# Comparative study on the economic importance of applied horticultural research

Programme 400-VI - EU-Access

Project report 2003 - 2004

R. Wustman, H. de Putter, T. Achterbosch & F. Adamicki

PPO internal project number: 510305

Authors:
- R. Wustman & H. de Putter, Applied Plant Research, Wageningen University and Research Centre (WUR), P.O. Box 430, 8200 AK Lelystad, the Netherlands
  Email addresses:    Romke.Wustman@wur.nl
                      Herman.deputter@wur.nl
- F. Adamicki, Research Institute of Vegetable Crops (INWARZ), Konstytucji 3 Maja 1/3, 96-100 Skierniewice, Poland
  Email address:    fadam@inwarz.skierniewice.pl
- T. Achterbosch, Agricultural Economics Research Institute (LEI), Wageningen University and Research Centre (WUR), P.O. Box 29703, 2502 LS The Hague, the Netherlands
  Email address:    Thom.Achterbosch@wur.nl

Applied Plant Research (Praktijkonderzoek Plant & Omgeving B.V.)
AGV Research Unit (Arable Farming, Field Production of Vegetables and Multifunctional Agriculture)
Adress       :   Edelhertweg 1
             :   P.O. Box 430, 8200 AK Lelystad, the Netherlands
Telephone :   +31 320 29 11 11
Fax          :   +31 320 23 04 79
E-mail      :   infoagv.ppo@wur.nl
Internet    :   www.ppo.wur.nl

# Table of contents

# Map of the EU



**Countries of
the EU**

- Austria
- Belgium
- Denmark
- Finland
- France
- Germany
- Greece
- Ireland
- Italy
- Luxembourg
- Netherlands
- Portugal
- Spain
- Sweden
- United Kingdom

**EU Accession Countries
(2004)**

- Cyprus
- Czech Republic
- Estonia
- Hungary
- Latvia
- Lithuania
- Malta
- Poland
- Slovakia
- Slovenia

**EU Candidate
Countries**

- Bulgaria
- Romania
- Turkey

# Acknowledgements

This report is the result of a project involving six countries. The text below acknowledges the contributions made by a number of persons.

The contributions are specified for:

1       Crop statistics: data for selection of crops.

Czech Republic      :      J. Zika; previously: Ministry of Agriculture, Prague
Hungary             :      A. Juhász; Research and Information Institute for Agricultural
                           Economics, Budapest
                           K. Hrotko; University of Agriculture, Budapest
Poland              :      F. Adamicki; Research Institute for Vegetable Crops, Skierniewice
                           J. Mierwinski; Institute for Agricultural and Food Economics,
                           Min. of Agriculture, Warsaw
                           K. Zmarlicki; Research Institute for Pomology and Floriculture,
                           Skierniewice
Slovac Republic     :      L. Nagyová; Faculty of Economics & Management,
                           Slovac Agricultural University,  Nitra
Slovenia            :      N. Fajt; Fruit-growing Centre, Bilje / Chamber for Agriculture and
                           Forestry of Slovenia, Agriculture and Forestry Institut, Nova Gorica

2       Specific data required for assembling cases required for calculations with the economic surplus method (model). The latter data were most important, as they were the basis for the actual study on the economic importance of applied horticultural research in EU-accession countries.

Netherlands         :      J. Baarends, M. Groot, F. Maas; Applied Plant Research, Randwijk
                           R. van den Broek, T. Huiskamp, H. Versluis; Applied Plant
                           Research, Lelystad
                           T. Loosjes; De Groene Vlieg, Oude Tonge
                           J. Schipper; De Groot & Slot Allium BV, Heerhugowaard
                           J. Schoneveld; former scientist Applied Plant Research, Lelystad
                           E. Steenge; consultant, onion specialist and former director
                           Netherlands Onion Federation, Colijnsplaat
                           D. van der Zeijden; Bejo Zaden, Warmenhuizen
Poland              :      F. Adamicki; Research Institute for Vegetable Crops, Skierniewice
                           K. Zmarlicki; Research Institute for Pomology and Floriculture,
                           Skierniewice

3       Comments
Netherlands         :      A.P. Everaarts, M. Hoorweg, S.F. Plaat, H. Schoorlemmer;
                           Applied Plant Research, Lelystad
                           P.P.L.M. Verhagen, National Reference Center for Agriculture,
                           Nature and Food Quality, Ede
Poland              :      M. Rogowska; Research Institute for Vegetable Crops, Skierniewice

# Summary

A study on the cost-benefit analysis of applied agricultural research was carried out in two EU member states: the Netherlands and Poland. Literature has shown many times the large benefits of agricultural research. Governments used to be committed to finance such research, however during recent years they have shifted their attention away. Privatisation and restructuring of agricultural research in new EU member states have put additional pressure on the continuity of applied agricultural research in these countries.

The report provides background information on economic impact assessment, methodologies and on the analysed cases. Four crops were selected for the study. Two fruit crops: apple, pear and two vegetable crops: carrot and onion.

The economic surplus approach was used to assess the costs and the benefits of seven research projects. A spreadsheet model developed by W. Masters was applied to calculate the returns to society relative to a hypothetical situation without the new technology. Important indicators for return are the Net Present Value (NPV) and the Internal Rate of Return (IRR).

The returns to society were mostly high. Computed IRRs varied from 81 to 14,113 %. The NPVs ranged from 1 million euro for the least profitable project to 464 million for the most profitable project. While results are probably overestimated, even if the true gains to society are less than a factor 10 the conclusion that applied horticultural research is a profitable investment remains firm. High NPV values were found in cases with high adoption rate, substantial size of the acreage and significant yield increase. High IRR values were found in cases with a short adoption period.

The results confirm that governments need not abandon applied agricultural research because it causes losses to society. We reached four conclusions in this study:

- Applied agricultural research provides large returns to society
- The scale of applied research in Polish horticulture is small compared to the Netherlands
- Impact assessment is hampered by data availability problems
- Continued (or even expanded) public agricultural research in the new EU member states is justified but the policy incentives for private R&D must be favourable.

In addition, it is argued that agriculture and food production are subject to strong dynamics to which the (applied) research system must be able to adapt. This will require an effective set-up of a system of applied research in horticultural crops on at least four elements: purpose; priority setting; organisational structure; and funding strategies.

This study was funded by the Ministry of Agriculture, Nature and Food Quality of the Netherlands, within the framework of the EU Access program (400-VI).

# Conclusions

This study reaches the following conclusions:

1) **Applied agricultural research provides large returns to society.** The impact assessment literature predicts that agricultural research provides substantial gains to society (measurements based on the concept of economic surplus). An evaluation of five applied research projects in horticulture, three in Poland, two in The Netherlands, confirms this pattern. There were large returns to seed treatment research in Poland. Carrot research produced a return of over four thousand %, onions returned over 700 %. A third project, on chemical thinning of apples, returned modest losses. These three projects only generated a total net present value of over 450 million euro. Results have been corrected downwards for the bias of evaluations on the project level instead of the programme level. Although the results are probably an overestimate, even if the true gains to society are less than a factor 10, the conclusion that applied horticultural research is a profitable investment, remains firm.

2) **The scale of applied research in Polish horticulture is small.** Relative to production volume, R&D expenses in the fruit sector in Poland are at least 3 to 4 times smaller than in The Netherlands. In order to remain competitive in the EU market agricultural research in Poland may have to expand substantially.

3) **Impact assessment is hampered by data problems.** The evaluation of agricultural research in the new EU member states in Central and Eastern Europe and in The Netherlands is hampered by a lack of data on costs and benefits of agricultural R&D. The research structure in Poland and in The Netherlands has no routine of assessment (ex-ante or ex-post) of the impact of their research programmes.

4) **Continued (or even expanded) public agricultural research in the new EU member states is justified but the policy incentives for private R&D must be favourable.** Concerns of rural development and the evolution of public concerns on agriculture—such as food safety, animal health, and environmental protection—provide strong justification for continued public involvement in agricultural research. In other areas of research, especially in plant breeding, governments best provide a favourable context for private research. This is done by defining and enforcing intellectual property rights, and by providing the options for effective linkages between basic research and applied research. Thus, governments can play a significant role for private investment in agricultural R&D.

# 1    Introduction

There are large benefits to public agricultural research, both to basic (science-oriented) research as to more applied (technology-driven) research. This message has been underlined many times by leading international institutes such as IFPRI or ISNAR (see Alston *et al.* 1998, 2000) and the Economic Research Service of the US Department of Agriculture (e.g. Fuglie *et al.* 1996). National governments have traditionally, provided most funding for agricultural research. The investment was in particular high when a government felt the need for either food self-sufficiency or saw great economic prospects in large export opportunities due to favourable production circumstances. While public agricultural research has maintained its volume over the years, there have been shifts in the orientation of research. During recent years, governments have shifted their attention away from applied agricultural research.
There are various possible explanations of this shift. One possible cause is that the returns in basic agricultural research or in product development are simply giving better returns. A second reason may be that governments have adjusted their priorities within agricultural research: i.e. from production oriented research to quality ('quality of life') type research. A third possible cause is that the private sector has taken over the public role in applied research. This relates to the development of chain control systems. Shelf life of products was often limited due to poor quality control. Once such control mechanisms improved, the need for food production in the respective home countries was reduced in favour of import of good quality and at financially attractive price levels. These market developments provided an incentive for many private firms to expand their activities in the area of applied research.

In the new EU member states in Central and Eastern Europe, privatisation and restructuring of agricultural research and extension systems put additional pressure on the system of applied agricultural research. In general, a sound infrastructure for horticultural research and development had previously been established over decades. Because of the presently rapidly changing conditions, with regard to funding, this structure, however, could face disintegration when no appropriate action is taken. A re-orientation and re-organisation of applied horticultural research is therefore necessary and unavoidable.

This report examines the economic importance of applied horticultural research in Poland and The Netherlands. The report provides background information on impact assessment, assessment methodologies and shows some results through a number of cases in the Netherlands and in Poland.

## 1.1    Objectives of the project 'Comparative study on the economic importance of applied horticultural research in EU countries'

The project 'Comparative study on the economic importance of applied horticultural research in EU countries' (or: R&D project) has two long-term and two short-term objectives. The long-term objectives are:
- The continuation or the establishment of an economically sound horticultural research and development network that includes effective knowledge transfer.

- The establishment of a market-oriented horticultural production sector that is supported by applied research.

A shortcoming in the discussion about horticultural research is that the value and contribution of research and development to the horticultural sector is generally not quantified, or taken into discussion. This contribution indeed is difficult to measure or to quantify. However, efficient and cost-effective horticultural research and development, may considerably contribute to strengthening horticultural production systems. This led to the definition of the following short-term objectives for this project:
- Analysis of the returns to applied horticultural research.
- Contribution to the continuation of applied horticultural research services funded both by governmental and non-governmental sources.

This study is undertaken within the research programme "Sustainable and competitive agricultural supply chains in pre- and post- European Union accession countries." The Netherlands Ministry of Agriculture, Nature and Food Quality (Anonymous 2002) finance this programme (400-VI).

## 1.2 Aims of the report

In accordance with the objectives, this study aims to calculate and evaluate the macro- and/or micro-economic benefits of horticultural research in two EU countries. The work is aimed at applied research as this type of research has a direct impact on the production by growers. Briefly the aims of this report are:
- to show the importance of calculating costs and benefits of applied agricultural research
- to provide insight in the tools to assess costs and benefits
- to encourage research institutes and researchers to apply such methods
- to provide a tool to stakeholders to evaluate research proposals
- to show how to prepare and collect necessary data for evaluation

# 2      Applied agricultural research

## 2.1      Research typology

What distinguishes applied agricultural research from other research efforts? The Economic Research Service (ERS) of the United States Department of Agriculture (USDA) maintains the following typology for agricultural research:

-        Basic research

Basic research is conducted to determine the basic cause or mechanism of why certain results are obtained.

-        Applied research

Applied research develops knowledge or information directly relevant to technology, to product development, or to market possibilities.

-        Developmental research

Developmental research generates a new or improved technology or product; supports market testing and introduction; maintains product performance and quality; or meets regulatory requirements (Fuglie *et al.* 1996).

## 2.2      Quantitative and qualitative research

The specific objective of applied research is to aim at direct implementation by end-users: growers, farmers. Two types of research projects can be distinguished:

1.  Quantitative (or yield-driven) research
2.  Qualitative (or quality-driven) research

### 2.2.1      Quantitative research

Quantitative research is characterised by generating productivity growth in the field, e.g. through:

- Cost price reduction:
    - o   Saving on the cost of labour
- Yield increase through the use of:
    - o   New higher yielding varieties (breeding and crop variety testing)
    - o   New crop protection compounds and techniques
    - o   New weed control techniques
    - o   New fertiliser formulations
    - o   Improved storage and handling methods

This type of yield-driven research is important as long as yield increases are considered to be of primary interest. In a number of countries, the importance of this type of research has decreased as attention has been shifted towards qualitative research.

The financial benefit of quantitative research can rather easily be assessed by measuring the impact of the innovation on changes in quantities of output or input.

### 2.2.2 Qualitative research

In markets where the supply of sufficient amounts of food has been secured, consumers respond in their purchase to concerns of quality and variety. In addition, government increased their regulation on such issues as food safety and the environment. This has posed a challenge for applied research to move from yield-driven to more qualitative research. At the same time, Northwest European countries funding of qualitative research has increased as it contributes more to a better price setting. This development has started in abundant supply markets where additional yield increases were not creating extra farm income. Simultaneous developments are markets (or processing industries) in need for specific raw material for a special end product. Qualitative research can be described by an increased value of (raw or fresh) products through:
- Improved external appearance of the product
- Improved internal quality for processing
- Availability of products out of season
- Substituting environmentally harmful pesticides by environmentally friendly techniques or less harmful pesticides (integrated control of diseases, pests and weeds)
- Introduction of new crops for specific markets requiring a specific quality

In addition, public policies have triggered research aimed at several fields, including:
- Cohesion between rural and urban areas
- Establishment of small scale nature parks
- Agriculture in relation to environment
- Introducing and maintaining biodiversity at farm and regional level
- Reduction of pollution by reduced use of fertilisers and pesticides
- Organic crop growing
- Agro-eco tourism (agro-tourism)
- Tracking and tracing (food quality)
- HACCP

Qualitative research has led to:
- Breeding programmes emphasizing on improved quality aspects rather than increased yield performance
- Development of integrated control approaches

## 2.3 Funding sources

Funding of agricultural research is done through a number of sources:
1. Public bodies
2. Producers' organisations
3. Third parties

Funding of applied research in arable and field grown vegetable crops in the Netherlands averaged over the period 2000-2003 was (Huiskamp 2004):
- 45 % Government
- 25 % Producers' organisations
- 30 % Third parties

The share of government funding is often higher in other countries. Funding of applied research in carrots and onions in Poland was 100 % by government during 1988-2002 (Adamicki 2004).

