RAPESEED IN A CHANGING WORLD: PLANT PRODUCTION POTENTIAL

G. Röbbelen

Institute of Agronomy and Plant Breeding, Georg-August-University, Von-Siebold-Str. 8, D-3400 Göttingen, Germany

INTRODUCTION

The task with which the Congress Organizers have charged me this morning, does not consist in presenting to you a great many technical details regarding the production potential of the rapeseed plant. I have rather been encouraged for you to review past and present situations and from such knowledge to extrapolate towards future developments of rapeseed productions.

In preparing this speech, my first idea had been to show you the scientific and economic changes which occurred since our last International Congress, to check for confirmation or disproval of statements made in Poznan, and to expose findings and concepts which newly emerged during the past four years. However, although I found quite a number of cases, where rapid progress if not breakthroughs had been promised even by prominent scientists and companies, I finally discovered that plant production potentials in fact need longer periods for definite changes.

For such reason, I will rather remind you of the earlier Rapeseed Congress back in the '70's, which had been held in Canada, and I will elaborate with you, which of the programmes and views that were issued during those Ste. Adèle days, proved durable and successful and which unforeseen developments and basically new ideas and facts turned up meanwhile. From looking twenty years back I may then try to look another 10 years ahead, which will conclude our 20th century.

Let me begin with saying that I regard Ste. Adèle to have been the opening of what more and more became the "rapeseed family of scientists" led on by Canadian colleages such as Baldur Stefansson and Keith Downey. This start a few years later led into the worldwide organization of GCIRC, competently represented by the CETIOM directors Yvan Guilhaumaud and Emile Chone. In thanking these and many more people in particular among our Canadian hosts, involved in the inauguration of this open atmosphere of cooperation and exchange, I am convinced that much of the remarkable progress in productivity and product quality of rapeseed to date results from this general agreement and frankness among the relevant persons and institutions in the area. Such attitude to my opinion is also the best guarantee for the continued increase of rapeseed production potential. Let us keep on to hold the walls of economic self-protection in rapeseed science and industry as low as possible.

The previous speaker has convincingly demonstrated the vigorous expansion of the rape crop since the early seventies. This development, indeed, has been a definite proof that the strategy agreed upon in Ste. Adèle has been valid and effective as based on the following two conclusions: (1) Under the climatic conditions given in particular in the more northern regions, Brassica species represent the most potential and productive oilcrops among all other possible botanical taxa, and (2) economic and competitive success of this crop in the world market depends on a few, but basic changes in the quality characteristics of its oil and meal products, as they have been achieved in B. napus during the last two decades by the plant breeders.

DIVERGENCE AND PERFORMANCE OF THE BOTANICAL BRASSICA SPECIES

As to the first topic, I may remind you that obviously at different times and locations man long ago has reckognized the economic value of adapted Brassica weeds. Thus, domestication of rapeseed not only dates back to a history of more than 3000 years, but it also concerns quite a number of different Brassica species, each exhibiting a noteworthy productivity at its region of natural distribution. Today, Brassica napus undoubtedly is the botanical species of top importance and performance worldwide. This superiority can partly be explained by its amphidiploid nature, which combines characteristics of B. campestris from the East-Asian centre of crop diversity with those of B. oleracea being one of the most versatile vegetables of Mediterranean culinary derivation. There are other amphiploid Brassica oilseeds, which presently do not reach similar yield levels in general, but which in specific areas of adaptation deserve much more attention. In particular, B. juncea offers high production potential in regions with frequent occurrence of heat and water stress, and preference of the diploid turnip rape, B. campestris, is well documented at the northern border of rape cultivation. However, there is almost no realistic way to determine the inherent species-specific production potential independent of its earlier history of domestication. Every comparison to a considerable degree will always reflect the attention and input previously granted to the crop by breeders and agronomists. This situation applies in particular to our main rape species, B. napus, not only because of the recent expenditures in quality breeding, but also regarding the fact already, that it is the only Brassica polyploid offering spring as well as winter cultivars in consequence of much earlier domestication efforts. For these reasons, the attempts for the analogous development of other Brassica species deserve every necessary support, such as those started by the late Paul KNOWLES at Davis with B. carinata for use in the lower latitudes or by some recent breeders with B. juncea for semi-arid cultivations. Already now yields of B. juncea materials have been 10-20% above B. napus under appropriate conditions. In addition, an essential breakthrough occurred recently here in Saskatoon with the establishment of a low glucosinolate genotype in B. juncea opening up for present work on the development of double low lines. Thus, B. juncea now has the prospective during the next one or two decades to become the dominating rape crop for Western Canada, Central China, or similar semi-arid regions. So far, the various Brassica relatives and allied species have mostly been regarded as gene sources for the breeding of rapeseed only. Such use is chiefly restricted to single or oligogenic traits, as for example disease and shattering resistance from B. nigra or yellow seed colour and pollen sterility from several other Brassica species. Today interspecific crossing techniques have been complemented by a most sophisticated biotechnological arsenal which makes almost any alien gene transfer technically accessible. Yet, the question still remains open in most cases, how effective such genes can be integrated into successful varieties without essential disturbance of field performance.

