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Trends in Agricultural Science with Special Reference to Research and Development in the Potato Sector

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Abstract This contribution highlights some developments in agricultural science in general and plant science in particular. It also describes some changes in the way society looks upon science and scientists and in the way scientists play their role in the scientific community. The paper provides a very brief overview of the achievements of potato science and the challenges ahead. It stresses the need for proper knowledge chains and scientific platforms to make better use of the resources provided to potato research. It also indicates where the European Association for Potato Research could play a significant role. The views expressed are those of the author and not based on an extensive literature review.

Keywords research strategy · scientific community · societal view on science · plant science · innovation

Introduction

The potato crop (*Solanum tuberosum* L.) has an image problem. Consumer behaviour in the western world suggests that the potato is considered as a dull meal component, a reflection of an old life style and part of a traditional cuisine. If it is not a dull component, the meal it is part of contains too much fat or is not "low-carb" thus contributing to the pandemic of obesity; and even if these issues do not scare the traditional consumer the acrylamide discussion has shown us how delicate the image of potato products can be (Buckenhüskes, 2005). On top of that, environmentalists have forcefully attacked potato: the intensive use of chemical crop protectants in the cultivation of the potato and the GMO discussion on this crop have increased consumers' concern.

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This negative image is enhanced by linguistic developments. The potato has become the symbol for an inactive life style as illustrated by the terms “tuber” [for a person who watches too much TV (the “tube”)] and potato couch (for a person who spends leisure time passively, especially by watching television or video tapes). Its putative potency as a medicine (Spire and Rousselle, 1996) does not help anymore. The potato is also associated with limited intellectual skills. It got its biggest moment of fame in this respect thanks to the discussion between William Figueroa and Dan Quayle on the spelling of the word potato. Presently, November 2005, Google finds 1,740,000 hits on the word potatoe. In short: a challenge ahead for marketers of potato products.

There is also good news. Many agronomic studies have shown the high use efficiency of some resources (e.g., land and energy) by the potato crop. It can feed many people per hectare. Nutrition studies show how healthy the potato can be in terms of vitamins, minerals, proteins, essential amino acids and carbohydrates (Buckenhüskes, 2005; Van Gijssel, 2005). Moreover, consumers with high purchasing power in the developing world are copying the western lifestyle including the consumption of the great diversity of processed potato products. There is a shift in the potato production and consumption from developed countries to the developing countries and this shift provides many new research questions.

The scientific significance of the potato crop goes well beyond its rank on the world’s list of crops. In fact the potato plant has become a model plant in many disciplines, including genomics, molecular physiology, tissue culture science, engineering and phytopathology, to name a few. Potato scientists are also fortunate that there are significant problems that persist in potato cultivation. These include the problems of pests and diseases, many of them re-emerging or newly emerging, and with a continuous increase in the threats due to intense international trade of seed tubers and ware potatoes for consumption or processing. These problems are associated with the vegetative way of reproduction: clonal propagation results in more and more intense disease problems than in crops that are propagated through true seeds. There are significant problems in engineering, storage and utilisation, the potato tuber being a vulnerable product. Agronomists are faced with the high water requirements and low fertilizer use efficiencies in the crop. Also the breeders can be satisfied: the tetrasomic inheritance is a complicating factor but there is a wealth of diversity available within the genus *Solanum*.

Trends in Agriculture

Over the entire period since World War II, labour inputs in agriculture reduced drastically through mechanisation and economy of scale while yields greatly increased. These processes have speeded up since the end of the 1960s, strongly supported by the European Union policy towards self-sufficiency and the associated large effort in publicly funded agricultural research everywhere in Europe. At that time the number of people fed by a single European Union farmer was only half the current number. The amount of produce provided by a single farmer more than doubled, because of increases in yield per hectare and in number of hectares cropped by a single farmer (Table 1).

These trends did not leave the potato crop untouched, as the potato was one of the most important staple crops and cash crops at the same time. Moreover, in the

Table 1 Some data on wheat production (early 1900s and late 1900s) and labour in agriculture (1993).