### 2.3.1 Public bodies

Governments whether national, local or international (i.e. EU) are important funding sources of applied agricultural research. In some countries, the level is 100 % government funding, in other

countries it may contribute to less than 50 %. Government funding is often based on specific programmes, highlighting governments' priorities in production or other matters.

Public body funding in the Netherlands has shifted from production-oriented research towards public interest research (Huiskamp 2004).

### 2.3.2 Producers
Producers are funding applied agricultural research through:
* special projects
* a systematic approach of priority setting at a national level by government and non-government (producers' and marketing organisations).

In the latter approach, the share of funding between government and producers' organisation often amounts to 50:50.

The Product Board for Arable Crops (HPA) and the Product Board for Horticultural Crops (PT) represent major contributors to the budgets of applied agricultural research in the Netherlands.

### 2.3.3 Third parties
Third parties active in agricultural research funding can be various:
* breeding companies
* mechanisation companies
* agrochemical industries (crop protection compound developing companies)
* auctions
* processing industries
* retail chains
* individual farmers

The activities for third parties may include very specific topics:
* testing of a new agrochemical
* development of a cultivation and storage regime for a new variety
* analysing the production and marketing chain of a product
* analysing crop production and storage system at growers' level
* strictly outlined objectives in terms of time frame

## 2.4 The justification for government intervention in applied agricultural research

The economic justification for governments to intervene in agricultural research is that there exist "market failures" due to which private companies undertake too little research of a type that is beneficial to society. One such failure is that it is often difficult to protect agricultural innovations; for instance, the procedure of a new cropping technique is easily copied by competing growers. This free-rider problem can put a brake on research, and can justify why the government makes public funds available in order to produce the desirable quantity and mix of research.

Because public funds are limited, governments generally support those types of research with high pay-offs to society but which private firms are little inclined to support. Historically, the private sector has undertaken much of the research on seeds, chemicals, and machinery, areas

where there are firm options to secure the gains through licenses and patents; also, in the area of post-harvest technologies much of the research is undertaken on the initiative of companies that use innovations to support their position in the market vis-à-vis competitors (Alston *et al.* 1998: 12). The organization of more basic research was left to governments because of the difficulty in capturing the private benefits of such research, or because of the scale or scope at which it this type of research is done efficiently.

Applied agricultural research is sometimes done by companies, sometimes by government, and sometimes in a joint public-private effort. Alternatively, the research is undertaken exclusively in the public sector, but on contributions from both sectors.

# 3     Agricultural research evaluation

The economic impact studies literature includes a wide range of levels of impact analysis, from national level to programme and project level. One popular type of partial impact study is adoption studies. The latter looks at the effects of a new technology (i.e. new cultivar) and takes a rather limited look at the effects of the research finding (i.e. a new variety) at farmers' level. Adoption cost studies are done only ex-post.

Non-economic impact assessments evaluate investments in terms of the impact on the natural social or institutional environment.

-     Environmental Impact Assessment

Environmental Impact Assessment (EIA) is defined as the process of identifying, predicting, evaluating and mitigating the biophysical, social and other relevant effects of development proposals prior to major decision being taken and commitments made. Agriculture being closely associated with natural and biological resources should use EIA as a tool in agricultural research planning. This applies in particular to environmental issue-oriented research institutes.

However, the meta-analysis by Alston *et al.* (2000) revealed that only 11 out of a total more than 1,100 research evaluations had included environmental variables in the rate of return analysis. A major drawback to use EIA in impact assessment is the lack of quantitative data. Most work has been done based on qualitative and speculative data. Methodology development in the environmental impact assessment has progressed but much slower than in the economic impact assessment field.

Agricultural R&D can positively affect the balance by generating technologies that are both privately and environmentally friendly in comparison to the current technology (Alston *et al.* 1998)

-     Social impact assessment

Social Impact Assessment (SIA) is described as the process of identifying the future consequences of a current or a proposed action, which are related to individuals, organisations and social macro-systems. SIA is an ex-ante assessment. SIA is relevant to agricultural research and technology development as both have an impact on social and human behaviour. There is little work done in this field.

-     Institutional impact assessment

Institutional impact assessment involves the evaluation of the performance of a research organisation in non-technological research activities such as training, networking, development of methodologies and advisory services in the areas of research, policies, organisation and management. As many research institutes spent money on such activities, an assessment of the institutional impacts of such activities should be an integrated part of an overall impact assessment. So far, little methodological work in this area has been done (TAC 2000).

## 3.1     Estimating the social returns of public investments

### 3.1.1     Impact assessment: past and present in agricultural research

Impact assessment is an established practice of evaluating the effects of public-goods investments projects and programmes such as infrastructure, health, education, transportation and urban development projects. Impact assessment is often used to estimate the impact of

future programmes (ex-ante evaluation) or to evaluate the impact of past programmes (ex-post impact assessment). There is an international association for impact assessment (IAIA). IAIA is the International Association for Impact Assessment (www.iaia.org), organized in 1980 to bring together researchers, practitioners, and users of various types of impact assessment from all parts of the world. IAIA is a forum for advancing innovation, development and communication of best practice in impact assessment.

Following TAC (2000), we define impact as the broad, long-term economic, social and environmental effects resulting from research. Such effects may be anticipated or unanticipated, positive or negative at individual level or at organisational level. Like most studies in the field, this study seeks to explore economic impact only.
In the case of agricultural research, economic impact assessment asks the question whether the research resulted in technologies, management strategies and capacity strengthening that lead to more agricultural production per hectare at lower cost per unit of output or to a similar output at lower cost per unit of output (modified after TAC 2000). Depending on the level of analysis, costs and benefits are measured at the level of the farmers adopting technologies, at a restricted geographical level, or at the level of society.

Studies on the returns of investment in agricultural research were initiated in the fifties of the twentieth century. Grilliches (1958) is considered the founding father of studies into the social returns of agricultural research.
The Netherlands Council for Agricultural Research (TNO 1970) initiated in 1966 a study on the economic evaluation of agricultural research in the Netherlands and published its report in 1970. The Dutch study separated policy-oriented research from farm-oriented research. The study concludes that quantification of farm-oriented research is easier. This also implies the more complicated comparison of policy-oriented with farm-oriented research as different methodologies have to be used.
Widespread international attention for the costs and the benefits of agricultural research received a boost with the establishment of the International Service for National Agricultural Research (ISNAR). ISNAR was founded in 1979 with headquarters in The Hague, the Netherlands. Its mandate was to promote "new arrangements that promote more effective generation of new knowledge" ([www.isnar.cgiar.org/about_isnar/mandate.htm](www.isnar.cgiar.org/about_isnar/mandate.htm)). ISNAR ceased operations on March 31, 2004. A new ISNAR programme is being developed under the governance of the International Food Policy Research Institute (IFPRI), another institute with an extensive record of accomplishment in evaluating research. In 2000, IFPRI published a meta-analysis on the rates of return to agricultural research and development that revealed high economic returns to farm-oriented research (Alston *et al.* 2000).

### 3.1.2 Impact assessment in agricultural research: pro and contra
Many agricultural research managers are not convinced of the usefulness of impact evaluation. There are a number of reasons for the reluctance to undertake impact assessment of agricultural research. ISNAR initiated a forum on priority setting in agricultural research in 1998. The informative results are still accessible on the internet (ISNAR undated) (http://www.isnar.cgiar.org/fora/priority/index.htm):
1. Resources are scarce: therefore, one would limit the amount of money spend on non-research issues (when impact assessment is considered as a non-research issue). The apparent thinking is that any money spend on a non-research issue does not contribute to the research and the implementation of the research findings.
2. Most research managers consider the benefits of applied research to be obvious. Therefore,

they appear not to see any reason for an evaluation of their work.

3. An impact assessment study requires human resources and materials. A study to evaluate the impact of research requires extra funding: capacity and materials. It can be expected that future developments will tend to emphasize the anticipated impact of research.

4. The fear that evaluation of research results would produce unfavourable cost-benefit ratios. This fear will require an ex-ante priority setting, minimizing the risk of unfavourable outcomes of a cost-benefit analysis.

5. The time lag between the investment in research and its impact can be critical. Long time lags between research investment and its implementation mean that serious consequences of reduced funding today will not be visible for many years. Consequently, under-investment in research may be visible only when it is too late (after Alston *et al.* 1998).

6. Impact assessment has a number of methodologies at its disposal. Different methodologies may lead to different conclusions. Differences in methodologies in estimating the benefits from some types of research may therefore be another reason for the reluctance to conduct impact assessment.

Assessing the effects of agricultural research is complex and expensive because it requires:
- Costly field work and analysis, building and institutionalizing data systems, organisational and financial resources
- Expertise and human resources to analyze data and assess the impacts

The cost of impact assessment depends on the scale of the assessment (national, programme or project level) and depth of the assessment. The economics of impact assessment are hardly documented in literature. Australia has carried out relatively many assessments and found 3-4 % of the research and development budget could profitably be spent on impact assessment (TAC 2000).

Despite these drawbacks, there are many arguments in favour of impact assessment. Agricultural innovations (i.e. technology, cultivar) will be adopted when they are profitable at farm level. These innovations change the relationship between inputs and outputs. Either more outputs for a given set of inputs or less inputs at a given level of outputs. This provides several reasons to undertake impact assessment:

1       Accountability: reporting to stakeholders
2       Improving programme design and implementation: improving efficiency of research
3       Planning and priority setting: ex-ante assessment

Stakeholders are persons or institutions having a vested interest in the success of a particular undertaking. Stakeholders for a priority setting exercise are the following categories:
- Users: farmers' organisations, food processors, consumers, Non-Governmental Organisations (NGOs), market brokers
- Suppliers: industry, commerce
- Scientists: researchers, extension officers
- Decision makers: research managers, policy makers, funding agencies

The role and the participation of a stakeholder category differ. The composition of a stakeholder group is crucial; however, communication may also differ in effectiveness (i.e. resource poor farmers).

### 3.1.3      Three stages of research evaluation

Three stages of research evaluation can be distinguished. There are ex-post assessment, assessment of on-going research and ex-ante assessment (TAC 2000).

1    Ex-post assessment. The result is used to account for the past use of resources and as a useful input for research policy making and future planning (kind of ex-ante assessment).
2    Monitoring and evaluation of on-going research. Aims at presenting on-going activities and revision of on-going plans.
3    Ex-ante impact assessment is looking at the future: specifically for expected impacts from research. The ex-ante assessment is usually done at project level but can be applied at research system level.

Impact assessments should be done when needed and as required. This means that all three stages of research evaluation can be done for a particular project. Most impact assessments are conducted because decision makers, policy makers, and research fund suppliers need them as a pre-condition for research support. The increased number of both ex-ante and ex-post evaluations are explained by this factor.

This increased capacity will also be a useful tool to conduct self-evaluation impact assessment. Actually, impact assessment, whichever type of assessment, should be internally driven and be used as a management tool. Implementation of this tool at institute level is desirable as it can contribute to the economic effectiveness of the institute.

The present report deals with ex-post assessment, which is the reason of providing limited information on the two latter mentioned stages of research evaluation.

## 3.2    The economic impact of applied research in fruits and vegetables in EU Accession countries

The present study aims to estimate the economic impact of applied research in horticultural crops in selected east-European countries that recently joined the EU. It is an ex-post estimate of the costs and benefits of selected research and development (R&D) projects aimed at a direct impact on growers of fruit and vegetables. The issue at stake is whether society as a whole has benefited from the research investment, i.e. whether the benefits to farmers and consumers outweigh the costs borne by government and producers.

Estimates of economic impact apply the concept of **economic surplus**. Economic surplus is a monetary value that comprises what economists call consumer surplus and producer surplus. Consumer surplus is a measure for the difference of what consumers are willing to pay for a product, and the price that they actually pay in the transaction; paying a price that is lower than you were prepared to pay adds to a sense of "welfare". Producer surplus is the difference between the price that producers receive for their products and the actual costs of production; the amount to which the price exceeds costs is a profit. Economic surplus, the sum of all surpluses of all producers and all consumers for all products, provides a measure of welfare in society.

To understand this, it is instructive to go through the basics of supply and demand theory, and refer to figure 1 below:
- The quantity of producer supply is determined by price through a relation defined as the supply curve. In its simplest form this is a straight line with the formula: $P_s = a_s + b_s Q_s$.
- The quantity of consumer demand curve is determined by price through a relation defined as the demand curve. In its simplest form this is a straight line with the formula: $P_d = a_d + b_d Q_d$.
- Market equilibrium occurs where the supply and demand curves intersect: at the equilibrium price, supply ($Q_s$) equals demand ($Q_d$). In formula: $Q_s = Q_d$ and $P_s = P_d$.

- The geometrical representation of the economic surplus can be found to the left of the equilibrium point: the triangle area between the demand curve and the P1 price level measures consumer surplus; the triangle area between the supply curve and P1 measures producer surplus.
- Project appraisal or impact assessment is all about estimating shifts in the supply curves or demand curves. A useful innovation in agriculture will improve the productivity of farmers' resources: adoption of the technique allows a larger value of production with a similar amount of resources; this implies an outward shift of the supply curve (to the right). All else equal, the increase in supply will push the price downwards, allowing for more demand and more sales. The adoption of technology causes consumer surplus to increase due to the price drop and the increased quantity consumed. Producer surplus will rise, but only if the increased quantity sold makes up for the decrease in price. Note that we always measure *changes* in economic surplus, rather than absolute values.

