replaced by sea freight. Performance in sea freight may become a new selection criterion in cut flower breeding.

Cut flower breeders have adapted more and more to this situation:

- Trial activities are intensified in the relevant countries
- Breeders purchase flower farms or start cooperations with farms for a better introduction and marketing of their varieties
- Complete breeding programs are moved to South America or Africa.

Important cut flower producers in South America and Africa are investing in breeding to develop their own varieties. One of the most important examples for this development is Esmeralda Farms.

Selecta has adapted their cut flower breeding activities to supply the markets in Africa, South America and Japan. For climate reasons, the crossing in carnation is done on Tenerife, selection of seedlings takes place in Kenya, the candidate stock and the gene pool are kept in Germany, variety trials are done in Germany, Italy, Kenya, Japan and Columbia. Breeders have to improve their management skills and have to be prepared to travel.

4. Biotechnology in ornamentals

Biotechnology has been intensively used in the breeding of ornamentals. Especially tissue culture techniques like embryo rescue, anther culture, induction of somaclonal variation and protoplasts have been implemented.
Genetic engineering and marker assisted breeding are the two most important technologies and it is still open which input they will have in the breeding of ornamentals.

a. Genetic engineering

Chandler and Lu (2005) give a detailed overview on genetic engineering in the field of ornamental horticulture. Already in 2005 more than 30 genera had been genetically modified successfully. The traits, among others, were different types of disease resistance, tolerance against abiotic stress, herbicide resistance, altered flower colour, extended flower life and improved vase life.

Nevertheless the number of transgenic commercial products is still very limited. Available in a number of countries are only colour modified carnation which had been developed in a cooperation of Suntory and Florigene. In Japan a blue rose developed by Suntory is commercially available since 2009.

Today the activities of breeding companies in genetic modification are very limited in ornamentals. The main reasons are well known:

- Relatively small market sizes for even the largest ornamental crops
- High deregulation costs
- Lack of access to intellectual property rights of enabling technology and interesting trait genes
- High costs for research and product development
- Fundamental opposition against GMO's in Europe

In 2007 Selecta Klemm and Mendel Biotechnology Inc. founded a joint venture: Ornamental Bioscience GmbH. Mendel Biotechnology is located in Hayward, California. And has put their focus on applied genomic research on Arabidopsis thaliana transcription factors. Ornamental Bioscience is testing the Arabidopsis transcription factors for increased abiotic stress tolerance and disease resistance in ornamentals. Ornamental Bioscience has through its shareholder Mendel Biotechnology access to the Monsanto enabling technology. The vision is to create a new generation of convenience plants which are easy to handle and maintain, stay healthy and are tolerant to reduced water supplies.

The first project of Ornamental Bioscience was the screening of interesting transcription factors in Petunia. Drought tolerant Petunia which need 30% less water and are robust against long drought periods are today tested intensively including field trials in the US.

Nevertheless genetic engineering will not have a huge impact on the breeding of ornamentals in the coming years. Besides the development of transgenic varieties the technology can help to get a much better understanding of complex traits.

b. Marker technology

Rout and Mohapatra (2006) and Byrne (2007) give an overview on molecular markers in ornamental plants and the usage of markers in breeding programs of fruit trees and perennial ornamentals. There had already been publications about molecular marker in more than 160 species before 2006. The fast majority of the marker applications in ornamentals are fingerprinting research for identification, diversity and taxonomy studies. The history of the gene pool including the commercial varieties is unknown in many ornamental genera or a secret of private breeders. Fingerprints offer the possibility to get a fast overview on the relationship between different breeding lines at reasonable costs and can help to make the start of a new breeding program more effective.

Marker assisted selection has still a very limited use in the practical breeding of ornamentals. Differently to fingerprints expensive and long term research including phenotyping and mapping has to be done before the technology can be applied. Genetic linkage maps are very important to get a better understanding of the inheritance of important traits, to tag genes and to establish marker assisted breeding programs.

One of the best reviewed groups is the garden and cut rose group. Beside a linkage map resistance genes for different diseases are well characterized (Schulz et.al, 2009). Nevertheless the impact of this research on the practical breeding has been very limited until now.

In many ornamental species knowledge about the inheritance of important traits is not available and not easy to analyse because of complex ploidy levels. We will need more research on the genetic base of disease resistance, abiotic stress tolerance, productivity, vase life etc. In most of the ornamental species we still need a better understanding of the genetics of important traits in combination with molecular marker research before marker assisted breeding can be implemented in breeding programs. As the marker technologies and DNA sequencing is developing very fast it is possible that the development will speed up in the near future.

Marker assisted selection had a strong input on the breeding of agricultural and vegetable crops. In ornamentals the development will be different. We will have specific cases where the technology is implemented but there will be more space for breeders left who can or will not use molecular markers.

5. Double Flowering Calibrachoa: A case study

Selecta started to breed Calibrachoa in 1996. Breeding targets were a wider colour range, improving production characteristics and early flowering.

In the season 2006/2007 Selecta was able to introduce the first variety with double flowers. This introduction received the Medal of Excellence Industry Choice Award of the Greenhouse Grower in the United States.

For the breeding of the first double flowers a lot of technology has been developed and directly or indirectly contributed to the success: protoplast fusion, anther culture, induction of mutation by radiation. Beside the technology new species have been integrated into the breeding program. The technical details are published in a US utility patent which was filed in 2006 and granted in 2010 (Double Flower Calibrachoa Breeding Methods and Plants Produced Therefrom / US Patent No. 7,786,342).

Already in 2008 varieties with double flowers were presented by a competitor on the US Pack Trials. AFLP and a cytology analysis showed that they were hybrids of our first released double variety. It took years and a lot of technology to develop a new trait. As the inheritance of the double flowering is following comparably simple genetics it was transferred very fast into the breeding lines of competitors.

6. Intellectual property rights and breeding progress

Plant Breeders Rights are a precondition for the commercial breeding of vegetatively propagated ornamentals. The UPOV convention from 1991 has improved the situation of the breeders of ornamentals. Now also mutations belong to the breeder of the original variety and this is fully accepted by the fast majority of the growers. Illegal propagation is still a severe problem and breeders have to defend constantly their position.

However discussions and conflicts between breeders in the field of EDV's and patents have become more serious. The Calibrachoa example shows how difficult it is to develop a new trait and how fast it can be copied. Investments in breeding need a sufficient time frame of protection. Patents can be an important addition to plant breeders' rights for ornamental breeders to get a sufficient scope of protection.

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Fruit Breeding Aims for the Twenty-First Century

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Novel cultivars, well-suited to a range of production situations, and delivering grower and consumer benefits, are demanded. As we progress into the 21st century, key fruit breeding objectives are still focused on consumer appeal and agronomic performance. However, the degree of sophistication in interpreting those objectives and employing them to achieve breeding success is evolving rapidly.

Fruit breeders are responding proactively, expanding their capabilities to leverage understanding of consumer preferences, changing production environments (climatic and technological), and are taking an increasingly "whole of science" approach to inform their breeding objectives and for cultivar creation.

Emphasis has moved to identifying genetic diversity and the capture of desirable traits through intensive pre-breeding and parental development. In the 21st century, cultivar assembly – the creation of readily commercially adoptable cultivars - must be a more customised and streamlined breeding process, with shorter development timelines.

Introduction

Notwithstanding some significant challenges (including the financial state of global economies), international fruit and vegetable markets have in many ways never been more ready or able to adopt new product innovations. Technologies are available today to enable the delivery of high quality fresh and minimally processed fruits and vegetables from growers to consumers worldwide. Fruits and vegetables have a significant "health halo" as the result of numerous peer-reviewed studies on the relationships between diet and human health and wellbeing. Information technologies and the rise of social networking mean that more consumers are more informed more rapidly than ever before.

In responding to this opportunity, organisations involved with fruit breeding are experiencing something of a dichotomy. On the one hand, the commercial fruit world is in a highly competitive mode, and plant breeders are caught up in the demand for new varieties, better than their predecessors, delivered in shorter timeframes, and demonstrating consumer benefits worthy of significant investment in product development, production, marketing, and intellectual property protections. The financial, genetic, and capability resources required for plant breeders to have impact and be competitive in this environment are significant. Alongside these proprietary drivers, the increase in collegial interactivity among research and development organisations is providing more ready sharing of resources, and offers economies of scale in access to, and development of, new technologies and genome mapping of plant species. All without compromising the "art" of the breeder in conceiving and developing new and novel cultivars from the application of multidisciplinary research approaches.

The insights into fruit breeding aims for the 21st century shared here are brought from the perspective and experience of our organisation, Plant & Food Research. Plant & Food Research is a New Zealand-based science company providing research and development that adds value to fruit, vegetable, ornamental, crop and food products. At the heart of our organisation is a goal to underpin the growth of plant and marine-based industry in New Zealand through the successful application and commercialisation of research-based innovation. Our science supports the sustainable production of high quality produce that earns a premium in international markets, as well as driving the design and development of new and novel functional foods that offer benefits to human health and wellbeing.

We are a major research provider to sector and grower organisations in New Zealand and internationally. We provide research services for a number of scientific and commercial partners, on a fee-for-service basis or through collaborative agreements. We also receive royalties and licensing fees through the commercialisation of our science, such as proprietary cultivars and other IP.

Our research enables our industry partners to meet their challenges of the 21st century – to produce more and better food with reduced environmental impacts and fewer inputs. We work with our partners to optimise each step of the food production supply chain, from field or sea through to consumer, maximising value, increasing efficiencies in resource allocation, and providing innovation in designing new, novel foods.

In all cases, our goal is to integrate science across production, manufacturing, distribution and marketing platforms, combining market insight with a deep and fundamental understanding of the biological potential of our food resources. We work with our partners to identify market opportunities and address issues to meet their targets. Our research enables food producers, manufacturers and exporters to supply and market fresh and processed foods successfully that meet consumer needs according to well-defined global food trends – health, sustainability, convenience, novelty and sensory appeal.