	Netherlands	Italy
Early 1900s		
Production (t per ha)	1.5	1.0
Labour need (man hours per ha)	300	700
Late 1900s		
Production (t/ha)	8.5	4.0
Labour need (man hours per ha)	15	30
1993		
Agricultural labour as % total population	3.9	7.3
Inhabitants per unit agricultural labour	59	39
Acreage cropped per unit labour (ha)	8.3	9.3

Data retrieved from Proceddu and Rabbinge (1997)

potato crop, it is also noteworthy that the harvest, post-harvest storage and post-harvest processing technologies have dramatically changed over the last decades. Product diversification and chain management have contributed greatly to the profitability of the production chain but have also changed the market demands. The potato crop was one of the first major crops in which farmers moved away from bulk production and tried to adjust cultural practices to specific end uses and higher added value.

This great success of science and technology development resulted in surpluses of many commodities, allowed governments to keep prices of food very low in their rapidly industrialising economies, but hardly contributed to the wealth of farmers.

This paper pictures some trends in agricultural science in general, and in plant science in particular. It also describes trends in the societal views on science and changes in the scientific community. I will end with the achievements and challenges in potato research, plead for knowledge chains and scientific platforms to enhance the transfer of scientific progress and comment on the role the EAPR may play. This paper is not a review but rather a personal account of observations on developments in science and research.

General Trends in Agricultural Science

Between 1945 and 1980, agricultural science mainly focused on increasing productivity through better cultivars, increased and improved use of resources, a higher resource use efficiency, efficient disease control and effective cultural practice (Struik, 1992). This period in agricultural research was called "the production wave" by Bouma and Hartemink (2002), although they timed it from 1945–1970. As a consequence, inputs per hectare and yields increased very rapidly, obviously with the usual built-in delay of effects in commercial agriculture. In the Netherlands, average tuber yields of potato more than doubled between 1945 and 1985 (Vos, 1992; Fig. 1). This production wave period in agricultural research was supply driven and characterised by a pursuit of knowledge (Bouma and Hartemink,

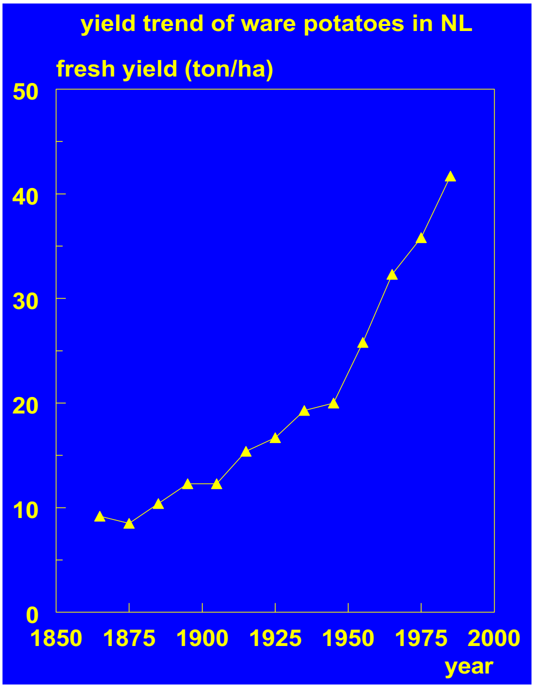

Figure 1 The development of the average commercial potato yield in the Netherlands before and during the production wave (Vos, 1992). Reprinted with kind permission from author and journal. Copyright PAA.

2002). Yet, the influence of farmers on the research agenda was large and the political influence of the farmers guaranteed strong commitment from governments to invest in agricultural research.

The production wave period was followed by a strong focus on the environmental impact of agriculture (Struik, 1992): the environmental wave. According to Bouma and Hartemink (2002) it lasted from 1970–1980, but in potato science the period from 1980–1999 is more appropriate. Supra-national, national and local governments all over Europe were worried about the environmental impact of excessive use of crop protectants, the leaching of nitrate associated with the current supply of fertilisers and the desiccation of (agro-)ecosystems caused by extensive use of water in crop production. Research in this phase was more market driven than in the first phase. Inputs of biocides in potato crops (in terms of kg active ingredients per ha) were huge, especially to control nematodes, late blight and fungal diseases, insects (Colorado potato beetle, aphids, etc.) and—to a lesser extent—weeds. Moreover, haulm killing was usually done chemically as well. Nitrogen fertiliser amounts were also very high in potato, there being no agronomic penalty for excessive supply and synthetic fertilizers being very cheap. Given these large quantities and the poor apparent recovery of nitrogen in potato cultivation (Vos, 1992), nitrogen residues in the soil after potato growing were high (Neeteson, 1989). The potato crop also responds very well to irrigation. In contrast to the success of research during the production wave, the research during the environmental wave had limited success

Table 2 Change in the use of pesticides (in tonnes per year) in the Netherlands during the environmental wave.