PROSPECTS AND CONSTRAINTS OF AGRONOMICAL RAPESEED PRODUCTION

Principally field performance is not the only responsability of the plant breeder. But it is primarily a consequence of agronomic skills. During the last two decades and in good harmony with the advancement of varieties, a bank of knowledge has been established on husbandry techniques, which has decisively contributed to the step increase in overall productivity of rapeseed. Of course, nowhere is productivity independent of invariables, such as plant type, i.e., winter versus summer form with its inherent differences in grain yield, or the agroecological situations of continental versus coastal regions. Such conditions have a major effect on the relative economic superiority of one location over another and of one crop over a possible substitute. But within given frames of production agronomic practices bear a considerable share of optimum yields. This fact is easily revealed by comparing the rapeseed yields, obtained under specially attentive crop management with that of an average farmer. In Schleswig-Holstein, yields in the 10 best farms were up to 20% higher than the state average in the same years. Provided that the input was grossly the same in these 10 farms of excellence, then such surplus yield reduces the cost of production per tonne and increases the profitability of production quite considerably.

The factors of successful husbandry in rapeseed are well-known in principle. But the devil comes with the detail and the details are changing continuously. Seeding can be a serious problem in dry fall seasons. Such problem has definitely limited rapeseed acreages for example in France in several recent years.

Harvesting is another process which requires a high portion of technical skills and good luck with weather conditions. Irrespective of continuous attention, plant breeders so far have not been able to provide their high yielding rape varieties with shattering resistance to a degree sufficient for every adverse dry and windy weather condition. Since spring type materials are particularly endangered, the distinguished shattering resistance of B. juncea is another reason for favouring this species.

Weed control in rapeseed fields has been performed in earlier decades in Germany by mechanical hoeing and there have been suggestions recently to revive this old fashioned approach. Such ideas are moved because chemical weeding is met with increasing public reservation for ecological reasons. With the same arguments, licences of herbicides so far in common use are withdrawn today and restrictions are imposed on their application in fields within regions of drinking water sources, which in certain districts may extend to up to 25% of the surface area. These facts force farmers to again and again test out new herbicides. But the same developments do also question the plausibility of strategies based on the use of herbicide tolerant varieties for coping with pressing weed or volunteer problems. Anyway, the experienced farmer will try to reduce the broadleafed weeds within his rapeseed by effective treatment with hormone based herbicides such as 2,4 D already in the preceeding cereal crop.

Increasing ecological concern also hits farmers today when applying the traditional chemical fertilizers, in particular nitrogen. The rapeseed plant and especially the winter form because of its high biomass production requires an appreciable amount of its nitrogen fertilizer at the very beginning of the growth season, when the biological activity of the soil is often not yet sufficiently predictable. However, with an early enough sowing the root system of the rape plant will be developed already in the fall reasonably extensive and deep, so that the suspected drainage of nitrate into the groundwater is a rather improbable event. Whatsoever, strategies of proper placement of fertilizer are as much desired as are varieties with a particularly high potential for nutrients acquisition. Plant breeders, however, will have to confess that such "low-input varieties" represent so far no more than an academic key word.

