SESSION 1/B

COOPERATION BETWEEN INDUSTRY AND RESEARCH INSTITUTIONS : THE POINT OF VIEW OF INDUSTRY

Chairman: Dr. Anthony WYLIE, CHILE

Cooperation between industry and research institutions: the point of view of the industry

by ***Paolo Celli***
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1. Introduction

The innovation is widely recognized to be one of the key factors for the success of a Company, whatever is the sector of the Industry in which it operates. The innovation is becoming more and more a frequent topic in round-tables and seminars where the future of the Industry is discussed, and the new management techniques and quality assurance processes regard the innovation as the corner stone on which people who like the challenge can build a better future for their organizations.

Unfortunately, in spite of all the efforts that people make into this direction, innovating is still not easy nowadays, especially because the cooperation between the Companies and the Institutions in many cases is not satisfactory at all.

Let us examine the various situations.

2. Why to innovate ?

Management researchers say that today innovating is a matter of survival, rather than a free choice, in a marketplace which is becoming more and more chaotic and competitive.

The advantages that Companies need to build up in order to maintain good market share and profitability are often related to the capacity of generating innovations of the products and the service offered. In other words customers become more and more demanding and the situation changes faster and faster; just doing well what we have always done is no longer enough. Everybody in business needs to re-discuss the position reached and the results already achieved, before a smart competitor corners him.

It is probably worth mentioning the fact that innovation is the result of a suitable environment and a flexible approach to new things: the help from outside will never be enough if there is no open minded entrepreneur to take advantage of it. For this reason it is a complicated process that external factors can make easier, but has to find its own strength inside the organizations.

3. How to innovate ?

What is needed in order to develop innovative projects ? Why Companies find it difficult ?

The main problems (**Table 1**) are usually the lack of information and knowledge, the lack of skilled work-force and of internal resources to reach good results in a reasonable time, the lack of spending capability.

Today the time-to-market is a very important factor and introducing new products means nothing if it is too late and the competitors are already on the spot, or the potential market has vanished in the meantime due to the continuously changing environment.

As explained there are both external and internal factors that can boost innovation: Research Institutions are the ideal counterpart for the Companies that, having a good view of their position and their skills, want to overcome the problems mentioned above.

Somebody distinguishes between the "conscious" and the "accidental" innovation, to underline the fact that we can properly talk about innovation when there is a comprehensive plan about it, when objectives have been set, people involved and sufficient financial resources are available.

Unfortunately rather often this is not the case, as the small structure of many organizations does not allow but an "accidental" innovation, which is the casual result of the owner's personal vision of the business.

This happens very frequently in the sector of agricultural machinery, but does not implies, as many people seem to believe, that making agricultural equipment means concentrating efforts in the supply of low technology equipment to old fashioned people resistant to change and progress.

In conclusion for all the reasons mentioned above it is evident that the Industry, which is a sort of antenna getting every day signals from the market, needs to create an internal environment open to innovation, and get help and advice from external Institutions in all the area where it is not strong enough by itself.

Except for the very big Companies, developing serious research projects by oneself is too difficult nowadays: finding the right partner seems the only choice.

4. The situation in Italy

In Italy the relationship between the Industry and the Research Institutions is not satisfactory in most cases, and this can be easily understood taking into consideration some peculiarity of our industrial system.

First aspect to consider is the big number of small firms, not so strong financially or enough organized to be able to invest important amounts of money into the R&D. Statistics show (**Table 2**) that in Italy, if 100 is the total amount of money spent in the different activities related to innovation (R&D, patenting, designing, prototypes production and testing, marketing and investments in new machinery), the percentage strictly referring to R&D varies from 14,9 % in the Companies with less than 50 employees, to 46,7 % in the Companies with more than 1.000 employees.

This is obvious, somebody may say, but the problem here is that the average size of an industrial Company in Italy is much smaller than in other partner countries of the EEC, like France or Germany for instance.

In **Table 3** you will see that in the machinery sector 55,6 % of the total number of Companies has less than 100 employees.

This leads to the conclusion that the activity of R&D is not so intense if we exclude high-tech companies and the big groups.

The small size guarantees flexibility and fast approach to new ideas, but on the other hand also a low-profile policy as far as true innovation is concerned. Researchers agree on the fact that these small Companies in general are very good at putting somebody else's technology at work, but very seldom take the initiative by themselves.

Second important aspect to be mentioned is the inefficiency of the public system in general, where the excess of bureaucracy risks to slow everything down and often prevents dynamic researchers and innovative Companies to meet and exchange experiences.

Third aspect is the mentality of many entrepreneurs, who often started their businesses immediately after the World War Two and still rely on a do-it-yourself approach, being pessimistic about the help they can get from the public sector in general.

If we add to it the fact that financing scheme for innovation are available but are so complicated, in many cases, that only Companies well structured and organized can apply and then follow up the procedure, we have a complete picture of the whole situation.

What is the result ? The Italian Industry is now living a difficult moment as far as innovation is concerned: we are beyond other European partners in the High Tech sectors (**Table 4**) and this gap seems difficult to reduce in the short run.

5. Positive experiences of cooperation

The whole picture risks to be too negative if we don't take into consideration positive experiences that show that, eventually, a good level of cooperation can be established in spite of all the difficulties.

We know that many small and medium size Companies have frequent contacts with the Universities in their area, in order to arrange field tests, for instance, that the use of sophisticated testing techniques makes particularly useful in order to collect data to increase the machinery performance or develop new models.

Now that safety regulations are getting stricter and the awareness of the risk involved is increasing, technical controls to check the compliance of the machinery with the new standards are frequently requested by the Companies.

Bigger Companies, like the tractor manufacturers, keep a tighter link with the Universities and the Research Institutions thanks to their better organization and take advantage of the common development of important and innovative projects.

An interesting idea to have the Companies, the Farmers Organization and the Research Institutions sat at the same table to study common activities, was the creation of the CONAMA, a consortium whose activities at the moment are probably the most interesting example of a tight and fruitful cooperation between the Industry and the Research Sector.

The recent start of the project aiming at the technical certification of machines, with regard to the performance in the field and the compliance with the CE marking requirements, is a particularly interesting opportunity for the manufacturers.

As already explained there are many obstacles to be removed and probably it will take years to improve the situation, but some important steps are being taken, like the setting up of new organizations where the offer and the demand of technology and research capability can meet and produce quick results (the Business Innovation Centers; the so called "Technology Nurseries", for instance).

Other good signals are coming from the local branches of important Universities (like Bologna University), that decided to transfer part of the courses to other towns where the closer contact between the students and the Industry is generating good opportunities (it is worth mentioning the period that students spend working at new projects in the Companies).

The fact that many Companies are structuring themselves in order to get a Quality Certification helps the process of innovation a lot: most of the techniques used are based on the concept of "continuous improvement", which is exactly what a Company willing to innovate has to do. The positive tension of the whole organization toward a common goal guarantees a steady stream of new ideas related to the products and the manufacturing system.

6. Opportunities to be investigated

Talking with the management of several Companies during the last couple of years we realized that in the field of agricultural machinery there are some subjects that people regard as particularly stimulating because of their technical contents (**Table 5**):

- the development of electronic systems to operate, adjust and control various types of machinery;
- the design of proper safety protections for the machines, the official certification of the level of safety reached;
- the field testing and performance certification of the machinery on the basis of scientific methods; the control of the results obtained in the field, to check whether they are agronomically acceptable;
- the study of new cultivating methods with low impact on the environment;

- the development of the mechanization of new, promising agricultural niches, that the Industry almost does not know yet;
- the development and use of new materials like ceramics or wear resistant steels.

All these subjects, if properly developed, may lead to substantial improvements of the technological level of the machinery manufactured and services offered, with extremely positive consequences both for the Companies and the end-users.

7. Conclusions

In the agricultural machinery sector, like in all the other sectors, innovating is important to survive and remain competitive. The Industry strongly need help from the Institutions but in Italy there is still a big problem of communication between the two sectors.

The recent new initiatives allow us to hope that things are going to change in the near future, therefore the whole picture cannot be considered negative at the moment.

Table 1 - Key factors for industry innovation

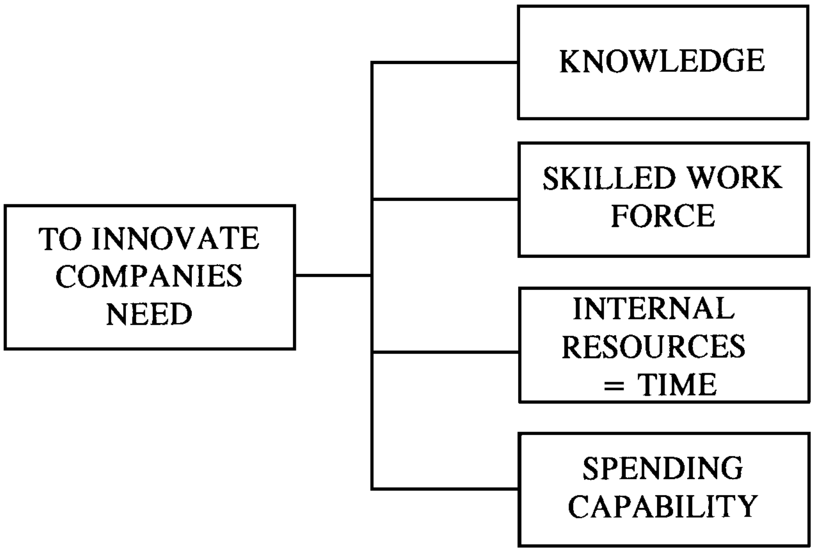


Table 2 - Percentage of expenses for innovation in Italy referred to the company dimension [Source: ISTAT, 1995]

EXPENSES	LESS OF 50 EMPLOYEES	MORE THAN 1000 EMPLOYEES	AVERAGE
Studies and researches	14,9	46,7	35,8
Patents and licences	1,5	0,8	1,2
Designing	9,4	4,8	7,4
Test production	7,7	5,7	6,9
Marketing	1,9	1,2	1,5
Investments	64,6	40,8	47,2

Table 3 - Size of the machinery sector companies [Source: INPS, 1995]

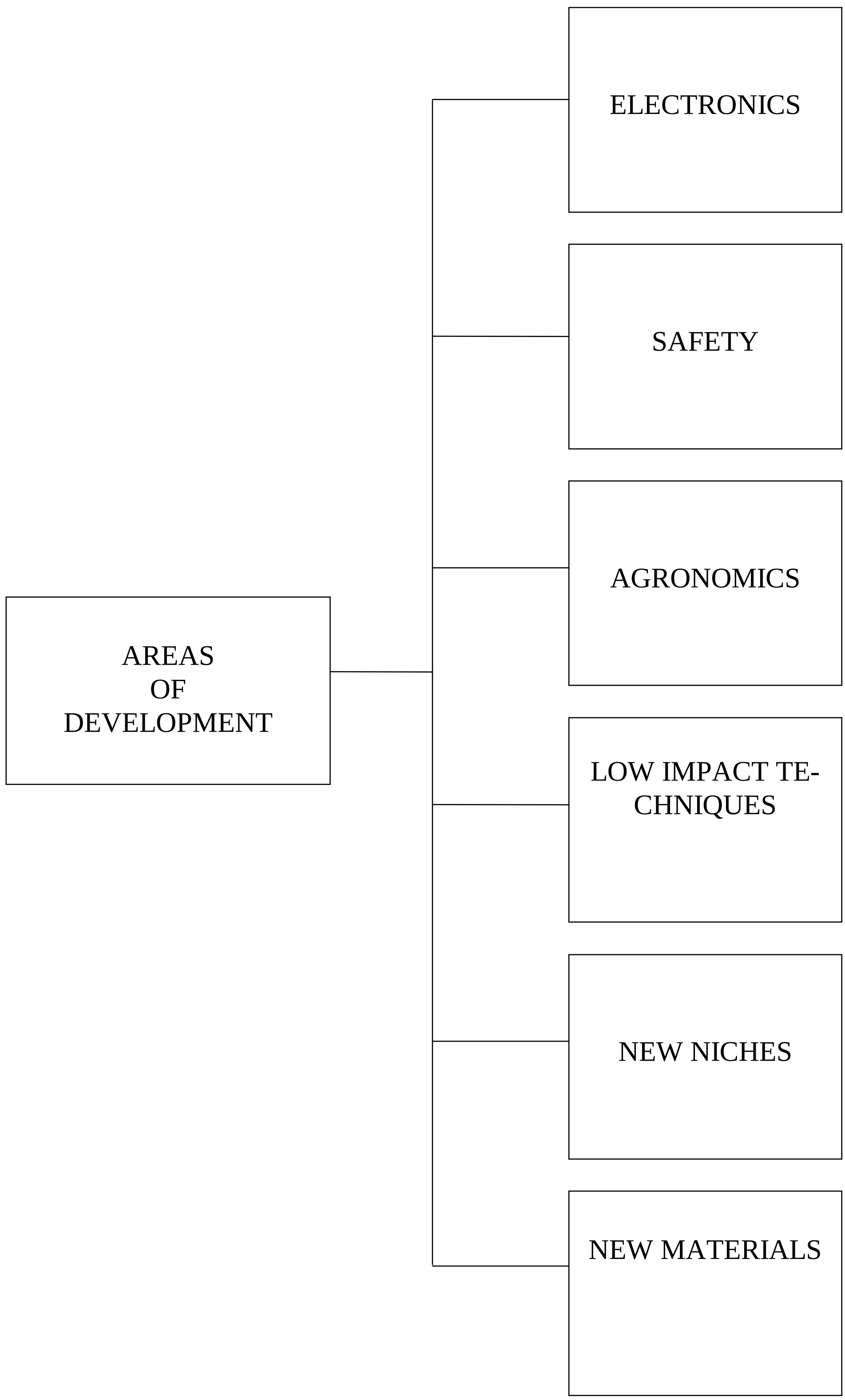
NUMBER OF EMPLOYEES	1995
1 - 19	21,20%
20 - 99	34,40%
10 - 499	27,40%
OVER 500	17%

Table 4 - Exports of main european countries based on total exports of the EU countries (percentage data)

	SPECIALIZED MECHANICAL SECTOR *1	HIGH ECONOMY SCALE SECTOR *2	HIGH TECHNOLOGY SECTOR *3	TRADITIONAL SECTOR *4	TOTAL PRODUCTION *5
Italy					
1992	15,5	10,2	7,4	27,5	13,2
1993	17,4	11,5	7,5	29,5	14,4
1994	17,4	11,1	7,1	30,3	14,2
*6 1995	18,8	12	7,6	30,5	14,9
Germany					
1992	37,1	34,1	30,6	21,6	32,7
1993	35	31,9	28,3	20	30,5
1994	34	32,2	28,3	19,4	30,3
*6 1995	33,3	32,5	28	19,7	30,3
France					
1992	14,3	17,5	15,2	12,6	15,5
1993	13,8	17,4	16,1	12	15,4
1994	13,5	16,7	14,8	11	14,7
*6 1995	13,2	15,7	15,1	11,4	14,4
United Kingdom					
1992	13,1	12	16,6	8,1	12,9
1993	12,7	11,6	16,5	7,8	12,6
1994	13,8	11,6	15,6	8,5	12,8
*6 1995	14,8	12	15,3	8,6	13,2

*1 Metal products, agricultural and industrial machines, electric material.
*2 Minerals, ferrous and non-ferrous metals, non-metalliferous minerals, motor vehicles, other transport means, paper and printing, rubber and plastic.
*3 Chemical products, office machines and precision instruments.
*4 Textiles and clothing, leather and shoes, wood and furniture.
*5 Food excluded.
*6 From January to June 1995.

Table 5 - Most promising development areas for the R & D sector in the next dew years



Cooperation between industry and research institutions: the point of view of the industry

by ***Hugo A. Cetrangolo***
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1. Introduction

In this paper, the technological cooperation agreement between INTA and the manufactures of farm machinery Apache is presented. This agreement allowed for the successful launching of an inter sowing machine designed by INTA.

The joint work of both institutions was not limited to the design and commercial adaptation, but included promotion of the inter flowing technique, making tests of adaptation to different conditions. The commercial success has determined that this inter-sowing machine is the sales leader in Argentina, with an important market share of the market.

2. The Argentine farm machinery market

In Argentina, farm's mechanization starts on the first decades of this century and, mainly due to the extensive nature of agriculture in Argentina, the use of machinery has been very efficient. A proof of the former is that 27 million hectares are cultivated using 19 million horsepower (HP), which means a lower relation compared to other countries.