	1984/1985	1999	1999 in % of 1984/1985
Soil disinfectants	10 247	1470	14
Fungicides	4039	5200	129
Herbicides and haulm desiccants	3854	3870	100
Insecticides and acaricides	603	410	68
Other products	1218	1050	86

Source: Website Ministry of Agriculture, Nature and Food Safety, The Hague, The Netherlands

(Table 2). Resource use efficiencies have increased but the dependence on chemical pesticides did not disappear. In the Netherlands, the reduction of the total use of biocides seemed to have reached the governmental targets, especially due to a strong reduction in the use of nematicides (Table 2). The use of fungicides to control late blight is still at a high level as the population of *Phytophthora infestans* has shown an increase in virulence (Smart and Fry, 2001), adaptability (Allefs et al., 2005) and resistance against some biocides (Cooke and Deahl, 2005). Old problems have increased in severity, new problems arose (such as *Ralstonia solanacearum*) and the increase in international travel and trade puts the industry at risk. Major disease disasters, as observed in animal production, have not occurred yet, but that does not mean that they may not happen.

The environmental wave was followed by a phase during which research is strongly driven by the need for policy support, the outcry from consumer and environmentalist organisations to make agriculture more environment-, animal- and consumer friendly and a strong focus on food safety. The latter was fuelled by the many disasters which jeopardised the production systems and food chains. This phase (starting around 2000) is characterised by an interaction between and integration of natural and social sciences (the so-called beta-gamma integration). This third wave may be called the "societal wave". New approaches have been developed to identify and prioritise problems together with stakeholders. However, generally accepted approaches for translating these priority problems into relevant questions for scientific endeavour are still lacking, despite much rhetoric about "demand driven research" (N. Röling, personal communication). Identifying the most significant and promising social and natural science questions for research in a transdisciplinary context is complex for many reasons. One of the most significant reasons is that uncertainties and knowledge gaps are often implicit and concealed in stakeholder interactions.

It is too early to evaluate the (significance of the) progress made during this societal wave. In general, however, there is a strong reduction in crop-oriented research. Traditional agronomic research is no longer financed by governments and farmers have lost their grip on the agenda of publicly funded agricultural research. Other stakeholders of potato research have taken over.

General Trends in Plant Sciences

Plant sciences underwent drastic changes during the past few decades. One obvious change is the shift from field experimentation to highly specialised laboratory