Figure 1. The Demand and Supply Framework



### 3.2.1 Masters' Economic Surplus method

Because we measure the change in economic surplus, the key to ex-post impact assessment is that one has to make assumptions on what the world would have been like had the research investment not been done. Several techniques are available to estimate economic surplus. These include simple cost-benefit techniques and econometric techniques that rely heavily on data. See Alston *et al.* (1998). This study applies a spreadsheet model developed by Dr. William Masters from Purdue University (USA) (Masters 2000): Masters' Economic Surplus method (MES). This model actually assesses the benefits of a selected research project on the hypothesis of reconstructing a situation without research. The purpose of the supply and demand curves in MES is to establish two scenarios simultaneously. A scenario what would happen with research and a scenario what would happen without research.

Economic surplus is the difference between these two situations as a result from a single measure. Any change in economic surplus is a measure of the social benefits (social gain) derived from implementing the new technology developed in a research project. Figures 2 and 3 show that the market can respond differently to adoption or improvement in the farm system. Figure 2 represents a scenario in which, as a result from new technology, the supply curve shifts to the right; however, the demand response to the resulting price decrease (to P2) is limited. In Figure 2, consumers are more responsive to a price decrease. Consumers benefit in both scenarios: increased availability results in a lower price. Producers are unlikely to gain from the technology adoption in scenario 1, but they are better of in benefit from the second scenario (increased demand from consumers). The impact on society is the sum of consumer and producer surplus (plus efficiency gains – see Alston *et al.* 1998), and society reaps positive gains in both scenarios.

Figure 2. Limited consumer response

Figure 3. Strong consumer response

| Scenario 1: Price decrease (P) leads to limited increase in market demand (Q) |
|---|

| Scenario 2: Limited price decrease (P) leads to sharp increase in market demand (Q) |
|---|



The diagrams reveal that the consumer surplus approach not only provides a measure for the total gain to society, but also on the distribution of gains and losses amongst consumers and producers.

### 3.2.2 Strengths and weaknesses of Masters' spreadsheet model

The following discusses the strengths and weaknesses of the Masters' spreadsheet model for impact assessment in agriculture.

**Strengths**

The key strength of MES is its simplicity, which relates to its the straightforward method of constructing the non-research scenario, and the modest data requirements:

- Simple solution to the "what if …?" question.

The most difficult task of research evaluators is that (for ex-post assessment) they must develop a notion of what the world would have been like if the research investment had not been done. Only then can the impact of the investment on society truly be assessed. MES is very straightforward in addressing the challenge: it simply assumes that all changes in consumer prices, and produced volumes can be attributed to the research under evaluation. MES is developed around a simple supply-demand framework in which all changes in the environment translate into altered prices or volumes.

- Data requirements are limited

The better the data, the more valid is your impact assessment. MES is no exception to the rule. However, due to transparent assumptions in the model MES can be applied with limited amounts of data. This is especially convenient in the representation of demand and supply structures: the spreadsheet easily incorporates elasticity's (coefficients that represent the structure of demand and supply) from literature.

- Tools and techniques are available on the web.

A major strength of MES is that the MS Excel spreadsheet and extensive documentation is available on the World Wide Web for free.

- The agricultural researchers can apply it themselves.

Calculations on the economic importance of applied horticultural research (cost and benefit calculations) are usually carried out by economists. However, a survey of literature revealed the availability of cost-benefit assessment methodologies that can be operated by non-economists.

The advantage of this approach is that agronomists can rather easily assess the anticipated value of their intended research.

**Weaknesses**

Masters' model has a number of limitations, which mostly relate to its sensitivity to the assumptions made. The below-listed considerations reflect the limitations of MES.

- Assumptions from model

The numerical results on economic surplus are very sensitive to assumptions regarding the market structure (demand and supply elasticity's) and the discount rate. To accommodate for this concern, a sensitivity analysis around the critical assumptions is provided in the chapter 5 (Table 6).

- Bias towards yield-driven research

MES cannot directly evaluate the impact of qualitative research, i.e. research aimed at improving quality-traits or aimed at addressing concerns regarding consumer health hazards, environmental degradation, animal health, etcetera. Such improvements have to be converted into a measure of volume or into prices. This can be done, but the assumptions in conversion are debatable.

- Effect(s) of basic (or fundamental) research

Applied research can be conducted once basic research has delivered findings, which after modification of specification can have an impact at farmers' level. The logical structure (or sequence) of research is:

Basic research→ Applied research→ Knowledge transfer→ Implementation by end-user

The cost of basic research and the cost of knowledge transfer are excluded from our model calculations. Therefore, the model predicted benefits are overestimated.

- Exclusions of spill-inns and spill-overs.

Agricultural research findings are published internationally and its results are therefore available in many regions around the globe. Agricultural research is operating in international markets and is not restricted to a single country. It is internationally exchangeable without money changing hands.

This implies that the benefits from research (funded and) developed in a certain country may be implemented in other countries. The (spill-over) benefits from this international use are excluded from our calculations.

On the other hand, the utilization of research findings (spill-in) in other countries may have contributed to the social gain in country A without country A having paid for it. The latter situation is excluded from our model calculations.

- The effect of the new technology must be substantial.

It must be feasible to achieve a quick adoption (and; for the supplier of the new technology; a large area (market volume)).

These conditions are important as subsequently developed 'new technologies' will try to 'overtake' the previously developed 'new technology' as quickly as possible.

## 3.3 Evaluation criteria: NPV and IRR

William Masters' application of the concept of economic surplus provides a pragmatic method to measure the benefits and the costs of agricultural research to society. The next step is to define criteria for the evaluation of benefits and costs. Two common criteria in project appraisal are the net present value, and the internal rate of return. Both are of use in the present study.

### 3.3.1 NPV
An important indicator to compare costs and benefits is the project's Net Present Value (NPV).

The NPV is a balance of all costs and benefits that will flow from the research activity in the future, discounted to one point in time. This is the amount of money by which total benefits exceed total cost of the project and its implementation. NPV is mostly calculated before making an investment (ex-ante assessment). A normal pattern in R&D is that the costs go ahead of the benefits: the cost of the research has to be earned back before the research will generate value for society. This makes the discount rate a crucial assumption in the evaluation: the discount rate reflects the time preference, i.e. the weight that is given to gains and expenses that occur in the future vis-à-vis those that occur on shorter notice.

Appendix 1 specifies through a formula the data required to calculate NPV. The highest NPV values are obtained under conditions with:
- High cash flow values ( P ) shortly after implementation (adoption) of the research findings
- Low discount rates in cases where the gains accrue more on the long run
- Short adoption period (= quick adoption of research findings)
- Large area of implementation (large area reflects a large impact on market volumes)

The related criterion is that NPV should be positive (larger than 0) to justify the investment. When NPV's return negative, the costs outweigh the gains. A shortcoming of NPV's is that these do not provide information on the proportion of the gains to the invested sum. A modest but positive NPV can be an acceptable result of a limited research project, but not acceptable if it is the result of a large multi-annual research programme. For that reason, NPV's are best interpreted in relation to the scale of the investment.

### 3.3.2 IRR

A second important indicator to compare costs and benefits is the Internal Rate of Return (IRR). The internal rate of return can be compared to any other return rate. Examples are: the cost of borrowing funds from a bank, the returns earned in other investments, or the interest earned from a bank savings account (Masters 2000). An example to explain IRR is: an initial investment of € 1 at an IRR of 435 % will generate € 4.35 after one year.

Appendix 2 specifies through a formula the data required to calculate IRR. The IRR relates strongly to the NPV as both indicators are computed from the same data: in fact, feeding the IRR as the discount rate into the computation of the net present value will return NPV=0. By implication, when the IRR exceeds the benchmark (i.e. the potential return to alternative investment) this is an indication that the prospected investment is a good destination for funds.

When the found (calculated through the input of actual data into the model) internal rate of return is higher than the calculated value in that situation, it implies a positive result (= justification) of the investment.

As they convey alternative information, the IRR and NPV are often applied jointly when evaluating research, in addition to information on the scale of investment.

Plum trees in full bloom

# 4 Data

## 4.1 Data requirements

Masters' model requires quantitative data, these data are historical data due to the nature of the model (ex-post assessment). The model uses agronomic data, which are converted into economic values. Five, occasionally four, sources are needed to acquire such data:

1. Growers, extension services: adoption cost, adoption rate
2. Ministries and statistical offices: acreage, yield levels, market prices
3. Economists: elasticity of supply, elasticity of demand
4. Research: cost of research, results of research
5. Own surveys: when data are lacking

The number of sources, the accessibility of data and the reliability of data can fluctuate. When insufficient data are available, one may decide to switch to expert knowledge through interviewing of experts.

MES is biased towards the evaluation of yield-increasing research. The effects of technology research that results in enhanced quality-traits or reduced environmental damage cannot be estimated directly through MES. It requires a conversion of such non-yield benefits into some measure of production volume or price.

In assessing research projects in East European countries, the present study excludes any spill-in effects from the application of research done elsewhere from the model calculations. Likewise, spillover effects of research into agricultural practices elsewhere are also ignored. In theory, spill-in or spillover effects could enter the project balance respectively as costs or benefits but this is not done due to a lack of data.

## 4.2 Conditions for data collection

It has been pointed out that data control and accessibility to data are very important conditions in order to conduct impact assessment studies. It is recommendable to document and maintain such data sets at research institute level.

1. Control is best maintained under such conditions.
2. The data can be used to assess the performance of such an institute. Performance meaning the contribution from the research institute to the social gains in the national community.

Literature cites a budget of 3-4 % of the total research cost should allow ex-post impact assessment to be made (TAC 2000).

## 4.3 Difficulties in obtaining required information and data

### 4.3.1 Project procedure

The project commenced with the very legitimate question on the economic benefits of financial means put into applied agricultural research. This question was formulated at the workshop held in Prague during October 2002 (Anonymous 2002) and has its origin in the experience of a number of EU-accession countries of reduced funding for agricultural research during recent years.

A major implication of the EU Access programme was that each participating country was to support the contributions of its own personnel. It was agreed that each government was to make funding (in terms of time) available to contribute to the 'Comparative study on the economic importance of applied horticultural research in pre-accession countries'. The major funding agency (Ministry of Agriculture, Nature and Food quality, The Hague, the Netherlands) confirmed this situation by making funding to the project team members available for international accommodation and international travel.

The implementation of the study consisted of a number of phases:
1. Selection of a methodology
2. Selection of crops based on statistical data
3. Selection of projects (= cases) within the selected crops
4. Acquirement of all relevant data per project (= case)
5. Using the real, historical data as input in Masters' model
6. Reporting and discussion of results

### 4.3.2 Data collection
Data collection, whether statistical or historical research data, requires time and therefore financial means. The project conducted the data collection on a step-by-step basis. The first step was to have a database on acreage, yield and production levels. The time involved in this step went rather smoothly.
The second step involved the identification of cases and the third step the collection of research data. Research data collection required more time and effort as such information is usually not easily assessable.

### 4.3.3 Data availability
The technical availability of data allowing the operations of the Masters' model appeared to be problematic. The model requires data from five, sometimes four, sources as described under 4.1. Pannell (1999) lists even more sources required for the (ex-post) estimation of on-farm benefits of agricultural research:
1. The estimated biological, technical and/or management changes from implementing research outcomes.
2. Any positive or negative side effects (internal or external to the farm) resulting from implementation of the research: including any environmental externalities and price impact from changes in supply and demand.
3. Costs to the farm of implementing findings from research.
4. Given (1), (2) and (3) the potential economic benefits per hectare or per farm.
5. The scale of the potential benefits: the number of hectares or farms potentially affected.
6. The proportion of the potential scale for which adoption occurs and the timing of the adoption.
7. The probabilities of different levels of success from the research.
8. Direct costs of undertaking the research over time.
9. The discount rate.
Pannell (1999) describes the uncertainty of obtaining accurate data of farm-level benefits and adoption with some interesting phrasing. Quote: 'economists often resort to heroic simplifying assumptions of dubious validity.'

Our experience showed that data sourcing for agricultural statistics was rather easy, as one can look for such data at Internet websites. Data on elasticity of supply and elasticity of demand can be obtained either from economic departments of ministries or from economic research

institutes.

Data sources 2 and 4 are more difficult to access as applied research scientists; governmental workers often are simply not aware where to get such data. Such data and information are not documented on a regular basis.

Moreover, the cost of agricultural research projects is often budgeted as lump sum funding for a research organisation. Only very recently, research organisations have been engaged in making and controlling specific budgets at project level.

Based on the persistence of scientists in the Netherlands and in Poland we have been able to collect data of research project costs.

Any analysis pursuing an evaluation of the benefits of applied agricultural research needs to have easy access to data sets. Such data sets need to be documented, stored and managed at research institute level. It may be a challenging task for a research director.


Data collection

# 5 Evaluating applied horticultural research projects in Poland and the Netherlands

## 5.1 Participating countries

The participating countries at the start of the project were: Czech Republic (CZ), Hungary (HU), Netherlands (NL), Poland (PL), Slovak Republic (SK) and Slovenia (SL).
As progress on collaboration was slow in some countries and because of withdrawal of persons, the project activities continued with two countries: Netherlands (NL), Poland (PL) and to concentrate data collecting on Hungary (HU). However no data from research projects carried out in Hungary were provided, due to the absence of persons willing to and able to provide data within the time limit set for this project. This situation clarifies the absence of output (except for the selection of the crops) from Czech Republic, Hungary, Slovak Republic and Slovenia.

## 5.2 Crops

The Agricultural Economics Research Institute (LEI) at The Hague advised to aim at similarity in research programmes. As there is more point in comparing seed treatment programmes for various crops, than making comparisons with alternative research programmes for similar crops: e.g. comparing seed dressing research with pest control research. This advice was formulated on the assumption that a limited number of cases would be available for the study. The restrictions on number of research programmes should have the positive effect to have better comparison possibilities within the programme. However due to a lack of data at programme level a shift towards project level had to be made during June 2003.