A effective reduction of chemical input is on the other hand, continuously elaborated regarding fungicides by most intensive and extended breeding programmes to establish genetic disease resistance. For example, the particular success of one of the biggest rapeseed varieties ever grown in Europe, namely 'Jet Neuf', resulted from its remarkable blackleg resistance. Again, the same variety was killed because of its sensitivity to the Cylindrosporium fungus spreading quickly throughout Western Europe during the mid '80's. Although this epidemics was partially promoted by the exceptionally mild winters of the last years, another reason for increased infestation has been the high density of cultivation reached with the present total of above 800.000 ha of rapeseed just only in Germany. The same reason holds true for the rapid expansion of the Verticillium pathogen. This disease is especially alarming since there are presently neither chemical nor genetic means of protection. Hopefully this problem is just a temporary one such as earlier disease incidences all meeting its master sooner or later. But control of this precocious ripening syndrome caused in particular by Verticillium will be a tough task, since an activation of genetic defence reactions at this late stage in the already senescing plant is a difficult notion. Chemical treatment by driving through the adult stands will also not be possible without considerable plant damage. Thus, the only remaining measure might finally be the observance of ever-longer intervals in crop rotation between successive rapeseed cultures on the same field.

BREEDING FOR IMPROVED PERFORMANCE OF RAPESEED VARIETIES

In general, disease resistance of plant varieties is the major character today for granting security against severe breaches of yield in single adverse years. Indeed, it is this stability rather than any higher yield per se, which attracts farmers' confidence in certain varieties. In Germany we estimate genetic yield potentials of present winter rapeseed varieties to be as high as 5.5 or even 6 tonnes per hectare, - with a country mean of above 3 tonnes/ha realized in recent years, with good farmers harvests of 4 tonnes/ha, and with some exceptional cases of up to 5 tonnes/ha produced even at field scales of 20 hectares and more. Therefore, the primary question in rapeseed production is how to best utilize this potential. Fortunately, the essential characters are genetically the less complex the more important they are for this end. The scale is led on by disease and lodging resistance, followed by resistance against winter kill and shattering and finally arrives at such traits as stress tolerance or input efficiency, which are the most difficult to select for. Because of this situation it seems just to assume that with continued variety improvement and backed by a corresponding progress of agronomic skills, effective yields of rapeseed will further increase for the coming one or even two decades at similar pace as they did during the last quarter of the century.

Such optimistic view is also based on the fact that in the past the vast majority of efforts in rapeseed development has been directed to basic improvements in seed quality, i.e., freedom from erucic acid in the oil and low content of glucosinolates in the meal. Each of these steps took its definite toll and the first varieties comprising the improved quality trait always were lower in yield than the traditional earlier ones. But continued breeding effort each time resulted in better varieties and these in succession soon outyielded not only the initial pioneers at the new level of quality but even the earlier commonly grown standard cultivars. This experience confers strong confidence that for the next decade genetic gain in yield will not be limited to any essential extent by physiological restrictions within the plant system, but will rather be proportional to the devotion of the rapeseed breeders and growers and to their continued input in work and development of this crop.

There are, indeed, several promising lines of progress on their way - more traditional and more unconventional ones and expectations and hopes are high in both cases. For quite some while it is well known that rapeseed yields are partially conditioned by heterotic effects. Therefore, the various means to utilized heterotic gain have been discussed in every great length already during the earlier Rapeseed Congress. It has been agreed that F_1 hybrid varieties do not all represent the only way of exploitation of heterosis, and in species like B. campestris it may well be that synthetic varieties are the much more realistic approach to catch most of the possible hybrid vigour. Again, cytoplasmic male sterility (CMS) in a complete genetic system of sterile seed parent, its corresponding maintainer and the effective restorer parent is a quite satisfying means if established. But using self-incompatibility or even more simple gene effects in supplementation with biotechnological measures still offer highly competitive alternatives. In summary, it appears to me that the broad array of bids present for pollination control in rapeseed more and more turns out into a load rather than an advantage. Every laboratory and company dives into other directions and efforts loose much in depth and efficacy by such dissipation.