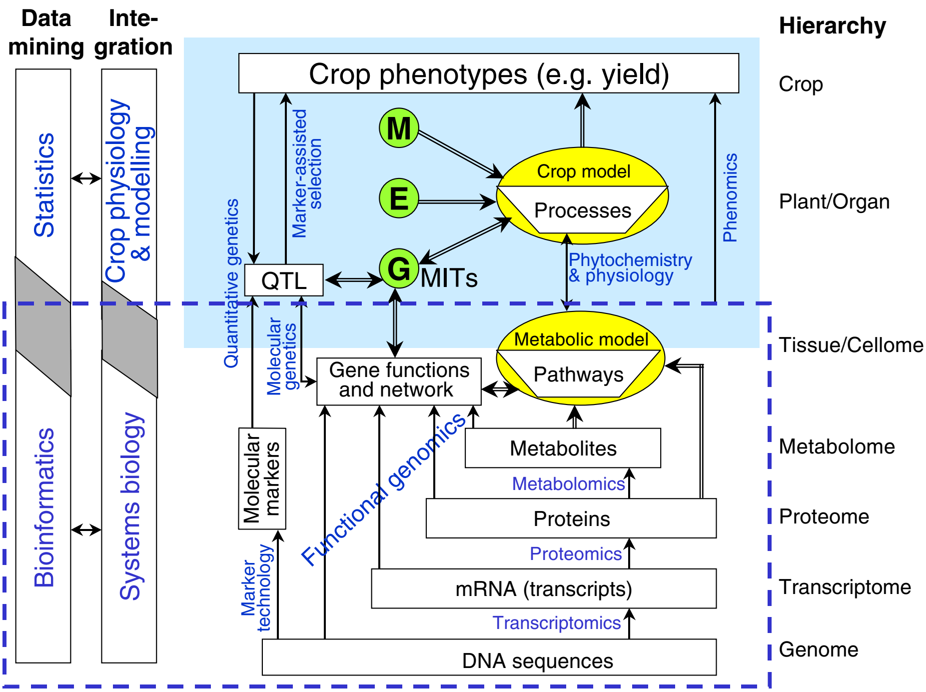

Figure 2 The position of crop physiology in the proposed knowledge chain of plant biology to study complex quantitative crop traits (Abbreviations: E, environmental variables, G, genotypic factors, M, managerial options, MITs, model input traits). *Single-lined arrow* shows a scientific discipline for the link between organisational hierarchies. *Double-lined arrow* refers to inputs or outputs of a model, for up- and down-scaling of insights between levels of understanding. In the left part of the scheme, the *grey parallelograms* and the *double arrows* mean a vertical and horizontal penetration, respectively, between the two concerned disciplines. The area squared by *blue dashed lines* is the region for modern plant sciences as a whole (plant 'omniomics'), emerged with the advent of high throughput experimental technologies. The area with the *light blue background* is the region for crop physiology where crop modelling will play a central role in bridging gaps between genes and phenotypes. Extended version of Fig. 2 in Yin et al. (2004). Reprinted with kind permission from Elsevier.

investigations. Especially the developments in genomics (including proteomics, metabolomics, and other "-omics") and in the design of high throughput technologies have created enormous opportunities to increase our insight into the biological processes of crops and their pests. Potato is one of the model species and the potato genome will be fully known in the near future. The importance of the potato crop in this new area is illustrated by the role it played in the development of metabolomics. Large-scale, comprehensive metabolite profiling was first approached by the group of Ute Roessner which detected 150 compounds simultaneously within a potato tuber using gas chromatographic mass spectrometry (Roessner et al., 2000). Of these 150 compounds, 77 could be identified as amino acids, organic acids or sugars (Bino et al., 2004). The new "-omics" are capable of producing an unprecedented mass of molecular data on DNA sequences, gene functioning, transcription, protein functions and metabolism of plants. The challenge of the future will be to process and mine these data. Systems biology and new technologies for data processing are required to be able to do so. Also the upscaling of these insights to crop relevant information making use of gene-based modelling approaches (Yin et al., 2004; Fig. 2) will be a complex and demanding task for generations of potato scientists to come.

However, these drastic changes in plant sciences also had a large impact on the way science is organised and funded. Investments in equipment and human capital needed to stay at the frontline of science in these fields are huge. Without continuous and high investments work will be out of date in no time. Massive data sets require new tools to process them which demands not only advanced software but also greatly challenges the creativity of the researchers involved. Cooperation between many fundamental disciplines is needed to collect and interpret data. Therefore, there is an enormous incentive on international cooperation and on multi- and interdisciplinarity. On the other hand, there is also a great potential and pressure to protect and commercialise the knowledge obtained. The economic potential of the findings, associated with the lack of public funding caused by the withdrawal of governments from research investments, has created a situation in which protection of knowledge has become the norm. This is certainly also true for potato science.

These changes in plant sciences also have an impact on the quality of the scientists serving these disciplines. Empirical knowledge, obtained through many years of field research is no longer valued, detailed analytical and specialised knowledge, based on sometimes short-term investigations supported by high-tech research instrumentation provides much more respect. Publications are based on increasingly less labour input and sometimes smaller data sets or on re-processed existing data sets. Scientists need to change their way of operation and base it on strategic alliances. They need to continuously upgrade their knowledge in several rapidly developing fields in which the revolutions in technique development are not always well orchestrated. Moreover, they need to grow beyond their own field of expertise. For example, every modern physiologist is also a geneticist and every modern geneticist can only work if he is an excellent physiologist. This trend is new after centuries of increasing specialisation. However, this type of integration is still focused on details and does not create the type of crop experts who have the interdisciplinary and multidisciplinary skills that make them so powerful in recognising and solving practical problems at the level of the crop and the cropping system.