Even though there is a certain obsolescence on tractors, it is more evident on those smaller than 75 HP, while above this power equipments have been manufactured more recently. Sales average 5.000 units per year.

With respect to agricultural machinery, there is an ample variety that is produced in the country competing with foreign models, that are currently selling with a very low import tariff (after the economy was opened).

In 1995 17.700 machines produced locally were sold, as well as 15.500 were imported. These figures are unusually high, because of the good grains and oilseed prices.

3. Argentine Institute of Agricultural Technology (INTA)

This National Institute was created in 1958. Its Directive Council is formed by representatives of the government (3), universities (2) and farmers (5). It has an ample geographic coverage that includes: the Castelar Research Station; more than 30 experimental stations and 230 extension agencies. 3.000 professionals are working there, most of them with an international post-graduate degree.

The Institute of Rural Engineering was created in 1944. It belonged to the Ministry of Agriculture and was incorporated to INTA in 1958.

Currently, it has a very well qualified professional staff and carries out the following main activities:

- engineering for optimal energetic use;
- safety and ergonomics;
- nature management;
- quality standardization and improvement;
- control, homologation and certification of agricultural equipment;
- automation and robotization;
- evaluation of alternative fuels.

Engineer Roberto Delafosse is the Director of this institute and has cooperated for the preparation of this paper, supplying essential information for the preparation of this paper.

4. Inter sowing in Argentina

A large share of the area with pastures for livestock grazing is not able for plant production, due to low soil quality. This area has drainage limitations as a direct consequence of high clay and lime content as well as of salt presence, lack of deepness and low organic matter content.

For these reasons, from 1960 the practice of inter-sowing natural pastures has become more common, so that grasses with higher nutritive value are being added to those already existing, without ploughing the ground and altering the natural soil characteristics.

The new grasses introduced through the practice of inter-sowing vary according to soil characteristics. However, the most commonly used are: *Trifolium repens* in low areas with acid pH; *Festuca sativa* and *Melilotus albus* or *Melilotus officinalis* in soils moderately alkaline and *Agropyrum elongatum* and *Lotus tenuis* in soils with pH > 8,2. These pastures are mainly used for breeding meat-cows and to start fattening bullocks and heifers.

The technique of inter-sowing was generally carried out with a machine equipped with a furrow opening shoe that prepares the soil to receive seeds and eventually fertilizers that are stored in conventional boxes.

From 1970, INTA worked on the inter-sowing technique and, to that aim, in 1980 it started developing a rotor to replace the old furrow opening shoe. There was some background in such machines equipped with rotors to opening furrows, but the design from INTA was substantially different from earlier ones because the Argentine soil structure was stronger.

The INTA working team was formed by four professionals, two of which specialized in rural engineering, one in soils, one in soils microbiology, so that all sides of the problem were taken into consideration. This team constructed a prototype of a four furrows machine that was used for experimental activity. A very good functioning of the machine and seed growth condition was verified.

5. The agreement to cooperate in the area of technology development

In 1988, due to the results achieved, INTA decides to offer that machine to the private industry, for a serial production. That process was made through the Chamber of Agricultural Machinery Producers, that interests the firm "Apache S.A".

Apache S.A. is a 40 years old Argentine firm in the farm machinery market, concentrating its operation in producing sowing machines for thinner grains, wider grains, complemented with its line of production for other machinery for farm use.

The inter-sowing machine allowed Apache S.A. to complete other machines designed for livestock production. From this contract onwards, a cooperation agreement between INTA and Apache was signed for joint cooperation. It was the first contract signed by this official institution and was the start of a new policy of private and state joint cooperation that has allowed for 100 joint ventures in different areas of agriculture at present.

The agreement signed gave Apache S.A. the exclusivity for the production of the inter-sowing machine. In exchange, it had to pay a 1,5% of sales royalty and to give INTA one free of charge machine for every hundred sold.

6. The technological development

In order to transform the INTA prototype in a commercial machine a team of technicians from INTA and Apache was formed. Such group met weekly, and after six months, adapted the machine according to the industry and market requirements and ended the final design.

The most important changes made were the incorporation of two more furrows, so that the machine would have six sowing lines. Following earlier experiences, structural supports were added.

In July 1990 the machine was presented in the Palermo Annual Rural Show, the most important in Argentina. During the ten days that the show lasted, 36 units were sold at a price of U$S 8.000 each, a high figure for the Argentine market, specially in those years of economic depression.

7. Characteristics of the inter sowing machine

The machine has six rotational devices with shovels, complemented with six seeding instruments, with furrow opening plates and compacting wheels (**Fig. 1**). The width of each seedeying line is of two inches (approx. 5 cm), and the maximum working depth is four inches (approx. 10 cm). The relation between the rotating devices regime and the speed of the whole machine determines the rate of soil structure erosion.

The distribution equipment has a system for fertilization in strips and a double independent system to seed grasses and legumes, respectively. The fertilizer will fall in front of the rotating device that will be driven by the tractor, and are then incorporated to the soil; so that a strip of soil, plant residues, and fertilizer is achieved similar to that of traditional practices. After that, an opening plate makes the soil open and the grass and legume seeds are separately placed into the ground.

With this technique, only ten percent of total area is altered, with the consequence of reducing soil structure losses and seed and fertilizer's density, achieving similar results as with traditional practices in good soils.

8. The commercial aspects

Since the first one appeared in the market,

Apache launched three models of this type of machine. New technological developments were included, step by step, specially affecting the fertilizers' distribution system, the transmission, the cover of the shovels etc. But basically the machine respect the first model.

Joint cooperation between INTA and Apache continued later, mainly in the areas of extension and adaptation of prototypes to the commercial units. To that aim, INTA made information meetings in its extension agencies. Meetings were held in the Buenos Aires, Entre Rios and Corrientes provinces.

Therefore, from 1990, around 500 machines have been sold, following the same tendencies as the rest of the machinery. It suffered a downturn in sales during the 1993/94 livestock crisis, and sales recovered in 1995, and continue that way.

In October 1996, a joint presentation of INTA and Apache has been made in the XXIX Agro industrial Show in Santa Maria (Rio Grande, Brazil), in which INTA's participation refers to agricultural aspects of inter-sowing and Apache markets the machine for MERCOSUR.

The commercial competition is given by the direct seeding machines that is a practice becoming recently very common. However, the technical characteristics of the two types of machines are completely different, as well as their price: the direct seeding machine is around three times more expensive than the inter-sowing machine.

Recently, New Zealand's Aitchinson inter sowing machine entered the market, directly competing with the INTA/Apache product but preparing the soil through an elastic arch with one shoe and two lateral wings. Its price is about two times that of Apache (U$S 15.000 approximately) and has had very limited commercial success.

9. The industry's point of view

When the people of Apache were consulted about this joint technological development, they considered it very valuable, because the totally innovative development by INTA would have required a strong effort of design in the company, even when they are very experienced in the field. The fact that during the development stage an interdisciplinary group including soil and microbiology experts was gathered to work together was a key point for the success of the project.

It would have been very difficult to gather such team by a medium size farm machinery producer. Probably, the royalties received would have been lower than the costs of research.

Apache was also grateful for the promotion to the concept of inter-sowing with the help of INTA, that allowed for a much more ample promotion program than the one that the company could achieved by itself. However, they expressed that a more intensive agricultural promotion program would have yielded a better commercial positioning of the machine.

10. INTA's point of view

The rural engineering institute considered that this experience has been very positive because it has confirmed that a jointly venture between an official and a private company is possible. They considered it a leading case, since it was the start of a group of cooperation projects with other institutions.

They pointed out that the royalties received have been rather low because of the fact that this was the first operation of the source that they worked on. Later, with a pneumatic sowing machine designed by INTA, the private partner payed 4% of the sales of the machines.

They have also pointed out that they are looking forward to a new cooperation agreement that would allow for a total re-engineering of the product, analysing the defects that farmers had and the ways to solve them incorporating the latest technological knowledge.

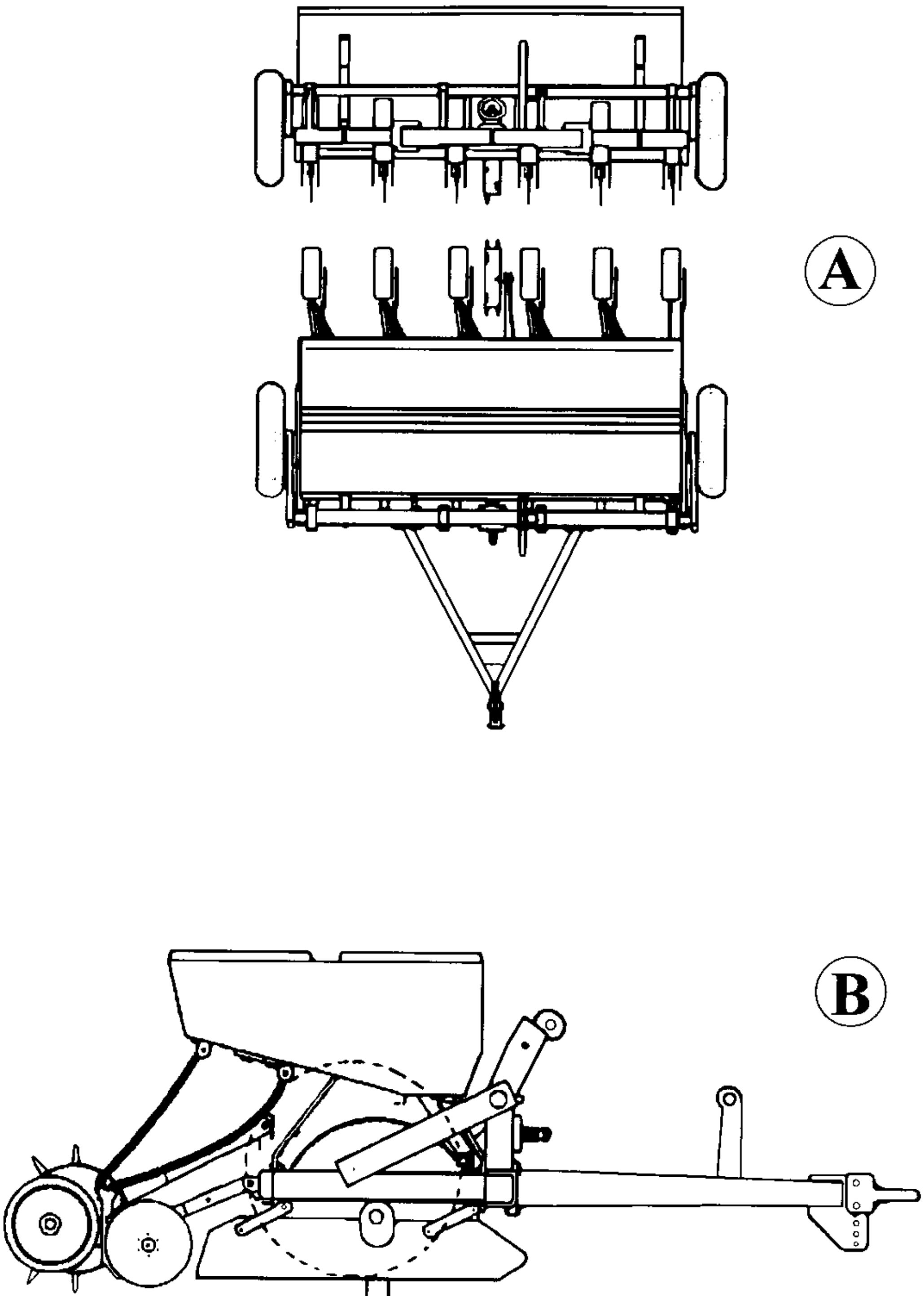
11. Conclusions

The analysis of the technological agreement between INTA and Apache S.A., underlines the importance of this type of cooperation.

The aspects of technological cooperation are not limited to farm machinery design, but also to other fields. In that sense, the identification of new agrochemical technologies that may impact on the improvement of agricultural production are responsibility of each country's research organizations and offer orientation on the trend to machinery development.

From a market point of view, if the institution that is launching a new machine has participation on its design the impact will be much larger. On appropriate technologies, such as farm machinery, there is no doubt that joint cooperation between research centers and industry is very much fruitful.

Fig. 1 - Inter-sowing machine: A) front and above view; B) side view



Cooperation between industry and research institutions: the point of view of the industry

by ***Toshiyuki Yotsumoto***
Japan

1. The present state of agriculture in Japan

Japanese agriculture is now confronted with some very difficult problems, the most serious being the rapid aging of farmers and lack of a younger generation of farm hands to take over the business. This is partly because farm villages experienced an excessive drain of young laborers during the high-economic-growth period following W.W.II as a result of the mechanization of agriculture, especially in integrated rice cropping systems from tillage to harvesting. Moreover, the Uruguay Round agreement to a "Minimum Access" to rice (an initial annual importation of 40 tons of rice, with gradual increases to follow), the main grain for Japanese, was brought into effect last year. The Staple Food Control Act (legislation regarding the stabilization of prices and supply and demand of staple foods) which had been supporting Japanese farmers was amended in 1995, thus initiating the open competition of rice. Recently, the import ratio of perishable foods such as vegetables has risen and the Japanese food self-sufficiency ratio has gone down to 46%, a calorie-based figure from 1994. This figure is quite low compared with other countries. In 1993, when we had a poor yield of rice, which is the staple crop of Japan, there occurred a sharp rise in its price and a lot of rice was imported from abroad. However, that did not solve the problem of the rice shortage because the taste of foreign-grown rice did not appeal to most Japanese. As a matter of fact, Japan has a large stock of imported rice. This experience has proved that it is necessary for Japan to have its own stable food supply. Given such a background, securing new farmers to succeed the present generation of aging farmers and improving agricultural productivity have become essential topics for revitalizing Japanese agriculture. For this purpose, the industry and national research institutes are promoting research and development to contribute to labor mitigation, labor saving, and efficiency improvement through the development of agricultural machinery.

2. The differences between industry and national research institutes in Japan

2.1 Research goals of industry
Industry's research goals are to satisfy farmers' needs and ultimately sell its products. That is to say, the research goal of industry is to develop and supply safe, useful, and easy-to-use machinery after having determined the needs of its customers and providing satisfactory solutions to those needs. In addition, the price of machinery should be affordable to farmers.

2.2 Research goals of national institutes
The research goals of national institutes are to contribute to improvement of farming productivity by bringing it up to efficient and stable agricultural business standards, which would result in lowering the cost of food and obtaining a stable food supply for the nation. Again, the ultimate goal of national institutes is to satisfy the short-term food consumer needs of the nation by securing and supplying a stable food supply. Therefore, they do not attach much importance to the cost of machinery in the short-term.

3. The present state of cooperation between industry and national research institutes

The goals of both industry and national institutes are not necessarily contrary to each other, and, in fact, coincide with each other at many points when seen from a long-term perspective. For example, both industry and national institutes are conducting development with long-term goals in mind, such as "increased productivity through labor saving", "increased efficiency through higher-performance machinery", and "liberation from heavy labor through mechanization". To achieve these goals, two approaches are required. One is to develop machinery and the other is to popularize the machinery among the farmers through customer acceptance tests. Two examples of this are "The Project for the Urgent Development of Agricultural Machinery" by Bio-oriented Technology Research Advancement Institution (BRAIN), which is developing innovative agricultural machinery which facilitates efficiency and comfort in farm operations, and the approach of the National Research Society for Agricultural Systematization, which promotes the improvement and the wide-spread adoption of farm machinery through empirical tests.

3.1 The project for the urgent development of agricultural machinery (by BRAIN)

In 1986, the Institute of Agricultural Machinery (IAM), which promoted agricultural mechanization by carrying out research and development and conducting inspections and appraisals for agricultural machinery, was renamed Bio-oriented Technology Research Advancement Institution (BRAIN) and given the additional responsibility of promoting private sector research that supports research and development in fields such as biotechnology. Recently, it has also attached importance to advanced research like the utilization of advanced technology corresponding to today's technological innovations. As the only agency specializing in agricultural machinery in Japan, the agricultural mechanization promotion department of BRAIN does not limit the scope of research to fundamentals but also includes applications of agricultural machinery development that comply with the demands of the Ministry of Agriculture, Forestry & Fisheries, which is the agricultural administration in the Japanese government.