Table 1 : Selected fruit and vegetable crops with acreage in 1.000 ha.

| | | | CZ | HU | NL | PL | SK | SL |
|---|---|---|---|---|---|---|---|---|
| Year | | | 2001 | 2002 | 2001 | 2001 | 2001 | 2000 |
| Total fruit acreage | | | 17 | 76 | 18 | 358 | 7 | 4 |
| Fruit | International | Apple | 9 | 36 | 11 | 169 | 4 | 2 |
| | National | Pear | | | 6 | | | 0.2 |
| | | Plum | 0.9 | 9 | | | 0.6 | |
| | | Strawberry | | | | 38 | | |
| Total vegetable acreage | | | 26 | 115 | 42 | 192 | 45 | 2 |
| Vegetables | International | Onion | 5 | 5 | 15 | 34 | 4 | 0.1 |
| | National | Cabbage | 3.4 | | | | | 0.4 |
| | | Carrot | | | 8 | 33 | | |
| | | Cauliflower | | | | | 2 | |
| | | Green pea | | 21 | | | | |

Sources of data: Central Statistical Office of Poland, Hungarian Central Statistic Office, Czech Statistical Office, Statistical Office of the Slovak Republic, Centraal Bureau voor de Statistiek (NL)

and Statistical Office of the Republic of Slovenia.

Following this reasoning one major fruit crop (international fruit crop) and a major vegetable crop (international vegetable crop) growing in all participating countries were selected. Besides the international fruit and vegetable, a national fruit crop and a national vegetable crop were selected. The selection criterion was the acreage of the crop in 2001.



Cauliflower neatly packed in plastic crates

# 5.3 Case description

The initial focus of the study was to aim for cost-benefit calculations at programme level. Due to the anticipated lack of data, the focus had to be shifted from programme to project level. Accessibility of specific data such as budgets, research results, and rate of research implementation at growers' level was anticipated to be less at programme level in comparison with project level. This pattern appeared to be rather realistic as time progressed (April – June 2003). During June 2003 it was decided to choose for project level calculations. Chapter5 provides more background on effects of major factors and thereby shifts the discussion from project level to programme level.

Each of the six countries participating in the R&D project had to deliver four projects (cases). This would have resulted in a total of 24 cases. As a result, from the development in data collection the number of cases stuck at a total of seven cases.

1) Chemical thinning of apples     (NL)
2) Chemical thinning of apples     (PL)
3) Root cutting of pears     (NL)
4) Integrated control carrot fly     (NL)
5) Seed treatment of carrots     (PL)
6) Seed treatment of onions     (NL)
7) Seed treatment of onions     (PL)

The basic data of each case are given in appendices 3-9.

### 5.3.1 Chemical thinning of apples in the Netherlands
Apple trees require thinning in order to produce more marketable apples. Thinning used to be done by, expensive, manual labour. The application of a chemical compound (carbaryl 50 %) was introduced as a mean to substitute manual labour. The method appeared to be successful as it both reduced labour cost (the major advantage) and simultaneously led to a slight yield increase. The latter was caused by a decrease in alternating crop production.

The method was investigated in the Netherlands during the four-year period 1963-1966. Growers started applying the technique from 1967 onwards. The adoption rate was rather high: 30 % annual increase in adoption from 1967 through to 1969 and reaching 100 % in 1970. Apple orchards acreage in the Netherlands during the early stages of adoption was substantial with acreage of about 30,000 ha at the end of the sixties. Average production level was 10 - 15 tonnes of apples per hectare. In 2002 the acreage had decreased to about 12,000 ha with an average yield of 25 - 30 tonnes per hectare.

### 5.3.2 Chemical thinning of apples in Poland

The research was conducted during a four-year period from 1985 - 1988. The adoption rate was 0.01 % in 1995, seven years after finalizing the research, and was 15 % in 2002.  Adoption was rather slow and is still at a low level. Reasons for the low adoption could be the presence of a large number of small orchards plots and the availability of inexpensive labour.

### 5.3.3 Root cutting of pears in the Netherlands

Manual pruning in a pear crop is labour intensive and therefore growers used to apply the chemical compound chloormequat (CCC) in order to control excessive growth of new shoots and to stimulate bloom in the following season. However, due to legislation the use of CCC in pears for controlling shoot growth is no longer allowed since 2001. Therefore, new means for controlling shoot growth had to be explored. Research revealed that the cutting of roots inhibited excessive shoot growth and therefore the vigour of pear trees was reduced. The next step was to fine-tune the root cutting method in order to achieve a maximum reduction in shoot growth combined with a minimum loss of pear production. Pear production will drastically decrease and pear size or grading will be negatively affected when too many roots are cut off by applying the method. Nowadays results of root cutting are comparable to a CCC treatment when used correctly.

The research was carried out during 2000 and 2001 with the varieties Conference and Comice du Doyenne. Conference is the major pear variety in the Netherlands with the largest acreage: about 4.000 hectares followed by Comice du Doyenne with acreage of about 1.100 ha.

The adoption of the root cutting practice had already started before the actual research was carried out. This occurred because a few growers were already experimenting with root cutting. Nowadays, the method is accepted by 100 % of the growers. However, the adoption level is estimated at 50 %, as it is not necessary to apply the method each year.

### 5.3.4 Integrated control of carrot fly in the Netherlands

Carrot fly (*Psila rosae*) incidence leads to a reduced marketability of the product which eventually leads to reduced financial returns per area of land. The damage occurs when larvae of the carrot fly start to feed on the carrot roots.

Applied Plant Research (Lelystad, the Netherlands) has developed a system of integrated control of the carrot fly. The principle of the integrated control system is to spray an insecticide when a threshold of with yellow sticky traps caught carrot flies is reached in order to reduce the carrot fly population. This approach will prevent oviposition of the carrot fly at the stem base of the carrots. The research was conducted during 1993-1994 and resulted in an average yield increase of 10 %. Adoption cost was Euro 132 per hectare in 1995 and reached Euro 220 per hectare in 2002.. Adoption rate was 34 % in 1995 and reached 48 % in 2002.

### 5.3.5 Seed treatment carrots in Poland

Carrot plants can be protected against carrot fly larvae through a seed dressing with an insecticide. The Polish investigation to reduce the carrot fly incidence included a number of chemicals. Zaprawa Marshal 250 DS was the most effective. The research was conducted during

1994-1995 and resulted in an average yield increase of 35 %. Adoption cost was low: Zloty 59 (about Euro 15) per hectare. Adoption rate was high: 90 % adoption within three years after completion of the research project.

### 5.3.6    Seed treatment onions in the Netherlands

Seed coating of onions reduces the incidence of rot caused by *Botrytis alli* and *Botrytis aclada* and improves thereby the post-harvest life of the onions. The research project was carried out from 1969-1971 and resulted in an average yield increase of 12.3 %. The adoption rate was very high: 100 % within one year after completion of the research. The cost of adopting the research finding at growers' level was low: Euro 2.41 per hectare.

### 5.3.7    Seed treatment onions in Poland

Seed dressing of onions with an insecticide reduces the incidence of damage caused by the onion fly (*Delia antiqua*). The cost of the applied insecticide (Zaprawa Marshal 250 DS) was Zloty 210 per kg. Cost of the chemical amounted to Zloty 44 (Euro 11) per hectare.
The research project was carried out during 1998-2000 and resulted in an average yield increase of 139 %. The average onion acreage during 2000-2001 was 30,850 ha; the average yield during the three previous years (1997-1999) was 20.55 tonnes per hectare. The adoption rate was rather high: 50 % in the first year (2000) and 80 % in the second year (2001) after completion of the research.

## 5.4    Impact estimates of R&D in apples, pears and carrots

Data from the described seven cases originating from two countries have been collected and run through the Masters' economic surplus (MES) model. This chapter provides the specified outcome per case. The levels of both IRR and NPV in all seven studied research projects appear to be high (table 2). It must be kept in mind that:
- The effects are the results of a model calculation using historical data and applied at project level.
- Each result is originating from applying the model to a single successful project.

Table   2    :    IRR and NPV values and rankings of seven cases and number of years from start of research untill 2002 over which the IRR and NPV values have been calculated

|   |   | IRR | Ranking IRR | NPV (millions Euro) | Ranking NPV | Number of years |
|---|---|---|---|---|---|---|
| 1 | Chemical thinning apples NL | 435 | 6 | 464 | 1 | 40 |
| 2 | Chemical thinning apples PL | 81 | 7 | 1 | 7 | 19 |
| 3 | Root cutting pears NL | 14,113 | 1 | 35 | 5 | 6 |
| 4 | Integrated control of carrot fly NL | 1,987 | 4 | 16 | 6 | 11 |
| 5 | Seed treatment carrots PL | 12,663 | 2 | 320 | 2 | 9 |
| 6 | Seed treatment onions NL | 599 | 5 | 125 | 4 | 34 |
| 7 | Seed treatment onions PL | 3,366 | 3 | 179 | 3 | 5 |

Moreover, it must also be realised that not all (applied) research projects are having similarly high IRR and NPV levels. In the reality of day-to-day life, we are dealing with projects having high returns

and with projects having low or even negative returns on investment. This picture is likely to remain the same as long as it remains difficult to forecast the effectiveness of investment into applied research.



Plum tree (cv. Felisio)

IRR values ranged from 81 % (Chemical thinning of apples in Poland) to a staggering 14,113 % (Root cutting of pears in the Netherlands). An extensive literature survey (Alston and Pardey 2000) shows the IRR to research in 1,144 cases fluctuating from -7,4 to 5,645 %. Mean value was 99.6. Alston *et al.* (2001) show higher rates of return to applied research (mean value: 163,5 ranging from 6 to 5,645 % per year) when compared to basic research (mean value 79,2 and ranging from -1 to 457% per year). They found higher rates of return for developed countries (mean value 98,2 and ranging from -15 to 5,645) as compared to developing countries (mean value 60,1 and ranging from -100 to 1,490). The results calculated in the present study are similar, in some cases even higher; but the data calculated in the present study are in line with literature.

The NPV values of the evaluated projects ranged from 1 million euro (Chemical thinning of apples in Poland) to 464 million euro (Chemical thinning of apples in Netherlands).

## 5.5    The results case-by-case

### 5.5.1    Chemical thinning of apples in the Netherlands
Chemical thinning of apples in the Netherlands resulted in the highest NPV value: Euro 464 million and the second lowest Internal Rate of Return (IRR): 435. This case can be characterized by:

- High adoption rate:       100 % in 4 years
- Large acreage:       33.867 ha at start, 11.900 ha in 2002
- Substantial labour saving:       Euro 2.051 per hectare
- Long period of implementation:       40 years

The social gain was high as adoption rate, size of the acreage and the saved labour were all substantial.

### 5.5.2 Chemical thinning of apples in Poland

Chemical thinning of apples in Poland had the lowest NPV value: Euro 1 million and the lowest IRR: 81. This case is characterised by:
- Low adoption rate (slow adoption):       15 %
- Long period of research (= cost of research):       7 years
- Labour saving effect was limited:       Euro 180 per hectare

Reasons for the low adoption could be the presence of a large number of small orchards and the availability of cheap labour.

### 5.5.3 Root cutting of pears in the Netherlands

Root cutting of pears in the Netherlands had the fifth largest NPV value: Euro 35 million and the highest Internal Rate of Return: 14,113. This case is characterised by:
- Substantial labour saving effect:       Euro 1,100 per hectare
- Adoption rate was limited:       50 % in just one year
- Acreage of the crop is limited:       about 4,800 hectare

Reasons for the limited NPV are the limited acreage and the limited adoption rate.

### 5.5.4 Integrated control of carrot fly in the Netherlands

Integrated control of carrot fly (Psila rosa) in the Netherlands had the sixth largest NPV value: Euro 16 million and the fourth highest IRR: 1,987.This case is characterised by:
- Limited acreage:       about 7.500 hectares
- Limited adoption:       50 %
- Rather high adoption cost:       Euro 220 per hectare

Reasons for the limited NPV value are the limited size of the acreage, the limited adoption rate and the rather high cost of adoption.



Carrot Fly: Psila Rosa



Carrots affected by larvae of the Carrot Fly

### 5.5.5    Seed dressing of carrots in Poland

Seed dressing of carrots in Poland had the second highest NPV value 320 million Euro and the second highest IRR: 12,663. This case is characterised by:

- o Sharp increase in production level:      about 35 % increase
- o High adoption rate:      90 % in 3 years
- o Low adoption cost:      Euro 15 per hectare
- o Large acreage:      32.467 ha in 2002

All four factors contribute to a high NPV output.



Sticky traps in a carrot field

### 5.5.6    Seed treatment of onions in the Netherlands

Seed treatment of onions in the Netherlands had the fourth largest NPV: Euro 125 million and the fourth highest IRR: 599. This case is characterised by:

- o Lower yield increase (as compared to Poland)      12 %
- o High adoption rate:      100 % in 2 years
- o Very low adoption cost:      Euro 2.30 per hectare
- o Large acreage:      starting at 8.300 ha and
       at present at 14.370 ha.

Reasons for the medium level outcome are the lower yield increase as compared to Poland, but on the other hand, the large acreage, the low adoption costs and the high adoption rate lead to a higher NPV level.



Onion field



Finger weeding equipment in onion crop

### 5.5.7 Seed dressing of onions in Poland

Seed dressing of onions in Poland had the third largest NPV: Euro 179 million and the third highest IRR: 3,366. This case can be characterised by:

- o Sharp increase in yield: 139 %
- o High adoption rate: 80 % in 2 years
- o Low adoption cost: Euro 11 per ha.
- o Large acreage: starting at 35.100 and at present at about 32.500 ha (2002).

All parameters lead to a high NPV level.

## 5.6 Discussion

Table 3 summarises the observations and findings of the empirical research. It specifies, by research project, the ranking on both economic criteria; the adoption speed to reach maximum adoption, the maximum adoption level and the present adoption costs per ha; and the changes in acreage and in the yield levels.

Table 3 : Summary Table

| Project (country) | Ranking | | Adoption | | | Acreage (ha) | | Yield (t/ha) | |
|---|---|---|---|---|---|---|---|---|---|
| | IRR | NPV | speed in years | maxi-mum level | cost in Euro/ha in 2002 | at start research | in 2002 | at start research | in 2002 |
| Chemical thinning apples (NL) | 6 | 1 | 4 | 100% | -2,051[1] | 33.867 | 11.900 | 11.4 | 34.2 |
| Chemical thinning apples (PL) | 7 | 7 | 7 | 15 | -180[1] | 131.670 | 140.480 | 12.2 | 14.3 |
| Root cutting pears (NL) | 1 | 5 | 1 | 50% | -1,100[1] | 4.733 | 4.982 | 23 | 24 |
| Integrated control of carrot fly (NL) | 4 | 6 | 1 | 50% | 220 | 7.095 | 8.114 | 55 | 44 |
| Seed treatment carrots (PL) | 2 | 2 | 3 | 90 % | 15 | 33.400 | 32.500 | 20 | 22 |
| Seed treatment onions (NL) | 3 | 4 | 2 | 100% | 2.3 | 8.333 | 14.370 | 37 | 56 |
| Seed treatment onions (PL) | 5 | 3 | 2 | 80% | 11 | 35.100 | 32.467 | 21 | 20 |

[1] Adoption of research results lead to a cost reduction due to savings on needed labour hours instead of increased expenses for introduction of a new technique.