Societal Views on Science

In Europe plant science has been strong traditionally. Yet there is a situation where its potential is not fully exploited because of fragmentation along national boundaries. This causes overlap, unnecessary competition, reduced visibility and a waste of efforts and funds. This is the more a problem as public funding has considerably been reduced over the last decades and competition for funds has strongly increased. Frequent staff reductions and budget cuts make the research fragmented again, induce a new need to re-organise to counter the fragmentation process, but make the larger unit vulnerable again to further downsizing. Funding agencies have changed the thinking about what to fund. Scientific excellence is no longer the overriding criterion; utilisation is in most cases much more important.

Moreover, time pressure and short-term strategies are very common. Many national organisations do not hesitate to outsource research assignments to research institutions in a different country. Labour costs will be an increasingly critical factor in decisions on who is given the tasks. There already is a trend visible to carry out molecular and other research in countries like China and India, where labour is cheap but of high quality and where research infrastructure is at a high level too. Fortunately, the European Union is at least partly successful in counterbalancing these negative trends, for example through its framework programme FP6, albeit at a price of increased bureaucracy.

Policymakers have the impression that in many fields research is no longer needed. There exists an impression that enough knowledge has been accumulated and that it is now time to use it in innovative ways. They argue that the interface between innovation and science needs to be strengthened and that there are strong cultural differences in the strength of this interface. European policymakers also claim that Europe is good in science but has a weaker interface than the USA or Japan. Many policymakers believe that the use of scientific knowledge does not require scientists but innovators and businessmen. In other fields there is a large societal need to get more information and hard data, such as in relation to environmental issues, global warming, risks of genetically modified organisms, risk assessments relating to food safety. This is also necessary to develop sustainable entrepreneurship (based on the three Ps: people, planet, profit).

Moreover scientists are no longer considered creative thinkers who perform best when left alone with a bag of money, but have to be workers who carry out a job according to a fixed and demanding time table with an outcome aimed at satisfying a customer. The return on investment in research has to be as high as possible. Although this has enhanced the productivity of scientists and the relevance of the scientific work, it has not necessarily enhanced the role science plays as a cultural element of our society aimed at increasing knowledge and understanding and educating people, both other scientists and the general public. Coupled with this is the lack of trust and respect the public has towards the scientific community. Scientists are sometimes considered guilty of misuse of knowledge (e.g., in the case of nuclear power), or at least blind for potential misuse or collateral damage of their inventions (e.g., in the case of genetic engineering). This can only be countered by a well-orchestrated process of democratisation of knowledge and science, and a public process of setting the research agenda. Scientists have to be empowered to contribute to that democratisation process; otherwise they will loose their political clout.

Simultaneously, the character of the economy changes. Economies are increasingly knowledge-based. The influence of processors, the multinational food industry and the retailers has increased. Knowledge is no longer a public good but an instrument in the competition for market share. Therefore, science has increasingly become a private enterprise and this is in strong conflict with the desirable democratisation of science.

The general public has lost knowledge of and contact with primary agricultural production and is no longer overseeing what is happening in the food chain from farmer to fork. The same is true for agricultural science. The advanced and complex technology in this chain creates uneasiness or even fear; the chemical and biotechnological innovations have certainly contributed to that, the more so as scientists failed to educate the public in the early stages of those developments.

Changes in the Scientific Community

The careers of scientists have changed dramatically. The mobility of scientists has increased. They no longer stay with one employer or in one discipline. They left field experimentation and were trained in laboratory techniques that were applicable to all living organisms. A life time career within one single crop, with its fruitful long-time experience, expertise and dedication, is less and less neither possible nor desirable.

Similarly, the potato scientific community has become a group of people for whom potato is the crop they work with, not the crop they work on. This creates a great lack of people with an overview, who are capable of putting new findings into a practical perspective or to warn for undesirable side-effects or collateral damage.

