provide well-planned objectives and budgets for their consideration. They must be realistic, yet sufficient to accomplish the objectives. Being successful on this project will greatly determine if this funding will be the first of many or the last received from your industry.

Provide leadership

Once funding is received, the researcher becomes the project leader in the eyes of the group who awarded the money. The project leader is responsible for success or failure. Results and progress are many times viewed differently by industry than from university administrators. In most instances, industry expects positive results quickly. This expectation must be understood, but care should be taken not to over commit on quick results. Therefore, it is important to be an efficient manager of time and money to be productive. Leadership must be displayed to co-workers at all levels. In many ways, it is a pressure situation no different than that of being a coach.

Produce results

Once industry funding is accepted, the researcher must accept the responsibility of producing results. Even if success is not always achieved, project leaders are obligated to put forth their best effort. If that effort is shown and failure results, the funding group will accept failure. However, I have seen many scientists make proposals, accept funding, and not put a good effort into the research. The message must be made clear that unless results are produced, industry funding in support of a program will be terminated.

The above 5 rules have been the author's guidelines for obtaining industry support. They have worked well and should work for any researcher. There are, however, alternative methods of funding.

Alternative methods for funding research

Gifts. Funding of a research program can be from other forms than money. A substantial portion of the author's support, in addition to the dollars mentioned previously, has been in the form of equipment, land use, and labor. The use of trucks, forklifts, planters, and land, including all cultural management and labor to help harvest, amount to thousands of dollars in a program. Direct gifts of money to help purchase equipment or to pay for rentals is an excellent source of funding and, in many instances, preferred as it eliminates the need for grant proposals and reports. Care must be taken to follow policy procedures of your university or agency before accepting any form of gift.

Grants. Grants are the primary method for obtaining additional support for research programs. They may be in the form of equipment loans or dollars. They may be short-term, such as 6 months to 1 year, or long-term covering several years. One grant obtained by the author was written for 10 years. It has been funded 11 years and prospects are excellent for continued renewal. Another grant was written for one year with an option for renewal. Notice has been just received for the 16th consecutive renewal. These examples are mentioned because each is developed to provide funding for specific objectives. Also, the grantors differ in the type of commitments they want to make to scientists. Generally, the 1st grants will be short-term and as a performance record is established, long-term support is obtained. Most gifts come from industry groups. However, grants can be obtained from many sources including industry, government, or private organizations. They may be generated from direct collections or from marketing orders. It is important that researchers become aware of collection systems in their state before making grant proposals. Be fair and honest in budget requests but do not commit your research time to an insufficient budget.

Plant variety protection. Plant variety protection is a new source of funds for public plant breeders. There are mixed feelings among commercial seed companies and public supported research agencies concerning the release of vegetable varieties under plant variety protection. If release and distribution of such varieties is handled in a fair manner, both commercial seed companies and public plant breeders will benefit. The breeder will receive research support in the form of royalties, and the seed companies will profit from the sale of the new variety. Recently, 4 new onion varieties were released under plant variety protection. Six major seed companies are participating, which indicates that our method of handling the release is an acceptable system.

Most public scientists need additional funding to maintain productive research programs. Alternative methods of obtaining that funding vary with the type of research and the location of the scientist. If the research is basic, the funding generally must come from government or private grant sources. If the research is more practical at the production level, funding generally comes from industry. With either type of research, the same principles discussed in this presentation must be adhered to if continued funding is expected for a research program.

Public and Private Plant Breeding of Horticultural Food Crops in Western Europe

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The well-being of plant breeding (1, 11, 14), and hence of agricultural and horticultural productivity, depends upon careful planning to make the maximum use of resources. This is as true for the individual plant breeder as it is for those political planners who control the relationship between public and private sector breeders, especially in relation to the respective roles of private and public plant breeders. The policies and experiences in different countries are helpful in pointing the way to a format that will be beneficial for all. I propose to describe the organization of public breeding programs for vegetables and fruit (but not ornamentals) in Western Europe. Inevitably, most references will be made to the current situation in the United Kingdom, and to other countries where there is a strong and thriving plant breeding industry, indicating the relationship between public and private sectors in such countries.

Organization of government-sponsored plant breeding research

In the Netherlands, where there are a number of highly successful private breeding companies with large domestic and export markets, the activities of government research institutes are strongly influenced by grower, breeder, and academic members of institute boards and by advisory committees for different groups of horticultural crops. The Coordination Committee of the National Board of Agricultural Research makes decisions at an official level, but there also are close personal relationships among private and public breeders which play a part in shaping priorities at government institutes.