Large net present values are linked to the following factors:
- A high adoption rate (= quick implementation by growers), allowing for gains to follow the investment costs without much delay.

- Size of acreage. A large area of implementation contributes to the gain for society.
- A substantial yield increase, whether obtained through productivity growth and / or through input-saving effects (including reduction of labour).

High IRR values are found in cases with a rather short period of implementation. The period of implementation is taken as the time between year of completion of the research and the year of the present study (usually 2002). A short implementation period contributes to a quick and substantial return of the research investment.

Seed treatments (or seed dressings) are low-cost techniques to increase yield levels. This applies to three of our seven cases: seed dressing of carrots and of onions in Poland and seed treatment of onions in the Netherlands.

### 5.6.1 Correcting the estimated returns for a project bias

The results reveal large to very large gains to society for all cases. Some of the gains are overestimated due to the fact that the evaluation was undertaken at the project level, and that all selected research projects were successful. This section examines what results are likely if we had evaluated research on the programme level, thus allowing for failed projects.

In other words what will be the outcome once we calculate the results of a larger set of projects over time (number of years). As over a longer period of time we usually have some successful and often also a number of less successful, including ceased, projects. Thus, the question is what happens to IRR and NPV levels, if we include the financial investment of a larger number of projects in the model calculations. So what will be the IRR and NPV outcome when we include the investment of all projects (all costs) and assume only one project to be successful through implementation at farmers' level (one beneficial project).

We have collected additional data on the costs of onion and carrot research programmes conducted at Applied Plant Research (Lelystad, the Netherlands) from 1998 until 2002. Also included were non-crop specific research projects, which could be beneficial to onion and to carrot production. Research costs for those projects have been assigned to the research costs per crop on the basis of the Netherlands acreage of the relevant crop. To arrive at indications of research programmes in Poland, data of research budgets for carrot, onion and apple research at the Fruit and Vegetable Research Institute at Skierniewice (Poland) were also collected. Data on strawberry research were obtained from the Pomology Research Institute at Skierniewice. Table 4 reports on the budgets for these crop research programmes between 1998 and 2002, both in money terms and in comparison to the average production values in these crops. The Netherlands has spent at least 3 to 4 times more on crop research than Poland relative to production.

Table 4 : Average research budgets and production values; 1998-2002.

| Crop | Country | Currency | Research budget x 1,000 | Production value x 1,000 | Budget as % of prod. value |
|------|---------|----------|------------------------|--------------------------|----------------------------|
| onion | PL | (PLN) | 565 | 404.893 | 0,14 |
| onion | NL | (Euro) | 397 | 62.174 | 0,64 |
| carrot | PL | (PLN) | 275 | 388.311 | 0,07 |
| carrot | NL | (Euro) | 400 | 6.570 | 0,65 |
| apple | PL | (PLN) | 1.122 | 556.578 | 0,20 |
| strawberry | PL | (PLN) | 466 | 322.214 | 0,14 |

Using the costs of an individual (successful) research project as the basic data for calculating the benefit of a research project has its limitations. Therefore, we have collected the data of average crop research budgets of the past five years. These annual crop research budget data were used to calculate NPV and IRR with two assumptions. The first assumption is that only one research project, the investigated case, was successful while all the other research projects carried out within the crop programme were not successful. The second assumption was that each year a similar amount of money is invested in research for a specific crop. This approach has led to a higher cost of each individual research project (table 5).

Table 5 : IRR and NPV values calculated on the basis of crop research budget costs

| Ranking as in 8.3 | | IRR | NPV (millions local currency) * | NPV (million euro) | Number of years |
|-------------------|--|-----|---------------------------------|--------------------|-----------------|
| 2 | Chemical thinning apples PL | - | -8 | -2 | 19 |
| 4 | Integrated control of carrot fly NL | 118 | 13 | 13 | 11 |
| 5 | Seed treatment carrots PL | 4,445 | 1,276 | 293 | 9 |
| 6 | Seed treatment onions NL | 195 | 115 | 115 | 34 |
| 7 | Seed treatment onions PL | 702 | 714 | 164 | 5 |

* ) : Zloty 1 = Euro 0.23

The IRR and NPV levels in table 5 are lower as compared to the same in table 2. The IRR values ranged from 118 % (carrot fly control in NL) to 4,445 % (seed dressing carrots in Poland). The NPV ranged from -2 million Euro (chemical thinning of apples in Poland) to 293 million Euro (seed dressing of carrots in Poland). These rates of return are more in line with the literature (Alston *et al.* 2000) than the uncorrected numbers: the outliers are corrected and in one case, the returns are actually negative. Apple thinning research in Poland put society to a net loss (it is impossible to calculate IRR when the costs outweigh the gains).

It is noteworthy to realise that in 4 out of 5 cases the returns to applied research remain quite high despite substantial increases in research costs. Apparently, more costly research can still result in very positive internal rates of return and of high levels of gains for society. In other words: one successful project within a programme may still generate substantial returns in investment and in substantial financial returns for society.

Plum fruit (cv. Felisio)

## 5.7 How robust are the results?

As was explained above, Masters' spreadsheet model allows evaluators to cut down on data collection by incorporating strict assumptions. This section examines how sensitive the results are to assumptions on supply, demand and the discount rate:

- Supply structure

The supply elasticity was fixed at 0.8, and accordingly the supply volume will expand by 8 % in response to a 10 % price increase. This is a substantial supply response, albeit a rather limited one, which reflects the fact that agricultural production cannot grow overnight. The supply elasticity provides a clue on the trade-off of technology versus opening up new land. In case of an elasticity of 0.1 supply will hardly expand. In such a supply structure, the value of innovative research is quite high, especially land-saving innovations if land availability is the constraining factor. Large price increases are required to overcome the costs of such innovations. At an elasticity of 2, producers can expand production much more easily as unused land can be brought into production.

- Demand structure

It is assumed that the demand structure remains unchanged under technological change. The analysis was done under a demand elasticity of 0.4. Following a 10 percent price decrease, consumption expands by just 4 percent. It is normal for food consumption to be quite insensitive to price changes as these are often basic products to mankind. This is less the case for horticultural products. Consumers can often choose from a wide variety of fruits and vegetables, which results in a stronger response to price changes.

- Discount rate

The discount rate reflects time preferences: what is it worth to reap the fruits from my investment now rather than in a year's time? A large discount implies that future gains are worth little in present. At a discount rate of 0, one is indifferent between future gains and present gains. There are many views on what is appropriate time preference (see Alston *et al.* 1998). Naturally, the assumptions on the discount rate affect NPVs only, as IRR represent time preferences by themselves.

The upper panel of table 6 reports on the sensitivity of the MES results to these assumptions. It turns out that the supply elasticity has a strong bearing on the results. The selected values of the discount rate and the demand elasticity are less critical. In general, it can be stated that the results are robust to the assumptions, in the sense that there are no sign switches (net gains turning to net costs) or order changes in the results.

The lower panel of the table shows the result of some simulations with hypothetical data. The sensitivity of factors incorporated in the (MES) model is calculated by using real (historical) data in an ex-post evaluation. Sensitivity provides insight in the behaviour and relative importance of each of the critical factors affecting costs and benefits.

Table 6 : Simulated effects on IRR and NPV

| Onions (NL) | Simulated levels | IRR | | NPV | |
|---|---|---|---|---|---|
| | | Actual | Hypothetical | Actual | Hypothetical |
| ASSUMPTIONS (base level in brackets) | | | | | |
| Supply elasticity (0.8) | 0.1 | 599 | 1281 | 125 | 982 |
| | 2 | 599 | 419 | 125 | 50 |
| Demand elasticity (0.4) | 0.1 | 599 | 602 | 125 | 127 |
| | 2 | 599 | 596 | 125 | 123 |
| Discount rate (5%) | 0% | 599 | – | 125 | 252 |
| | 10% | 599 | – | 125 | 74 |
| HYPOTHETICAL DATA | | | | | |
| Reduction of producers' price | 50% | 599 | 457 | 125 | 62,5 |
| | 90% | 599 | 233 | 125 | 12,5 |
| Improvement by new technology | 1% | 599 | 212 | 125 | 10 |
| | 2% | 599 | 289 | 125 | 20 |
| | 5% | 599 | 423 | 125 | 51 |
| | 10% | 599 | 555 | 125 | 102 |
| Research costs (0.03 $10^6$ Euro) | 0.003 | 599 | 1378 | 125 | 125 |
| | 0.015 | 599 | 779 | 125 | 125 |
| | 0.06 | 599 | 458 | 125 | 125 |
| | 3 | 599 | 72 | 125 | 117 |
| Annual adoption rate (1972-1982) | 10% | 599 | 277 | 125 | 83 |
| Annual adoption rate (1972-1992) | 5% | 599 | 212 | 125 | 55 |

The sensitivity of the factors used in the model differs. Our simulations (table 6) show the effects of a number of factors on IRR and NPV:
- Level of improvement of the new technology
  - high improvement levels (i.e. substantial yield increase, reduction of manual labour) lead to high IRR and to high NPV
- Size of the market volume on demand side
  - large market volume leads to high IRR and to high NPV
  - reduced demand leads to sharp decrease in NPV; while the effect on IRR is limited
- Lower prices for farmers' produce
  - lead to a similarly reduced level of NPV; while the effect on IRR is limited
- Cost of the initial research
  - low research cost leads to high IRR and to high NPV
  - high research costs leads to reduced IRR and has almost no effect on NPV
- Adoption rate
  - quick adoption leads to higher IRR and higher NPV
  - slower adoption has a stronger effect (more decrease) on NPV

# 6    Sharing the responsibilities in applied horticultural research

The availability of public funds for applied agricultural research is under pressure. Our results confirm that governments need not abandon applied agricultural research because it causes losses to society. In fact, it is made clear that applied research in fruit and vegetable crops in Poland brings great benefits to society. Out of the three crop research projects evaluated, one produced a return rate of over 700 %, another of over four thousand % (see table 5, Chapter 5). One research project on apples brought only modest gains that failed to survive the correction for failed research efforts. These three projects generated a total net present value of over 450 million euro. Even if these gains to society are overestimated by a factor 10 the conclusion that applied horticultural research is a profitable investment remains firm. Institutes such as IFPRI and the Economic Research Service of the US Department of Agriculture share this insight.

> So why would governments step back in supporting applied research? Governments must appreciate the large positive returns from applied agricultural R&D.

What are in fact public responsibilities in applied research in view of the increasing expenses of private firms in this field? What sort of arrangements is most appropriate to share the responsibilities between the public and the private sector?

## 6.1    Public responsibilities

While exceptions exist, in emerging economies agricultural development is the key to poverty alleviation and rural development, and to transforming the structure of the economy (Timmer 2002). And when emerging economies do develop, the demands on agriculture change: consumers shift their diet towards higher quality products; governments increasingly seek to satisfy public concerns concerning consumer health hazards and environmental degradation. Many of the new EU members in Central and Eastern Europe are in such a phase of agricultural transformation. An effective agricultural research system is a critical support to the process of change—as important as competitive markets for input and output, and proper incentives for entrepreneurship (IFAD 2001). There are several responsibilities for the public sector in supporting an effective agricultural research system.

### 6.1.1    Incentives for private research
During the last decades the research orientation in the public sector and in private firms has changed in response to changes in global food markets (Jansen and Braunschweig 2003) and public priorities, especially in developing countries (Sundquist 1990). Private sector research has increasingly ventured beyond traditional areas such as the mechanisation of production and the use of chemicals for yield improvements.
In plant breeding, private firms have taken over the dominant position from the governmental research system. Fuglie *et al* (1996) document this feature for the US where firms have responded duly to profitable R&D opportunities in plant breeding. However, the (perceived) profit potential of plant breeding technologies has been unequal across various crops. As a result, private breeding investments have increased for hybrid crops like corn, soybean and vegetables; they proved stagnant for non-hybrid crops as wheat and rice. Perceptions of profit potential in the seed industry were based on "…expectations about future growth, the ability to protect

intellectual property, and technological opportunities in biotechnology and plant breeding" (Fuglie *et al.* 1996: 52).

Growth prospects in the variety development (breeding) and the seed industry are positive. The worldwide decline of food prices that is continuing for several decades pushes the need for ongoing productivity gains. In addition, maturing consumer markets around the world demand an increasing variety of products and product qualities.

With such obvious outlet opportunities for improved seed, whether private firms will actually invest in R&D depends to a large extent on government policies.

1. The intellectual property rights (IPR) policy will provide incentives (or disincentives) for private investment. The more firms can secure that they will reap the exclusive benefits from R&D, the more they will be inclined to invest.

2. Insights from basic agricultural research must be made available for applied research and technology transfer. The productivity of the total research system depends to a large extent on the interaction between the basic-applied-technology components and the required technology transfer to and implementation by end-users. By organising a system to make the results from basic research and applied research (either done at home or imported from abroad) accessible within the country, government provides critical support and favourable incentives to private sector investment. As Fuglie notes "…effective linkages between public and private research laboratories can increase the productivity of both parts of the system" (Fuglie *et al.* 1996: 52).

It appears that governments have a direct impact on the profit potential of private R&D in breeding, and thereby on scale of private agricultural R&D.

## 6.1.2 Public research in case of private underinvestment

Even when IPR policies and the options for interaction between research subsystems are favourable, it cannot be guaranteed that private firms will actually invest in R&D up to desired levels. Then, government may want to step in and provide public research. There are at least two fields where this is justified that are relevant to the new EU members in Central and Eastern Europe.