There is a general trend towards more emphasis on detail and less on the general picture and on research at very low levels of aggregation. Reductionistic approaches are the norm but are hardly followed by holistic integration. Solutions for scientific problems are sought at the molecular and cellular level without proof that they also work at the plant, crop or cropping system level, in breeding for example. Crop physiologists with a general understanding of potato physiology have become scarce; the same is true for people with a good vision on seed potato production systems. Generalists in pathology also become increasingly rare.

There is one obvious exception. In research on organic agriculture the usual approach is a holistic one. Farmers and scientists in organic agriculture understand that reductionistic solutions to complex problems at the system level may not work and that reducing a farm organism to a set of genes or metabolites will ultimately result in the violation of its integrity or naturalness (Lammerts van Bueren and Struik, 2005). The proportion of research resources spent on this type of research is still low.

Yet, there is a great need for generalists, at least among the research project leaders. The continuous flow of new pathological problems in the potato industry cries for people who have seen this happening before. The fact that some problems (like late blight) just don't go away demands an overview of the long-term battle against these problems. International transfer of material asks for experts capable of early warning.

A positive element of the mobility of potato scientists and the job hopping in science is that everybody has a strong inclination in sharing scarce resources. Hopefully financers of potato research will allow, for example, the sharing of data sets, models, information on gene sequences.

Achievements and Challenges

Achievements over the last decades in potato have been large. The focus has always been on pathology (potato is a crop which is affected by many pests and diseases), breeding (with the complicated tetrasomic inheritance) and fewer people working on physiology and agronomy. Since the potato became a model crop in rapid multiplication, molecular biology and genomics much of the research efforts were concentrated on those aspects.

In agronomy, great achievements have been the re-design of seed production systems, the mechanisation of planting systems, changes in haulm destruction techniques (both in seed and ware), volunteer control, the development of (partly self-learning) decision support systems related to pest and disease control, water supply and fertiliser recommendations, and progress in storage techniques (see e.g., MacKerron and Haverkort, 2004; Haverkort and Struik, 2005). The orientation has changed from the crop level to the cropping system level, with systems analysis as a major research tool. In potato breeding, innovations include the use of wild germplasm, selection at diploid level, in vitro techniques, marker-assisted breeding and genetic modification. Physiologists made great progress in unravelling the process of stolon and tuber formation. Pathologists have made considerable progress in understanding pathogens and pests and the complex interactions at various trophic levels. Yet, they could not prevent that some diseases kept imposing such great threats on the crop that some diseases increased in diversity and virulence (e.g., late blight; Smart and Fry, 2001; Allefs et al., 2005), and were able to stay ahead of the potato crop in their evolution. In the case of late blight, some resistance genes were already broken before the first variety containing these genes became available on the market. Other diseases adapted to new environments or cropping systems. Even national or international initiatives for concerted actions to fight certain diseases were not successful (e.g., in several cases of bacterial diseases including ring rot and brown rot). Biological and biochemical control strategies are worth investigating but have not yielded what they promised (e.g., in the case of Rhizoctonia). System acquired resistance is interesting but also still far away from application. Fortunately, diagnostics have greatly improved using novel tools. At least we know what is causing the trouble.

Soil tillage (including seed bed preparation, mechanical weed control and earthing up), planting techniques (also of pre-sprouted seed) and harvesting techniques (both green harvesting and harvesting after desiccation or natural senescence) have greatly improved thanks to continuous efforts in the field of mechanisation. This resulted in better growth, more stable yields and a much higher quality in terms of tuber-size distribution, physical tuber quality and suitability for processing. It also resulted in fewer volunteers. Engineering has also changed the technology of storage, reduced storage losses and improved tuber quality.

Potato increasingly is processed before it is sold to the end-user. The diversity of potato products has increased greatly. Ware potato may even play its own role in human health as a functional food.

However, many challenges still lie ahead of us. Potato bruising is still a major concern, there are still no early cultivars with adequate late blight resistance, organic production of potato is still very difficult in many parts of Europe, tuber-size distribution often still is inadequate, and potato is still considered as an environmentally unfriendly crop which uses large quantities of resources (water, nitrogen, energy) and crop protectants while leaving a soil behind with strongly reduced physical, chemical and biological soil fertility.