It is becoming more and more important for Japanese agriculture in particular to develop innovative agricultural machinery which provides labor savings and user comfort and increases productivity in order to attract a new generation of farmers and to establish an efficient production system by making maximum use of the land. In order to promote the development of advanced machinery, its practical use, and the introduction of the machinery in an efficient manner, "The Project for the Urgent Development of Agricultural Machinery" was put forward as a part of the government policy known as "The Basic Direction of New Policy for Food, Agriculture and Rural Areas", which the Japanese government indicated in 1993 as being what Japanese agriculture should be like in the twenty-first century. The agricultural machinery that is the object of R&D and its goals (features and specifications) were determined by the basic policy announced by the Minister of Agriculture, Forestry and Fisheries. This policy indicated the urgent needs of people who are engaged in agricultural production.

The following are several machines which have already been developed.

3.1.1 Combine Harvester (**Fig. 1**)

This machine makes possible highly efficient harvesting for plural grains other than rice, such as wheat, soybeans, buckwheat, and so forth. It has a cutting width of 3.5 m and is equipped with a reel header or pickup header for rice. The working speed is around 1 m/s and grain loss is less than 3%. This machine reduces the production costs of rice, saves labor time, and increases user comfort in large-scale rice fields, which are expected to increase in the future.

3.1.2 Grafting robot for gourd-like vegetables (**Fig. 2**)

The scion and the stock are fed into this robot by hand and grafted by cutting off a cotyledon. The robot is used only for gourd-like vegetables. Even a beginner can graft like a skilled worker. Grafting loss is less than 5% with a group of three workers. 750-770 grafted seedlings can be produced per hour (compared with 100 per hour with one worker), which is three times as efficient as by hand. The present goal is to fully automate this process.

3.1.3 Cabbage harvester (**Fig. 3**)

This operator-ridden cabbage harvester pinches stems off cabbage, cuts off roots and outer leaves, loads head only into a container and harvests non-selectively. It makes possible substantial labor savings when harvesting large quantities of cabbage. The work efficiency is about 3 are per hour which is around twice as efficient as the conventional method. However, selective harvesting is popular at present, so this machine which harvests non-selectively is not easily accepted by farmers. It is necessary not only to develop a breed and a cultivation which is suitable for harvesting machines, but also to reform the marketing system. It is also necessary to change the minds of farmers and consumers.

3.1.4 Fully automatic vegetable transplanter (**Fig. 4**)
This small operator-ridden transplanter has a 2-row planting section mounted at the rear of the machine, which enables the high-speed planting of cabbage, Chinese cabbage (hakusai), lettuce, and so forth. Using standardized cell-plug seedlings, it can transplant under various conditions, such as various hill spacing within rows, different inter-row spacing, various ridge heights, etc. Its planting capability is about 10 are per hour with one operator. In the future, as vegetable harvesters are developed, the need for multi-row transplanters is expected to increase. Therefore it is necessary to promote feasibility studies of multi-row planters through empirical testing.

3.1.5 Burdock harvester (**Fig. 5**)
This operator-ridden one-row burdock harvester carries out a series of operations which includes having the burdock floated up from the soil via vibrating digging blades, picking them up with a feed belt, and transporting them to a loading platform in one process. Applicable inter-row spacing is over 60 cm, and it allows digging up burdock from a depth of 1 to 1.2 m in the soil. It can harvest about 2.6 are per hour with two workers.

3.1.6 Other machines
A microcomputer-controlled unmanned sprayer for orchards, a simple-type grassland renovator, a three-wheeled automatic sprayer for orchards, a heavy vegetable carrier, a vegetable residuum collector, a paddy field vehicle, a composting device for agricultural by-products, a high-speed rotary tiller, a tuber harvester, a strawberry harvesting cart, a granular organic fertilizer, and twenty-seven other machines which are now under development.

In addition to these, image processing technologies, remote control systems for farm vehicles, tilling robots, and so forth are subjects of major technological developments that have been achieved.

3.2 The national research society for agricultural systematization
In 1969, when rice transplanters were seen here and there in farmers' paddy fields, the rationalization of rice planting was an extremely important topic in Japan. Therefore, the question of how to effectively utilize the transplanters, which were beginning to be put into practical use, and improve them for easy maneuverability was a common problem for the local technical experts who belonged to the administration, farmers and manufacturers who were developing and producing the machines.

To cope with these problems and for the purpose of developing labor saving and effective techniques of cultivation for rice cropping, the Society for the Mechanization of Rice-Planting was established with each local technical expert as a leader.

This led to the establishment of a nationwide standard for the raising of rice seedlings. As a result, rice farming mechanization in Japan made remarkable progress. In 1974, it grew into the National Research Society for Agricultural Systematization and its activities were expanded to all areas of agriculture. Selection of project themes and the location of testing sites are discussed by a board made up of representatives of technical experts from all Japanese prefectures, at which time the manufactures' opinions are also taken into consideration. Here are several examples they are currently promoting.

3.2.1 Paddy field tractor for intermediate work (star-wheeled tractor) (**Fig. 6**)
This machine was developed for the purpose of saving labor, particularly in large scale rice farming (20 to 30 ha fields) and also for the intermediate work which had not yet been

mechanized in the operation of rice crops. It has features such as special large diameter high-lug tires with a width of 15 cm (Star Wheels), HST, high crop clearance (67 cm), horizontal control system for 3-point linkage, light weight, etc. It increases the efficiency of trenching, spraying, topdressing, weeding, etc. Profitability studies for this product remain to be completed.

3.2.2 Paddy field vehicle (**Fig. 7**)
This machine was developed by an Urgent Development Project that made possible the integration of an operator-ridden system whose aim was substantial labor savings in planting and intermediate cultivation of paddy fields on middle-scale rice farms (about 10 ha). It is a multipurpose operator-ridden vehicle which has the same planting capability as a rice transplanter and which also handles such operations as fertilization, weeding, and spraying of around 0.8-1.2 ha/h

It has continuous variable speed transmission and Live PTO, as well as Ground PTO. The planting section has 6-8 rows, and the boom application width is 7.5 m.

The current ground clearance is 50 cm in order to obtain acceptable performance during planting operations, but prototypes with higher clearances will be tested in the future.

3.2.3 Walk-behind, fully automatic vegetable transplanter (**Fig. 8**)
This walk-behind machine allows high-speed one-row planting of cabbage, Chinese cabbage (hakusai), lettuce, etc. It allows planting cell-plug seedlings (128 cells or 200 cells) of the beforementioned vegetables under such various conditions as hill spacing of 18-56 cm within rows, inter-row spacing of 45-60 cm, and ridge heights of 0-30 cm. It has a leveling system which makes possible easy operability, keeping the machine horizontal when used for contouring on slopes. It also allows simultaneous planting with boring in mulch film. It transplants about 5 are per hour with one operator.

Remaining subjects, such as the raising of seedlings, investigation of operational systems, economic influences, and the like for establishing mechanized vegetable cultivation will be studied in the future.

4. The advantages for industry in cooperating with the administration on development

The development of agricultural machinery and its practical implementations in Japan have concentrated mainly on small mechanization systems for rice cropping. Cooperative development enables industry to recognize areas, such as vegetable farming, that have been left behind and makes coordinated development in these areas possible. As a result, the development of machinery will progress and, in so doing, contribute to the revitalization of Japanese agriculture.

Cooperative development with the government administration enables the speedy development of machinery, for which mechanization needs are intense but quantity needs are relatively small, and makes possible the development of high-level, complex technological solutions by reducing the burden on each manufacturer.

Cooperative development lowers production costs of machinery through the use of common parts and common metal molds, as well as contributing to the diffusion of the machinery.

The support of the administration, which has accumulated know-how, fundamental technology, and large funds, makes possible the promotion of risky development projects for new technologies, like robots and unmanned operations in the future.

Using the national organization of the administration, the exact needs of farmers can be determined through nation-wide testing at the same time that the working system, machinery and other equipment are integrated by transmitting technology with assistance from the administration. This results in the ultimate reduction of machinery costs.

5. Conclusions

In Japanese agriculture at this stage, what we have to seriously take into consideration is the lack of a new generation of farmers in farm villages due to the loss of young laborers to cities. The problem is most serious in small-scale farming close to mountain areas which produce 40% of the agricultural products in Japan.

The farmland of this district has the important function of cultivating water resources and preserving the physical condition of the land, which is relatively vulnerable to damage from such disasters as floods, landslides, and erosion or outflow of soil. Moreover, it maintains and cultivates the natural environment and scenery of the countryside, and provides space for relaxation to the urban population in particular.

In the future, all Japanese citizens should become aware of these circumstances and both the administration and industry should give their full support to each region of the country so that they can revitalize their unique agricultural features and enhance local products.

Last but not least, I would like to express my heart-felt appreciation to both the Bio-Technology Research Advancement Institution and the National Research Society for Agricultural Systematization for providing us with materials, advice and cooperation for this speech.

Fig. 1 - Combine harvester

Fig. 2 - Grafting robot for gourdlike vegetables

Fig. 3 - Cabbage harvester

Fig. 4 - Fully automatic vegetable transplanter

Fig. 5 - Burdock harvester

Fig. 6 - Paddy field tractor for intermediate work (star-wheeled tractor)

Fig. 7 - Paddy field vehicle

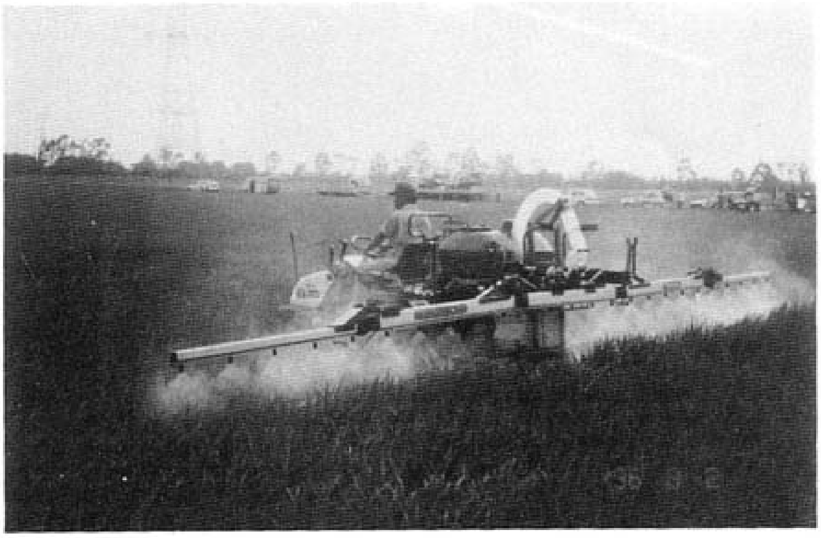


Fig. 8 - Walk-behind, fully automatic vegetable transplanter

Cooperation between industry and research institutions: the point of view of the industry

by ***K. Dieter Wilkens***
Germany

1. Introduction

Research cooperation between industry and public research institutions can be an excellent possiblity to provide ideal conditions for advanced engineering projects. Cooperation conditions and management is dicussed in detail in connection with a carried out project. Besides the project organization it is essential that responsibilities and the schedule are clearly defined. Furthermore a ranking method of performance criteria is demonstrated.

Fundamental research work today is still of outstanding importance for future development of the agricultural industry nation. Unfortunately fundamental research work demands 2 basic requirements:

- the capacity of highly educated staff;
- the Money to pay them and of course for the necessary material.

Nowadays both the capacity and the money is a problem at least in small and mid size companies. This fact could consequently lead to the result that fundamental research work can only be carried out by either public research institutions or big multinational operating companies.

However, there is a good third option which I would like to report: This is the cooperation between industry and research institutions.

2. Research project compact roller

As an example of research cooperation between industry and research institutions I would like to give you a detailed report of a project which has been carried out in practice. At the same time I will give you some additional information about how this specific project was handled.

In 1991 Matthies of T.U. Braunschweig [1] presented a new concept of an agricultural round baler. The basic handicap of a conventional round baler regardless whether it is a fixed chamber type or a flex chamber type is the fact that the driver has to interrupt the baling process every time the bale has to be bound and to be ejected. The new concept consists of a round baler which could work continuously. Furthermore the first lab tests indicated a much higher possible bale density compared to conventional round balers. Therefore Matthies called this type of baler the Compact Roller [2].

The presentation of this laboratory unit was followed by a cooperation with an agricultural machinery company respectively a cooperation with 2 mid size companies which surprisingly enough are competitors in the main markets. The involved companies are Welger in Wolfenbüttel and Krone in Spelle/Germany.

2.1 Project preliminaries

Of course you can imagine that this specific constellation of cooperation partners was a very delicate one. Therefore it was absolutely necessary to develop clearly structured project targets, project conditions, project organization as well as responsibilities, schedules and last but not least budgets. In order to give you a complete survey of all project planning characteristics I would like to present some of the main fundamentals in the following charts.

In detail **Table 1** gives some of the very important conditions which are imperative if such a cooperation project is to be successful. Especially in case of cooperation partners with different potentials or interests, or as in our case competitive partners they should not be neglected.

A general scheme of an objective-setting process is shown in **Fig. 1**. It is always very important to structure every process in clear phases which give the framework for detailed planning work and presentation milestones.

2.2 Project organization

In the case of the research project Compact Roller the project organization consists of 4 parties. Beside the T.U. Braunschweig the 2 companies Welger and Krone and a professional consultant build the project organization shown by **Fig. 2**.

The project organization is structured in the steering committee, in which the top management and scientists are integrated, the core team, and the expert teams. In all teams both the research institute and the 2 companies are represented. Furthermore a professional consultant completes the project organization. The consultant acts on all levels of the project organization. This principle ensures that the results are presented in a consistently high quality standard and the action plans are coordinated.

Table 2 shows the responsibilities of the steering committee as well as the core team and expert teams.

The main milestones of the CRP project schedule are given in **Table 3**. The activities are divided into 3 phases. Phase 1 mainly contains evaluation activities, phase 2 contains the planing activities, and phase 3 contains all realization activities. Each phase is finalized by a review meeting and presentation to the steering committee. The steering committee decides either to add further detailed information or to start the next phase.

In all phases of activities both staff members of the companies and scientists of the T.U. Braunschweig are involved. After the first laboratory tests were finalized public funds were applied for. Therefore it was possible to add to the main line activities supported by the industry further scientific evaluations supported by public funds. For instance of lot of Diploma and Ph. D thesis [3, 4, 5] have contributed to the advanced research project. Also the Bavarian Landtechnik Weihenstephan carried out research work on feasibility to use to bales for energetic usage [6]. Another important side project relates to the handling and logistics of compact roller bales for industrial usage carried out by the ATB Potsdam Bornim near Berlin [7].

During the whole project work it is always imperative to double check the targets and reached results. A typical method to clarify the status is the ranking of selected performance criteria as shown in **Fig. 3**. By selecting 10 - 20 main criterias divided into the categories crucial, very important and important and adding market relevant multipliers a neutral view of the reached status is achieved. This method is extremely helpful in comparing different solutions.

3. The compact roller pilots

The **Figg. 4** and **5** demonstrate the realized Compact Roller pilots in 2 different principles.

The CRP 400 shown in **Fig. 4** is a continuos working machine ejecting the endless built bale against the driving direction. The balelength can be chosen according to requirements. The density of this machine is considerably higher than all other known balers.

The CRP 800 is based on the same principle as the CRP 400 with the difference that the bale ejection is sidewise. The throughput of this machine is much higher than CRP 400, the density is below that of CRP 400.

The evaluation and test program of both type of machine is still going on under various harvesting conditions. Many of the scientific research programs based on the machines realized by the cooperation between industry and research institutions have contributed further knowledge in high density harvesting conditions.

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Table 1 - Conditions

Exact Definition of Research Subject
Persons involved have to be named
Confidence and Acceptance have to be proved
Exact Contract of Co-operation
Project Organization has to be established
Project Objectives have to be defined
Action Areas have to be determined
Performance Criterias have to be fixed
Reporting has to be announced
Project Budget has to be fixed

Table 2 - Responsibilities

The CRP project oganization works in teams consisting of varios departments and companies institutions.
The hierachy is simple and the managment is directly involved.

The responsible parties are:

Steering Committee:	Steers the whole process and provides the necessary decisions based on the compiled results of the core team and clears the way for the next phase.
Core Team:	Compiles the results according to the aggreed tasks. Special responsibility for the concept draft. Steers and completes the work of the expert teams.
Expert Teams:	Compiles the results of the specifically defined tasks and components.