Future Focused Research

Fruit breeders internationally recognise that the horticultural industries they serve must continue to innovate to meet consumer demands for quality, flavour, visual appeal, and novelty, in order to remain relevant and competitive in the global marketplace. Producers worldwide are meeting the challenge to become ever more productive, sustainable, efficient, responsive, and of course adaptable to the vagaries of weather, markets, and regulators.

Around the world, fruit breeders and producers are responding to a multitude of sometimes conflicting research, commercial, and market trends, including:

- The rise of multilateral free trade agreements worldwide in response to GATT
- The increased availability of intellectual property protections for plant varieties worldwide driven by TRIPS and adoption of the UPOV system
- Consumer demand for novelty, flavour and year-round availability – along with social and environmental responsibility
- Production considerations around carbon and water "footprinting"
- Increased market development, affluence, and segmentation, creating new opportunities and target demographics
- Proprietary branding of fruits and fruit-based products
- Market recognition of health messages associated with the so-called "Superfruits", which is generating increased interest, value, and demand.
- Increasing prices of commodity food products
- The imperative to feed the world and for nations to consider their future food security
- Increased cost of access to productive land and natural resources for fruit production
- Climate change impacts on future production
- Increasing costs of storage and transport logistics, with benefits for near-market production
- Competition among producers internationally driving demand for increased productivity, mechanisation, and higher value product (whether fresh or minimally processed e.g. IQF)
- Increased compliance costs in the areas of food safety, product authentication, assurance, labelling, and environmental responsibility
- The purported use of quarantine as a de facto trade barrier
- Increased awareness of the potential value of new genetics and technologies
- The evolution of targeted pest-specific, and more environmentally friendly, "soft" chemicals for pest and disease management
- New research technologies and genome maps to increase the selection efficiency of conventional "classical" plant breeding
- The rise (and in some markets stall) of genetic engineering.

New fruit cultivar development incorporates long product development timeframes, so it is important for those involved to be able to sift the fleeting fashions in fruits from those enduring mega-trends that might provide a more reliable pointer to the markets of the future. As an organisation, we have identified three big themes that recognise the latest and future science trends to inform our science:

1. A systems approach – there is increasing recognition that environmental and biological boundaries are being broken down and analysis of scientific problems, whether they be genomics, bioprotection, or sustainable production, need to involve analysis and modelling of whole systems.

2. Sustainability – this affects breeding, plant production for efficiency and minimal environmental impact, food production systems and logistics, consumer preferences and demands.

3. The human response – increasing sophistication of the consumer in terms of science, genetics, the environment, and social issues. This has influence on research across all disciplines.

Breeding New Fruit Varieties

In many established fruit crops, the last one hundred years has seen the introduction of many new varieties that largely meet current consumer needs and expectations. For these crops, the standard has been lifted to the extent that any new variety must demonstrate exceptional agronomic and consumer benefits in order to gain a place on supermarket shelves and in the modern fruit orchard.

There are other crops that may not have reached their commercial potential for the fruit trade and require the hand of the plant breeder to make genetic gains that could improve their environmental adaptation, diversity, pest and disease resistance, productivity, storage life, and consumer appeal to enable them to reach that potential.

Plant & Food Research combines traditional breeding with modern genomics techniques to develop better cultivars, faster.

Reflecting an integrated and cross-functional research approach, our principal breeding science targets are:

- New markers, and breeding tools to get cultivars to market quicker
- Design and development of cultivars in response to international consumer drivers
- Cultivars and propagation systems developed for better adaptation to climatic change
- New cultivars resistant to key pests and diseases.

In the genera and species with which we work, our extensive germplasm collections contain thousands of genetically different examples. These collections represent a unique genetic resource for use in our breeding programmes. They also provide a wide source of genetic variability that can be investigated by our researchers to identify the molecular controls of key commercial traits. Our genomics research seeks to identify the molecular controls of traits of interest, and to use this information to inform breeding programmes.

Strategically, we are looking at immediate, near future, and "over the horizon" targets for our fruit breeding.

Immediate and near-future targets:

- A platform with new genomic and breeding tools delivering cultivars, against jointly agreed development targets, in half the time
- Tailored cultivars for particular production systems, environmental variability and change
- Complete genomic sequencing and deep sequencing of germplasm characterising allelic differences to provide numerous ecotypes both for New Zealand and global environments.

Anticipated and "over the horizon" targets:

- Enriched germplasm for next-generation cultivars with stacked premium traits for whole fresh foods and ingredients
- New Zealand crops all having cultivars enabling sustainable production in climates and environments that will be encountered in 2050

- Developing a completely new set of breeding approaches (including next generation whole-genome sequencing, mapping and whole-genome selection and phenotyping) to halve the time taken to deliver new cultivars
- Coordinating our teams and facilities to provide a platform approach in several areas (including bioinformatics, quantitative genetics and analytical chemistry).

Today, the main targets for our breeding programmes include:

Producer Traits	Consumer traits
Yield	Quality
Environmental adaptability	Flavour and aroma
Pest and disease resistance	Texture
Postharvest storage	Colour
Seasonality	Health
Processing quality	Convenience

Overall, our strategic breeding aim for the 21st century is "Better Cultivars Faster". We are implementing this through:

- New cultivar development from smart breeding of elite germplasm
- New breeding tools to accelerate development of cultivars
- New cultivars which:
  - » address international consumer trends
  - » are adapted to climatic change
  - » are resistant to key pests and diseases.

Key actions we are taking to accelerate our cultivar breeding programmes include:

- Reducing generation time and speeding up delivery of improved products
- Fast tracking the "winners"
- Being more effective and increasing efficiencies in the breeding cycle
- Reducing the probability of releasing a failure by reducing the carry-over of inferior genotypes.

We're aiming to minimise the time between parental selection and full commercial release. Key actions to increase speed in the breeding pipeline include:

- Developing and maintaining diverse germplasm
- Use of molecular markers for key traits
- Rapid, high-throughput genotyping, whole-genome selection, sequencing individual genotypes
- Growing trees faster – reducing juvenility period
- Rapid, high-throughput, non-destructive phenotyping technologies e.g. NIR
- Efficient databases and data analysis.

While our organisation has extensive experience in breeding new fruits with novel characteristics that appeal to the consumer, such as flavour, texture, colour and shape, or producer, including higher yield, pest and disease resistance, seasonality and storage potential, we are constantly evolving our approaches. As for other fruit breeders, this does not necessarily mean radical change, but more a conscious additive and purposeful improvement of our capabilities.

In this context, our organisation uses conventional breeding techniques to create new cultivars, using our knowledge of the genetics of key traits to inform the breeding process. Our extensive germplasm collection provides us with a wide range of genetic diversity that can be included in our breeding programmes. We undertake genetic screening for parent plants that offer the best chance of producing offspring with desired traits. Our genomics researchers identify and isolate new genes, allowing our breeding team to screen for these genes and narrow the search for parents with the ideal genetic traits. We also screen offspring and isolate those plants with the most promising genetic potential for further breeding or commercial success, reducing the number and increasing the quality of selections entering assessment trials.

The Plant & Food Research Breeding & Genomics portfolio has three science groups structured around a product development pipeline. The portfolio spans a range of disciplines from underpinning laboratory research to applied field trials. Importantly, it includes the Institute's research orchards, spanning the major horticultural regions of New Zealand, which in turn allows us to work closely with our industry partners. Our farm research network, which comprises more than 300 hectares of orchard and farmland, provides our researchers with the opportunity to evaluate potential new cultivars extensively under different climatic conditions, before commencing larger-scale grower trials. We are a member of several global genome sequencing and mapping projects, working with other research organisations worldwide to understand the genetic blueprint of crops of interest. We also hold patents for a number of key plant genes and genomic technologies.

Plant & Food Research is known worldwide for innovation in plant breeding. Products such as the JAZZ™ brand apple (the cultivar 'Scifresh') and ZESPRI® GOLD Kiwifruit (the cultivar 'Hort16A') have afforded us a reputation for developing new and novel produce that delivers a premium consumer experience.