1. Rural development
   Poverty and unemployment in Central and Eastern Europe is concentrated in the rural areas. For most rural regions, the very kernel of economic growth lies with increased agricultural productivity (Timmer 2002). Private firms, however, may well under invest in regions where there is the strongest need for productivity growth. Several elements of why the rural R&D might fail to deliver exist.
   (a) Typically, it will take a long time before the benefits of research can be reaped. It was shown in the previous chapter that the returns under gradual development (or slow adoption rates of new technology) are much lower than under rapid technological change and quick adoption. Private firms are generally less patient.
   (b) The institutional setting in the poorer regions is typically less favourable to investment than more developed regions: remoteness reduces the links with basic research and applied research. IPR policies are enforced less, so that firms experience difficulties in securing the exclusive returns to their investment due to lack of law-enforced intellectual property rights).
   (c) The local demand for improved varieties is low.

2. Evolving public concerns regarding agriculture
   The accession to the EU has boosted regulation on public concerns relating to agriculture production and the food supply chain. Such concerns include food safety, animal health, animal welfare and environmental degradation, and have been implemented in requirements on food products and the process of production, processing, handling and transport. The process of

change requires support from research, especially in support of the smaller firms. Business strategies to comply with the new regulations differ across firms (Reardon *et al* 2001). Large (often international) "agribusiness" firms will use the change in policy to differentiate from other competitors by raising standards above mandatory levels. The firms of medium and small scale will often respond to changes in regulation by asking for support from government. While agribusiness dwells on the insights from global product development and product quality control, the medium and smaller companies will turn to the agricultural research system for guidance in complying with evolving public concerns.

## 6.2    Elements of an effective applied research system

### 6.2.1    Purpose
In our view, the system for applied agricultural research should support agricultural development by making possible:
-       Production of quality food commodities
-       New concepts of production, handling and marketing
-       Contributions from agriculture to nature conservation and biodiversity

The system should be able to deal with the present dynamics in agriculture and food production. We follow Janssen and Braunschweig (2003) who argue that society's demands on the agricultural research system are evolving from preoccupation with the yield and cost of individual products to concerns with safety, quality and variety on the one hand and environmental implications of production processes on the other. The driving forces behind such changes include globalisation (outsourcing of raw materials, supply of primary products); market liberalisation; technological advances; and the changing role of national governments. Additional challenges are presented by the increasing desire for a sustainable production.

The objective for the applied research system is to incorporate such dynamics and to translate relevant basic research into custom-made solutions in the green chain and/or in the food chain.

### 6.2.2    Priority setting
When funding gets scarce, priority setting must gain importance. This should then possibly result not so much in ex-post but in ex-ante assessments and priority setting. The priority setting must be in line with governmental interests. Governments have their own specific interests: food safety, animal health, animal welfare, environmental degradation and biodiversity.
Priority setting in applied agricultural R&D should be applied as ex-ante instrument. Three factors are contributing to a success story of the new technology:
- Large effect
- Quick adoption
- Large market volume
The subsequent transfer of technology (knowledge transfer) must apply advanced methods of knowledge transfer including knowledge exchange.

### 6.2.3    The organisational structure
Sundquist (1990) mentions a number of aspects affecting the effectiveness of the organisational structure for and the delivery capability of agricultural research institutions and systems:
1.  Availability of trained professional research staff
2.  Existence of an effective research strategy

3. Availability of adequate state-of-art research equipment and facilities
4. Availability of strong research leadership and administration
5. Availability of effective inter-institutional communication, planning, coordination on research and knowledge dissemination.

Wright & Zilberman (1994) also argue that society's (social and therefore political) demands on the agricultural research system are evolving from preoccupation with the yield and cost of individual products to concerns with safety, quality and variety on the one hand and environmental implications of production processes on the other. In other words agricultural research, at least in the developed world, has shifted from production statistics to issues affecting matters such as quality of life: food safety, environmental issues.
However, it must also be stated that this world has regions, which still need to attach high priority to basic matters such as food production to feed its population before starting to think of export commodities.

This study has occupied itself with applied agricultural R&D. However, it is obvious to the authors that a strong linkage must exist between applied research and technology transfer to and implementation by farmers: knowledge transfer is an essential element.

### 6.2.4 Funding strategies

#### 6.2.4.1 Government funding
Traditionally most funding for agricultural research originates from national government budgets (funding for international agricultural research is relatively small on a global scale (Alston *et al.* 1998)). National funding may be appropriate when agriculture is associated with or considered as a public good.

#### 6.2.4.2 Private funding
Once private companies or certain market sectors identify benefits from research, it is rather to be expected to consider such companies and sectors as potential funding organisations. Private funding is driven by the expected increase in profits.

#### 6.2.4.3 Producers' organisations
Farmers can combine forces through an alliance. The most well known alliance is through a Producers' Organisation. A producers' organisation is more powerful and is in a better position to steer and manage funding allocations.
The situation improves once farmers get themselves organised and use their newly structured alliance to raise funds for the development of new technologies through research. The term commodity levy funding explains this option quite well. Commodity levies are relatively efficient (probably cheaper to 'collect' as compared to tax collection). Secondly, industry funding arrangements can be organised to provide incentives for efficient use of both the levy and other funding resources.
Levy funding is often applicable to market goods, goods traded at either national or at international level. Trading of such goods is usually recorded, which is a pre-requisite for fair levy funding. The advantage of levy funding is its being closely attached to the levy source. Levy schemes are less applicable to research that deals with multiple commodities and issues (after Alston *et al* 1998). Levy funding may remain to be an efficient system directed at research benefiting a certain interest group. The latter requires a well organised system of growers whether through producers or through producer-marketing organisations.
Around the world, the levy system appears to be underutilized possibly because of the lack of

well-organised and well-structured producers' organisations.

# 7    References

Adamicki, F., 2004. Personal communication.

Alston, J.M., P.G. Pardey and J. Roseboom, 1998. Financing Agricultural Research: International Investment Patterns and Policy Perspectives. World Development. 26, 1057-1071.

Alston, J.M., C. Chan-Kang, M.C. Marra, P.G. Pardey and T.J. Wyatt, 2000. A meta-analysis of rates of return to agricultural R&D. IFPRI Research report 113. International Food Policy Research Institute. Washington D.C., USA. 148 pp.

Alston, J.M. and P.G. Pardey, 2001. Attribution and other problems in assessing the returns to agricultural R&D. Agricultural economics. 25, 141-152.

Anonymous, 2002. Report of workshop. Vegetable and fruit production in an expanding European Union. Implications for Policy and Research. Prague, October 7-10, 2002. Praktijkonderzoek Plant & Omgeving (Applied Plant Research), Lelystad, the Netherlands. 32 pp.

Barry, P.J., P.N. Elleger, J.A. Hopkin and C.B. Baker, 1995. Financial management in agriculture. 5 th edition. Interstate Publishers Inc., Denville, Illinois, USA. 657 pp.

Griliches, Z., 1958. Research costs and social returns: hybrid corn and related innovations. Journal of Political Economy. 66, 419-431.

Fuglie, K., N. Ballenger, K. Day, C. Klotz, M. Ollinger, J. Reilly, U. Vasavada and J. Yee, 1996. Agricultural research and developments: public and private investments under alternative markets and institutions. Agricultural Economics Report No. 735. Economic Research Service (ERS), United States Department of Agriculture (USDA). Washington D.C., USA. 88 pp.

Huiskamp, T., 2004. Personal communication.

IFAD (International Fund for Agricultural Development), 2001. Rural Poverty Report 2001. Oxford University Press, New York, USA.

ISNAR, undated. www.isnar.cgiar.org/fora/priority/index.htm. ISNAR – Discussion forum on priority setting in agricultural research.

Janssen, W. and T. Braunschweig, 2003. Trends in the organisation and financing of agricultural research in developed countries: implications for developing countries. ISNAR Research Report 22. International Service for National Agricultural Research (ISNAR), The Hague, the Netherlands. 84 pp.

Johansson, P-O., 1991. An Introduction to Modern Welfare Economics. University Press Cambridge, UK. 175 pp.

Masters, W., 2000. The economic impact of agricultural research. A practical guide. Department of Agricultural Economics. Purdue University, West Lafayette. USA. 43 pp.

Norton, G. and J. Davis, 1979. Review of methods used to evaluate returns to agricultural research. Staff Papers Series. Staff Paper P79-16. May 1979. Department of Agricultural and Applied Economics. University of Minnesota. St. Paul, Minnesota, USA. 48 pp.

Pannell, D.J., 1999. On the estimation of on-farm benefits of agricultural research. Agricultural Systems. 61, 123-134.

TAC, 2000. Impact assessment of agricultural research: context and state of the art. Revised version of a paper prepared by the Impact Assessment and Evaluation Group (IAEG) of the Consultative Group on International Agricultural Research (CGIAR) for the ASARECA / ECART / CTA Workshop on Impact Assessment of Agricultural Research in Eastern and Central Africa (Uganda, Nvember 1999). TAC Secretariat. FAO, Rome, Italy. April 2000. 43 pp.

Sundquist, W.B., 1990. Agricultural research and technology policies – Their relevance to Today's issues. Staff Papers Series. Staff Paper P90-9. February 1990. Department of Agricultural and Applied Economics. University of Minnesota. St. Paul, Minnesota, USA. 7 pp.

Reardon, T., J.M. Codron, L. Busch, J. Bingen and C. Harris, 2001. Global Change in Agrifood Grades and Standards: Agribusiness Strategic Responses in Developing Countries. International Food and Agribusiness Management Review, 2 (3).

Timmer, C.P., 2002. Agriculture and Economic Development, in B. Gardner and G. Rausser eds. Handbook of Agricultural Economics, Volume 2: Elsevier Science B.V.

TNO, 1970. Economische evaluatie van het landbouwkundige onderzoek. Nationale raad voor landbouwkundig onderzoek TNO. 's Gravenhage, the Netherlands. 50 pp.

Wright, B.D. and D. Zilberman, 1994. Agricultural research structures in a changing world. In: Evaluating agricultural research and productivity in an area of resource scarcity. Proceedings of a symposum 'Impact analysis and decision strategies for agricultural research'. Orlando, Florida, USA. March 4, 1993. Compiled by: W.B. Sundquist.

# Appendix 1. Net Present Value (NPV)

In general, the Net Present Value (NPV) represents the net gains to society (social gains) from different kinds of research.

NPV uses formulas to value the projected cash flow for each investment alternative at one point in time. Consequently, the net present value directly accounts for the timing and magnitude of the projected cash flow.

NPV's are used to establish the sensitivity for showing the effect of variations in different critical factors affecting benefits and costs.

According to Alston *et al* (2000), the present value model can be formulated as follows:

$$PV(B)_t = B_t + \frac{B_{t+1}}{(1+i)} + \frac{B_{t+2}}{(1+i)^2} + \ldots \frac{B_{t+n}}{(1+i)^n}$$

PV = Present Value in year t

B = the research Benefit in individual years or the stream of research Benefits over the years

$B_{t+i}$ = the research Benefit in the year t = i

i = the interest rate used to discount future Benefits

The Net Present Value (NPV) is the Present Value (PV) minus the Costs C:

Barry *et al* (1995) provide the following formula for the same:

$$NPVt = PV(B)t - PV(C)t$$

$$NPV = -INV + \frac{P_1}{(1+i)} + \frac{P_2}{(1+i)^2} + \ldots + \frac{P_N}{(1+i)^N} + \frac{V_N}{(1+i)^N}$$

Five types of data are required:

INV : the initial investment. INV is always negative as it reflects the cost of the initial investment.

$P_N$ : the net cash flow attributed to the investment that can be withdrawn each year. The $P_N$ can be either positive or negative. A projected loss in a certain year will be discounted from the NPV

$V_N$ : any salvage or terminal investment value

N : length of planning horizon. N is often taken as number of years.

i : the interest rate or required rate-of-return. It is also called the cost of capital or discount rate.

This NPV model indicates that each projected net cash flow is discounted to its present value. The resulting present values are added up together to yield a net present value over a period of time (often a number of years).
The $V_N$ (a terminal investment) is included in the calculation as a cash flow in the last year of the

planning horizon.

The acceptance of each investment depends on whether the net present value is positive or negative. One can distinguish three situations:

- If the NPV is positive: accept the investment.
- If NPV = 0: be indifferent.
- If NPV is negative: reject the investment.

In general, the net cash flow ( P ) is highest in the first year after the investment. Its value decreases with each following year.

A low interest rate ( i ) contributes to high cash flow ( P ) values and therefore to a high NPV. High interest rates are unfavourable for a high NPV.

The best way to gain quick (= positive) benefits from the initial investment is at a combination of:

Low i values    :    low discount (interest) rates

High P values   :    high cash flows after (implementation) of the investment: large effect of the research findings

Low N values    :    quick implementation (short period of adoption) of the (research) findings

Large area      :    A large area of implementation leads to a quick increase of NPV

# Appendix 2. Internal Rate of Return (IRR)

Internal Rate of Return (IRR) is the calculated rate of interest in the project (project level !) as a whole at which the NPV would be exactly zero. The IRR is used to assess the economic attractiveness of investments in infrastructural development projects but can also be used for ranking research or ranking projects.

IRR is also called:
- Discounted rate-of-return
- Marginal efficiency of capital
- Yield of an investment

The IRR is the interest rate that equals the net present value of the projected series of cash flows payments to zero.

In order to find the internal rate-of-return for an investment, we need to use the formula introduced in Appendix 1 (Net Present Value). Use NPV = 0 and calculate the i ( IRR ) value (Barry *et al* 1995).

$$0 = -INV + \frac{P_1}{(1 + i)} + \frac{P_2}{(1 + i)^2} + \ldots \frac{P_N}{(1 + i)^N} + \frac{V_N}{(1 + i)^N}$$

Or:

$$INV = \frac{P_1}{(1 + i)} + \frac{P_2}{(1 + i)^2} + \ldots \frac{P_N}{(1 + i)^N} + \frac{V_N}{(1 + i)^N}$$

The latter formula shows the present value of the cash flow series ( P ) equals the initial investment at the calculated I value.

At priority setting (in agricultural research) the project with the highest calculated IRR should be chosen. The choice must be carried out when the IRR is higher than the discounting rate of return. The latter discount rate should be read as the actual interest rate prevailing in an economy.