A certain unanimity has recently come out regarding the application of the Polima CMS, and hybrid varieties are being developed on this base in many countries. However, the economic advantage of a F_1 hybrid over the best conventional, open pollinated variety is still an open question. Although the Polima system is genetically complete with its three necessary lines, the male sterility of the seed parent is not sufficiently stable under the various conditions of field propagation. Moreover, the heterotic gain in performance of F_1 hybrid varieties may not be sufficient to balance for the additional cost of hybrid seed production. In addition, rapeseed during domestication has not arrived at genetically separate gene pools, like the flints and dents in maize. Worldwide free exchange of germplasm in recent years has rather levelled out any genetic divergence earlier existing between eco-geographic origins. Also, systematic selection of inbred lines with high combining ability and the development of gene pools for hybrid breeding in rape is just in its beginning and satisfying performance of present hybrids may be not much more than merely accidental. However, new inbreds are readily accessible in any number in rapeseed, e.g., by using microspore culture, and genetic diversity is truely abundant within the Brassicas. Therefore, major problem of hybrid breeding in rapeseed is not the creation of sufficiently unrelated parent lines, but rather the effective sorting out of useful divergence in well established, high performing gene pools. This for sure will occur and open up promising prospects for further yield increases. But this also will take time, and since at present selection gain in conventional rape breeding programmes is still extraordinarily high, open pollinated varieties at least for this century will continue to keep their competitive position in crop production.

BREEDING FOR AN IMPROVED NUTRITIONAL QUALITY OF THE RAPESEED

While exploitation of hybrids has proven more difficult than it was earlier anticipated, quality improvement of the rapeseed since the Ste. Adèle Congress has been successful beyond all expectation. At this place and to this audience I need not review the triumph of the new crop, which is called Canola in this country and which is characterized by an essentially zero content of erucic acid in the seedoil and a sufficiently low glucosinolate content in the meal to secure an easy disappearence in the market of both, the oil for human food and the meal for animal feed consumptions. High oil and high protein content in conjunction with this "00-quality", therefore, must remain the primary considerations in the release of new cultivars.

An essential requisite for this successful history has been the always timely disposition of appropriate analytical methods for the accurate as well as for the quick and cheap determination of the quality traits in question. Although inventions are inaccessible to prediction, there are as yet no signs that these developments have arrived at their end. For example, Near Infrared Reflection Spectrometry (NIRS) has been developed only recently to become a powerful tool for the non-destructive and simultaneous determination of oil, protein, glucosinolate, water and fibre content in breeding materials. Such effective method is now broadly applied for genetic selection and will inevitably result in further rapid progress. Similar breakthrough has come from a new screening method developed by THIES and based on photometry of a coloured coupling product of the indole glucosinolates with p-diazobenzene sulfonic acid. Using this quick and simple assay, first genotypes of *B. napus* with essentially no indole glucosinolates have been found serving for the desired further reduction of total glucosinolate contents in the seed. It is worth mentioning, however, in this context that sincere discussions have been raised in Europe on the desirability of keeping the glucosinolate content of the green plant high for reasons of plant disease or pest resistance or even for securing its full vigour, when reducing the seed glucosinolate level to the utmost possible.

Other work directed to quality improvement of the rapeseed meal has been less successful so far. Selection for low sinigrin and low phytin content, irrespective of an effective analytics and broad genetic materials investigated, did not reveal sufficient genetic variance to allow for promising breeding. Protein quality of the rapeseed meal is generally high in view of its amino acid composition. But the lysine though reported at amounts of about 2.3% is available to hogs and poultry only at roughly 3/4 of this value and thus often becomes a limiting factor in the amount of rapeseed meal included in diets. Similar restrictions are due to the higher fibre content of rapeseed as compared to soybean meal. Yellow seed coat being an easy marker for low fiber content of the seed, could not yet be established in successful B. napus for reasons of unexplained variability in colour expression as well as pleiotropic correlation to undesired seed sprouting. For this reason, I look forward to the following speaker who hopefully will report on promising developments in dehulling of rapeseed prior to the usual oil milling procedures.