Apple Case Study

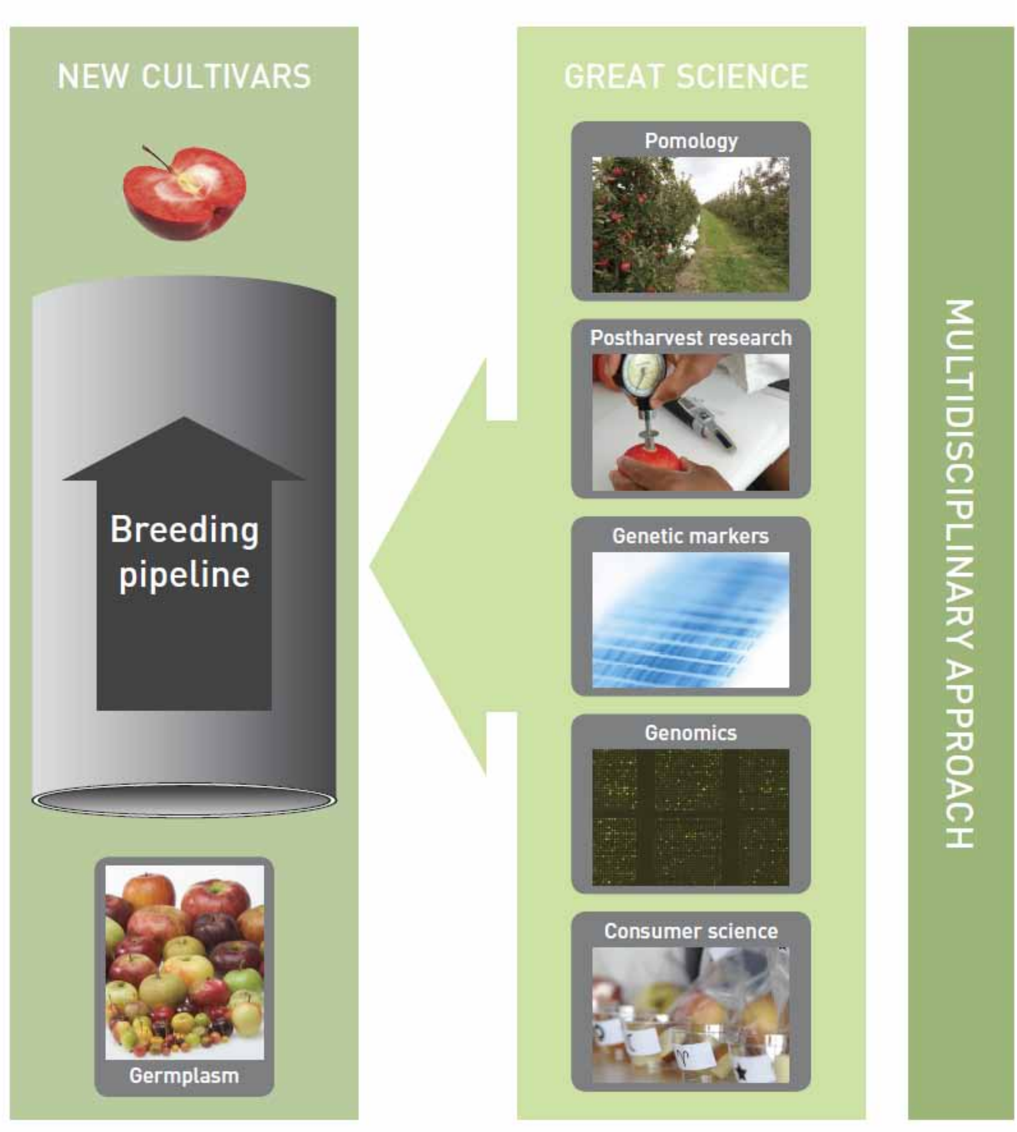
Marketed under the Jazz™ brand, the Plant & Food Research-developed apple cultivar 'Scifresh' results from crossing the apple cultivars 'Braeburn' and 'Royal Gala' and introduces a combination of traits and consumer experience superior to both parents. While the parent varieties were both developed in New Zealand (and New Zealand is recognised for its development of new apple varieties e.g. the World Apple Review (2004) reported that apple varieties bred and selected in New Zealand after the 1950s account for 11.5% of the world's apple crop, with the proportion expected to rise over time), they are freely grown in other countries, production developed by competitors to New Zealand growers and marketers. The new cultivar, marketed under the Jazz™ brand, has been an exemplar of a new commercialisation strategy. The commercial development of Jazz™ is controlled by ENZA International Limited, a New Zealand-based company. With trees planted in key production regions around the world, and contractual controls around fruit supply, ENZA is able to ensure continuing economic benefits flow back to New Zealand. Plant Variety Rights and Trademarks have been tools for New Zealand to look innovatively at ways of doing business on a global scale and capturing the benefits of local innovation. This example also underpins how science and industry can work together to develop a new apple variety and protect the intellectual property for global development, with benefits flowing back to New Zealand.

New Apples and Pears

While Plant & Food Research has had significant commercial success with its apple cultivars – including the Pacific series apples, Jazz™, and more recently Envy™ - we recognise there are a large number of apple breeding programmes around the world (~50). Typically, the main focus for apple and pear breeding programmes is on improving fruit quality – especially texture. Many of the programmes are using parental material similar to our own.

In creating a new apple or pear cultivar, there are a large number of fruit and tree characteristics to be considered. We have taken the position we must consider those and we need to add something special to our new cultivars – and these new cultivars need to be developed as quickly as possible.

Figure 2. Plant and Food Research's Pipfruit Breeding Framework.



Looking forward, we have adopted new customised breeding objectives for our pipfruit programme:

- High flavour characters in apples and pears
- Durable in-plant resistance to major pests and diseases
  - » allows cultivars to be sustainably grown in low spray management systems
- Different flesh colours
- potential links to health benefits.

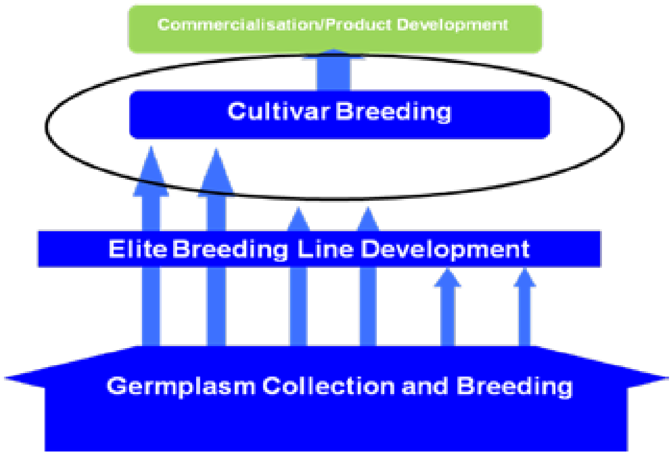
While our breeders consider over 40 important fruit and tree traits, the key selection criteria are:

- Post-storage fruit quality
- Fruit appearance
- High productivity and packout.

Our apple and pear breeding pipeline has evolved extensively over time. Today it operates as illustrated in Figure 3. Changes brought about during this evolution to enable the cultivar breeding to go faster, be more efficient, and to improve chances of success, include:

- More pre-breeding for more parental choices
- More seedlings produced (a six-fold increase p.a.)
- Shortening of timeframes from seedling to in-orchard evaluation
- New data analysis techniques of better predicting seedling performance
- Consumer testing of elite selections to better estimate future product worth.

Figure 3. Pipfruit Breeding Pipeline.



Kiwifruit Case Study

New Zealand was instrumental in introducing green-fleshed kiwifruit to international fruit markets in the 1960s. This development arose from initial amateur interest, with the horticulturist Hayward Wright producing the now market dominant green-fleshed 'Hayward' variety in 1925. Kiwifruit is one of the few new fruit crops introduced to international trade in the 20^{th} century and the crop is now grown in many countries. However, this commercial development was based on only one selection, from one species of one genus. Development of the new yellow-fleshed kiwifruit cultivar 'Hort16A', with the fruit marketed under the ZESPRI™ GOLD Kiwifruit brand, was a significant step forward – relieving industry concerns around reliance on a monoculture. With its different flesh colour, fewer hairs, and a sweeter more tropical fruit taste, the new variety complements the 'Hayward' variety. Selection of 'Hort16A' was the start, but commercialising required fast-track propagation, industry acceptance, research on vine management, quality and postharvest physiology, together with a focused international commercialisation strategy.

New Kiwifruit

Together, Plant & Food Research and ZESPRI are determined to produce further significantly commercially successful new kiwifruit cultivars. The industry strategy is to have:

- Consistent supply of high quality fruit 7 days/week, 365 days/year
- To grow from \$NZ1B to \$NZ3B of export earnings by 2025
    - » and to underpin this through differentiated, proprietary new varieties.

Objectives for breeding new kiwifruit cultivars include:

- A range of flesh colours
- Good storage
- Extended harvest window
- Novel/new flavours
- Convenience e.g. peelable.

Significant changes have been brought about in the kiwifruit breeding programme over the last 5 years, for example, changes in product concepts, scale and management of seedling populations, and the breeding strategies and tools used. Key changes are set out below.

Pre 2005	2005-2010
No Product concepts	Product concepts developed through annual meetings between PFR and ZESPRI
Consumer data being collected	Consumer and market research driving breeding programme
<5000 seedlings /year	4-5 fold increase seedlings/year
Low planting densities	High planting densities
Mass selection	Mass selection and recurrent selection/population breeding
Mixed populations	Functional populations
No Marker Assisted Breeding	Marker Assisted Breeding in use
Data collection	Data analysis for important traits

Conclusions

Fruit breeders are setting themselves some audacious goals for the 21st century. The potential for future genetic improvement to take traditional fruit species into new market spaces should not be underestimated. After all, kiwifruit were widely perceived to be green and hairy for 30 years and have only recently undergone a commercial renaissance in colour, flavour and appearance. The range and novelty being developed among those species is likely to be replicated in other crops. Other fruit genera and species that do not currently feature in commercial cultivation may yet also be turned into economically viable crops for producers.

In responding to demands for novel cultivars, well-suited to a range of production situations, and delivering grower and consumer benefits, breeding objectives will be increasingly driven by consumer and market research. One of the key challenges for fruit breeders is to deliver new and real consumer benefits i.e. there are now many good cultivars across many fruit crops that will satisfy most consumers' needs - what are going to be the next break-throughs ?

New technologies will speed up varietal development, and breeders are rising to the challenges in using those to their full potential, for example:

- The fast pace of change in new technologies
- Handling and analysing large data sets.

Although intellectual property rights are well established in the mainstream fruit business and will continue to be developed in further territories, the way that proprietary business is structured will play a bigger role in the future. The dichotomy of market and product competiveness and greater consolidation of research interaction will continue too.

The ability to manage larger seedling populations through improved selection methodologies, and reductions in the cultivar assembly timeline, are real and manifest - marker-assisted breeding is now in use. For the future, fruit breeders can realistically look to more genetic markers, whole-genome selection – and more cultivars faster (a greater rate of genetic gain).

For organisations such Plant & Food Research, analysis of the value we bring and the unique value propositions and technologies we will bring to the field of plant breeding, alongside robust intellectual property legislation that enables a return on investment, will set our course for the 21st century. This will enable us to pursue our goal of rapidly delivering the latest new cultivar innovation and technology, to meet demand in all parts of a changing world.

Discussion (Transcriptions)

SESSION 1: Plant science and the future of plant breeding

The role of genomics in crop improvement

Mike Bevan

Konstantin G. Skryabin: Maybe the bottleneck in all the genomic research will be in informatics, because now we have so many sequences that you need to analyze the sequences. What can you recommend for the breeders and the scientists who do this sequencing ?

Mike Bevan: You are quite right there. The challenge will be doing sensible, intelligent things with this vast amount of data. The challenge is not just data production at the moment: we are able to do that with improved sequencing technologies. We believe we have a good strategy for tackling the wheat genome and for re-sequencing a large number of wild varieties. The trick, as you say, is to get the best minds working in bio-informatics, data analysis and modeling to be able to identify important genetic variation and take that, as quickly as possible, into crop production.

Niels Louwaars, Plantum NL: We are here talking about intellectual property rights and you put a lot of emphasis on the openness of the work that you do, the public sector part. Why is it so important, according to you, that this is done in the public sector and not in the private sector ?