The IRR represents a ratio, it does not reflect the actual size of the investment neither the size of the gain obtained by the investment.

The actual development of the level of the IRR will be less clear when the period of generating the benefits from the investments requires a longer period of time.

# Appendix 3. Thinning research of apples in the Netherlands

Statistical and research data of thinning research of apples in the Netherlands

| Yer | Quantity Produced (t) | Nominal Price (cent/kg) | Consumer Price Indx (2002=1) | Real Price Euro/t | Yield: New Technol. (t/ha) | Tradi- tional Technol. (t/ha) | Yield Increase (t/ha) | AREA PLANTED: Total in prod- uction (ha) | With the New Technol. (ha) | Mean National Yield (t/ha) | ADOPTION COSTS Nominal Euro/ha | Real Euro/ha |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | [Q] | | | [P] | [Yn] | [Yt] | [dY] | (ha) | (ha) | [Ym] | | [dC] |
| 1963 | 281600 | 14 | 0,2 | 710 | 40,4 | 40 | 0,4 | 34100 | 0 | 8,3 | 0 | 0 |
| 1964 | 514800 | 10 | 0,2 | 472 | 40,4 | 40 | 0,4 | 34100 | 0 | 15,1 | 0 | 0 |
| 1965 | 358300 | 15 | 0,2 | 663 | 40,4 | 40 | 0,4 | 33400 | 0 | 10,7 | 0 | 0 |
| 1966 | 345000 | 15 | 0,2 | 642 | 40,4 | 40 | 0,4 | 33100 | 0 | 10,4 | 0 | 0 |
| 1967 | 488000 | 15 | 0,2 | 604 | | | 0,4 | 32600 | 9930 | 15,0 | -301 | -1213 |
| 1968 | 340000 | 13 | 0,3 | 509 | | | 0,4 | 31700 | 19020 | 10,7 | -315 | -1233 |
| 1969 | 475000 | 13 | 0,3 | 470 | | | 0,4 | 29600 | 26640 | 16,0 | -343 | -1239 |
| 1970 | 450000 | 11 | 0,3 | 397 | | | 0,4 | 26400 | 26400 | 17,0 | -385 | -1391 |
| 1971 | 520000 | 14 | 0,3 | 469 | | | 0,4 | 24100 | 24100 | 21,6 | -441 | -1476 |
| 1972 | 400000 | 19 | 0,3 | 580 | | | 0,4 | 23000 | 23000 | 17,4 | -483 | -1473 |
| 1973 | 450000 | 23 | 0,3 | 658 | | | 0,4 | 22000 | 22000 | 20,5 | -553 | -1581 |
| 1974 | 385000 | 20 | 0,4 | 528 | | | 0,4 | 22000 | 22000 | 17,5 | -637 | -1681 |
| 1975 | 393000 | 26 | 0,4 | 605 | | | 0,4 | 21900 | 21900 | 17,9 | -721 | -1677 |
| 1976 | 380000 | 23 | 0,5 | 501 | | | 0,4 | 21500 | 21500 | 17,7 | -777 | -1693 |
| 1977 | 315000 | 36 | 0,5 | 727 | | | 0,4 | 20100 | 20100 | 15,7 | -847 | -1710 |
| 1978 | 510000 | 25 | 0,5 | 490 | | | 0,4 | 19800 | 19800 | 25,8 | -903 | -1771 |
| 1979 | 450000 | 15 | 0,5 | 282 | | | 0,4 | 19200 | 19200 | 23,4 | -959 | -1803 |
| 1980 | 434000 | 22 | 0,6 | 387 | | | 0,4 | 17200 | 17200 | 25,2 | -1001 | -1761 |
| 1981 | 260000 | 35 | 0,6 | 572 | | | 0,4 | 16300 | 16300 | 16,0 | -1057 | -1727 |
| 1982 | 440000 | 35 | 0,6 | 545,9 | | | 0,4 | 16000 | 16000 | 27,5 | -1113 | -1736 |
| 1983 | 364000 | 36 | 0,7 | 543,0 | | | 0,4 | 15800 | 15800 | 23,0 | -1127 | -1700 |
| 1984 | 431000 | 41 | 0,7 | 598,7 | | | 0,4 | 15800 | 15800 | 27,3 | -1141 | -1666 |
| 1985 | 347000 | 33 | 0,7 | 471,8 | | | 0,4 | 15600 | 15600 | 22,2 | -1155 | -1651 |
| 1986 | 400000 | 30 | 0,7 | 428,9 | | | 0,4 | 15400 | 15400 | 26,0 | -1169 | -1671 |
| 1987 | 306000 | 34 | 0,7 | 491,2 | | | 0,4 | 15900 | 15900 | 19,2 | -1197 | -1729 |
| 1988 | 327000 | 36 | 0,7 | 514,7 | | | 0,4 | 15400 | 15400 | 21,2 | -1211 | -1731 |
| 1989 | 375000 | 33 | 0,7 | 467,0 | | | 0,4 | 15900 | 15900 | 23,6 | -1239 | -1753 |
| 1990 | 382000 | 44 | 0,7 | 603,9 | | | 0,4 | 16300 | 16300 | 23,4 | -1281 | -1758 |
| 1991 | 204000 | 66 | 0,8 | 879,5 | | | 0,4 | 16800 | 16800 | 12,1 | -1337 | -1782 |
| 1992 | 395000 | 36 | 0,8 | 466,2 | | | 0,4 | 17000 | 17000 | 23,2 | -1407 | -1822 |
| 1993 | 597000 | 21 | 0,8 | 264,4 | | | 0,4 | 16600 | 16600 | 36,0 | -1435 | -1807 |
| 1994 | 530000 | 28 | 0,8 | 343,1 | | | 0,4 | 16500 | 16500 | 32,1 | -1533 | -1879 |
| 1995 | 560000 | 31 | 0,8 | 373,2 | | | 0,4 | 15300 | 15300 | 36,6 | -1631 | -1964 |
| 1996 | 432000 | 43 | 0,8 | 507,6 | | | 0,4 | 15100 | 15100 | 28,6 | -1673 | -1975 |
| 1997 | 420000 | 33 | 0,9 | 381,3 | | | 0,4 | 15200 | 15200 | 27,6 | -1757 | -2030 |
| 1998 | 518000 | 24 | 0,9 | 271,8 | | | 0,4 | 14700 | 14700 | 35,2 | -1841 | -2085 |
| 1999 | 570000 | 23 | 0,9 | 255,0 | | | 0,4 | 14200 | 14200 | 40,1 | -1911 | -2119 |
| 2000 | 461000 | 29 | 0,9 | 313,4 | | | 0,4 | 12800 | 12800 | 36,0 | -1953 | -2111 |
| 2001 | 408000 | 33 | 1,0 | 341,3 | | | 0,4 | 11700 | 11700 | 34,9 | -1995 | -2064 |
| 2002 | 354000 | 28,4 | 1,0 | 284,0 | | | 0,4 | 11200 | 11200 | 31,6 | -2051 | -2051 |

# Appendix 4. Thinning research of apples in Poland

Statistical and research data of thinning research of apples in Poland

| Year | Quantity Produced (t) [Q] | Nominal Price (old Zloty/t) | Consumer Price Index | Real Price (Old Zloty/t) [P] | Yield: New Technol. (t/ha) [Yn] | Traditional Technol. (t/ha) [Yt] | Yield Increase (t/ha) [dY] | AREA PLANTED: Total in production (ha) | With the New Technol. (ha) | Mean National Yield (t/ha) [Ym] | ADOPTION COSTS Nominal (Old ZLoty/ha) | Real (Old PLN/ha) [dC] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1984 | 1564400 | 34830 | 1,1 | 30862 | | | 1,09 | 126000 | 0 | 12,4 | -6403 | -5674 |
| 1985 | 1343142 | 27000 | 1,1 | 23904 | 88,0 | 87,2 | 0,78 | 114000 | 0 | 11,8 | -7093 | -6280 |
| 1986 | 1920051 | 34000 | 1,2 | 29436 | 157,7 | 156,1 | 1,56 | 155000 | 0 | 12,4 | -7760 | -6718 |
| 1987 | 504428 | 145000 | 1,2 | 118015 | 67,0 | 66,4 | 0,63 | 155000 | 0 | 3,3 | -9093 | -7401 |
| 1988 | 1392946 | 322000 | 1,6 | 204818 | 139,3 | 137,9 | 1,38 | 131000 | 0 | 10,6 | -21680 | -13790 |
| 1989 | 1312026 | 480000 | 3,4 | 139311 | | | 1,09 | 120000 | 0 | 10,9 | -205676 | -59693 |
| 1990 | 812340 | 700000 | 6,7 | 104010 | | | 1,09 | 128000 | 0 | 6,3 | -260905 | -38767 |
| 1991 | 1145544 | 1600000 | 1,7 | 957369 | | | 1,09 | 99510 | 0 | 11,5 | -313347 | -187493 |
| 1992 | 1569690 | 1600000 | 1,4 | 1140140 | | | 1,09 | 142000 | 0 | 11,1 | -383535 | -273302 |
| 1993 | 1841755 | 1000000 | 1,3 | 753141 | | | 1,09 | 136000 | 0 | 13,5 | -488317 | -367772 |
| 1994 | 1441124 | 1800000 | 1,3 | 1387443 | | | 1,09 | 155000 | 0 | 9,3 | -578982 | -446280 |
| 1995 | 1288289 | 4100000 | 1,3 | 3269092 | | | 1,09 | 116580 | 116,6 | 11,1 | -5250000 | -4186033 |
| 1996 | 1951515 | 2700000 | 1,2 | 2294662 | | | 1,09 | 116800 | 350,4 | 16,7 | -5540000 | -4708307 |
| 1997 | 2098297 | 2400000 | 1,1 | 2128460 | | | 1,09 | 106200 | 743,4 | 19,8 | -5850000 | -5188120 |
| 1998 | 1687226 | 2800000 | 1,1 | 2552057 | | | 1,09 | 103060 | 1133,7 | 16,4 | -6030000 | -5496038 |
| 1999 | 1604221 | 6600000 | 1,1 | 6267847 | | | 1,09 | 140030 | 1680,4 | 11,5 | -6560000 | -6229860 |
| 2000 | 1450376 | 2600000 | 1,1 | 2406358 | | | 1,09 | 132440 | 1721,7 | 11,0 | -7870000 | -7283860 |
| 2001 | 2433940 | 2000000 | 1,0 | 1931754 | | | 1,09 | 141100 | 1975,4 | 17,2 | -7870000 | -7601450 |
| 2002 | 2168856 | 2300000 | 1,0 | 2300000 | | | 1,09 | 147890 | 2218,4 | 14,7 | -7820000 | -7820000 |

# Appendix 5. Integrated control of carrot fly in the Netherlands

Statistical and research data of integrated control of the carrot fly research in the Netherlands

| Year | bunched carrot Quantity Produced (t) [Q] | Nominal Price (euro/ton) | Consumer Price Index (1993=1) | Real Price (euro/ton) [P] | Yield: New Technol. (t/ha) [Yn] | Tradi-tional Technol. (t/ha) [Yt] | Yield Increase (t/ha) [dY] | AREA PLANTED : Total in prod-uction (ha) | With the New Technol. (ha) | Mean National Yield (t/ha) [Ym] | ADOPTION COSTS Nominal (euro/ha) | Real (euro/ha) [dC] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1992 | 29000 | 310 | 0,77 | 401,4 | | | 2,0 | 971 | 0 | 29,9 | 110 | 142 |
| 1993 | 28500 | 500 | 0,79 | 629,6 | 29 | 25 | 3,8 | 905 | 20 | 31,5 | 110 | 139 |
| 1994 | 29000 | 480 | 0,82 | 588,2 | 28 | 27 | 1,2 | 975 | 99 | 29,7 | 110 | 135 |
| 1995 | 30000 | 390 | 0,83 | 469,6 | | | 2,0 | 1062 | 158 | 28,2 | 110 | 132 |
| 1996 | 24000 | 510 | 0,85 | 602,0 | | | 2,0 | 755 | 198 | 31,8 | 110 | 130 |
| 1997 | 24000 | 370 | 0,87 | 427,5 | | | 2,0 | 734 | 215 | 32,7 | 110 | 127 |
| 1998 | 24000 | 480 | 0,88 | 543,7 | | | 2,0 | 795 | 231 | 30,2 | 150 | 170 |
| 1999 | 25000 | 470 | 0,90 | 521,1 | | | 2,0 | 784 | 248 | 31,9 | 190 | 211 |
| 2000 | 26000 | 450 | 0,93 | 486,4 | | | 2,0 | 573 | 198 | 45,4 | 216 | 233 |
| 2001 | 16000 | 450 | 0,97 | 465,5 | 31 | 29 | 2,0 | 510 | 218 | 31,4 | 216 | 223 |
| 2002 | 15000 | 450 | 1,00 | 450,0 | 30 | 29 | 1,0 | 500 | 238 | 30,0 | 220 | 220 |
| | **Small carrot** | | | | | | | | | | | |
| 1992 | 137000 | 130 | | 168,3 | | | 4,0 | 2265 | 0 | 60,5 | 110 | 142 |
| 1993 | 130300 | 130 | | 163,7 | 71 | 62 | 9,0 | 2110 | 112 | 61,8 | 110 | 139 |
| 1994 | 121800 | 130 | | 159,3 | 56,4 | 54 | 2,4 | 2250 | 561 | 54,1 | 110 | 135 |
| 1995 | 121200 | 150 | | 180,6 | | | 4,0 | 2636 | 902 | 46,0 | 110 | 132 |
| 1996 | 130300 | 330 | | 389,5 | | | 4,0 | 3379 | 1122 | 38,6 | 110 | 130 |
| 1997 | 121200 | 150 | | 173,3 | | | 4,0 | 2060 | 1210 | 58,8 | 110 | 127 |
| 1998 | 80000 | 310 | | 351,1 | | | 4,0 | 2777 | 1309 | 28,8 | 150 | 170 |
| 1999 | 125000 | 130 | | 144,1 | | | 4,0 | 2888 | 1397 | 43,3 | 190 | 211 |
| 2000 | 114000 | 70 | | 75,7 | | | 4,0 | 2861 | 1122 | 39,8 | 216 | 233 |
| 2001 | 102000 | 140 | | 144,8 | 40 | 37 | 3,0 | 2550 | 1232 | 40,0 | 216 | 223 |
| 2002 | 120000 | 140 | | 140,0 | 43 | 41,5 | 1,5 | 2800 | 1342 | 42,9 | 220 | 220 |
| | **Large carrot** | | | | | | | | | | | |
| 1992 | 315000 | 110 | | 142,4 | | | 5,0 | 3585 | 0 | 87,9 | 110 | 142 |
| 1993 | 299700 | 110 | | 138,5 | 87 | 76 | 11,0 | 3929 | 198 | 76,3 | 110 | 139 |
| 1994 | 280200 | 120 | | 147,1 | 68 | 65 | 3,0 | 4296 | 990 | 65,2 | 110 | 135 |
| 1995 | 278800 | 130 | | 156,5 | | | 5,0 | 4675 | 1580 | 59,6 | 110 | 132 |
| 1996 | 299700 | 130 | | 153,5 | | | 5,0 | 4404 | 1980 | 68,1 | 110 | 130 |
| 1997 | 278800 | 140 | | 161,8 | | | 5,0 | 4197 | 2150 | 66,4 | 110 | 127 |
| 1998 | 170000 | 310 | | 351,1 | | | 5,0 | 4822 | 2310 | 35,3 | 150 | 170 |
| 1999 | 309000 | 45 | | 49,9 | | | 5,0 | 5753 | 2480 | 53,7 | 190 | 211 |
| 2000 | 253000 | 160 | | 172,9 | | | 5,0 | 4729 | 1980 | 53,5 | 216 | 233 |
| 2001 | 260000 | 160 | | 165,5 | 54 | 50 | 4,0 | 4837 | 2186 | 53,8 | 216 | 223 |
| 2002 | 287000 | 105 | | 105,0 | 58 | 56 | 2,0 | 4981 | 2380 | 57,6 | 220 | 220 |