Knowledge Chains and Scientific Platforms

From early school years, people are trained to think in a reductionistic and analytical way; scientists have developed this way of thinking into an art and a skill which has contributed enormously to mankind. Thanks to that approach we are now unravelling the basic building stones of our daily life: atoms, molecules, base pairs, etc. Each discipline has the tendency to dig deeper and you can only get your paper published if the digging has been deep enough. However, potato scientists know that digging deep is not always good. Upscaling of knowledge and integration of knowledge from different disciplines into new knowledge at a higher level of aggregation is scientifically even more challenging and requires filling up the knowledge gaps. Even more importantly, it requires a different (holistic) thinking, which is often more fundamental science and certainly more challenging than digging deeper. It requires systems analysis, special research instruments, special skills (such as understanding the different languages of the different sciences) and a special mind set and way of thinking. Too often scientists have the opinion that other people should do that. Holistic thinking and multi-disciplinary science are thought to be highly relevant but do not pay in the scientific community. How interesting this integration can be, is shown in Fig. 2, which showed the integration of all hierarchical levels from the genome to the crop.

Cooperation between disciplines (and filling up the gaps that exist between them) is essential to create knowledge chains that allow upscaling, downscaling and integration of knowledge. To make this interaction possible key-players at crucial parts of the knowledge chain must play an essential role in transferring, interpreting and transforming knowledge. There is a great need for leading scientists who can orchestrate and direct these processes. This will only work if they understand all disciplines involved at a cognitive and analytical level, if they speak the language of the different disciplines and if they are capable of using research instruments especially designed to allow for the integration (e.g., modelling, simulation, systems-analysis, etc.). The joint activity itself may create a common platform for addressing complex scientific questions along the entire continuum of the knowledge chain.

The need for joint activities to create these knowledge chains and platforms for scientific renewal are already evident in a few cases. The re-emergence or spread of important pests and diseases calls for a new approach, especially since traditional approaches obviously were not successful. World-wide movements of seed potatoes, ware potatoes and soil will make the need even greater. There is an urgent need to have a closer interaction between phytopathology, plant breeding and agronomy, to apply new knowledge in practice, especially to solve problems related to late blight, storage diseases, nematodes, bacterial wilt and Verticillium wilt, to name just a few.

Quality becomes increasingly important as the consumer will become more demanding and as the consumer has many attractive alternatives for potato consumption. Problems with bruising, reducing sugars, after cooking darkening, hollow hearts and internal rust spots have not been solved satisfactory. Again, physiology, breeding and agronomy will play an essential role in this knowledge chain. How complicated quality is, is illustrated in Fig. 3. Engineering of harvesting and storage, processing and utilisation will then have to assist in reducing the quality loss during the product chain after the primary production. These technologies can only be successful if the information on the quality of the product and its variability is properly used to optimise procedures and processes.

This element of knowledge chains and platform requires a strengthening of the ties between the disciplines, a common language to communicate and a shared set of research instruments to cooperate.