Mike Bevan: This concerned my comment that the new varieties that we are producing here in the pre-breeding program will be freely available for breeders around the world to use and that the sequence data that we are generating will be made freely available. We believe this is the most rapid route to make progress. The people who make commercial lines, they will be the people responsible for making things that people grow, that farmers use. It is those organizations that have well-established ways of protecting their innovations. What we aim to do is to provide to them, equally, a lot of new material and information, such that they can use it according to their own wishes. Now, this probably may create some issues and tensions between companies and organizations that can best exploit the data, so it is a competitive situation, that's for sure. But as scientists, as publicly funded scientists, we believe that this is the most rapid way we can do this.

Frank Ordon, Head Institute of Resistance Research and Stress Tolerance, Julius Kühn-Institute (JKI): What is your opinion on how long will it take until sequence-based breeding will find its way into applied plant breeding ?

Mike Bevan: That's a good question. In maize it is already a reality, I believe. I am not familiar with the details, but I know that major corporations in the United States of America and in Europe use marker-assisted breeding regularly and this has really sped up the breeding program. As far as wheat is concerned, I think that useful sequences will be out there, sequence variation markers, early next year from our program; that's all I can speak about. Wheat breeding is done classically by many smaller organizations and the particular challenge we face, as a part of achieving better impact through our research, is to generate new training programs such that small companies, possibly in collaboration with other small companies that know how to manage the data, will be able to manage the data: this is the challenge that Professor Skryabin mentioned,. I would say that it would be a few years. But because of the advantages of the technology, things will move very quickly.

Joël Guiard, GEVES: You showed us what the impact of this technology could be for the breeding of new varieties. I would like to know what you think about the impact of these new technologies on the aspects that directly concern UPOV, particularly the characterization of new varieties for the purposes of granting a plant breeder's right ?

Mike Bevan: That is a question that I was afraid you would ask ! I am sorry. I can't answer that excellent question because I am not an expert, but it may be that part of the criteria that you use for the distinctness of a variety may include sequence data, because plants could otherwise be phenotypically indistinguishable, but genetically they would be distinct. Perhaps you could start to include sequence data, saying that the genotype of this particular line is distinct because it has got the haplotype of tarragon, for example, and it has an introduced DNA-sequence from *Aegilops tauschii*. that confirms drought tolerance or disease resistance.

Bionegineering

Konstantin Skryabin

Gerhard Deneken, Danish Agrifish Agency: You have mentioned the terms patents and plant breeders' rights. Do you have any idea how you would commercialize biotech patents on a construct you have developed ?

Konstantin G. Skryabin (speaker): I do not have any idea with such patents. However, alot of companies are interested in the way the construction is organized with the gene that gives the resistance, which is why there is interest in patents.

Marcel Bruins, ISF: Earlier this year, I attended a conference in Moscow at the Foundation of the National Plant Breeders' Association and there I understood from the Government, that it wants to limit the influx of foreign germplasm. It wants to be more reliant on domestic germplasm and I have some concerns about that policy, because it would deprive the Russian plant breeders of a lot of valuable germplasm from other countries. Could you comment on that ?

Konstantin G. Skryabin (speaker): You definitely cannot limit it – if you look at the varieties which we now grow in the Russian Federation, I would say that 40-45% are varieties from outside the Russian breeding programs. However, if you consider sugar beet, which we traditionally store outside over the winter, foreign varieties can provide a high yield but there can be a problem with diseases if there is insufficient storage capacity. That is why the Russian varieties are very good – it is a complex problem – definitely we will use all the worlds' knowledge.

Heterosis in rye

Stanislau Hardzei

Bernard Le Buanec: I am a little surprised when you say that hybrid rye does not give good results in poor soils because, in general, it is the contrary in wheat. We have seen that hybrid wheat is also better in difficult dry and poor conditions. So how can you explain the difference between the experiences in hybrid rye and in wheat ?

Stanislau Hardzei (speaker): This is a very interesting question. I have also seen the results with hybrid wheat, but wheat is self-pollinated and rye is an open-pollinated crop. Furthermore, we need to bear in mind that on poor sandy soils hybrid varieties of a rye will not display an increase of productivity in comparison with population rye varieties. A comparison with wheat varieties has not been made, which in any case require richer soils.

Breeding for virus resistance in cereals

Frank Ordon

Stanislau Hardzei (speaker): If we have a new variety with resistance to different pathogens and a new race of pathogens appears how long, in your opinion, can we cultivate the variety and how long will it be resistant to all pathogens ?

Frank Ordon (speaker): This is a good question that requires a long answer. But I would say it depends. For example, Hawaian No. 4 was already present in 1978 and in 1989 the first resistant virus breaking strains were observed. On the other hand, if we look at mildew resistance in barley, MLO has been used since the 1970s and it is still effective today. Therefore, I think it depends on how the resistant genes react and, for example, I said it about the translation initiation factor for yield. The viral genomyn protein binds to this gene, most likely, and so mutation in the sequence of this gene will prevent binding resistance but, on the other hand, a mutation in the viral genomyn protein will facilitate binding – its like the key and the lock – and the plant will become susceptible.

Pierre Devaud, ISF: You affirm that for the two diseases - barley yellow mosaic and barley yellow dwarf -, the combination of three genes is enough to control the disease. However, we have a good reservoir of different genes in other crops – do you think that it might be interesting to use them ?

Frank Ordon (speaker): If I have understood your question, you wonder if a single new gene could be sufficient for resistance. Of course, this is the easiest way for plant breeders, because they only have to follow one gene, instead of three, in the breeding process. However,, in my opinion, it is only a matter a time until a new virus strain will appear because RNA viruses have a very high mutation rate. So I think we should always have reservoir of genes, maybe combine, which can then be used in applied breeding.

Jari Valkonen (speaker): I think the sustainability question about resistance is an important topic. There are many choices of resistance alleles against these soil borne viruses, so would a rotation of varieties with different resistance alleles suppress the evolution of a resistance breaking strain or,eventually, would different variants of the virus evolve in equal proportions in the population ? Can we use rotation as a strategy ?

Frank Ordon (speaker): That is a good question, but I don't have an answer: it has not been tested and could only be speculation as to what would happen.

Stress resistance in maize

Marianne Bänziger

Radha Ranganathan, ISF: One of the issues that seems to be getting more and more difficult is access to genetic resources. Do you have any ideas ? You said the Mexican government had made money available. Is the Mexican government concerned about the benefit sharing that it is going to get from access to its genetic resources ?

Marianne Bänziger (speaker): This project is a donation to the world – the donation comes from a middle income country and it is a very impressive donation. There is no hidden agenda behind this. However, with regard to access to genetic resources, you made a very valid point; it is a little perverse that since the International Treaty on Plant Genetic Resources (ITPGRA) came into force, which should have increased the exchange of germplasm, we have seen the opposite happening. I think we need to reassess the situation in order to truly meet the objectives of the treaty.

Molecular virus-plant interactions and pathogen defense in tuber crop plants
Jari Valkonen

Konstantin G. Skryabin (speaker): We think that, if you stop the virus transfer from one cell to another, this would be one of the most efficient mechanisms of virus protection – what is your comment on that ?

Jari Valkonen (speaker): Yes, for example, with viral genome linked protein can be one of the viral interaction partners in that kind of interaction which stays at the cell to cell transport. However, I think that this kind of resistance, as such, is rather vulnerable if there are mixed infections of viruses in the plant, which is almost always the case in the field, because other viruses may complement this function. Professor Atabek in Moscow published information on this some time ago, with some good examples, and I think that there could be a risk with that type of resistance.

Concluding Remark on Session

Kitisri Sukhapinda (Chairperson, Session 1): As a concluding remark for this morning's session, I see that a lot of molecular tools have been developed over the past few years and they are starting to be used in the development of new and improved varieties. UPOV is considering the role of molecular techniques and we will try to see if those techniques can be used to help support plant breeders' rights. It is very good that we have heard today from scientists that there is a lot more to come in the future. UPOV members will have to be prepared to look into the possibilities of all of these technologies and incoming information that will affect what we do within the UPOV mandate. I am very excited to see a lot of applications with molecular biology tools and I am looking forward to seeing some more usage and the real results of molecular biology and I would like to thank all the speakers of this morning.

SESSION 2: Applying the science: challenges and opportunities

Plant variety protection and technology transfer
Peter Button

[no questions]

Variety traits for the future
David Nevill

[no questions]

Vegetable and field crop strategies in East Africa
Yashwant Bhargava

[no questions]

Breeding prospects for horticulture in Asia
Ki-Byung Lim

[no questions]

Flower breeding for the global market
Ulrich Sander

[no questions]

Fruit breeding aims for the twenty-first century
Wendy Cashmore

[no questions]

Round Table discussions
[all speakers]

Bernard Le Buanec (speaker): I have a comment on the discussion of this morning. My comment is that Niels Louwaars, asked a question to Mike Bevan and said that it is only public research that can do genomic research and make the results publicly available; and, of course, it is clearly a misunderstanding. I have discussed with Mike to be sure that I was on the right track, the research presented by Mike was not public research, but was research made by a consortium financed by both the public and the private sector and all the results are freely available to all companies because it is pre-competitive research as was also mentioned in the presentation of Marianne Bänziger. That pre-competitive research is not something that is new – I remember that 17 years ago we already had pre-competitive research with the industry and then, of course, as Mike Bevan said, there was competition at the end to make the final product on the market, but not on that level of research. That is the comment I wanted to make to ensure that there was no misunderstanding concerning the question of Niels Louwaars. Now I have a question to Marianne Bänziger: when you presented the results for drought-tolerance, you said that we had up to 50% improvement between the old and the new varieties, either with open-pollinated varieties or hybrids, and with genetic engineering I would say the improvement was 8-15%. Is the comparison made with the new, improved varieties or with the old varieties ?