# Appendix 6. Seed dressing of carrot in Poland

Statitistical and research data of insecticide seed dressing of carrot in Poland

| Year | Quantity Produced (t) [Q] | Nominal Price (Zloty/t) | Consumer Price Index (2002=1) | Real Price (Zloty/t) [P] | Yield: New Technol. (t/ha) [Yn] | Tradi- tional Technol. (t/ha) [Yt] | Yield Increase (t/ha) [dY] | AREA PLANTED: Total in prod- uction (ha) | With the New Technol. (ha) | Mean National Yield (t/ha) [Ym] | ADOPTION COSTS Nominal (Zloty/ha) | Real (Zloty/ha) [dC] |
|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 1994 | 591000 | 567,0 | 1,3 | 437,0 | 79,4 | 56,7 | 22,7 | 35600 | 0 | 16,6 | 0 | 0,0 |
| 1995 | 760000 | 567,0 | 1,3 | 452,1 | 41,3 | 32,6 | 8,7 | 32900 | 0 | 23,1 | 0 | 0,0 |
| 1996 | 646000 | 567,0 | 1,2 | 481,9 | | | 15,7 | 31700 | 14285 | 20,4 | 54 | 45,9 |
| 1997 | 611000 | 500,8 | 1,1 | 444,2 | | | 15,7 | 31800 | 22260 | 19,2 | 54 | 47,9 |
| 1998 | 756000 | 570,0 | 1,1 | 519,5 | | | 15,7 | 35200 | 31680 | 21,5 | 54 | 49,2 |
| 1999 | 688000 | 527,5 | 1,1 | 501,0 | | | 15,7 | 34400 | 30960 | 20,0 | 54 | 51,3 |
| 2000 | 720000 | 551,7 | 1,1 | 510,6 | | | 15,7 | 35700 | 32130 | 20,2 | 54 | 50,0 |
| 2001 | 660000 | 620,9 | 1,0 | 599,7 | | | 15,7 | 34000 | 30600 | 19,4 | 54 | 52,2 |
| 2002 | 692000 | 655,0 | 1,0 | 655,0 | | | 15,7 | 27800 | 25020 | 24,9 | 54 | 54,0 |

# Appendix 7. Seed dressing of onions in the Netherlands

Statistical and research data of fungicide seed dressing research of onions in the Netherlands

| Year | Quantity Produced (t) [Q] | Nominal Price (cent/kg) | Consumer Price Index (2002=1) | Real Price (Euro/t) [P] | Yield: New Technol. (t/ha) [Yn] | Tradi- tional Technol. (t/ha) [Yt] | Yield Increase (t/ha) [dY] | AREA PLANTED: Total in prod- uction (ha) | With the New Technol. (ha) | Mean National Yield (t/ha) [Ym] | ADOPTION COSTS Nominal Euro/ha | Real Euro/ha [dC] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1969 | 255592 | 9,71 | 0,28 | 350,73 | 36,2 | 33,1 | 3,08 | 7000 | 0 | 36,5 | 0 | 0 |
| 1970 | 304961 | 9,71 | 0,28 | 350,73 | 34,1 | 31,7 | 2,44 | 8000 | 0 | 38,1 | 0 | 0 |
| 1971 | 347708 | 9,71 | 0,30 | 325,06 | 36,6 | 30,4 | 6,15 | 10000 | 0 | 34,8 | 0 | 0 |
| 1972 | 302130 | 9,71 | 0,33 | 296,17 | | | 3,89 | 7000 | 7000 | 43,2 | 0,82 | 2,49 |
| 1973 | 379000 | 9,71 | 0,35 | 277,66 | | | 3,89 | 9000 | 9000 | 42,1 | 0,80 | 2,29 |
| 1974 | 386200 | 9,71 | 0,38 | 256,30 | | | 3,89 | 10000 | 10000 | 38,6 | 0,90 | 2,38 |
| 1975 | 369400 | 18,04 | 0,43 | 419,68 | | | 3,89 | 10000 | 10000 | 36,9 | 0,86 | 2,01 |
| 1976 | 326400 | 26,4 | 0,46 | 575,17 | | | 3,89 | 11000 | 11000 | 29,7 | 1,03 | 2,24 |
| 1977 | 455000 | 1,76 | 0,50 | 35,53 | | | 3,89 | 13000 | 13000 | 35,0 | 1,06 | 2,14 |
| 1978 | 487000 | 2,2 | 0,51 | 43,14 | | | 3,89 | 12000 | 12000 | 40,6 | 1,18 | 2,31 |
| 1979 | 493000 | 12,32 | 0,53 | 231,64 | | | 3,89 | 11000 | 11000 | 44,8 | 1,26 | 2,37 |
| 1980 | 433000 | 15,04 | 0,57 | 264,66 | | | 3,89 | 10880 | 10880 | 39,8 | 1,29 | 2,27 |
| 1981 | 497400 | 7,96 | 0,61 | 130,07 | | | 3,89 | 11784 | 11784 | 42,2 | 1,36 | 2,22 |
| 1982 | 564300 | 4,59 | 0,64 | 71,59 | | | 3,89 | 11916 | 11916 | 47,4 | 1,42 | 2,21 |
| 1983 | 409800 | 25,96 | 0,66 | 391,56 | | | 3,89 | 11294 | 11294 | 36,3 | 1,50 | 2,27 |
| 1984 | 457300 | 3,81 | 0,68 | 55,63 | | | 3,89 | 12412 | 12412 | 36,8 | 1,56 | 2,27 |
| 1985 | 436600 | 3,61 | 0,70 | 51,61 | | | 3,89 | 12552 | 12552 | 34,8 | 1,63 | 2,34 |
| 1986 | 497000 | 6,5 | 0,70 | 92,93 | | | 3,89 | 11416 | 11416 | 43,5 | 2,34 | 3,35 |
| 1987 | 478200 | 3,42 | 0,69 | 49,41 | | | 3,89 | 9881 | 9881 | 48,4 | 2,01 | 2,91 |
| 1988 | 452000 | 5,68 | 0,70 | 81,21 | | | 3,89 | 10076 | 10076 | 44,9 | 2,06 | 2,94 |
| 1989 | 438800 | 14,03 | 0,71 | 198,53 | | | 3,89 | 8477 | 8477 | 51,8 | 1,83 | 2,59 |
| 1990 | 497400 | 7,96 | 0,73 | 109,26 | | | 3,89 | 9172 | 9172 | 54,2 | 2,12 | 2,91 |
| 1991 | 462485 | 5,72 | 0,75 | 76,22 | | | 3,89 | 9948 | 9948 | 46,5 | 2,11 | 2,81 |
| 1992 | 568600 | 3,1 | 0,77 | 40,14 | | | 3,89 | 10485 | 10485 | 54,2 | 1,92 | 2,49 |
| 1993 | 601800 | 7,5 | 0,79 | 94,44 | | | 3,89 | 9757 | 9757 | 61,7 | 1,62 | 2,04 |
| 1994 | 464654 | 19,8 | 0,82 | 242,65 | | | 3,89 | 10865 | 10865 | 42,8 | 1,91 | 2,34 |
| 1995 | 479139 | 4,8 | 0,83 | 57,79 | | | 3,89 | 11659 | 11659 | 41,1 | 1,90 | 2,29 |
| 1996 | 623171 | 24,2 | 0,85 | 285,65 | | | 3,89 | 11678 | 11678 | 53,4 | 2,00 | 2,36 |
| 1997 | 574518 | 7,48 | 0,87 | 86,43 | | | 3,89 | 10620 | 10620 | 54,1 | 2,04 | 2,36 |
| 1998 | 652399 | 3,96 | 0,88 | 44,85 | | | 3,89 | 13225 | 13225 | 49,3 | 2,10 | 2,38 |
| 1999 | 754786 | 3,99 | 0,90 | 44,24 | | | 3,89 | 14003 | 14003 | 53,9 | 2,10 | 2,33 |
| 2000 | 821022 | 7,7 | 0,93 | 83,22 | | | 3,89 | 13988 | 13988 | 58,7 | 2,19 | 2,36 |
| 2001 | 765340 | 14,1 | 0,97 | 145,85 | | | 3,89 | 14206 | 14206 | 53,9 | 2,20 | 2,28 |
| 2002 | 816662 | 10,26 | 1,00 | 102,60 | | | 3,89 | 14916 | 14916 | 54,8 | 2,19 | 2,19 |

# Appendix 8. Seed dressing of onions in Poland

Statistical and research data of fungicide seed dressing research of onions in Poland

| Year | Quantity Produced (t) [Q] | Nominal Price (Zloty/t) | Consumer Price Index (2002=1) | Real Price (Zloty/t) [P] | Yield: New Technol. (t/ha) [Yn] | Tradi- tional Technol. (t/ha) [Yt] | Yield Increase (t/ha) [dY] | AREA PLANTED: Total in prod- uction (ha) | With the New Technol. (ha) | Mean National Yield (t/ha) [Ym] | ADOPTION COSTS Nominal (Zloty/ha) | Real (Zloty/ha) [dC] |
|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 1998 | 756000 | 540,83 | 1,10 | 492,94 | 29 | 14 | 15,2 | 35200 | 0 | 21,5 |  | 0 |
| 1999 | 688000 | 506,67 | 1,05 | 481,17 | 69 | 33 | 35,9 | 34400 | 0 | 20,0 |  | 0 |
| 2000 | 720000 | 455,00 | 1,08 | 421,11 | 56 | 17 | 38,4 | 35700 | 0 | 20,2 |  | 0 |
| 2001 | 660000 | 803,64 | 1,04 | 776,21 |  |  | 29,8 | 34000 | 17000 | 19,4 | 180 | 173,9 |
| 2002 | 585000 | 699,17 | 1,00 | 699,17 |  |  | 29,8 | 27700 | 22160 | 21,1 | 180 | 180,0 |

# Appendix 9. Root cutting of pears in the Netherlands

Statistical and research data of root cutting of pears research in the Netherlands

| Year | Quantity Produced (t) [Q] | Nominal Price (euro/t) | Consumer Price Index (2002=1) | Real Price (euro/t) [P] | Yield: New Technol. (t/ha) [Yn] | Traditional Technol. (t/ha) [Yt] | Yield Increase (t/ha) [dY] | Total in production (ha) | With the New Technol. (ha) | Mean National Yield (t/ha) [Ym] | Nominal (euro/ha) | Real (euro/ha) [dC] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CONFERENCE | | | | | | | | AREA PLANTED: | | | ADOPTION COSTS | |
| 1997 | 86000 | 615 | 0,87 | 660 | | | 3,25 | 3444 | 0 | 25,0 | -1395 | -1611,9 |
| 1998 | 88000 | 475 | 0,88 | 560 | | | 3,25 | 3449 | 1724,5 | 25,5 | -1395 | -1580,0 |
| 1999 | 95000 | 590 | 0,90 | 590 | | | 3,25 | 3590 | 1795 | 26,5 | -1395 | -1546,6 |
| 2000 | 135000 | 435 | 0,93 | 540 | 38,1 | 34,1 | 4,00 | 3658 | 1829 | 36,9 | -1395 | -1507,7 |
| 2001 | 54000 | 920 | 0,97 | 930 | 7,6 | 5,1 | 2,50 | 3793 | 1896,5 | 14,2 | -1395 | -1442,9 |
| 2002 | 107000 | 545 | 1,00 | 600 | | | 3,25 | 4035 | 2017,5 | 26,5 | -1395 | -1395,0 |
| | | | | | | | | | | | | |
| DOYENNE | | | | | | | | | | | | |
| 1997 | 29000 | 615 | | 630 | | | 1,85 | 1274 | 0 | 22,8 | -824 | -952,1 |
| 1998 | 24000 | 475 | | 560 | | | 1,85 | 1229 | 614,5 | 19,5 | -824 | -933,3 |
| 1999 | 24000 | 590 | | 570 | | | 1,85 | 1213 | 606,5 | 19,8 | -824 | -913,5 |
| 2000 | 35000 | 435 | | 310 | 25,1 | 23,7 | 1,40 | 1180 | 590 | 29,7 | -824 | -890,6 |
| 2001 | 9000 | 920 | | 960 | 3,4 | 1,1 | 2,30 | 1160 | 580 | 7,8 | -824 | -852,3 |
| 2002 | 30000 | 545 | | 440 | | | 1,85 | 1119 | 559,5 | 26,8 | -824 | -824,0 |