Zero erucic rapeseed oil is well accepted in the market because of its particular fatty acid composition. Pure Canola oil is advertised by the Proctor & Gamble Company as a health food under the name of "Crisco" labelled as the "oil with the lowest saturated fat content on the market". For technical reasons, i.e., longer shelf life and flavour stability, additional low levels of linolenic acid are highly desired. Early mutation experiments with zero erucic varieties produced genetic materials which exhibited not only below 3% of linolenic, but at the same time more than 30% linoleic acid. While the original mutants and first breeding lines did not perform at acceptable levels agronomically, continued efforts meanwhile succeeded to develop genotypes, the yield of which equals to that of the widely grown German variety "Ceres". The hypothesis of the plant physiologists that a low content of linolenic acid in the stored triglycerides will concomitantly condition for low photosynthetic capacity and poor seed development because of inadequate composition of the plastidic membrane lipids in the embryonic tissue, has been ruled out today by the unbiased work of the plant breeder.

The "Blueprint for the '90's" of the Canola Council of Canada mentions disadvantages for the texture of margarines regarding spreadability, smoothness and rapid mouth melt, which over time may result from the rather uniform composition of the Canola oil with its dominating C18 fatty acids. But I think it would be an attack in the own rear if the conclusion was for designing a Canola oil with a 12-14% palmitic acid content. A small amount of, e.g., palm oil added to the formulations is surely an easier solution of this problem of graininess and undesired crystal growth with ageing in high Canola margarines.

In any case, the Canola concept of rapeseed as a unique, high quality commodity for food and feed consumptions must not be weakened whatsoever. This also applies to the widely accepted nomenclature of "double low" (00-) rapeseed quality, where the first zero designates the essential absence of erucic acid in the oil and the second zero stands for the low glucosinolate content, i.e., the high quality of the rapeseed meal. Recently, with reports on further quality improvements here and there terms like "triple zero" or even "quadruple low" have been heared referring to low linolenic acid, or yellow seed coat (i.e., low fibre content) or to low indole glucosinolates or sinapine amounts. This for sure will quickly create perfect confusion. Therefore, I herewith propose for your resolution at this Congress that the well established term "double low" be maintained unchanged to designate rapeseed for the high quality food and feed uses and in par-

ticular to keep fixed that the first designation invariably refers to the oil and the second to the meal. In the case that additional criteria of quality are to be declared, an appropriate suffix could be attached, e.g.:
00 = zero erucic and low in alkenyl glucosinolates,
0_l0 = oil with an additional low linolenic acid content,
00_i = meal with an additional low content of indole glucosinolates,
00_s = meal with an additional low sinapin content,
00_{if} = meal low in indoles and fibre (=yellow seed),
0_l0_{ifs} etc, etc.

All this is included by the term "double low" and it all specifies nothing but the world known trade mark "Canola".

BREEDING FOR NON-FOOD USES OF THE RAPESEED OIL

Recently, surplus productions of some agricultural commodities, in particular cereal grains, posed the question of alternative, i.e., non-food uses of farmers produces. Since centuries, vegetable oils have been used for illumination purposes in specially designed, sometimes highly artistic lamps. They have also been applied for chemo-technical purposes, i.e., for soaps and surfactants, coatings and fabric softeners as well as more recently for synthetics, plastics additives and various base oleochemicals.

If in recent discussions attention is directed to maximum disappearance in the market, then, of course, it is worth mentioning that the French Otto Company demonstrated a Diesel engine running on peanut oil at the Paris World Exposition already in 1900, and that the Japanese navy desperate for fuel during the closing months of World War II bunkered soybean oil to fire the boilers of the 65.000 tonnes Yamato, the most powerful battleship of this time. Nowadays, renewable "bio-fuels" whether by direct combustion or after prior methylation attract wide interest of the public because of the definite limits of petroleum world supplies as well as for urgent reasons of CO_2 recycling from the atmosphere using plant photosynthetic rather than fossil energy sources. Rapeseed breeders and farmers are confronted in this context with the only demand to produce maximum oil yields per hectare in order to keep the price of the unit crude oil as low as possible. This is just on their line anyhow, and thus not much is left with them - except their uneasiness with the fact that the rapeseed is first pressed to produce highly valuable oil materials which then are fulminated just for a crude release of their built-in energy.