Marianne Bänziger (speaker): The comparison was done with the old varieties. At the moment we are incorporating the transgenics into the best new varieties and we want to see whether there is an added benefit, but I think there is quite a bit of insight that has led to a different approach in how to test transgenics. There is insight that transgenics too often show an advantage because they are incorporated into an inadequate background and once you move them into an elite background, essentially the effect disappears. There is a very high dropout rate between what is potentially a positive event and what, in the field, translates into a positive event. So, if we are lucky, we get 8-15%; however, we can achieve that with a single gene. Conventional selection is an accumulation of a large number of genetic effects through conventional breeding. There are certain attempts to try to go straight for gene networks, making modifications on four, five genes simultaneously and there has been some discussion in terms of how the regulators would deal with that. Would they consider that as if it were one trait, because you essentially introduce it simultaneously and how extensive would the testing need to be ? So definitely, for us, it is something to continue to follow-up with, even though it is quite expensive.

Doug Waterhouse (AU): My question is directed to Dr. Bänziger. I wonder if you could elaborate your comments about the role of intellectual property (IP) and its opportunity to connect with the benefit-sharing arrangements for the use of plant genetic resources.

Marianne Bänziger (speaker): I think that just by walking around the corridors here I hear quite a lot of critique about the effectiveness of the ITPGRA and the Standard Material Transfer Agreement (SMTA) for benefit sharing. There is dissatisfaction, I think, on both sides. The potential recipients and the potential people who would like to use the SMTA, it is probably rather a more political document than a licensing agreement that is easy to use for the private sector. For seeds of discovery, it is the first time that you can associate a value to a trait and to an originator and that, essentially, would be conducive for benefit-sharing. What has been highlighted, is the need to let the potential recipients decide on how they would like to benefit: in that sense it doesn't necessarily need to go into the plant breeding community. Maybe the communities have a very different understanding on how they would like to receive benefits and that could be for example, in terms of agronomy advice –with reduced investment in agriculture, research and development in the public sector since the 1980s, that is now down to one quarter, there is a huge gap of information with resourceful farmers in terms of information on production approaches and value chains, markets, and so on, so maybe the beneficiaries themselves would set different priorities than other organizations in terms of how these benefits may want to be used. It was just recognized that this is just a very powerful opportunity.

Radha Ranganathan, ISF: From the experience we have had with the SMTA, perhaps it should be said that the SMTA works. It is not the SMTA in itself that doesn't work. I am talking now in terms of the ITPGRFA. It is just that the SMTA is for access. The benefit-sharing comes much, much later and that is where problems begin. Just to clarify that the SMTA is fine, largely fine from our perspective.

Marianne Bänziger (speaker): I see from here shaking heads in the audience and what I hear, and what I can confirm from the users, that the SMTA is not liked because it has open-ended obligations, which is a major disincentive, because you do not know what you sign on to. So maybe it would be good if we had an independent study on whether the ITPGRFA and the SMTA their clearly-stated objectives.

Peter Button (UPOV): I should like to emphasize that here in UPOV we are not directly involved in the ITPGRFA and the SMTA, but of course, we are always pleased to give the opportunity for questions on any subject.

Marcel Bruins, ISF: I have a question for Mr. Nevill, Mr. Sander and Mrs. Cashmore, because I read in the three of your presentations that you were expecting UPOV to adapt itself to the changes in the technologies. In slightly different wordings, but I read this in all three of your presentations. So I was wondering if you were implying that we should steer towards a possible revision of the UPOV Convention ? Perhaps you can enlighten us with your ideas on this topic ?

David Nevill (speaker): I don't think it is up to me to steer UPOV in one direction or another. I can just look at the facts and just comment on them. The facts from an industrial perspective are that if we are looking at the uniformity and the distinctness of our materials internally, we will genetically fingerprint that material. We will not be looking at the phenotype and that is in order both to understand and make sure we are different from competitive products and also for quality management purposes in things like production – to actually be able to separate our own materials from one another when they basically look the same. That's really where my comments come from, we use technology in a certain way so UPOV could also potentially think about that too.

Wendy Cashmore (speaker): I think the context that I was wanting to convey is also not to be steering UPOV particularly, but drawing on some of the introductory topics from Mr. Le Buanec this morning, that the whole concept of UPOV is to help and to assist and support innovation and a sense of dynamic change. Since we are all working in science areas and commercial areas that also rely on innovation and dynamic change, it is fitting for us that all component parts react in a similar way. Again reiterating the things that Dr. Nevill has said, if there are tools and techniques that are becoming available and wide usage of practice, then I don't think that any of the agencies or any of the contributing parts should be blind to those things. Whether that requires a vast overhaul of the system, I am not in a good position to be able to answer that, but I would just call on all parties to keep that debate and that innovation very much to the forefront of thinking.

Ulrich Sander (speaker): I have given one example where we have applied for PBR and at the same time applied for a utility patent in the United States of America and I think that this is not very unusual. I believe that many of the commercial breeding companies apply also for patents to get a certain level of protection for their innovations. At the end I believe that, at least small and medium-sized companies do not like patents as much as plant breeders' rights because, as you know, the PBR system has been developed for breeders and it is very easy to handle for us; we sometimes have the feeling that the patent system is more for lawyers than for plant breeders, but as the scope of the protection under PBR has certain limitations, which starts with the breeder's exemption, I think that, to a certain degree, breeders are forced to use also patents to protect their intellectual property. If UPOV can adapt to such a situation I cannot say, it is up to UPOV.

Peter Button (UPOV): I think there are two issues within these questions and I think that Dr. Bänziger you have also mentioned about molecular tools in relation to the characterization of varieties. One is to do with forms of intellectual property and the other is to do with the characterization of varieties, for the granting of PBR and for variety identification. For those who would like to understand more about the co-existence of patents and plant breeders' rights, UPOV organized two seminars here in Geneva on exactly that subject, where it was clearly explained that these are two separate systems and breeders are free to use both systems or either system as they wish[30]. These two systems are not, in any way, mutually exclusive and other forms of intellectual property are also available. It is up to each breeder to decide which form of IP to use.

With regard to the use of molecular tools in the examination of varieties for the granting of PBR, the question is why don't we use these molecular techniques for the examination of distinctness, uniformity and stability ("DUS"). We have had this discussion for almost 20 years within UPOV. Breeders and authorities have come to understand that there are some areas where these techniques may be useful, but at the same time have agreed that we should not assume that they are necessarily cheaper or more effective. There is continuing discussion and we have a working party within UPOV specifically to look at that matter, the Working Group on Biochemical and Molecular Techniques, and DNA-Profiling in Particular (BMT).

Then, of course, molecular tools are extremely powerful for variety identification in the domain of breeders, for the enforcement of their PBRs. However, that is a different issue to whether they are used in the DUS examination of varieties.

30 (*www.upov.int/meetings/en/topic.jsp ?group_id=73*)
WIPO-UPOV/SYM/03: WIPO-UPOV Symposium on Intellectual Property Rights in Plant Biotechnology, October 24, 2003 (Geneva, Switzerland)
WIPO-UPOV/SYM/02: WIPO-UPOV Symposium on the Co-Existence of Patents and Plant Breeders' Rights in the Promotion of Biotechnological Developments, October 25, 2002 (Geneva, Switzerland)

Conclusions

Mr. Keun-Jin Choi,
President of the Council of UPOV

Ladies and Gentlemen,

I would like to start my closing remarks by expressing my appreciation for the messages from the Ministers of France, Germany, the Netherlands and the United Kingdom.

It is my pleasure to thank the speakers, who have travelled from all around the World to join us today:

Mr. Bernard Le Buanec, Mr. Mike Bevan, Mr. Konstantin Skryabin, Mr. Stanislau Hardzei, Mr. Frank Ordon, Mrs. Marianne Bänziger, Mr. Jari P.T. Valkonen, Mr. David Nevill, Mr. Yashwant Bhargava, Mr. KiByung Lim, Mr. Ulrich Sander, and Mrs. Wendy Cashmore

and the chairs of the sessions: Ms. Kitisri Sukhapinda and Mr. Peter Button for their contributions.

The Fiftieth Anniversary of UPOV and this Symposium have come at a time when there are many challenges for agriculture. At the global level, increasing population, climate change, parallel demands for food and energy production and evolving human needs require a response in agricultural production. There are also many challenges for economic development.

For these reasons, scientific progress and innovation are of greater importance than ever to provide a dynamic and sustainable agriculture and to provide for economic development in the rural sector.

In the first session of the Symposium: “Plant science and the future for plant breeding”, we had the opportunity to look at today’s science and to see some of the tools that are becoming available to breeders. We have seen exciting science that is being conducted in the fields of genomics, bioengineering and heterosis, and have seen the work that is being done in disease and stress resistance – essential elements in the support of a dynamic and sustainable agriculture.

In the second session: “Applying the science: challenges and opportunities”, we heard about the work of plant breeders and how they are translating science into plant breeding and, as a result, new plant varieties. We have seen the breeding tools and breeding methods that are being employed. We have seen some of the traits that are being developed in order to improve agricultural productivity and sustainability. We have seen the work to improve the quality of the food that we eat and the flowers that brighten our daily lives.

Ladies and gentlemen, we started with a review of the development of plant breeding and plant variety protection and heard about the importance of plant variety protection for technology transfer. To achieve the maximum harvest of the fruits of plant science and plant breeding we need an effective system of plant variety protection. We have seen that the UPOV system of plant variety protection encourages the development of new varieties of plants that will benefit farmers, growers and consumers – in other words “society as a whole”. As we heard in the messages from the Ministers of France, Germany, the Netherlands and the United Kingdom, UPOV and the UPOV system of plant variety protection are as relevant today as when they were founded 50 years ago and have a vital role to play for the future.

Before closing, I would like to thank the interpreters for their valuable assistance.

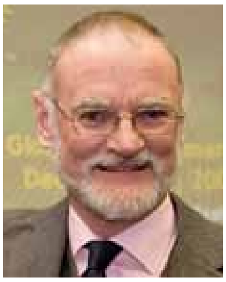
Finally, I would like to thank all participants for your attendance and active contributions to this Symposium.

It only leaves me to wish you all a safe journey back to your respective homes and to bring this Symposium to a close.