Table 3 - Milestones of the CRP - project schedule

Phase 1:	Estimation of technical Potentials based upon the CRP Fundamentals.
	Evaluation of the Price / Customer Benefit Position in comparison to existing Market and its development.
	Definition of the Performance Criteria
	Portfolio Analysis
	Review
Phase 2:	Detailed Specifications
	Concept Draft A (Natural Raw Materials)
	Concept Draft B (agricultural Harvesting)
	Review
Phase 3:	Realization (Design + Prototypebuilding)
	Fundamental Test Concept A
	Fundamental Test Concept B
	Scientific Systems Analysis
	Scientific Environmental Studies
	Review

Fig. 1 - Objective-setting process

Policy Guidelines

↓

Key Areas

↓

Objectives

↓

Action Plans / Tasks

↓

Performance Criteria

↓

Review

Fig. 2 - Project organization CRP

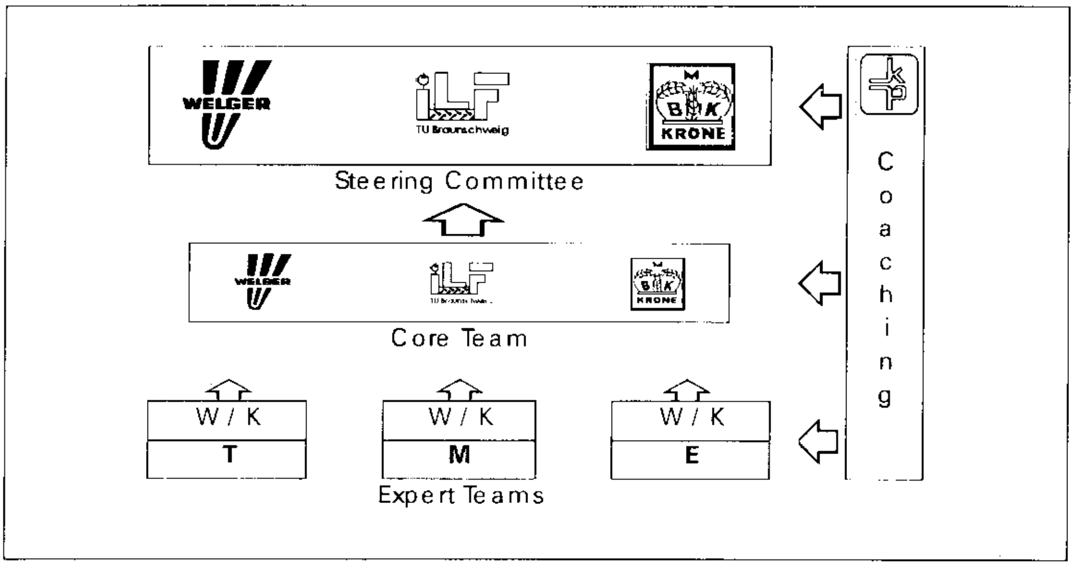


Fig. 3 - Ranking of the performance criteria

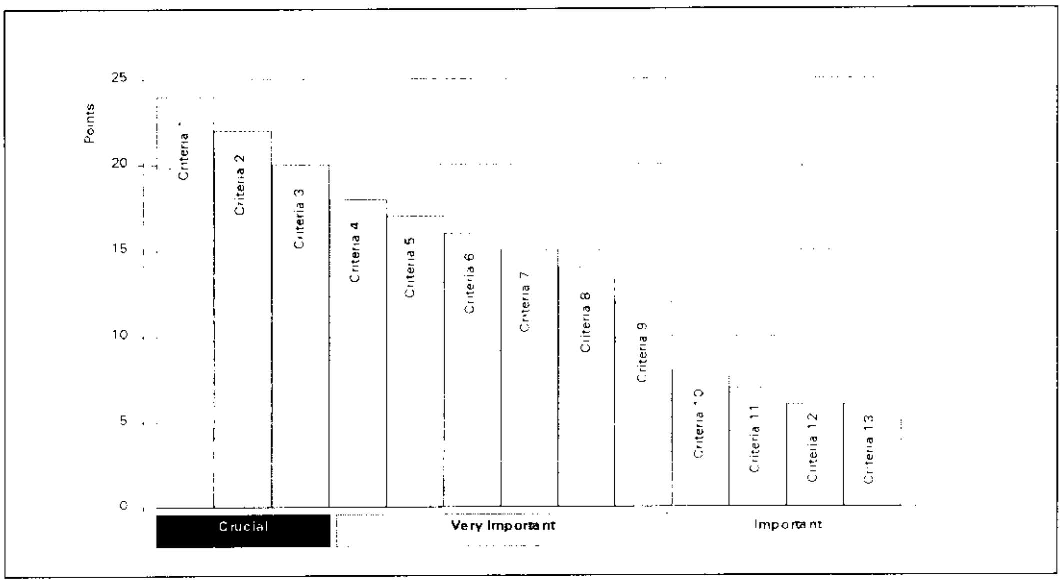


Fig. 4 - Schematic diagram of the CRP 400

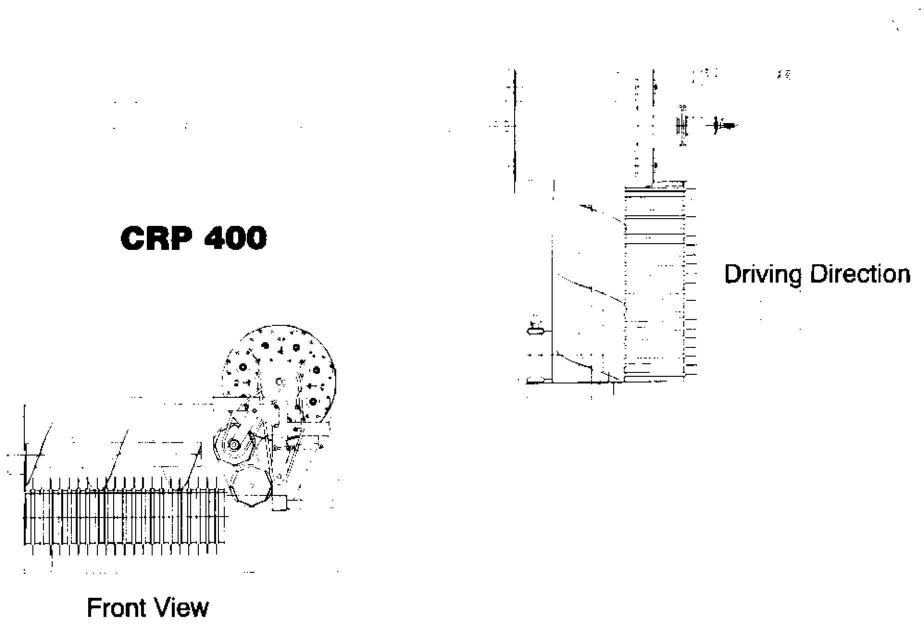
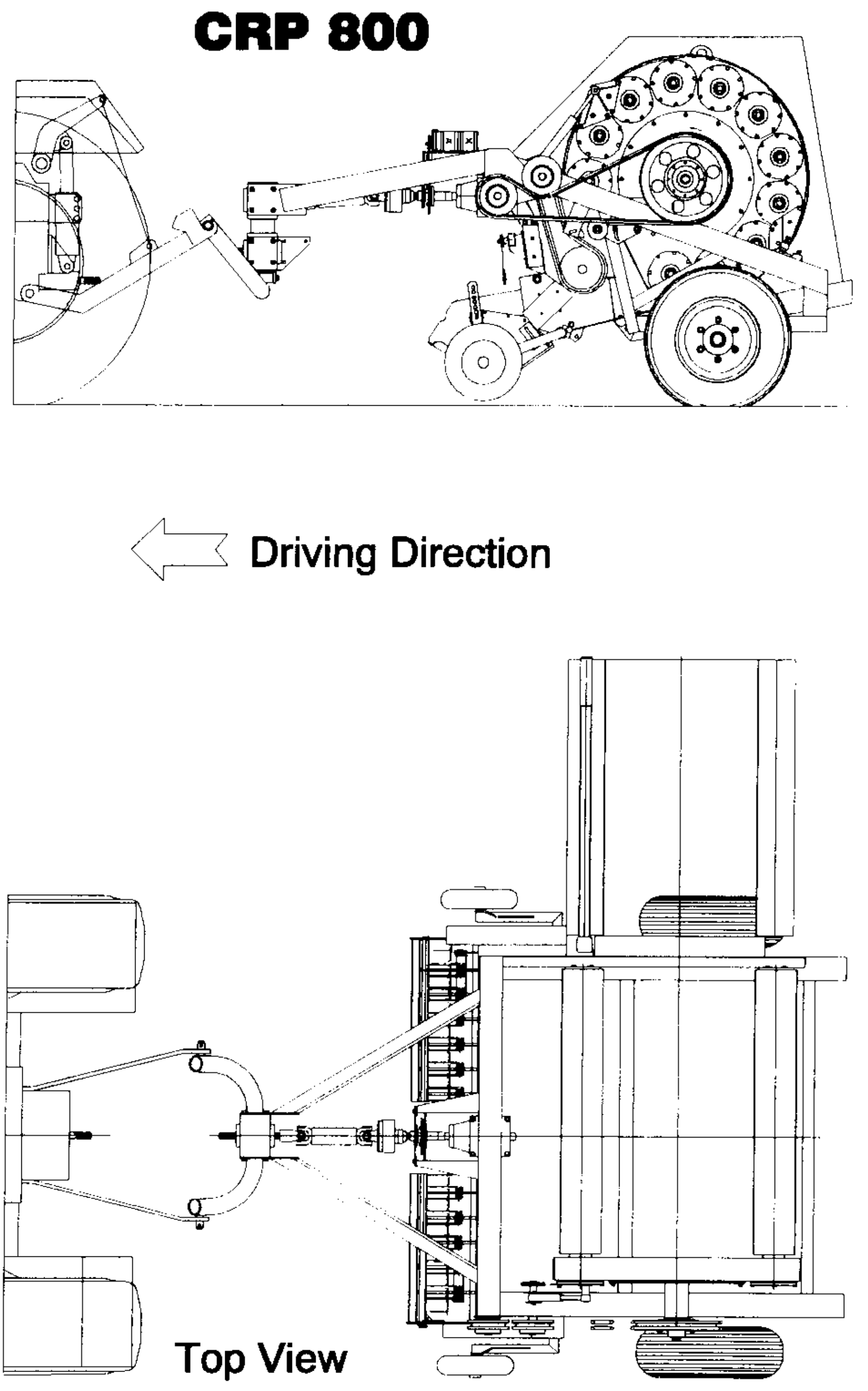


Fig. 5 - Schematic diagram of the CRP 800



DISCUSSION

A. WYLIE

I would like first of all to make a couple of comments on something that was said by Giuseppe Pellizzi about why the voice of industry has not been heard. Perhaps one of the reasons is that industry is very much outnumbered in this room. I was looking through the list of members of the Club, and not more than about ten or twelve percent of the Club's members are from industry. Perhaps also industry was watching and waiting for the time to come, and perhaps, also, people from industry are not as good talkers as people from research institutions.

And now, I would like to emphasise one difference, that was pointed out indirectly, between the points of view of industry and research institutions. Industry—much more than the research or academic community—is always watching its own particular interests. This means, as the speakers have said, that most often its priorities, the pressures it is suffering, and the time frame in which it has to work are different from those of research institutions or university research centres. This obviously gives them a different slant, but that doesn't mean that collaboration is not possible. I think that an overall view of the problems facing industry has been well exposed during this session, with specific reference to medium-sized industries. However I believe these points are applicable to all of industry. Obviously the major issues common to all sides are things like funding, and this becomes especially critical for the medium and smaller sized-industries when they have to face innovation and development of new products. A point that was made, and which I think is very important and worth emphasising, is that it is essential that research institutions gain the confidence of industry if they are to be successful in their work. I think this is critical. It's not only the institutions but the researcher himself who must gain the confidence of his counterpart. As Doctor Wilkens pointed out in this connection, it helps to have a clear structure, with a clear definition of responsibilities, of what each side expects from the other throughout the process, and obviously of where the funding will come from. And, as you get more and more into publicly supported funding, you have to start looking at the other end of it—what is the real cost of your development work, which industry has a very clear and concise need for. To finish up, I think information on what the user wants has come through very clearly from some of the presentations in this session: the user needs quick response to its questions and its timing; innovation involves risk, and the quicker you get that out of the problem the cheaper innovation will be. This points to the need for continuous market intelligence, market research, and takes you to what the textbooks call "market pull" rather than "technology push". This is obviously a constant point of discussion in meetings such as ours. If both of these are brought into focus, the chances for improving the result of long-term collaboration are much greater, and I think that we can look with optimism to the fact that, if the communication lines are kept clear and each side understands the other side's priorities, good collaboration between industry and research institutions can be expected and, as a result of this, good user satisfaction can be achieved. It's interesting to note, from Mr. Yotsumoto's presentation, how the user can vary from one situation to another or how the needs that drive research can change from one area to another.

A.M. EL HOSSARY

Mr. Yotsumoto indicated, in his interesting presentation, the new approach to solving the problem of the lack of a new generation of farmers. This was based on two main concepts. The first concept—which I accept—is the shift from single-crop machines to multi-crop machines. This is really a positive result of the cooperation between industry and research. The second concept is the shift from small-scale farming to large-scale farming. I think that Japan is characterised by its small, midget plots. Have they done any market research in this respect? And, I wonder, how are they going to solve the problem of these midget plots that characterise the Japanese farming system?

A. WYLIE

That's a very pertinent question. Something which always comes to mind when you're looking at different agricultural situations. Number one: the size of the farms. Number two: the degree of technological development that exists there. And number three, of course, the educational and skill level of the operators.

K.Th. RENIUS

On the issue of the next generation of farmers, I think this is a problem that exists in almost all countries, especially in highly-developed countries. In Germany it's interesting to see that the problem could be solved in many areas by part-time farming. The philosophy is that these younger part-time farmers see it as a hobby, and not primarily as a money-making activity. Though they do also make some extra money with it, which represents an additional input to the gross national income, even if they don't pay tax, it helps to run the system. But the main thing is that they see it as a hobby, they take care of the landscape and they minimise this type of problem in Germany—mainly in Bavaria.

T. YOTSUMOTO

As you know, we have almost four million farmers in Japan. And only about 10% of these are full-time farmers who are exclusively dedicated to farming. The average size of a paddy field is about one hectare, and there are fewer successor to the farmers due to the ageing population, and also because young people are not interested in taking up farming. That's why the Japanese government is trying to increase the farm size as much as possible. But the situation is such that it's not so easy to *make farms larger. The trend is for contractors, and I imagine also some farmers, to set up private companies in order to promote their productivity and reduce their costs. So the size of farm machinery is currently increasing, though not dramatically. In the past fifteen to twenty years, for example, typical tractor horsepower has increased from 15 hp to 30-45 hp. The scale of production has also been changing. About twenty years ago, maximum production was around two hundred thousand units per year, whereas now I'd say it's less than one hundred thousand per year—I'm talking about agricultural tractors in Japan. So that's the situation.*

Y. KISHIDA

I'd like to add a few comments concerning the future of agriculture. This is the present situation of the agricultural workers: the number of workers—their distribution pattern by age from fifteen to ninety-nine years old. This data comes from the agricultural census conducted by our Ministry of Agriculture, who put the maximum age at ninety-nine years old. We have three types of indexes for agricultural workers. One index is equal agricultural engagement. That means that the worker who devotes more than 50% of his working time to agriculture, we count as agricultural engagement. Of these, we have a total of about four million, including the women. That means the men are a total of two million. Here you see that the peak age is now at seventy years, and the proportion of workers over 65 years old accounts for about 50% of the total labour force. You know that the Japanese are very long-lived—the average life expectancy for men is 77 years. This means that, in the next eight years, fifty percent of the labour force will be lost. Up to now, the peak age continued to be shifted upwards, and by doing this we were able to retain some of the labour force. However the peak age is now approaching the life expectancy, so in the near future we can expect to see a very sudden and dramatic decrease in the agricultural labour force. I predicted this about seventeen years ago, and told our Ministry people that we had to prepare the mechanical power. But at that time our Ministry of Agriculture had a policy of reducing mechanical input to reduce costs. So for the past fifteen years they discouraged mechanisation, and that means we will now face a very big problem. Recently, the Ministry of Agriculture has become aware of this fact, and they have now suddenly said that agricultural mechanisation is the most important policy. But I am afraid we may not have enough time to avoid the labour shortage problem. As Mr. *Yotsumoto said, our self-sufficiency ratio for food is already less than 50%. That means that in the year 2000, over the next ten years, our self sufficiency ratio will drop even more. And, as Mr. Yotsumoto told us, the average size of farms is very small as compared to Europe or the US: an average of 1.2 hectares. Our total acreage is about 5 million hectares, and the number of farms is now about 3.5 million. To overcome this problem, government turned to industry saying: "shall we cooperate to develop an emergency project?". So they started a five-year project for the development of 50 different new machines. That means ten new machines every year. It seems to have been very successful so far, but one problem is that, although they have developed these machines, sales of these machines are not so good. However, we must do our best to overcome this problem. Dr. El Hossary's question is important: how will Japanese culture survive? You know, in the case of Japan, even the small farmers are very creative and do direct marketing. They produce very special qualities of products, and I think the future of Japanese agriculture lies in good-quality high-priced marketing. Another very important trend is part-time farming. I believe that, if we prepare an adequate mechanisation system, a farmer can easily handle 2-3 hectares and still have enough time to work for another industry. However, our Ministry of Agriculture has a different policy. They want to develop specialised full-time farming, which is not realistic. But perhaps the Ministry of Agriculture doesn't want to see farmers also working in another industry, under another ministry. And perhaps we should set up a new ministry that includes agricultural industry.*

A. MUNACK

I have a direct question for Dr. Wilkens. I think you gave us a very clear contribution, and we were able to easily follow your cooperation approach. However, when I look at the "rules of the game" which you presented, it seems to me that these are the rules of industrial project management. Do you think this is applicable to all cooperation between research and industry? Perhaps this industrial-type project management of cooperation was applicable here because the necessary conditions existed—your project was a complete laboratory unit, so it was 50% research and 50% development. Or do you think it's a general approach which could be very fruitful in all situations?