Utilizing the sophisticated chemical structure of the vegetable triglyceride more specifically is, therefore, a much more intelligent way with prospects of rapid increase in market shares and new opportunities for a vast number of attractive applications. In Western Germany, a yearly average of 160.000 tonnes of hydraulic oils is consumed, but only 40.000 of these are recollected for discharge; the rest is spilled to grounds and water drains causing heavy ecological loads. The same holds true for saw chain oils which since a few years are fully replaced, e.g., in German state forest work by vegetable oil products which are easily bio-degradable when lost into the soils of the woodlands. There is no formulated requirement regarding the oil quality for such technical applications.

This situation is principally different to most of the oleochemical uses where the chances of competitive substitution of petrochemicals often reside in the relatively high purity of the desired compound derived from the seedoil. Such standard is well known for the high erucic acid rapeseed oil from its earlier uses as an antifoaming agent in washing machines. Erucic acid today has found several new oleochemical applications and for all of these the highest possible content of erucic acid in the oil is a set demand. Fortunately, the highest concentration of erucic acid coincides with the highest general seedoil content which happens to occur in the

European winter rapeseeds, as far as the Brassicas are concerned. But more than 70% erucic acid are only reported from non-cruciferous plants, such as the caper spurge, Tropaeolum majus. This species obviously possesses a transacylase enzyme of different stereospecifity which is able to also place long chain erucic acid molecules into the medium position of the triglyceride, thereby surpassing the theoretical maximum of 66% in present rapeseed materials. Promising work now has been set out to isolate this effective transacylase enzyme and to transfer the correspondent gene into the rapeseed by biotechnological means.

Other quality improvement programmes aim at a very high oleic acid content of about 90% which is technically equivalent to almost a pure oleochemical. Such vegetable oil has for the first time been demonstrated to occur in certain sunflower accessions. It has recently also been claimed by European Patent Application to be produced in rapeseed materials after experimental mutagenesis.

In a third programme, molecular biologists have started in Cuphea species to identify the factor(s) for early chain termination during fatty acid synthesis in these unusual seedoils. Since the world market has been quite often in high demand of lauric oils with a main C12 fatty acid content, some groups in Germany, England and the USA try tracing the genetic mechanism responsible for such kind of seedoil storage. But the way to go until final construction of a transgenic rape plant producing medium chain triglycerides (MCT) within a rapeseed oil, is no doubt a long, although a most challenging one, for reasons which I will shortly describe in the following last chapter of my presentation.

CHALLENGES OF BIOTECHNOLOGY FOR RAPESEED PRODUCTION POTENTIALS

Since the Ste. Adèle Congress, rapeseed has gained its remarkable reputation not only in world production and markets because of its dramatic economic success, but also in scientific circles for its particular suitability for a great many of outstanding biotechnological innovations. This is why these Rapeseed Congresses every four years anew are such an attractive happening. We all do expect a wealth of intriguing news from the lectures and posters during the next congress days, as they are made feasible by microspore culture, in vitro selection, protoplast fusion, molecular transformation, new gene constructions, gene tagging and diagnosis, RFLP mapping etc. etc. As an introductory lecturer and with the time available for this task I would be totally overcharged to draw for you even the faintest picture of this lively scientific fair to which you will be a witness at these Saskatoon days.

If in this opening hour I may provide you with a personal word of advice, then this is not meant to spoil your intellectual pleasure. It is also not directed to our host, since the Canola Council's Bluebock for the '90's just cites as the only objective in this direction: "develop Canola varieties ready for field testing with insect resistance and herbicide resistance by 2000". This indeed, is a most modest desire, and I can well imagine some more objectives realized by this time than just these two. But one should always be aware when valuating biotechnological advances that the only true proof of successful crop genetic manipulation and plant breeding is a new variety with a performance potential superior to any preexisting cultivar.