Speaker Biographies

MARIANNE BÄNZIGER

Marianne Bänziger is the Deputy Director General for Research and Partnerships of CIMMYT, the International Maize and Wheat Improvement Center, known by its Spanish acronym. CIMMYT (*www.cimmyt.org*) is an international, not-for-profit research and training organization. With partners in over 100 countries, the center applies science to increase food security, improve the productivity and profitability of maize and wheat farming systems, and sustain natural resources in the developing world. As a crop physiologist with a PhD from the Swiss Federal Institute of Technology ETH in Zurich (1992), Marianne Bänziger's disciplinary expertise is in maize research targeted at stress environments. She has published over 40 articles and book chapters in peer-reviewed international journals and books, and contributed significantly to the development of drought tolerant maize varieties in Africa.



MICHAEL BEVAN

Deputy Director, John Innes Centre, Norwich, United Kingdom

michael.bevan@jic.ac.uk

BSc and MSc; Auckland University 1975
PhD; Cambridge University 1979
Post-doctoral research; Washington University in St Louis
Research Interests; Plant growth control, plant genomics and plant functional genomics.

YASHWANT BHARGAVA

Mr. Yashwant Bhargava is an Indian National with doctorate degree in Botany-Genetics and Plant Breeding (1984) from Nagpur University and vouched to work with private sector in agriculture – Ankur Seeds (5 years) in Nagpur as Head, Research and Development, Hoechst AgrEvo (6 years) as Manager Seeds in Mumbai. In 1995, he joined Sandoz, now Syngenta as Development Manager, in Pune. He was instrumental in giving these seed companies a good number of varieties and hybrids in Vegetable and Field crops. He has been on the advisory board of research journal(s) in India and also has more than 50 publications in national and international journals. He was able to do a crash course in Business Administration from IIM, Ahmedabad. Dr. Bhargava held positions of Sales Manager and later headed the Business Development in Cotton and Bio-fuels, with Syngenta for 15 years. Dr. Bhargava was the key person to have beet sugar introduced in India through Syngenta and was Honorary Director of first beet sugar factory, near Baramati. His hobbies are Sports and Reading Books. He has been a good sportsman, representing at national level in Athletics and Football.

Presently as head of Research and Development, he is based in Nairobi since 2010 and co-ordinates the research and development, seed production and quality control activities with group companies of East African Seed Company Limited in Kenya, United Republic of Tanzania and Uganda.

PETER BUTTON

Mr. Peter Button was appointed Vice Secretary-General of UPOV on December 1, 2010, having previously held the role of Technical Director at UPOV since 2000.

Mr. Button, a national of the United Kingdom, holds a B.Sc. Honors degree in Biological Sciences. From 1981 to 1987 he worked for Twyford Seeds Ltd., a UK plant breeding company, in the development of new cereal varieties. Between 1987 and 1994 he was the General Manager of Twygen Ltd., a company which developed micropropagation systems for the commercial production of seed potatoes and soft fruit stocks and continued as General Manager, following the change of ownership, of GenTech Propagation Ltd. In 1994. In 1996, Mr. Button joined the British Society of Plant Breeders as Technical Liaison Manager, where his responsibilities included the operation of officially licensed variety trials. In 1998, he became Technical Liaison Officer for the UK Ministry of Agriculture, Fisheries and Food (Plant Variety and Seeds Division), where he was responsible for the operation of the tests and trials associated with the UK Plant Breeders' Rights and National List schemes and Seed Certification in England and Wales and was the United Kingdom representative in the UPOV Technical Committee.

WENDY CASHMORE

Qualifications
DipHort, Nursery Management, Massey University, New Zealand

Responsibilities
Oversight of breeding business and related IP management, including managing commercialisation of Plant Variety Intellectual Property (IP) and leading plant variety licensing and protection for the organisation. Leading a cross-functional approach combining science/technical competence, legal approaches, and business acumen to maximise profitability and business opportunities for new plant varieties.

Background

2003-2008	Leader, Plant Variety Management Team, HortResearch, New Zealand
1999-2003	Technical Manager, Plant Variety Management Team, HortResearch, New Zealand
1997-1999	Independent horticultural contractor undertaking mainly technology transfer projects. During this time also set-up and ran a company to enable a grower group to engage in an R&D project (total project value >$250k, project duration 3 years)
1985-1997	Technical roles in pipfruit physiology research team through various divisions of DSIR, and then HortResearch, New Zealand.

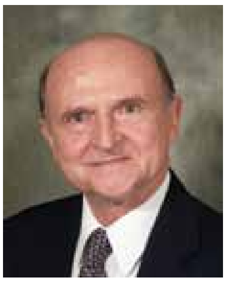
HARDZEI STANISLAU

17.07.1964	Was born in village Trukhanovichi, Minsk region, Belarus
1981-1986	Student of Belorussian Agricultural Academy, faculty of Agronomy, specialization - plant breeding.
1986 – 1989	Chief Agronomist of State Farm.
1989-1991	Postgraduate at the Institute of Genetics and Cytology, Minsk, Belarus
1991-2010	Breeder of rye of Laboratory of winter rye of the Scientific and Practical Centre of Belorussian NAS for Arable Farming (SPCAF).
1992	Doctor of biological sciences.
2010	Till today - head of the laboratory of genetics and biotechnology of the Scientific and Practical Centre of Belorussian NAS for Arable Farming (SPCAF)

Practical studies abroad:

1993	practical study at the Plant Breeding and Acclimatization Institute, Radzikow, Poland, Dr. L.Madej
1996 - 1997	practical study at the Munich Technical University, Freising, Germany, Prof. F. Zeller.
1998	practical study at "EpiLogic GmbH", Freising, Germany, Dr. F.Felsenstein.
2001 - 2005	practical study and work at "PZG-Planzenzuechtung GmbH", Guelzow, Germany, Dr.G.Melz (1-4 months in a year).
Since 2006	member of EUCARPIA (European Association for Research on Plant Breeding), Cereal Section

Scientific publications – 52.
Author of rye varieties – 4 (Spadchina, Zavea-2, Praleska, Plisa-F1)



BERNARD LE BUANEC

Bernard Le Buanec is a member and secretary of the first section of the French Academy of Agriculture, founding member of the French Academy of Technologies and Honorary Life member the International Seed Federation. From 1965 to 1975 he was a scientist at CIRAD, working in Africa; from 1976 to 1984 CEO of various seed companies; from 1984 to 1993, director of the research programs of the Limagrain Group and, from 1993 to 2008, Secretary General of the International Seed Federation. He has been the President of ASSINSEL, and a member of: the French High Council for Research and Technology; the French committee for the protection of plant varieties (CPOV); the scientific committees of INRA; the life sciences committee of the CEA; the scientific committee of the CTPS; the orientation committee of the Evry Genopôle; the working group of the World Bank on biotechnologies and intellectual property; and of the Plant Genetic Resource Committee of the CGIAR Centers.

In 2007 he was awarded the UPOV gold medal in recognition of his work for the plant breeding industry and, in 2008, the Medal of the Agricultural Marketing Service from the United States Department of Agriculture in recognition of his work for the United States and the international seed industry.

KI-BYUNG LIM

Personal data
E-Mail address: *kblim@knu.ac.kr*, *kibyunglim@gmail.com*
Homepage: *www.knuflower.org*, *www.flowerinfo.biz*
Current position: Associate Professor of Department of Horticultural Science, Kyungpook National University, Republic of Korea

Education

1998 - 2000	PhD(2), Wageningen University, Wageningen, The Netherlands
1997 - 1998	Post-Doc. CPRO-DLO (currently Plant Research Int'l), The Netherlands
1989 - 1996	PhD(1), KyungPook National University, Daegu, Republic of Korea
1984 - 1988	MSc, KyungPook National University, Daegu, Republic of Korea
1980 - 1984	BSc, KyungPook National University, Daegu, Republic of Korea

Employment record

2006.3 - present	Associate Professor, Kyungpook National University, Daegu, Republic of Korea
2002.3 - 2006.2	Researcher, National Institute of Agricultural Biotechnology, RDA, Republic of Korea
1997.9 - 2002.3	Researcher, Plant Research International, The Netherlands
1990.1 - 1995.9	Researcher, Hungnong Seed Co. Korea (currently Seminis, Republic of Korea)
1985.1 - 1987.12	Researcher, ShinNong Co. Ltd. Republic of Korea

DAVID NEVILL
Head of R&D for Cereal Seeds, Syngenta, Switzerland

With over 30 years of experience in agricultural R&D, David has broad knowledge of the Seeds, Biotechnology and Crop Protection areas. His initial qualifications in Applied Biology, comprising Masters and Doctorate degrees from Cambridge University, England, led him to an international career, first in public research and later with industry. David worked in plant breeding in Nigeria, India and the USA, before moving to Switzerland to join Ciba-Geigy. There he worked in Seed Technology research, and subsequently moved into chemical crop protection through R&D in seed treatments, foliar fungicides and finally weed control. During this time, he led R&D teams not only in Switzerland but also in Indonesia and the USA. Since 2002, David has focused his research interests on plant biotechnology and breeding for Syngenta. His work has included the leadership of teams to develop novel GM traits as well as in the responsible management and stewardship of GM products. Most recently he has led seeds R&D in field crops with current focus on cereals. Currently he not only leads our global programs in cereals genetics, but also ensures integration of seeds and crop protection R&D, interfacing with Syngenta's global business team for cereals.

FRANK ORDON

Personal
Name Frank ORDON, Dir. & Prof. PD Dr. agr.
Date of birth 17.05.1963 in Hildesheim/Germany

Recent Position
Since 01.01.2008 Head of the Institute for Resistance Research and Stress Tolerance of the Julius Kühn-Institute, Federal Research Centre for Cultivated Plants.