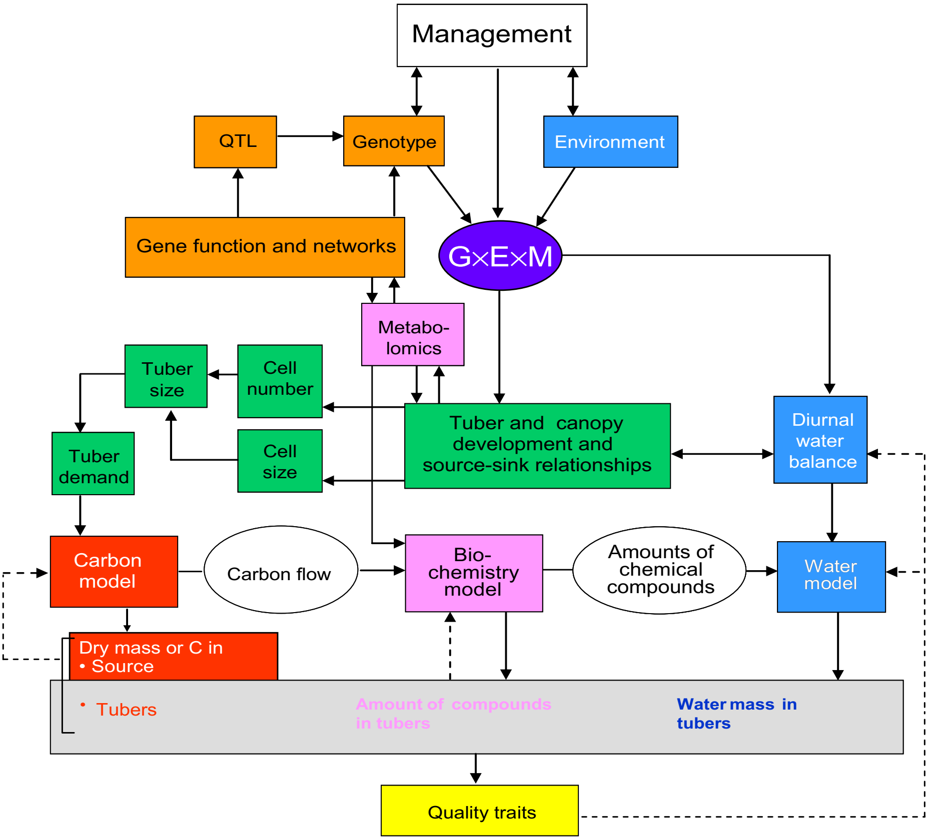

Figure 3 An extended model including possible links that allow upscaling the information from genomics and metabolomics to understand complex quality traits at organ and plant level via a computational systems biology approach, for predicting genotype × environment × management interactions (G × E × M) on quality characteristics for potato tubers. The lower part of the model combines a carbon model (which quantifies the production of dry mass or carbon in the source and in the tubers), a biochemistry model (which quantifies the amounts of different quality determining compounds) and a water model (which quantifies the flows of water into and out of the tubers). The carbon flow from the carbon model influences the biochemistry which again influences the water flow. The processes described in the carbon and water models are under the influence of environmental factors, whereas the processes in the biochemistry model are very much influenced by the phenology of the plant or the plant part. The biochemistry model can be fed with information from metabolomics that can be linked to gene function and gene networks and the model can be made genotype-specific by including the molecular-genetic information. A further expansion takes into account the effects of phenology both of the tubers and of the canopy. Cell number is a function of rate and duration of cell division. Cell size is determined by rate and duration of cell elongation. *Orange*: genetic components; *blue*: environmental factors, and water model; *violet*: genotype × environment × management interactions; *green*: intrinsic factors, phenology, source-sink relationships and fruit demand; *red*: dry mass and carbon part of the model; *magenta*: biochemistry model and metabolomics; *yellow*: resulting quality traits. *Continuous arrow*: information flow; *dashed arrow*: feedback mechanism. Based on Struik et al. (2005). Reproduced with kind permission from Elsevier.

The Role of the EAPR

The original aims of the EAPR (Wilson, 1958) were:

- to promote the exchange of scientific and general information relating to all phases of the potato industry between the various countries of Europe; and
- to encourage and assist international co-operation in the study of problems of common interest in this field.

The EAPR has been more effective in the first of these aims than in the second.

Typically, the EAPR has always been a crop and commodity-oriented society. With the trends in the agricultural and plant sciences described above, the need for such a society seems to lessen. However, the changes in the role of science in the society and the changes in the scientific community itself as indicated above, may provide new reasons for existence and create new opportunities. In the future, the EAPR might play a significant role by:

- establishing an effective interface between policymakers at the European level to gain support for potato science;
- contributing to public understanding of progress in potato science;
- contributing to public understanding of socio-economic benefits of potato science;
- providing information that will help policymakers to develop research strategies in potato science;
- assisting in harnessing the full potential of European potato science;
- assisting in establishing the knowledge chains and scientific platforms required for interaction between disciplines.

The EAPR may be able to take up this role by assisting in establishing large-scale projects, for example on developing systems approaches in biological processes, increasing industrial use and processing and designing more sustainable potato production systems.

Closing Remarks

I would like to end with a statement published as one of the propositions submitted with the thesis by Bjarne-Rask Poulsen (2005):

"The increasing tendency to see science as a job only is unfortunate: truth in science is like peace in the world: we will never get it, but must continuously fight for it."

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