Viewed even with such critical attention there is no doubt that the ready availability of doubled haploids through micropore culture has been a revolutionary breakthrough for rapeseed cultivar development. This statement does not deny still pending gaps and difficulties with adopting the technique into current breeding programmes. These at least have to effectively care for compensating the inbreeding depression by appropriate hybridization measures. Also gene pools highly performing in open pollinated varieties may not do best when forced into full homozygosity or unpreselected heterozygosity as well. But genetic segregation and selection at the haploid level is superior to the conventional diploid to such an extent that the benefits from this technique can hardly be overestimated in principle.

My biotechnological enthusiasm as a plant breeder slows down considerably when it comes to protoplast techniques. There are undoubtedly cases where desired recombinations are not possible by conventional crossing even with the inclusion of in vitro embryo rescue techniques. But one must not forget the difficulties in recovering genetically balanced genotypes from wide combinations, so that asymmetric protoplast fusions recently are gaining much in attraction. Protoplast fusions are also the only effective means to bring about genetic recombinations of cytoplasmic elements. This has most elegantly been demonstrated by PELLETIER and colleagues in creating a functional CMS transfer from Raphanus into rape ten years ago. This material is still being tested at present and further developed through conventional breeding. But it has also been proven that the same material includes a few cybrids with recombined, new mitochondrial genomes, which shows an entirely novel dimension of genetic diversification for future breeding.

Regenerable protoplasts, as they are now available in rapeseed, also offer most promising conditions for quite an array of gene transfer methods with or without using transfer vectors. It can justly be stated that the procedure of gene transfer into rapeseed poses no principle problem today any longer. What remains to be decided is the selection of genes to employ for such manipulations. First discussions, as already mentioned, center around herbicide and insecticide resistance. Relevant herbicides are Round-up (Monsanto), Glean (Dupont) and Basta (Hoechst). But present transgenic materials still show considerable weaknesses when grown in the field, such as lateness;slow growth and low yields. Altogether, it is subject to personal judgement which potential one ascribes to any future herbicide-tolerant variety in practical rapeseed production and breeding. To my opinion this topic has already passed its climax before it became effective. Insect resistance offers the much more attractive chance to avoid passing through the high rapeseed stands when chemical protection is needed. But the consequences of such transgenic manipulation for further breeding strategies as well as field ecology are also far from being sufficiently well understood.

More attractive and likely to be most profitable are biotechnological efforts towards improvement of disease resistance of given rapeseed varieties, in particular where effective genes are not at hand in any related genotype. Earlier optimism regarding in vitro selection procedures with applying pathogen derived pathotoxins has only been confirmed in less cases than expected; but cross protection or antisense RNA may become most valuable for creating virus resistance where and when needed. Similarly acceptable will be the transfer of genes controlling biosynthetic processes in seed storage and thus resulting in improved harvest quality. Transfer of the gene controlling the napin storage protein has been one of the very first successful cases of transgenic rape and others, e.g., with the brazilnut protein meanwhile have followed.Since evidently the fatty acid pattern in oilseeds exhibits wide evolutionary flexibility, it is obvious to hope for easy chances of corresponding success. Such manipulations may create entirely new qualities of seed storage products, and since these genes by appropriate promotors can be made to express in the seed tissue and stage only and the kind of storage material may have no or only negligible effect on seed and germination vigour such transformation is most likely to be free of any agronomical and ecological drawbacks.

Finally I like to mention two highly prospective and intelligent transgenic systems to provide manipulable male sterility for hybrid breeding. Furthermore, plant breeders hope for rapid development of RFLP mapping in support of better selection efficiency for all quantitative traits, such as yield, yield components, and most characteristics of field performance. Altogether, these and many more biotechnological developments will drive the scientific rapeseed arena in a most fascinating and may even be revolutionary future.

Nevertheless, my earlier call for caution remains valid: The majority of plant breeding progress during the forthcoming decade will still come from the conventional breeding programmes through intravarietal crossing and pedigree selection and they will largely depend on the genetic resources of present days plant breeding lines and stocks. Based on these traditional grounds and spiced with some biotechnological delicacies, at least similar progress rates will be secured in rapeseed production as those which we have experienced during the past two decades.