Public breeding of fruit and vegetable crops is concentrated at the Institute for Horticultural Plant Breeding (IVT), Wageningen. There are a number of very large private breeding companies specializing in vegetable crops, but hardly any private breeding is done on fruit. IVT policy is to stimulate private plant breeding and to act as a bridge between private breeding and the research program in the Dept. of Plant Breeding (IVP) at the Agricultural Univ., Wageningen.
The vegetable seed market in the United Kingdom has been dominated by Dutch-bred varieties. Recently, however, vegetable breeders in the United Kingdom have increased their efforts, supported by a change in the policy followed in government-financed vegetable breeding. The financing of this research is, in England and Wales, through the Agricultural Research Council (ARC) Agricultural and Food Research Council (AFRS) as from Oct. 1983, which is one of 5 Research Councils responsible to the Secretary of State for Education and Science, and which coordinates the activities of the research institutes under its aegis (3, 4). About one-half of the ARC's budget currently is provided by the Dept. of Education and Science (DES); the other half by the Ministry of Agriculture, Fisheries and Food (MAFF).

During the last decade, breeding programs at ARC institutes have been "rationalized" and overlap has been reduced considerably. Top fruit breeding has been concentrated at East Malling Research Station (EMRS) Soft fruit breeding is shared by EMRS and the Scottish Crop Research Institute (SCRI), financed by the Dept. of Agriculture and Fisheries, Scotland (DAFS). Whereas strawberry breeding was done at 3 institutes, the effort is now concentrated at one. Nearly all public sector breeding of field vegetables is now done at the National Vegetable Research Station (NVRS), but peas, particularly dried peas, are the responsibility of the John Innes Institute (JII), and the Glasshouse Crops Research Institute (GCRI) breeds glasshouse lettuce.

In recent years, coordination of private and public vegetable breeding in the United Kingdom has improved, partly as a result of membership of the British Association of Plant Breeders (BAPB) by both government institutes and private breeders. Exchange of ideas and information between public and private breeders occurs through BAPB crop groups. The importance attached to a forum for the meeting of public and private sector breeders is seen in both the Dutch and United Kingdom organizations.

The Belgian public research system also is complex, and the Agricultural Research Council is similar to that in the United Kingdom. Most public breeding research on horticultural crops is done at Gembloux at the Dept. of Agricultural Research Station for Fruit and Vegetables. Special working groups are now being set up as required by the Ministry of Agriculture to tackle urgent research problems. Fundamental horticultural research is carried out at several universities, including those at Gembloux, Ghent, Liege, Brussel, and Louvain. Several private and independent institutions also receive some government support.

In the Federal Republic of Germany, the Vegetable Working Group for Coordination of Breeding Priorities works in close collaboration with the Federal Research Center for Horticultural Plant Breeding (FRCHPB), Ahrensburg. Moreover, the Advisory Committee of the FRCHPB, on which serve private breeders or propagators, academics and administrators, ensures a coordination of effort on vegetable and fruit tree breeding.

In France, government plant breeding work is done mainly by the National Institute of Agronomic Research (INRA), based at Paris with a number of stations throughout France (5). In addition, the National Center for Scientific Research (CNRS) and university laboratories have a role in fundamental work related to plant breeding. Research associations such as the Association for the Development of Application of Research in Plant Breeding (ADAR), which has members from plant breeding establishments and research and technical institutes, also undertake fundamental research on novel techniques. ADAR's research is done through contacts with university laboratories.

Although arrangements in other western European countries are less formalized, the general picture is one whereby government-financed research is very much under scrutiny, and decisions involving such research depend upon special committees appointed by government, for this purpose.

Release of public breeding material to private breeders

There is little or no release of fruit breeding material by government institutes in western Europe to the very few private breeders. Most fruit breeding is done at public institutes to the varietal level. For vegetables, policies vary considerably from country to country. In the Netherlands, government institutes release basic or "half-bred" material to Dutch private breeders at relatively low prices, which can vary from about 10,000 to 150,000 Dutch guilders for each important release. Money from such sales is returned, via IVT, to the Dutch treasury. Prices, which are determined after discussions among private and public breeders, fall short of actual development costs. Only companies recognized by the Dutch authorities are entitled to receive breeding material. Where there are several applicants, material often is shared equally, as are costs. For advanced breeding material, however, a lottery is used to decide which applicant is successful. This approach avoids a profusion of similar varieties from different companies. Material recently released by IVT is listed in Table 1.