Studies and Academic career

01.10.1983 – 14.04.1989	Studies "Agriculture – Crop Science" at the Justus-Liebig-University, Giessen
01.05.1989 - 15.05.1992	PhD student at the Institute of Crop Science and Plant Breeding I (Prof. Dr. Wolfgang Friedt), Justus-Liebig-University. Thesis:"Genetic analysis of resistance of exotic barley germplasm against soil-borne viruses"
15.05.1992 – 01.04.1996	Senior scientists at the Institute of Crop Science and Plant Breeding I, Justus-Liebig-University, Giessen
24.02.1995	Kurt von Rümker award
01.04.1996 – 30.10.2002	Assistant Professor at the Justus-Liebig-University, Giessen
01.07.1998	State doctorate (Dr. habil. "Marker based resistance breeding in cereals with special consideration of the pathosystem barley (*Hordeum vulgare* L.) – bymoviruses (BaMMV, BaYMV, BaYMV-2)"
30.10.1998	Inaugural lecture; *venia legendi* for Plant Breeding and Crop Production
01.11.2002 – 31.12.2007	Head of the Institute of Epidemiology and Resistance Resources, Federal Centre for Breeding Research on Cultivated plants

Research
- Molecular plant breeding
- Estimation of genetic diversity in several crop species and exploitation of genetic diversity by marker based breeding.
- Development of molecular markers for resistance genes to fungal and viral pathogens up to gene isolation.
- Identification of QTL and genes for resistance/tolerance to abiotic stress (drought/heat).

Board memberships

01.12.2004 – 30.9.2008	Board of the German Society of Plant Breeding (GPZ)
since 01.01.2005	Editorial Board of Plant Breeding
since 01.10.2005	Editorial Board of Theoretical and Applied Genetics
since 01.04.2006	Editorial Board of Journal of Applied Genetics
since 01.01.2008	Editor in chief of Plant Breeding
since 01.01.2008	Advisory Board of the gene bank of the Leibniz Institute of Plant Genetics and Crop Plant Research, Gatersleben (IPK)
since 15.07.2008	Peer Review College of the Danish Council for Strategic Research
since 12.08.2008	Advisory Board of the State Breeding Institute of the University of Hohenheim
since 01.10.2008	Acting Vice President of the German Society of Plant Breeding
since 01.01.2009	Board of directors of the Interdisciplinary Centre for Crop Science (IZN) at the University of Halle
since 01.01.2009	Editorial board of Journal of Cultivated Plants

ULRICH SANDER

Ulrich Sander is Managing Director of Selecta Klemm and responsible for sales and marketing of the pot plant division of Selecta Klemm in Europe and for the R&D activities of the Selecta group worldwide. He is a board member of the Ornamental Bioscience, founded in 2007, a joint venture between Mendel Biotechnology, Inc. and Selecta Klemm. Ulrich Sander joined Selecta in 1995. He has a PhD and Master Degree in Horticultural Science of the University of Hannover. For his PhD thesis he had been working on the Transformation of Beta vulgaris. In Selecta he started as Director of Breeding and Research managing the R&D activities and breeding himself a range of varieties of different ornamental species including carnation, petunia and calibrachoa.

KONSTANTIN G. SKRYABIN

Date of birth
29 April 1948
Place of birth
Moscow (Russian Federation)
Address
Centre «Bioengineering», The Russian Academy of Sciences; Prosp. 60-let Oktyabrya, bld. 7-1, Moscow, 117312 Russia.
Tel. +007 499 135-73-19. E-mail: *office@biengi.ac.ru*

Education

1965-1970 Moscow State University, Biological Faculty, Department of Molecular Biology

Training

1970-1973	Moscow State University, Russia, postgraduate student, Biological Faculty, Department of Molecular Biology. Ph.D. in 1974.
1976-1977	Honorary research fellow in Biology, Harvard University, USA, (Prof. W.Gilbert, Head of the Department).

Positions

1974-1984	Senior researcher at the Institute of Molecular Biology, USSR Academy of Sciences.
1984-1991	Head of the Department, Institute of Molecular Biology, USSR Academy of Sciences.
1986 - present	Professor, Faculty of Biology, Moscow State University.
1991 - present	Director and founder of the Centre «Bioengineering», Russian Academy of Sciences.
2007 - present	Vice-Director, National Research Centre "Kurchatov Institute".
2007 – present	Head, Chair of Biotechnology, Faculty of Biology, Lomonosov Moscow State University.
2009 - present	Member, Presidium of the Russian Academy of Agricultural Sciences.

Society Memberships and Honors

2008	Russian Academy of Sciences, Full member (academician).
1999	Russian Academy of Agricultural Sciences, Full member (academician).
1997	European Molecular Biology Organization, Associate member.
2005	Honorary Doctor of the Moscow State Academy of Veterinary Medicine and Biotechnology
2007	Honorary Doctor of the National Agricultural University of Ukraine.

Research activities

- Establishing genome sequencing techniques in Russia, pioneering research projects on sequencing of eukaryotic ribosomal RNA genes, genomes of plant viruses and bacteriophages.
- Development of systems for production of growth hormones, other biologically active proteins in bacterial and eukaryotic cells, structural studies of pharmaceutically important proteins.

- Construction of transgenic plants resistant to herbicides, pathogens and abiotic stresses.
- Scientific and regulation activities in transgenic plants field trials, including the UPOV-based testing of variety identity.
- Genetic analysis and mathematical modeling of plant flower development
- Development of new techniques for expression of target proteins in plants based on the use of self-replicating plant viral vectors. Production of vaccine proteins in plants.
- Design and engineering of artificial proteins, protein complexes and viral-like particles with predetermined properties for nanobiotechnological applications.
- Sequencing and analyzing the genomes of extremophilic microorganisms,
- search and isolation of new enzymes for biotechnological applications.
- Plant genome studies and biodiversity assessment using DNA-based approaches.
- Analysis of genetic diversity of human populations, identification of polymorphic loci associated with various diseases in different ethnic groups.
- First complete human genome of kidney cancer patient.
- Biosafety and ethical issues of genetic engineering.

Public activities

1989-1997	COBIOTECH (Committee on Biotechnology of International Council of Scientific Unions), Secretary General/ Treasurer COBIOTECH
1993 - present	Chairman, Scientific Council on Biotechnology, Russian Academy of Sciences
2001 - present	Member, The Council at the President of the Russian Federation on Science, Technologies and Education
1997 – present	Vice Chairman of Inter-Agency Committee on Genetic Engineering
2006 – present	Vice Chairman of Russian Bioethics Committee under the Commission of Russian Federation for UNESCO
2008 - present	Member, Scientific and Technical Council of the state corporation “RUSNANO”

International collaborations

Prof. K. Skryabin is actively promoting collaboration of Russia with EU within the 7th Framework program in biotechnology, as well as bilateral collaborations with Poland, France and Germany in the areas of post-genomic biotechnology, plant sciences and bioinformatics. He promoted organization of two Polish-Russian meetings in biotechnology (Moscow, 2008 and Gdansk, 2009). He was invited as a speaker and chairman of several international scientific conferences. Prof. Skryabin is a member of two working groups of the OECD, - “Working group on the Harmonization of Regulatory Oversight of Biotechnology” and “Task Force for the Safety of Novel Foods and Feeds”; he organized in Moscow and St.-Petersburg five international meetings for Biosafety with participation of the OECD experts.

Editorial Posts in different years:

Prof. K. Skryabin has been associated with the Editorial Boards of several peer reviewed journals in Russia and abroad, including FASEB Journal (USA), The Plant Journal (UK), Trends in Biotechnology, BioEssays, Biotechnology (Russia), Problems of Biological, Medical and Pharmaceutical Chemistry (Russia), Reports of the Russian Academy Agricultural Sciences (Russia), Plant Protection News (Russia), Ecological genetics (Russia), Russian Nanotechnologies (Russia), Medical Science and Practice (Russia), Cell Technology in biology and medicine (Russia), Agricultural Biology (Russia), Biotechnology (Ukraine).

Publications

450 scientific papers, including over 59 patents and inventions.

Awards

1983	State Prize of the USSR in Science and Technology
2006	Officer of Order of the Academic Palm (France)
2008	Order for Services to Motherland 4thRank (Russian Federation)

JARI VALKONEN

Dr. Jari P.T. Valkonen (born 1964) is professor (chair) of plant pathology at University of Helsinki, Finland. His research and teaching subjects cover plant virology, plant pathology and plant biotechnology. During his career he has been employed as a junior fellow, senior research fellow and professor of the Academy of Finland, and professor (chair) of virology at the Swedish University of Agricultural Science (SLU), Uppsala, Sweden. He has spent periods of time as a researcher in the UK, USA and the International Potato Center, Peru. Valkonen's areas of expertise are molecular virus-plant interactions and pathogen defence in plants. Most of his studies concentrate on potato, sweetpotato or cassava. Studies aim to identify and isolate resistance genes that provide sustainable control against virus diseases in plants, and to understand the mechanisms by which viruses overcome or suppress resistance. His published work cover, e.g., molecular plant virology; gene mapping; genomics, transcriptomics and proteomics analyses on plants; and plant biotechnology. Besides projects directed to basic science, Valkonen leads projects with applied goals in disease management of crop plants and which involve many partners from the private sector. He has been involved in EU-funded projects since 1995 and has long-term collaboration in research capacity building with developing countries such as Uganda, United Republic of Tanzania and Nicaragua. Twenty PhD students have graduated and ten PhD students are currently doing their thesis research under his supervision. He has published 200 papers in refereed scientific journals.