D. WILKENS

It's true that this project did not involve particularly fundamental work, because a laboratory test unit was already in existence. Furthermore, we had two companies and one research institution as partners, so it was necessary to somehow achieve really clear management of the entire project. But, to answer your question, of course it might be a little different, depending on whether you have an advanced project like this one or a project that is very fundamental. But I think some major elements of what I have reported here are valid in all situations, because in any case you must be clear on what you want to achieve, what you want to get out of the project, regardless of whether it's an advanced project like this one, or a very fundamental project. So, I think when you reach the stage of cooperating with a company, it is necessary to establish certain rules for handling the project as a whole. Otherwise, the entire relationship can get a little bit tricky. If you don't lay down the rules for managing the project, and if you don't establish a set of principles for your reviews, then all the partners will end up taking only their own goals into consideration. And they may lose interest in certain common objectives, *which may have been valid at the outset, but in the meantime some difficulties have arisen and everybody has a different idea of what he should do and what the project should bring out in the end. So, getting back to the question, it is true that this project management is similar to industrial project management, but I think many of the basic elements are also valid for pure research and industry collaborations.*

M.E. MCKAY

I'd like to comment on Dr. Wilkens' presentation. I think that he highlighted a couple of crucial elements in the success of interaction between industry and research. In Australia we talk about confidence and acceptance: that there needs to be confidence between the people involved, and acceptance of a common aim. And, in my experience, one of the major contributing factors in this exercise comes down to a limited number of people who have actually had experience on both sides of the fence. This was a comment that Dieter made in his introduction, that he had in fact had experience in both the research and industrial areas. I would support that very strongly; in my experience that is a major contributor to success. And I think that a group like this ought to be making a strong recommendation for the movement of people between industry and research organisations. It's not a new concept, and it's a very difficult one because of career paths and all the things that basically stand in the way. But it's also, in my view, one of the biggest things working against cooperation between industry and research organisations: the fact that they operate in different fields, and have different objectives. So it generally requires somebody who has been around, and been in both camps or in several camps, to actually be able to perform the role of the intermediary.

Y. KISHIDA

I have some questions to put to the speakers. The first one is to Mr. Celli: you mentioned that in Italy there are about 160 soil tillage machinery companies, but when I visited one company I was told that, in the case of rotary tillers, there are 400 companies in Italy—which puzzles me. Also, your presentation was very interesting and very important because no agricultural operation can be performed without the implement. In fact the basic nature of agriculture requires variety, meaning that many different types of specialised machines must be developed, produced and marketed. However, this kind of specialised equipment is not offered by large-scale manufacturers. Not only in Italy, but also in Japan and other countries, the farm machinery industry is characterised by a small number of tractor and engine manufacturers and a great many small-scale manufacturers of specialised implements and machines. In the case of Japan, we have more than 1000 different small-scale manufacturers. But these manufacturers have the same problem as in Italy. For example, I mentioned the government's emergency project to develop 50 different kinds of machines quickly. However, when I visit small-scale machinery manufacturers in rural areas they know nothing about it and ask "what is that, Mr. Kishida?". So it is often the case, with this kind of government project, that some large-scale and medium-sized manufacturers can perhaps benefit from the project, but 90% of the small-scale manufacturers cannot gain any advantage from such projects. Their attitude is always to directly communicate with the farmer and the area-level agriculture, and to rely on governmental help only in very rare cases. Likewise for the university or research institutes: they are very independent. In connection with the question put by Prof. El Hossary, I think we need to help certain small-scale farm machinery industries, but I have never seen a public project of this type in Japan; maybe they exist in other countries. Particularly in developing countries, the focus is always on tractors and engines, but it's very difficult to find a good policy for promoting implement manufacturers. Not only in developing countries, but also in Japan, we lack a good public policy to assist the small-scale industries. I think the situation is the same in Italy as well. For example, at this meeting we have several manufacturers, but the only representative from an implement manufacturers is Dr. Celli, and other people come from big companies in the tractor manufacturing industry. In certain occasions it is difficult to have delegates from small or medium-scale implement manufacturers. I would like to suggest, for the conclusions, that we think about how we can help these small-scale implement manufacturers in the world.

P. CELLI

On the subject of the figures, I would just like to tell you that 160 companies is the official figure from UNACOMA. But I must say that this is a very dynamic sector, with new companies springing up all the time. Four hundred seems to be too much, but maybe 160 is not up-to-date.

Y. KISHIDA

I'd like to put a question to Mr. Wilkens, about this compact roller project. When will the study phase be complete, and when will the commercialised machine come out? Because yesterday, during our visit of the EIMA show, I found a new round baler that is very highly automated. Fully automated. So I fear that when the product described by Mr. Wilkens is commercialised, it may no longer find a market.

D. WILKENS

The current phase of this project was started in 1991 and it is still ongoing. As Prof. Renius mentioned, there are further tests that have to be done, and the production launch date for this project has not yet been defined. It won't be until these final tests have been finished.

Y. KISHIDA

The reason for my question is that, I have often had discussions with industrial people, and industrial people need to do things very quickly. As an example, take the two competitors here, Kubota and Yamaha. Say that Yamaha announces a new product; maybe after six *months Kubota has to develop a new product as well. Their style is very quick, which is somewhat different from the timescales of research institutes.*

Prof. L. SPEELMANN
The Netherlands
A few minutes ago Mr. Kishida showed us a fairly old target group, but I want to address myself to a somewhat younger target group: the students in agricultural engineering. I learned from Mr. Celli's contribution that agricultural engineers are fairly valuable in his industry, and it has been stated in this discussion that industry and research institutions should speak a common language: I believe that such a common language should be learned at a fairly early stage, maybe even in universities. My question, which I direct in particular to Mr. Celli and Dr. Wilkens, is the following: what special subjects should we include in our curricula for agricultural engineering? Let me give an example: since 1995 we have had a close cooperation between Wageningen Agriculture University and Oklahoma State University. What we did was put students from both universities working together on a design project, in which the problem was formulated by industry. Last year it was the Deere company and this year it will be New Holland. And I think it is very worthwhile to teach the students to work together, giving them not only knowledge but also training in skills like project management.

D. WILKENS
You asked what subjects should be added to the curriculum. In terms of specific items, one that has already been mentioned, and which from my point of view is very important, is skills in electronics and sensor applications—that is definitely something that is missing today. Mechanical engineers, in particular, are a little bit weak in that field. And project management, which you mentioned yourself, is definitely also something which is of certain interest. We have to expect an engineer to know how to manage a project, how to handle a team of experts from various disciplines. Thirdly, I would add a basic knowledge of cost calculation— that's always something I find mechanical engineers lacking in: when they come out of university, many of them really haven't a clue about the cost implications of the different design alternatives.

P. CELLI
I don't know if I'm the right person to reply, but in my opinion, the problem we have at the moment in Italy is that there are many good engineering schools in which no courses on agricultural machinery are available. The problem is that, in most cases, the courses in agricultural machinery are offered within the university agricultural courses, but there is not a good link between the two worlds. In my case, for instance, when I started mechanical engineering, I had a preparation in many different subjects, but none of them was related to agricultural machinery, even though it was possible to choose a different courses in other universities and other schools. So I believe that, first of all, it would be important to set up proper courses. In this way there would be more agricultural engineers available on the market. However, I'm sure that the professors here know the situation much better than I do.

B.A. STOUT
In the US we have easier mobility between faculties. I think in Europe it's perhaps not so easy for mechanical engineers to come over and take a course in agricultural engineering. Beyond that, I would just add another thing: in the US, the demand from the machinery industry for our graduates has been so low that most of the departments have almost abandoned the teaching of tractors and machinery, and have moved in the direction of biological and environmental subjects. However the industry has recovered, and now there's a great demand for graduates from our universities, with skills in design of machines and so forth, but there aren't enough students to meet that demand. So we go through these cycles, and we're in a cycle now that's good for a student who happens to have such skills. But there aren't enough of them.

H.A. CETRANGOLO
The problem in Argentina is that there aren't any good universities with specialised studies in farm machinery engineering. Engineers don't know enough about agriculture, and agronomists do not know enough about engineering. The only possibility is to set up interdisciplinary groups, and that is how medium and large-sized companies work.

R.O. HEGG
The speakers highlighted and described some very good examples of industrial and university cooperation, but I would like them to respond to a question: in what way can additional cooperation be developed? We heard some very good specific examples. I think from the university standpoint, and from the institute standpoint, we would welcome opportunities to work with industry, but we need to know how we can make this more advantageous, how we can encourage this possibility. I'd be interested if each of the four speakers might comment on what they see as the ways in which the university can enhance additional possibilities.

A. WYLIE
Just to give the speakers a little time to think about it, I have a comment to make on that. I think one of the problems here is semantic. It's terms of communication. I was interested to hear Prof. Stout's comments this morning: when the same subject was mentioned, your first reaction was that industry should find ways of moving closer to the universities. That is a mindset, I suppose, and I think your point now is coming from the opposite direction. So I think both sides have to bend, and if you get the pendulums crossing in the middle maybe they can talk to each other when the cross.

H.A. CETRANGOLO

One of the problems is that the work of research institutes in universities, and other research centres, is driven by their own technological capability, and not by the demands of industry or the farmers, or by government policy in each field. I think that we're improving in terms of joint cooperation between industry and universities. But it's not enough yet, and I think that the government agencies that finance research projects can play a very important role, by financing projects that meet the demands of industry and farmers, and not simply the projects that the research institutions offer to do. I think that in this way, with the three players in this game—industry, research centres and the government agencies—we can achieve good results by financing those projects that are truly needed by people and society.

D. WILKENS

Back to your question, Prof. Hegg: what can we do to get the research institutes more involved in industrial affairs? There have been some attempts move a little bit further forward in this respect. There are a lot of subjects—not major ones, but small or minor subjects—that can be used as the basis for diploma or PhD theses: this also goes in the direction of the kinds of subjects we can add to the curriculum. In our company we always have one or two students working on their theses, which enables them to get an idea of how the work in industry is carried out; this is definitely not a big thing, but I do want to mention it as a good means of bringing the two sides a little bit closer. Very often, this type of work ends up leading to another one or two-year subject, with the involvement of additional staff from the research institute. This also works pretty well and has been successful. But getting back to the main question, of why industry is taking is so little advantage of the potential of research institutes, I think there's a very simple answer. We've already mentioned that many of the fundamental research subjects are focusing things on five or ten-years timescales, whereas most of the companies aim to see results within a five year period: they don't consider it essential to embark on major projects that will only give results in five or ten years' time. So it's a horizon, or timescale, problem. I don't know whether any other of the speakers in this particular panel want to comment on this.

D.H. SUTTON

Just to come back to Richard Hegg's question, and to perhaps turn our attention to a subject that has been touched on by Malcolm Mckay and Dieter Wilkens. Institutions and organisations don't collaborate: people do. And I think Dr. Wilken's point, about building a team with competent named individuals, is a crucial aspect which also links up with the earlier question of what we're doing with students. We need to instil this understanding of how to work together in multidisciplinary teams, building confidence and teamwork. Perhaps that's something that ought to be incorporated more into university curriculums.

P.F.J. ABEELS

I would like to share my experience of cooperation between industry and university. Twenty years ago, our university was moved away from the site where it had been built, and which it had occupied since 1425. We had to move to a new city: not a campus, but a real city. And during the past twenty years the city has expanded thanks to the many laboratories located near the university. Why are those laboratories situated close to the university? Because research equipment is becoming increasingly expensive, and there they have a collective kind of agreement to obtain very expensive equipment from the university, for their own use. At present there are a lot of industries whose only research and development department is just with the labs, with the auditoriums, with the students. And because it's a city, rather than a campus, everything is mixed together: buildings, housing, academia and research. I think there lies another opportunity for collaboration: offering industry the technological infrastructure for testing. Because small companies—many speakers have underlined this point—cannot afford big equipment of any kind: mechanical, electronic, etc. But the universities are able to use it for teaching, and then to educate the people in the elementary electronics for the next step in the industry. And that is perhaps another way we can promote future collaboration in both directions.

K.Th. RENIUS

I will try to give another answer to the question of how to get more out of universities. I think good research people should perhaps advertise their skills a little more. In the yearbook here, every year thirty experts show how they are able to handle the progress and the technical developments. I know of several cases of companies that are picking up the experts and inviting them to participate in seclusion meetings—for which they pay very well. They spend one or two days in a nice hotel discussing strategies and potential for new products. Having participated in several such meetings, I can give you two examples of the results of this type of cooperation. The first is the development of the electronic drive line management of Walterscheid, which will be continued, there are new products in preparation. The second is a self-propelled mower which was developed from zero to working prototype in about fourteen months. And the company had never before built a self-propelled machine. So the main message is to offer the skills and then to look for new products in seclusion meetings. This has been very successful in some cases.

A. WYLIE

We have a program in Chile where we're trying to get university people closer to industry, and one of the things we have found is that if you teach university research workers how to put their technical words into a more commercial language, and help them set up a business plan so that they have common linkages with industry, then you can get them closer to industry.

A.U. KHAN

I think Malcolm mentioned the importance of interchange of personnel between research institutes and industry. I feel very strongly that this is something that has been missing, especially in academic institutions, and I think there are several ways of looking at it. For example, people taking a Sabbatical could go and work in industry, to help improve reciprocal understanding; similarly for students, some universities have apprenticeship programs where students work at the universities. Those are probably good ways for achieving this interchange of personnel for short periods between the two. I also want to go back to the issue that was raised about the subjects in the curriculum. I have worked with a number of engineers trained in many countries, and I've found that although ag-engineers are better at testing agricultural machinery, they very seldom work out very well for the design of tractors and any higher-level agricultural equipment. Mechanical engineers, on the other hand, do much better in the design process. So there are some weaknesses in the ag-engineering training, and I would say that this is the case in the US, as well as in many of the Asian countries: the ag-engineers are not so well trained in machinery design, in metallurgy, metal materials and things of this sort. So if you want to have ag-engineers working in design they need to have a better knowledge of design as well as of metallurgy and materials sciences.

Prof. Bassam A. SNOBAR
Jordan

Actually this problem of the new generation of farmers is not exclusive to Japan. I have seen and heard about it from many different countries. I have heard people complaining that the new generation will not take over the farms in the United States, in Europe, in the Middle East, in Africa. I don't know what the reason is for this, I would like to hear from the other speakers if the reason is lack of mechanisation, or because it doesn't pay to work in agriculture. I know that part of the reason: particularly in developing countries like Jordan, people do shy away from agriculture because of the lack of mechanisation, because of the hard work, because of the high cost of labour, because of low returns and so on. The other comment I would like to make is that we are really talking about lack of cooperation and linkages between universities and research institutions and industry. And we've heard from Mr. Celli that there is also a lack of communication and cooperation between different industries. Tractor manufacturers are not cooperating with implement manufacturers, and this is a shame. Perhaps we can afford the lack of cooperation between industry and research institutions, but we certainly cannot afford the lack of cooperation and linkages between different industries. For example, in Jordan we wanted to buy a certain type of plough, and the manufacturer recommended a tractor of 150 hp minimum. Now the whole of Jordan doesn't have even one single 150 hp tractor. The largest ones are 125 hp, and the most commonly used ones are the 70-75 hp. Nevertheless, the manufacturer said the only way we could have this implement, which is very important and useful for desert areas, is to have this large tractor. I asked them if they could make it smaller, so that we could put it on a 70 or 80 hp tractor, and they said they would try. So I would suggest that one recommendation be that cooperation must be promoted not just between research institutions and industry, but also internally between different industries, and also between different research institutions.

A. WYLIE

Two comments on the first half of your question. I think it's a very difficult problem to face as to why people are shying away from agriculture. The statistics can sometimes be confusing. They show that there are fewer farmers, but there's not less farm output: so the farm size is obviously affecting the percentage of the population that's on the farm. From what I have heard, and this is not a personal experience, there are certain countries, especially in the mid-African continent, where government policies tend to be against helping farmers and against farming in general, so that also obviously has an effect. Undoubtedly there's a status problem related to being a farm labourer. I think this is something which is the effect of television and the media. Also, in some developing countries, and I would put Chile in that category, the living conditions in the farm areas are not as good: schools may not be as good, hospitals may not be as good. All of this mixes in together and you get a trend towards the city and away from the farm.

If we have to wrap up, maybe just a couple of short comments. I think that a very pertinent point made is that cooperation is a people-to-people problem and it's an institution-to-institution problem. The problem is that institutions are made up of a bunch of people and this puts a shell around so you don't get as much as you would like. I would tend to think that it's very difficult to get a fully rounded agricultural engineer, because of the different areas that have to go into his makeup. So I would go along with the suggestion that the multidisciplinary approach to problems is probably *going to be more effective than trying to get it all into one superman, as it were. Lastly, something that has come up all the way through is that if enough importance is not given to what the market wants, you will not be able to distribute your funding and efforts in a way that will be most productive to the overall process. So that has to be the key to most of the programs.*

SESSION 2

MECHANISATION REQUIREMENTS FOR L.I.S.A.

Chairman: Prof. Bill A. STOUT, USA

Mechanization Requirements for Low Input Sustainable Agriculture

by ***Aad A. Jongebreur***
The Netherlands

1. Introduction

Low input sustainable agriculture (LISA) as a concept started as a USDA-program in 1987 to achieve an improved utilization of resources [1]. Matthews [2] has mentioned mechanization concepts, a.o. robotic milking, dial a crop sprayer, gantry cauliflower growing, to be applicated in order to reduce costs of labour and inputs. Improving the sustainability of agricultural production processes requires in the Netherlands large efforts in innovative investments in machinery and equipment. The main topics of sustainability are laid in the field of the relation agriculture - environment: use of agrochemicals, emissions of carbon dioxide by the use of fossil fuels, the emission of ammonia and the application of manure and fertilizers.

In **Table 1** emissions of greenhouse gases (global warming), ammonia (acidification), plant nutrients (pollution of groundwater and surface water) and agrochemicals from agricultural activities are mentioned. Conclusion is that the emissions of ammonia and agrochemicals are decreasing.

Many definitions are used for the concept sustainability, which is used for the first time in the report 'Our common future' of Brundtland. Gips cited by Speelman [3] gives as a definition for sustainability: "Sustainable agriculture is ecologically sound, economically viable, socially justified and human". Governmental policy in the field of 'agro-environment' may have different effects, e.g. decrease of production activities, slowing-down of growth and scaling up. Larger farms can afford better the costs of the environmental measures. Estimation of these environmental costs for improving sustainability is not easy, but the most accurate shows net costs of approx. 485 million guilders per year, mainly due to investments in plant nutrients saving techniques and more efficient and environmental friendly use of agrochemicals [4].

There is - besides maintaining intensive production systems in combination with technical solutions - another possibility to achieve more sustainability in agricultural production, namely extensification. Especially biological and ecological crop production methods show a gradual growth during the period 1986 - 1995 to 0.6% of the total agricultural production area. Characteristics of these types of production are absence of use of agrochemicals, special requirements related to the animal husbandry systems, application of plant nutrients in balance with the environment restrictions with regard to nature aspects. However Silvis and Van Bruchem [4] state that the gap between common farming and biological farming is decreasing. It is also a fact that the consumers market in the Netherlands for biological foodstuffs is more or less stabilizing and not growing.

In the following, with special reference to the situation in the Netherlands, a more detailed approach is worked out for three important themes in the relation agriculture - environment. These are:

- application of agrochemicals;
- nutrient application;
- use of energy.

2. Application of agrochemicals

2.1 *General remarks*
Within the frame of the Multi Year Crop Protection Plan [5] the goals for the reduction of emissions to air, soil, groundwater and surface water were determined. These reduction figures are mentioned in **Table 2**. From the total estimated emission of 6 million active ingredient more than 90% is emitted in the air during the period of 1984 - 1988.

The total use of agrochemicals in the Netherlands amounted in 1995 approx. 13.10^6 kg active ingredient. This means a reduction of the volume of approx. 45% in comparison with the period 1984 - 1988. Demonstration projects on approx.

450 farms with the aim to decrease the dependence on chemical protection in arable crops have resulted in an average reduction of 60% in the volume [6]. In the chemicals applicated for soil contamination quite a high volume reduction has been achieved by governmental regulations Also remarkable is that the emission to the air is very high (95%) in comparison with the emission to surface water.

2.2 *Model calculations*

Improving the utilization of plant protection agents can be carried out by adaptations in the spraying process. With the help of a two-dimensional model (IDEFICS) [7] - which describes spray deposits from a conventional boom sprayer - the effects of technical measures are evaluated. The model is validated under varying cirucumstances using a single nozzle boom sprayer. Computations are made of the following technical measures:

- decrease of the number of drift-prone drops by low-drift nozzle, coarse nozzles;
- control of direction of drops towards the crops (air-assistance, shielding of the sprayer boom, asymmetric "edge nozzle" at the boom tip, lowering of the spray boom);
- increase of the distance between spraying equipment and area outside the field, unsprayed boundary zone around the field, application of hedge or screen [8].

The results indicate that sprayer boom height and wind velocity are major factors determining spray drift. Overall drift reduction percentages which can be achieved through combination of technical measures - e.g. low drift nozzle, edge nozzle (which is an asynmetric nozzle) and reduced boom height - are approx. 87%. Unsprayed zones are unpopular among farmers, nevertheless in bulb

crops it is actually applicated (approx. 1-1.5 m distance to the ditch). Comparison between results of model computations and results from field experiments have indicated a good agreement.

2.3 *Application techniques*

Spraying technique has the aim to optimize the following goals:

- minimalisation of the emission;
- minimalisation of the exposure to the user/worker;
- maximalisation of the biological effectivity of the spraying procedure.

In crop protection improvement in spraying application techniques can contribute to better deposition on the leaves and reduced emissions to air, soil and surface water. In orchard spraying a step forward is made by the development of tunnel spraying devices (**Fig. 1**). The trees are enclosed by a canopy in which the spraying takes place. Spray missing the tree is deposited on the sides of the tunnel and recirculated. Also cross-flow sprayers with a reflection shield at the opposite site of the tree sprayed have been developed. Recirculation of the air flow within the tunnel is the well-known concept op the Closed Loop System (CLS). Measurements in fruit crop orchards on deposition distribution on the leaves and emissions to the ground and air with four different devices of spraying techniques were carried out. A conventional air assisted cross-flow sprayer, tunnel sprayers with and without air recirculation and a cross-flow sprayer with reflection shield were compared. The tunnel sprayer with air recirculation has given low emission values to the soil next to the orchard. The tunnel sprayer with CLS had low emission values to the soil and the air. Application of the CLS-principle for spraying devices in flower bulbs in cultivation beds is studied now. With shielding the transport of the drops to the crop is more independent from wind (**Fig. 2**).

Besides that 10 - 20% of the spraying liquid can be recirculated. This means direct saving on the volume and thus positive for economy and ecology [9].

In potato crops experiments were carried out to determine the effects of air assistance, spray volumes and drop size on the emission. Use of air support in field sprayers results in reductions of emissions to the air and the soil of approx. 50%.

For spraying of crops the main conclusions of the experiments are:

- lowering of the spray boom from 1.0 to 0.5 m above the crop;
- spraying at a wind velocity of 2 ms^{-1} in stead of 5 ms^{-1};
- spraying with a coarse drop size spectrum or drift-reducing nozzle;
- application of air assistance the droplets get an extra push in the direction of the crops (**Fig. 3**);
- increase the distance of the last nozzle to the next area from 2 to 4 m.

Research work is carried out on spray boom stabilization. Spray boom movements are responsible for irregular deposition of spray on crop leaves. A better stability gives the possibility to lower the spray boom. Measurement of these movements (**Fig. 4**) has lead to research and development of a fuzzy logic control system with the perspective of saving of 20 - 50% of the spraying liquid [10].

In order to decrease the dependency on chemicals in potato cropping research work is carried out on a non-chemical haulm-killing technique called 'green-crop-lifting'. This technique consists of three operations: green haulm removal, lifting in collected rows and covering with soil. For growing bulbs in nets combined with a bed cultivation planters and lifters are developed (**Fig. 5**). A lower amount of soil tare, reduction of water use and reduced use of chemicals are profitable for the environment. Besides that flower bulb growing on heavy soils is with the help of these techniques more attractive.

3. Nutrient application

The Dutch government has established the policy on animal manure until the year 2010. The obligation to keep a mineral-balance for those farms with more than 2 LU (Livestock Units) is the basis for the policy. With the help of this balance the surplus of nitrogen and phosphate can be calculated through inputs minus outputs. A levy is determined on the surplus above a certain exempted amount - the so-called "surplus norms". These surplus-norms are given in **Table 3** for phosfate (P_2O_5) and nitrogen.

The basic problem of these "surplus-norms" is that that there is a gap between "environmental-acceptable" (As Low As Reasonable Achievable = ALARA-principle) and an optimal yield on the basis of good soil fertility and Good Agricultural Practice.

The average surplus for phosphate for dairy farms in 1993 was approx. 70 kg ha^{-1} and for arable crops 54 kg ha^{-1} with a substantial variation. On dairy farms the average surplus N ha^{-1} is approx. 400 kg whereas on arable farms it amounts 160 kg ha^{-1} [4].

The nitrogen input for total agricultural production was in 1993 943.10^6 kg with main contributions from animal feeds (approx. 50%) and fertilizers (41%). The figures give rise to the conclusion that a decrease in the average surpluses of minerals is necessary and for a larger part also possible. There are already "early-adopters" in practice which achieve surpluses below 300 kg N ha^{-1}. However, in the frame of the European countries the average net surplus was in '90/'91 71 kg N ha^{-1} with a variation of 6 to 321 kg N ha^{-1} [11]. The use of fertilizers indicates an increasing efficiency of approx. 5% per year that means higher output per unit of fertlizer [12]. An improved utilization of animal manure can be achieved by different application techniques.

3.1 *Application techniques*

Depending on the weather conditions, soil type and condition, slurry composition and farm, management factors (amount of manure applied, grass height at the time of application) surface spreading results in an evaporation of an avarage of $\pm$ 65% of the ammonia from the manure with variation from 20 to 100% [13,14] with the help of the technique of injection at 0.15 m depth by hollow, rigid tines equipped with lateral wings the losses by evaporation could be reduced almost completely. However, injection cannot be applied under all conditions a.o. on heavy soils. New techniques are narrow band application and shallow injection. Narrow band application is carried out with a narrow sliding shoe over the soil surface without cutting the sward while pushing aside the grass leaves. The narrow bands of slurry are 30 mm with an intermediate spacing of 0.2 m.

Shallow injector designs of different shaped knife or disc coulters cut a vertical slot in the grass sward and slurry is released into the slot. There are quite a number of ammonia emission-reducing manure application techniques both for grassland and arable land available (**Fig. 6**). Besides the already mentioned techniques the acidification with nitric acid and the dilution with water can be mentioned. Low-emitting manure application techniques are obligatory in the Netherlands. The reduction percentages of ammonia evaporation in comparison with traditional surface spreading vary with the different techniques from 20 to 95 [14]. This variation is due to weather and soil conditions, farm management factors and manure composition. It may also be underlined that these new application techniques in combination with limitation of application time mainly restricted to the growing season and the quantity of manure per ha^{-1} (in 1995: 150 kg P_2O_5 on grassland, 110 kg P_2O_5 on arable crops) improve the nitrogen efficiency on average with a factor 2 [14]. The better utilization of nitrogen from animal manure results in a lower application of nitrogen fertilizers. Also the risks for run-off as a source for pollution can be reduced with these techniques.

The efficiency of the use of artificial fertilizers is still growing with an average of 5 percent per year [12]. In order to decrease the nitrogen surplus research is carried out to optimize the grassland utilization. Recommendations to support the farmers are developed, depending on soil type and the use of grassland. On grassland it is technical possible to omit the fertilization of the urine patches. On the other hand it is obvious that decreasing of mineral surplus will lead to more extensive use of the land.

Application of a gantry for the field work in arable crops (**Fig. 7**) can save on fertilizer and chemicals for crop protection. The traffic lanes and the rows are located in fixed position. Navigation of active hitch bars is performed automatically by means of a laser beam with an accuracy of less than 10 mm.

Dairy farming systems which achieve both economic and environmental goals at a satisfactory level were studied by Van de Ven [16]. With the help of a multi-criteria decision method combined with linear programming the loss of labour income of 62% with a dairy system characterized by low nitrogen application, low-emission housing system, was calculated. This in comparison with an intensive dairy system characterized by mainly economic goals.

In horticulture monitoring and control the nutrient and water supply in closed growing systems is needed to meet environmental standards. The high use of minerals for growing glasshouse vegetables require recirculation systems for nutrient solutions. Special developed chemo-sensors are under research and in development. With the help of these sensors the supply of different minerals in a nutrient solution can be carried out more accurate [16] (**Fig. 8**). A multi-point sensor for soil and water parameters at several depths is in development in a EU-financially supported project Waterman [17]. These sensors may help to prevent pollution of surface water and groundwater.

4. Energy use

Monitoring of the energy consumption in agriculture is carried out with respect to the contribution of a standstill to a $\pm$ 5% lower carbon dioxide emission. The consumption of direct energy in agriculture amounted in 1993 174 PJ (1 PJ = 10^{15}J), which was 7.8% of total energy use in the Netherlands (N.N., 1995). On the holdings with horticulture under glass the energy consumption is about 80% of the total use in agriculture. Energy saving options have therefore the interest of policy and growers.

Energy use in arable farming and animal husbandry is relatively low. However, there are possibilities to improve energy efficieny by optimizing tractor power for field work and tractor-implement combinations. Also the working speed and working width play a role in the energy use [18]. The production and use of biomass for energy production is also an important option for the future (**Fig. 9**).

5. Final remark

With respect to the sustainability concept the inputs of energy and water are not extensively discussed. It seems that these factors become in the coming years more attention from policy makers. In agricultural machinery much attention is paid to aspects of productivity and economy. Ecology and sustainability are factors which must play an equal role in the design of agriculture production processes and thus in machinery and automation.