Liste des participants
List of Participants
Teilnehmerliste
Lista de participantes

(dans l'ordre alphabétique des noms français des membres
in the alphabetical order of the names in French of the members
in alphabetischer Reihenfolge der französischen Namen der Mitglieder
por orden alfabético de los nombres en francés de los miembros)

I. Membres / Members / Verbandsmitglieder / Miembros

Afrique du Sud / South Africa / Südafrika / Sudáfrica

Noluthando NETNOU-NKOANA (Mrs.) Registrar: Plant Breeders' Rights Act, Directorate: Genetic Resources, Department of Agriculture, Forestry and Fisheries, Pretoria

Allemagne / Germany / Deutschland / Alemania

Friedel CRAMER Referatsleiter, Referat 511, Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (BMELV), Bonn

Michael KÖLLER Referent, Ministerium für Ernährung, Landwirtschaft und Verbraucherschutz, Berlin

Clemens NEUMANN Abteilungsleiter, Biobasierte Wirtschaft, Nachhaltige Land- und Forstwirtschaft, Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz, Berlin

Udo VON KRÖCHER Präsident, Bundessortenamt, Hannover

Beate RÜCKER (Mrs.), Abteilungsleiterin Registerprüfung, Bundessortenamt, Hannover

Argentine / Argentina / Argentinien / Argentina

Carmen Amelia M. GIANNI (Sra.) Coordinadora de Propiedad Intelectual y Recursos Fitogenéticos, Instituto Nacional de Semillas (INASE), Buenos Aires

Australie / Australia / Australien / Australia

Doug WATERHOUSE Chief, Plant Breeder's Rights, IP Australia, Woden

Autriche / Austria / Österreich / Austria

Heinz-Peter ZACH Leiter des Referates III/9c für Saatgut und Sortenwesen, Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, Wien

Bélarus / Belarus / Belarus / Belarús

Uladzimir BEINIA Director, State Inspection for Testing and Protection of Plant Varieties, Minsk

Tatsiana SIAMASHKA (Mrs.) Deputy Director of DUS Testing, State Inspection for Testing and Protection of Plant Varieties, Minsk

Maryna SALADUKHA (Mrs.) Main Specialist, International Cooperation Department, Ministry of Agriculture and Food, Minsk

Belgique / Belgium / Belgien / Bélgica

Camille VANSLEMBROUCK (Mme)	Responsable droits d'obtenteurs et brevets, Office de la propriété intellectuelle, Bruxelles
Erik J. VAN BOCKSTAELE	Administrator-General ILVO, Merelbeke

Bolivie (État plurinational de) / Bolivia (Plurinational State of) Bolivien (Plurinationaler Staat) / Bolivia (Estado plurinacional de)

Sergio Rider ANDRADE CÁCERES	Director Nacional de Semillas, Instituto Nacional de Innovación Agropecuaria y Forestal (INIAF), La Paz

Brésil / Brazil / Brasilien / Brasil

Daniela DE MORAES AVIANI (Mrs.)	Coordinator, National Plant Variety Protection Service (SNPC), Ministry of Agriculture, Livestock and Food Supply, Brasilia

Canada / Canada / Kanada / Canadá

Sandy MARSHALL (Ms.)	Senior Policy Specialist, Plant Breeders' Rights Office, Canadian Food Inspection Agency (CFIA), Ottawa
Julie LAPLANTE (Ms.)	Examiner, Plant Breeders' Rights Office, Canadian Food Inspection Agency (CFIA), Ottawa

Chili / Chile / Chile / Chile

Jaime IBIETA S.	Director, División Semillas, Servicio Agrícola y Ganadero (SAG), Ministerio de Agricultura, Santiago de Chile

Chine / China / China / China

LIU Ping	Vice Director-General, Development Center for Science and Technology, Ministry of Agriculture, Beijing
LÜ Bo	Director, Division of Variety Management, Bureau of Seed Management, Ministry of Agriculture, =Beijing
Yinan LIU	Official, International Cooperation Department, State Intellectual Property Office, Beijing
Qiong WANG	Official, Office of Plant Variety Protection, State Forestry Administration, Beijing

Colombie / Colombia / Kolumbien / Colombia

Ana Luisa DÍAZ JIMÉNEZ (Sra.)	Directora Técnica de Semillas, Dirección Técnica de Semillas, Instituto Colombiano Agropecuario (ICA), Bogotá D.C.

Croatie / Croatia / Kroatien / Croacia

Ružica JURIĆ (Ms.)	Head of Plant Variety Protection and Registration, Institute for Seeds and Seedlings, Croatian Centre for Agriculture Food and Rural Affairs, Institute for Seed and Seedlings, Osijek

Danemark / Denmark / Dänemark / Dinamarca

Gerhard DENEKEN	Head, Department of Variety Testing, Danish AgriFish Agency, Ministry of Food, Agriculture and Fisheries, Skaelskoer

Espagne / Spain / Spanien / España

Alicia CRESPO PAZOS (Sra.)	Directora, Oficina Española de Variedades Vegetales (OEVV), Ministerio de Medio Ambiente y Medio Rural y Marino (MARM), Madrid
Luis SALAICES	Jefe de Área del Registro de Variedades, Oficina Española de Variedades Vegetales (OEVV), Ministerio de Medio Ambiente y Medio Rural y Marino (MARM), Madrid

Estonie / Estonia / Estland / Estonia

Laima PUUR (Ms.)	Head, Variety Department, Estonian Agricultural Board, Viljandi
Renata TSATURJAN (Ms.)	Chief Specialist, Plant Production Bureau, Ministry of Agriculture, Tallinn

États-Unis d'Amérique / United States of America Vereinigte Staaten von Amerika / Estados Unidos de América

Kitisri SUKHAPINDA (Ms.)	Patent Attorney, Office of Policy and External Affairs, United States Patent and Trademark Office (USPTO), Alexandria
Karin L. FERRITER (Ms.)	Intellectual Property Attaché, United States Mission to the WTO, Chambesy, Switzerland

Fédération de Russie / Russian Federation / Russische Föderation / Federación de Rusia

Yulia GORYUNOVA (Mlle)	Spécialiste principal, Moscow

Finlande / Finland / Finnland / Finlandia

Tapio LAHTI	Senior Officer, Legal Affairs, Finnish Food Safety Authority (EVIRA), Helsinki
Marja SAVONMAKI (Mrs.)	Consulting Officer, Government

France / France / Frankreich / Francia

Jean-Marc BOURNIGAL	Directeur de Cabinet au MAAPRAT, Cabinet B, Ministère de l'agriculture, de l'alimentation, de la pêche, de la ruralité et de l'aménagement du territoire (MAAPRAT), Paris
Elodie GALKO (Mme)	Conseillère technique au MAAPRAT, Ministère de l'agriculture, de l'alimentation, de la pêche, de la ruralité et de l'aménagement du territoire (MAAPRAT), Paris
Robert TESSIER	Sous-directeur de la qualité et de la protection des végétaux, Direction générale de l'alimentation, Service de la prévention des risques sanitaires de la production primaire, Ministère de l'agriculture, de l'alimentation, de la pêche, de la ruralité et de l'aménagement du territoire (MAAPRAT), Paris
Sylvie DUTARTRE (Mme)	Directrice, Groupe d'étude et de contrôle des variétés et des semences (GEVES), Beaucouzé
Joël GUIARD	Directeur adjoint, Groupe d'étude et de contrôle des variétés et des semences (GEVES), Beaucouzé
Muriel LIGHTBOURNE (Mme)	Responsable juridique, Groupe d'étude et de contrôle des variétés et des semences (GEVES), Beaucouzé

Jean PERCHET	Seed Policy Officer, Direction générale de l'alimentation, Ministère de l'agriculture, de l'alimentation, de la pêche, de la ruralité et de l'aménagement du territoire (MAAPRAT), Paris
Marie-France CAZALÈRE (Mme)	Groupement national interprofessionel des semences et plants (GNIS), Paris

Hongrie / Hungary / Ungarn / Hungría

Szenci ÁGNES GYÖZÖNÉ (Mrs.)	Senior Chief Advisor, Agricultural Department, Ministry of Rural Development, Budapest

Irlande / Ireland / Irland / Irlanda

Donal COLEMAN	Controller of Plant Breeders' Rights, Department of Agriculture, Backweston Farm, Leixlip

Islande / Iceland / Island / Islandia

Thorsteinn TÓMASSON	Director, Agricultural Research Institute, Ministry of Fisheries and Agriculture, Reykjavik

Italie / Italy / Italien / Italia

Pier Giacomo BIANCHI	Head General Affairs, National Office for Seed Certification INRAN, Milano

Japon / Japan / Japan / Japón

Mr. Takashi UEKI	Director, Plant Variety Protection Office, New Business and Intellectual Property Division, Food Industry Affairs Bureau, Ministry of Agriculture, Forestry and Fisheries, Tokyo
Mitsutaro FUJISADA	Senior Policy Advisor, Intellectual Property, Plant Variety Office, New Business and Intellectual Property Division, Food Industry Affairs Bureau, Ministry of Agriculture, Forestry and Fisheries (MAFF), Tokyo
Tsukasa KAWAKAMI	Associate Director, New Business and Intellectual Property Division, Food Industry Affairs Bureau, Ministry of Agriculture, Forestry and Fisheries (MAFF), Tokyo

Kenya / Kenya / Kenia / Kenya

James M. ONSANDO	Managing Director, Kenya Plant Health Inspectorate Service (KEPHIS), Nairobi

Lituanie / Lithuania / Litauen / Lituania

Sigita JUCIUVIENE (Mrs.)	Head, Division of Plant Variety, Registration and Legal Protection, State Plant Service under the Ministry of Agriculture, Vilnius

Maroc / Morocco / Marokko / Marruecos

Amar TAHIRI	Chef, Division de contrôle des semences et plants, Office national de sécurité sanitaire des produits alimentaires (ONSSA), Ministère de l'agriculture et de la peche maritime, Rabat

Mexique / Mexico / Mexiko / México

Enriqueta MOLINA MACÍAS (Srta.)	Directora General, Servicio Nacional de Inspección y Certificación de Semillas (SNICS), Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA), Tlalnepantla de Baz
Eduardo PADILLA VACA	Subdirector, Registro y Control de Variedades Vegetales, Servicio Nacional de Inspección y Certificación de Semillas (SNICS), Tlalnepantla de Baz

Norvège / Norway / Norwegen / Noruega

Tor Erik JØRGENSEN	Head of Section, Norwegian Food Safety Authority, National Registration Section, Felles postmottak, Brumunddal
Bell Batta TORHEIM (Mrs.)	Advisor, The Development Fund, Grensen 9b, Miljohuset, N-0159 Oslo

Nouvelle-Zélande / New Zealand / Neuseeland / Nueva Zelandia

Christopher J. BARNABY	Assistant Commissioner / Principal Examiner, Plant Variety Rights, Intellectual Property Office of New Zealand, Christchurch

Oman / Oman / Oman / Omán

Fatima AL-GHAZALI (Ms.)	Minister Plenipotentiary, Commercial Affairs, Permanent Mission, Chambésy, Switzerland

Pays-Bas / Netherlands / Niederlande / Países Bajos

Marien VALSTAR	Sector Manager, Plant Propagation Material, Ministerie van Economische Zaken, Den Haag
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