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Table 1 - Major emissions from agriculture to the environment in the Netherlands in million kg [Source: RIVM, Environmental Balance cited by Silvis and Van Bruchem [4]]

	1985	1990	1994
Emission carbon dioxide [a)]	8	9	10
Emission methane	525	500	478
Emission dinitrogen oxide	27	26	30
Emission ammonia	239	219	159
Phosphorus surplus	87	71	67
Nitrogen surplus	530	429	448
Emission agrochemicals [b)]	---	6,0 [c)]	3,3

a) million tonnes
b) active ingredient
c) period 1984 - 1988

Table 2 - Targets for emission reduction in % (air, soil, water)

	1995	2000
Air	30 - 35	> 50
Soil/Groundwater	40 - 45	> 75
Surface water	> 70	> 90

Table 3 - Surplus-norms in kg a^{-1} for phosphate P_2O_5 and nitrogen (grassland and arable land) in the years 1998 en 2010

	PHOSPHATE	NITROGEN GRASSLAND	NITROGEN ARABLE LAND
1998	40	300	175
2010	20	180	100

Fig. 1 - Closed-loop spraying system for orchards

Fig. 2 - Shielded spraying in flower bulbs

Fig. 3 - Air-assisted spraying

Fig. 4 - Measuring of sprayer boom movements by laser techniques

Fig. 5 - Lifting of flower bulbs planted in nets

Fig. 6 - Different techniques for low-emission slurry application. Above: irrigating diluted slurry and irrigation of surface-applied manure slurry

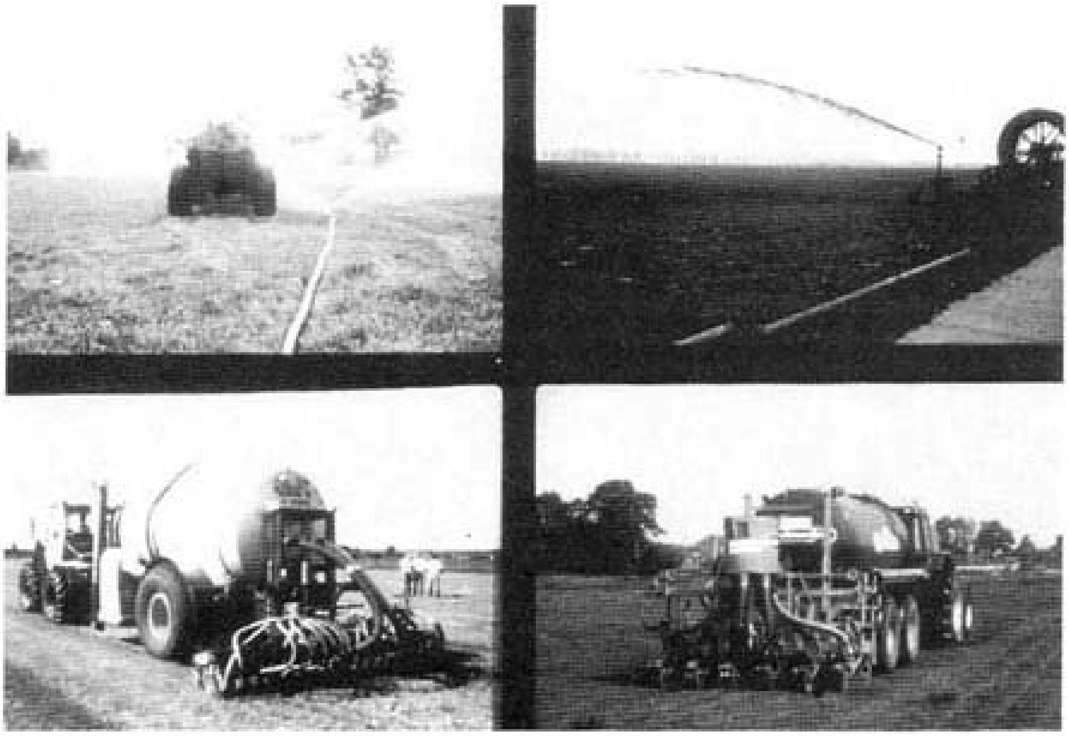

Fig. 7 - Gantry for controlled traffic and precision steering

Fig. 8 - Layout of a closed-loop growing system in greenhouses

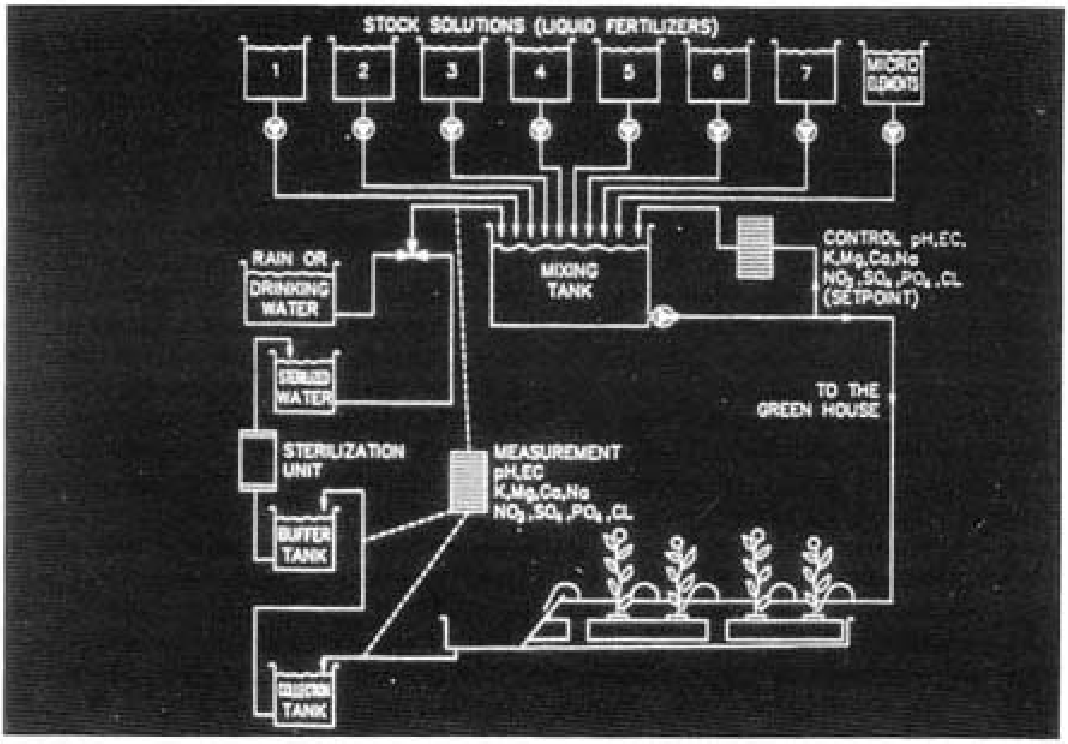

Fig.9 – Harvesting of willow for energy purposes

DISCUSSION

H.J. HELLEBRAND

I would like to raise several issues here. The first concerns nitrogen. There were some figures shown for surplus of phosphorous and nitrogen, but you cannot do it in that way because nitrogen has very dynamic behaviour in soil, and the environmental effects of nitrogen depends on the time of its input. So the significant parameter is input of nitrogen. In Europe we have widely accepted figures for the release of nitrous oxide, which is about 1.5% of the nitrogen input into the soil, independently of the type of nitrogen: that means manure or mineral fertilisers. And you cannot balance it over one year: you can do it compared to phosphorous, but it's not possible for nitrogen. So the figures given here cannot be used for an environmental evaluation. This is the first problem. The second problem is the question of animal density. One important factor in low input sustainable agriculture is animal density per unit area, i.e. the number of cattle per hectare. The main source of methane is cattle breeding, which yields approximately sixty kilograms per year per head, and the best way to reduce it is to reduce the number of cattle or to have the value of methane emissions related to the product. The mad cow disease has somewhat changed the behaviour of European consumers, and might result in a reduction of emissions, however this is not the question. The only way to implement the concept of low input sustainable agriculture is to adapt the number of cattle to the area, and to the production. Thirdly, another question that hasn't been mentioned, but which I think is very important, is the problem of heavy metal irons. When we feed our cattle and other animals, then with manure not only do we put phosphorous and nitrogen into the soil, but also an increasing concentration of heavy metal irons. We discussed this in Germany and we saw that in several types of elements there is a steadily increasing concentration of heavy metal irons that are not being reduced naturally, by being taken up by plants: they are added to the soil by the effects of civilisation, and they may change the protein character of the food that is produced, leading to negative effects on soil conditions in Europe. Especially now, we have the situation that bio-waste should be utilised, and one limiting question is the concentration of heavy metal irons: this too must be considered in a LISA concept. The fourth problem I see has not been discussed: the presentation dealt with engineering solutions for spreading agrochemicals, but there are also new developments such as agrochemicals that act selectively on plants. Admittedly, these are not always accepted by consumers or by the distribution, but you can reduce the mass of the input number and use it in a completely different time, or combine it with site-specific treatments in order to achieve a definite reduction in agrochemicals. Another development is genetically-manipulated plants, which offer additional possibilities for selective agrochemicals. This is not widely accepted at present, but I think it too should be considered within the LISA concept. My last remark concerns the question of energy consumption: we've discussed fuel reduction of tractors, where there is a little potential in general. However, I think the most substantial energy inputs in agriculture are mineral fertilisers, especially nitrogen. Moreover, there is great potential for reducing energy through improved heat insulation, meaning the reduction of heat losses, especially in the middle European and northern European areas.

A.A. JONGEBREUR

I would like to respond to the different questions brought up by Prof. Hellebrand. Firstly, it is true that nitrogen is a very dynamic mineral in soil, but let me try to better explain certain points that I only touched on in my lecture. When calculating surplus norms we take into account factors such as denitrification, and we've also developed "fertiliser programs" in which we calculate with the nitrogen content in the soil. So in order to reach maximum utilisation of the nitrogen, you have to look at these surplus norms. I think it's quite clear that when you calculate the difference between the inputs—the fertilisers, the concentrates—and the outputs, it must be and can be also reduced as one of the methods, because in our country every farmer must have a book-keeping on the minerals. So you can calculate your different measures and also you can see the effects of those different measures. You say it cannot be used for environmental evaluation—well we have a slightly different opinion on that point. But I totally agree with you that the number of cattle per hectare very much influences the environmental aspect. For example, when you calculate the difference between four or five cattle per hectare as opposed to two cattle per hectare, you see the effects on the surplus norm that can be achieved: with a lower concentration of cattle per hectare, the surplus norm is lower. That is an important factor, and from model studies we have calculated that with more extensive agriculture the environmental situation improves, but there is a loss of labour income and a loss of labour productivity, because you also have lower fertilisation. You mentioned the problem of heavy metals. Our approach to tackling this problem is to control the inputs at the farm level: we have certain regulations for the compost used on farms, which must meet certain official criteria in terms of heavy metal content. So there is a system for checking the heavy metal content of the inputs—a very important point. You mentioned selective use of plant protection agents, which I believe is one of the approaches that is currently being used. In our country there are a number of agents that are forbidden, and I expect that even more agents will be banned in years to come. As a result, selective use will become increasingly important. Also, those agents that are less toxic for the environment are extremely important. For *instance, there is currently a trend towards greater use of biological agents, especially in horticulture. This is a fairly recent phenomenon, but particularly for fruit and vegetable crops, biological agents are being increasingly used. Your remark on genetically-manipulated plants is also quite true, but there we have the problem of whether they will be acceptable to consumers. However, it is certainly a way to reduce dependence on agrochemicals. Your last two points concerned energy use: I agree completely that mineral fertilisers represent one of the main energy inputs, particularly in arable farming and dairy farming. We mentioned indirect use of energy: that is not the case in horticulture where the main use is for heat and electricity. Your remark on heat insulation is true: improved heat insulation of buildings, especially for greenhouses, offers great energy-saving potential. And there was one other question on methane emissions: you mentioned methane emissions of dairy cattle, and I think it is true that you cannot influence that so much, so the number of cattle per hectare is very important. Apart from that you have the comparatively low emissions of manure storage and animal houses, and those you can try to do something about.*

B. CHÈZE

You mentioned greenhouses, and it's true that greenhouses are interesting, but they are artificial objects. Why not envision that all plants should be cultivated in their native regions, where they can grow without any artificial support? But of course I realise this is not realistic. My first question concerns your mention of optimal yields: is it really an optimal yield, or is it a maximum yield? What are the criteria used to optimise—just economic criteria like cost-return ratio? Is it a real optimisation? The second question is: you're trying to convince the farmers to move from productivity to sustainability. What are the most efficient means. I believe that at the moment you're using regulations but, if you use regulations, is there any financial compensation for farmers? Because it is most likely to result in a reduction in income. And finally, are the farmer's ideas really changing? What's your feeling on that?

A.A. JONGEBREUR

In response to your first question about greenhouse production, it is indeed possible to grow those products in places where no covering is needed. I will refer to some studies that have been conducted, where they looked at the total production chain, which includes not only the energy used during production, but also the energy used for product transport, processing and so on. It is important to look at energy consumption over the entire production chain. However, the idea of moving the greenhouse production to countries with warmer climates is not always valid, because some model calculations have shown that in the summer you would need energy fro cooling. So you have to look at the climate conditions year-round to decide which is the most favourable location. For the question about optimal yield: I think you can only describe optimal yield with the concept of yield minus costs, i.e. in terms of money. So when you lower the inputs but maintain the same yield, you have optimised your yield. But, especially in the case of nitrogen, when you lower the average amount of nitrogen per hectare on dairy farms from 300 kg per hectare to about 100 kg per hectare per year, then you also lower the labour income of the farm. So you have to calculate that on the benefits minus the costs of the inputs. For your question about sustainability: what helps sustainability? Is it regulations? Well, quite a long discussion has been going on in our country over the years, and it is my opinion that you need regulations to improve sustainability, especially when it influences the farmer's income. There are, however certain win-win situations in which environmental improvement goes hand in hand with increased income for the farmer, and in those cases regulations are not needed. But if there is a tension between farmer income and improving sustainability on the farm, I am convinced you need some regulations. There are some subsidies for investments on nutrient application—i.e. for special sprayers with low-drift nozzles—, and these subsidies are mainly connected with the tax system in our country. Our government is increasingly moving away from direct subsidies in favour of indirect subsidies connected to the tax system. That is the general governmental guideline. Your last question concerned the farmers' attitude concerning sustainability? Are they ready to change their minds about sustainability or not? Well, what we're seeing is that, especially in horticulture, the farmer's ideas are being increasingly influenced by the consumer. This is a trend that has been continuing over the years, particularly in horticulture production. We have a special mark called "environment-friendly crops", and that is doing quite well in the market. So the image of the products is becoming more and more important to the consumer, and we've been seeing a change in the minds of farmers and producers in our country.

A. MUNACK

My remark concerns the assessment of different measures for achieving low input sustainable agriculture. You gave a very good example of that in your talk, when you mentioned injection of slurry, which is a very good means to reduce ammonia emissions. However, if you inject as deep as you did—fifteen centimetres—our measurements in the FAL found out that then the amount of dinitrogen oxide emissions goes up very steeply. Therefore, I think the overall balance is not very clear—whether this is in fact environmentally friendly or not. So we reach the situation of comparing something like apples and pears: ammonia emissions and nitrous oxide emissions. I think we must find a means to sum up the different environmental loads of the whole production chain, or even the whole nitrogen cycle, and develop methods to somehow reduce the overall load. If we do not conduct research to define such means of evaluation, then we will have trouble proving that we are in fact striving for sustainability.

A.A. JONGEBREUR

Axel Munack's question is quite clear, and you can in fact have greater emissions of dinitrogen oxides with deep injection. In any case, deep injection is not used so much in practice, for reasons other than this, because you need a great deal more energy for your tractor: so it is more the shallow injection and the narrow bend application of manure that are used in practice. Nevertheless I agree completely with you that we have to look at the nitrogen cycle: in our country, I was director of the ammonia and manure program for seven or eight years, and one of my frustrations was that we do not have a clear understanding of the nitrogen cycle. And in particular the point you mentioned—denitrification, we do not understand as yet under what conditions it is occurring in practice. That is one of the points that is not clear today, and which gives us some uncertainty concerning the surplus norms: what is happening, what is not happening? So the nitrogen cycle is a very important research topic for the future.

Prof. Jan PAWLAK
Poland

I have some remarks about the situation in the field of fertilisation, in connection with water pollution in Poland. The level of fertilisation in Poland is very low, and used to be much lower than in the Netherlands or in Western Europe in general. It used to be about 189 kg per hectare in the eighties; then, at the beginning of the nineties, fertiliser use dropped dramatically due to rising prices of agricultural inputs and means of production in general, including fertilisers: the level dropped to 62 kg per hectare of NPK in 1992. Subsequently it began to increase, but is still below 100 kg NPK per hectare. And yet, even under such conditions, we still have problems with water pollution. The main cause of this is animal production, even though the cattle concentration is less than one head per hectare: it's about 0.6 in the village we have under observation. We are in fact carrying out a research project together with Cemagref of France in one village north of Warsaw. Anyway, the analyses of water in ditches near the farms show that norms for nitrogen content in water for the third grade—the lowest quality grade of water—are exceeded several times over. Even though the level of fertilisation is so low, and the concentration of animals is rather low too. The main cause of this is incorrect storage of manure on farms. There are losses of nutrients and pollution of water. Another reason is that even mineral fertilisers and organic fertilisers are not always applied at the proper time. There is a tradeoff between energy-saving and fertiliser-saving: the farmers prefer to use mixtures of different fertilisers and apply them once or twice a year, to save energy and money on operations costs. But on the other hand, there are the nitrogen losses. So we need to find a compromise between saving energy, saving on operations costs, and saving on nitrogen and other fertilisers, and reducing water pollution. There are methods for calculating fertiliser losses, but we do not have correct data to evaluate the degradation of the environment. I think that interdisciplinary research should be carried out in this field, and perhaps some international cooperation would be very useful; because we have methods, but we don't have the necessary input data to evaluate the costs. To conclude, there are some solutions that we have proposed together with our French collaborators: construction of correct manure-storage facilities, for both fixed manure and liquid manure; introduction of aftercrops before spring crops, including the share of winter crops to keep the soil covered as much as possible; and more timely use of fertilisers and proper proportions between NPK and microelements.

A.A. JONGEBREUR

I agree with Prof. Pawlak about the calculations and the practical data. In our country we are in the situation of having established the norms, and are now starting a project involving some 400 farms, to monitor what is possible in practice; not just in terms of norms but also in terms of the complete operation of the farms. In particular, those farms that can achieve a very low norm and a very good income are especially interesting from the research standpoint.

R.O. HEGG

The sustainable agriculture programme in the United States, as it was initially brought out, used the term "low input sustainable agriculture". But not very long after that they dropped the words "low input" because it had many negative connotations: the typical large, mechanised commercial producer couldn't identify with it, so the common term that we would use today is "sustainable agriculture", as a comprehensive term. Certainly in the United States, we're continuing to see large animal production facilities, and a tendency for farms to become less family-oriented: we saw that in the poultry operations, and now also in swine operations and dairy operations: large concentrated systems. And in my opinion, many of our agricultural systems are, in some ways, not very sustainable. Compare that to the family-type farms of the past, with their integrated system of livestock, crop production, and recycling of nutrients. Of course, back then—decades or centuries ago—we had lower populations, and hence these very sustainable operations. Today, on the other hand, we have these intense systems and, as was pointed out by Bill Stout, we certainly need to consider what's happening in some of the developing countries, which in some cases are adopting these more mechanised and intensive production systems. You might be dealing with crops that don't lend themselves to that climate or that situation, and you have greatly increased erosion problems. I would say the major resources we're dealing with are soil, water and air. Soil being certainly a very important one, and probably one that hasn't been mentioned too much today. If we look at the degradation of soil world-wide, there's been a substantial loss of productive land, due to pollution-related problems, soil-salinity problems, erosion problems, soil-compaction problems, and in some cases and countries, growing urban communities that *cause productive land to be taken out of production. Those are all going to be continuing serious problems in the future. One thing that Aad Jongebreur mentioned is how, certainly in their country, governmental policies have stepped in and said: "you are going to do certain things". That's probably the way it's going to have to take place in most of our countries. I would cite, for example, the concern about erosion in the United States: in the late 1980s a federal program was put in place to encourage farmers to go to cropping systems that would leave the crop residues on the surface: this really has been very successful, very widely adopted. You don't see many of the old mouldboard ploughs in the midwest anymore. It's all changed to tillage systems that leave these residues on the surface, and greatly reduce erosion problems. This has been widely adopted but, without a government policy, I believe it would not have taken place as it has. So I would be interested in any other comments on your particular countries: have there been governmental policies that have really encouraged changes in cropping patterns? Also, will we ever see again the continuation of the family farm type situation, with its integration of plant systems and animal systems?*

A.M. EL HOSSARY

We of the developing countries are always coming to you with problems, and seeking your advice. Our problem is that we always receive technology from the industrialised countries and, also, we sometimes hear the slogan of "sustainable agriculture". As I said, sometimes the government misuses its authority concerning systems which affect pollution. We have had very successful campaigns using ground spraying for cotton. But as you know, cotton is a major export crop in Egypt, and If a minister fails to improve cotton production, in terms of quantity, he is fired. Therefore, what happened in Egypt and in Sudan as well, was that they shifted from ground spraying to helicopter spraying, with disastrous environmental effects. The farmer perhaps managed to improve his income, but at the expense not only of his own health but also that of all the Egyptian people. So I am seeking your advice on this and, particularly to Mr. Jongebreur, I would ask whether you have conducted any experiments or research on helicopter spraying. This method is really the fashion in the developing countries. I remember that, four years ago, a PhD thesis came out illustrating the benefits of using helicopters, and as a result there was a ministerial decree cancelling grants to other equipment. Now we have about sixteen companies with helicopters, coming from Europe, and joint ventures, and they are polluting more and more. So to Aad Jongebreur, I ask if there is any kind of research being done that could help us with this problem. And a second important point is that the recommendations of the Club of Bologna really have the capacity to prohibit or draw attention to the danger of using such harmful equipment. I don't want to say helicopters specifically, but harmful equipment in general. Because when we get these recommendations, I translate them into Arabic and I give a version to the Minister, and I send a copy to each Arab country, through the Arab Organisation of Agricultural Development. And they highly respect our recommendations.

A.A. JONGEBREUR

Concerning the first question, about the use of helicopters instead of ground spraying machinery: the situation in our country is that we have some companies who are spraying by plane, and this is already being questioned for some years. I know that in the US, also, they have some companies doing this. You asked about the emissions of this type of method. I must say we have no experimental data on this spraying method. Some calculations have been made, which I believe originate from the US, and we plans to carry out some measurements during spraying by plane. However It is a very difficult experiment, which also takes a long time and is very expensive. So at the moment our Ministry is thinking about whether to allow it in the future. The standpoint of our institute is that, if it is allowed, you have to perform measurements on the spraying of these fungicides by plane. So at the moment we have no data available.

B.A. STOUT

I would just confirm that, yes, aeroplanes and helicopters are widely used for chemical application in some parts of the US. I cannot give you any numbers, that's not my field, but they are certainly widely used. I think there have been some drift studies, but I don't have the numbers. If the group wants, I can look into that and report back.

P. KIC

In this discussion about low input sustainable agriculture I would like to mention the question of suitable capacity of farms, suitable size. That means how many hectares, for example, or how many animals there should be in one production unit. We have had many years of experience with large-scale farming, with the agricultural conditions typical of really big farms. But in recent years, during the process of transforming our agriculture to a market economy, new small private farms have also emerged. So now we can make some sort of comparison between big and small farms. It appears that if we want to achieve lower agricultural inputs, we must also pay attention to efficient use of machinery. The conditions of large-scale farming make it easy to use and buy sophisticated equipment, such as was mentioned in the lecture, but I must say that for our small private farms it's impossible to buy it. But we have transformed to private ownership, many cooperative farms of one or several thousand hectares, which can buy such equipment and use it very efficiently. A similar situation exists in the field of animal production. We discussed the question of the use of energy. If we want to use heat pumps or heat-recovery systems, for example, it is necessary to have the buildings for animals of suitable capacity. On this point I want to add that such systems must be very reliable, simple to operate, and not require a great deal of servicing.

A.A. JONGEBREUR
On the question about farm size and availability and application of new technologies: what we see in our country is that farm size is growing with respect to the investments made in more sustainable production. We see it in horticulture and arable farming, and somewhat less so in dairy farming: there is an increase in farm size. I also want to underline that the use of sophisticated machinery can also be improved and extended by the contractors. We have quite a number of contractors in our country who carry out the work on dairy farms and arable farms. And this way of working is more or less expanding because they are able to buy very expensive machinery.

G. PELLIZZI
It seems to me that no-one up to now has mentioned the techniques incorporated into the machines, concerning precision agriculture systems. That could contribute to reducing inputs. A second point concerns energy consumption. I think that there is also a need to study and precisely define what are the optimum tractor-implement combinations. Because if we are able to find the right tractor for the right implement, we can then reduce the energy consumption. The third point concerns the problem of additional investments on the machines, taking into account the different outputs. From our experience we have seen that we can have additional investments with a payback period of up to three years. For instance, for the application of chemicals in vineyards, there is the possibility to save about 100 dollars per hectare per year. This means that if we use this machine on 15-20 hectares, depending on the number of applications, we are sure that the additional costs for investments could be paid back within a three year period.

A.A. JONGEBREUR
I agree with Giuseppe Pellizzi that precision farming offers excellent potential, however I didn't cover it in my presentation because that possibility has already been underlined in other different conferences. I agree completely that it is very important for the future. The need for optimal tractor-implement combinations is one of the lines we have taken up in our energy research, especially for arable farming and dairy farming. And there you have the possibility to save energy. It is very important. Additional investments against cost savings on inputs is very important—especially in the use of spraying machinery. The amount of money you mentioned is I think rather low, because average costs for chemicals in the different branches of agriculture are quite high. We have quite a lot of farms that spend between 10-15 thousand dollars per year on chemical agents. So there are possibilities to lower these inputs and make more investments in precision machinery.

U.M. PEIPER
I'd like to make a few comments. We are in a unique position because the Minister for Environmental Affairs and the Minister for Agriculture are the same person in our country these days. But this of course, from some points of view, puts some restraints on us. We have to be very careful not to throw out the baby with the bath water: in the enthusiasm for implementing good environmental regulations you can sometimes end up killing agriculture, and we must be careful not to do that. Although we do try to reduce emissions and, I believe, the number of animals per hectare. Of course, if you are talking about intensive animal husbandry then the numbers are much higher: you can get very dangerous concentrations and injection of slurry into groundwater, and there aren't any good solutions in sight yet. On the subject of greenhouses, one interesting new development we tried to put forward is miniature irrigation: we irrigate with pulses on very low flow, so that there is almost no recycling of water. In this way, the whole problem of replenishing or reusing the water is very much reduced and rendered almost insignificant. I like Dr. Chèze's "global village" idea of growing vegetables or other products outside, wherever the sun is, although the reason for growing in greenhouses sometimes is also quality—quality is of course a major factor affecting agricultural production. Last but not least, we have climate control in greenhouses. One recent developments we have worked on, and which are gradually coming in, is the "talking plant" system in which, instead of controlling the atmosphere, which is easier to do in greenhouses, we try to look at the plant, taking measurements from the plant itself. Of course, we then have statistical problems of which plant is really significant or which is really representative of the whole greenhouse, but the control according to plant leaf temperature instead air temperature is an interesting approach.

A.A. JONGEBREUR
I think it is very important to combine ecology or sustainability with economy. I think that is also the main approach in the Netherlands at the moment. It's not just the environmental requirements that count: the possibilities for realisation in practice are also taken into consideration. Concerning the climate control situation, in one of my slides I showed a combination climate- and growth-control system. You mentioned the "talking plant", and I think there too it is another combination, between the greenhouse climate factors and the physiological factors which control plant growth. That is an optimal control problem which must be tackled in the coming years, it's very important. And also the price of the product, you can calculate and then strike the right balance between the various factors.

B.J. LEGG
My first point is that, if we're looking world-wide at sustainability, then I agree with Richard Hegg that soil erosion and salination must be very high on the agenda. Those are the areas where very large areas are being lost to production, or production is going down. The second point I wanted to make was that I sometimes try to

imagine what agriculture would be like if we had not invented pesticides and herbicides. Because for sure we would not still be hand-hoeing in the fields. And I think what we would be doing is, first of all, using rotations much more effectively than we do now. A lot of the problems we have exist because we are mono-cropping and having to use chemicals to control the weeds and the disease that develops. I think we should look more carefully at rotations, and maybe we should look at intercropping again: quite a lot of work has been done in the UK, showing that if you intercrop you get higher yields than by growing crops in separate fields, and that you also get the benefits of less disease and fewer weed problems. And yet, surprisingly, very little of this research is being taken up. I think engineering may be required to make these intercropping systems commercially viable: at present perhaps they're not, but I believe they have much to offer. The third point, of course, is that using much more precise mechanical control and mechanisms all the way through—more precise weed control, mechanical control, sowing, fertiliser application and so forth—would have a very big impact. I'd like to say a little bit about organic farming. Because, although I don't feel there is any moral or ethical imperative to look at organic farming, I personally think that as a research tool it has an enormous amount to offer. If you're trying to see how you can reduce chemical inputs, there can be no better method of approaching that than saying: "let us try to produce crops with no chemical inputs at all, and see where the problems really come". I think we ought to be putting more money into seeing how we can grow crops with no chemicals, as a research tool that will then show us how we can use chemicals only at the points where they really are essential, rather than as a total management method. The next point is that a lot of work, again in the UK, has shown that in practice, many pesticides are applied when they are not needed. More than half the fungicides applied in the UK are a waste of money, as well as being environmentally undesirable. The reason is that farmers are using pesticides prophylactically: they're using them as an insurance policy. And it can be shown that if they had better information on the timing of pesticides and the concentrations to use, then the quantities could be reduced very substantially. Another point is that with many pesticides, if you apply them a week early or a week late you have to use twice as much to get the same effect. If you can get the timing right then there can be very big benefits. I think nobody has yet mentioned the role for decision support in use of pesticides, to make sure that the best information is available to the farmer, and that all the results of research are available to allow the farmer to use chemicals only as needed and not as an insurance policy. The final point, related to energy: there was a survey or review done by the Department of Trade and Industry on the various non-fossil energy sources that could be found within the UK. They looked at wind power, tidal power, wave power and solar power—every form you might think of. And if you look forwards, the volume potential for energy from biomass exceeds all of the others put together by about a factor of four. And so although wind energy, for example, may look more attractive initially, if you look at the total potential it has to be biomass. I might say that if we cover the whole of the UK with biomass, we would only supply 10 or 15% of our energy use, which just shows our dependence on fossil fuels. But I think we should look more clearly at energy saving, but also at the role of biomass in energy production.

A.A. JONGEBREUR

Some comments, first of all on organic farming. I think what Brian Legg mentioned is very important: I see organic farming as a great challenge for agricultural engineering to incorporate that type of farming in our research. It's not very easy, but I think with our possibilities, especially on system analysis and the knowledge we have of farming systems, I think it is a real challenge to do research in this field. The point about decision-support systems for the use of chemical agents for plant protection is also very important. There we need more data, especially on the biological effects of the spraying. That is what we are lacking at the moment: the integration between deposition and biological effects of the spraying. And when we have that I think we can also put progress in building of decision support systems at the moment.

H.A. CETRANGOLO

I want to make two comments about the situation in developing countries. My point of view is that agriculture in developing countries, with the exception of some crops like cotton, uses less agrochemical products per hectare than in developed countries. But the use of these products is not efficient, because often they use old machines, old sprayers, without care and without any training on their operation, and that causes major environmental problems. The second important point is the type of agrochemical products that are used in developing countries. Sometimes there are old products on the market, that are no longer allowed in developed countries, and these types of products cause a high level of pollution.

A.C.W. WYLIE

Two very brief questions. You mentioned in one of your comments that consumers in your country were very appreciative of the environmentally-friendly farm products. The question is: are they willing to pay more for those products? Have any surveys been done? I'm familiar with some that have been done in Scandinavia on environmentally friendly detergents, and all the housewives think they're terrific but they won't buy them because they're more expensive. My second question is: if they are willing to pay for them—I'm going back to something Prof. Stout mentioned—do you think that European consumers would be willing to pay more for products produced with less energy per kilogram, in the developing countries?

A.A. JONGEBREUR

First of all, I think the consumers are influencing the behaviour of the producers. That is the situation especially with respect to some horticulture products. It is not a question of consumers being ready to pay more for the products, but I think it is a question of marketing or not marketing the products: it's sale or no sale, to be or not to be, for the producers. In our country we have quite a high population density, and we have intensive agriculture and horticulture, but I think that regulations concerning environment-friendly production will come in more and more. So it is not a question of whether consumers are ready to pay more, but I think that, when they want to have a good market position, there is a need to sell the product. And I agree with you that if the products are more expensive, consumers are not willing to pay more: only a very small part of the consumers do so. Are consumers ready to pay more for energy-friendly products? I don't think so. Energy, especially for greenhouse vegetables and greenhouse flowers, accounts for between 15 and 18% of the production costs. So, on that side, I think it is important to reduce costs. We expect that in future, for the reductions of carbon dioxide emissions, there will be some sort of levy on the use of fossil fuels for production. In that way, I believe producers will come to lower their energy consumption.

B. BONICELLI

I think that in the LISA concept, the development of good mechanisation depends on quality of cooperation between all the partners of LISA. For example, testing labs, industry, farmers and consumers. And a global approach is very important. Secondly, a technical point: I think that in addition to innovation, there are also a lot of classical technologies that can be optimised. This is very important and, in order to do it, it is necessary to model, to have a good comprehension, and to work on education also. Thirdly, I propose that the best way to build a good project, for utilisation.

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