The close links (Fig. 1) between private and public sector vegetable breeders in the United Kingdom which have been all but weakened from a special BAPB agreement whereby public sector vegetable breeding material from NVRS, SCR, GCRI, and JII is released to bona fide British private breeders. This agreement does not apply to other crops except for special releases, such as parental gene-bank type germplasm. From 1980 to 1983, a number of United Kingdom private breeders (numbers in parentheses) have received vegetable breeding material from NVRS, e.g., lettuce resistant to downy mildew (race specific) (1); field resistance to downy mildew (3); male sterile carrots and maintainers (5); Dutch white cabbage resistance to viruses (5); autumn sown onions (5);
annual x biennial cauliflowers (4), Brussels sprouts early generation inbreds (6); Phaseolus beans resistant to viruses and halo blight (2); winter hardy peas (5); and swedes resistant to viruses (2). The SCRI has released cabbage breeding material, the JII leafless- and semi-leafless peas and the GCRI, glasshouse tomatoes and lettuce. One commercial company is about to release a commercial hybrid tomato bred using GCRI material. No charge is made to companies for breeding material, but there is an understanding that when new varieties containing government institute germplasm are entered for the Plant Variety Rights or National Listing, the private company will negotiate with and may make payment to the National Seed Development Organization (NSDO). The NSDO is the general commercial agent for British public plant breeders, and its Chairman and Governors are appointed by MAFF. The release of vegetable breeding material is controlled by a committee on which serve representatives from MAFF, ARC, the institutes, and private sector breeders. The institutes still retain the right to breed their own commercial varieties marketed through the NSDO. A recent development has been a joint scheme involving government institutes and British private vegetable breeders whereby hybrid varieties are bred with one parent from the institute and one from the private breeder. The private company is responsible for commercial development and marketing, making a payment to the NSDO based on the sale of seed. This scheme has been successful with Brussels sprouts (involving NVRS and 3 private breeders) and cabbage (involving SCRI and 1 private breeder), and is now being pursued with F1 hybrid onions (NVRS and 3 private breeders). NVRS inbreds of Brussels sprouts which have been used in this scheme are now being sold by NSDO to overseas firms. Such inbreds cannot be sold overseas until 3 years after the initiation of a joint program involving British companies. The availability of public sector breeding material and the collaborative joint hybrid programs have undoubtedly encouraged British private vegetable breeders to invest in more resources and to employ additional university-trained staff. An interesting development in the United Kingdom has been the appointment of an NVRS breeder to improve growers' stocks of winter cauliflower (Roscoff broccoli) in Cornwall. This breeder is based at the Rosewarne Experimental Horticultural Station [run by the Agricultural Development and Advisory service (ADAS) of MAFF] where he has the support of ADAS staff, selects breeding material from growers fields, and growers are prepared to run trials with him. There is now pressure from other cauliflower growers groups and cooperatives in other parts of the country to provide a similar service.

In France, the Association of Breeders of Flower and Vegetable Varieties (ACVF) oversees the distribution of material from INRA to private breeders. In addition to well-established French firms, ACVF also has foreign members who have companies in France, such as Royal Sluis & Sluis en Groot from the Netherlands and Asgrow International. According to H. Bannerot (personal communication), the rules for release of INRA material vary considerably. Material from highly variable populations to varieties may be available to any one who asks for it, available only to some people, or sold or licensed for commercial use. From 1960 to 1975, the INRA released a considerable amount of breeding material through ACVF which has been incorporated into varieties developed by private companies (Table 2).

### Government research programs

Research programs at government research institutes such as NVRS United Kingdom, IVT (the Netherlands), INRA (France), FRCHPB (Federal Republic of Germany) and Gembloux (Belgium) are similar, concentrating on selection and breeding methods; searches for plant resistance to pests, diseases, and physiological disorders; the transfer of such resistances to commercial material allied to studies on the genetics of host resistance/pathogen pathogenicity; techniques for interspecific and intergeneric hybridization, and cyto-genetic studies. Physiological and biochemical research often is involved, especially with the recent interest in "biotechnology", which has seen increased efforts in areas such as somatic hybridization, embryo culture of difficult crosses, another culture to produce "instant" inbreds, iso-enzyme work for the detection of "sibs" in hybrid breeding, DNA/RNA biochemistry of plant resistance, and male sterility. Such research is essential for the continuing success of plant breeding. In times of recession, public research programs undoubtedly suffer. Although the level of public expenditure on the breeding of horticultural crops has been roughly maintained in the United Kingdom there have been changes. Breeding research on some crops, such as glasshouse tomatoes and cucumbers, has been terminated, while fruit breeding has been reduced and field vegetable breeding slightly increased, especially studies of genetics of plant resistance to pests. Yet, compared to major crops such as cereals and potatoes, research on minor horticultural crops is still in its infancy. As private investment increases, there will be increased pressure on government institutes to provide improved techniques to speed breeding programs and to make them more efficient. Contractual service work has also been done on a small scale for private Brassica breeders by the NVRS and the SCRI. The NVRS has, using its world reference collection of S-alleles, identified incompatibility S-alleles in inbred lines of Brassica. Sengana GmbH (Federal Republic of Germany) and Gembloux (Belgium) are similar, concentrating on selection and breeding methods; searches for plant resistance to pests, diseases, and physiological disorders; the transfer of such resistances to commercial material allied to studies on the genetics of host resistance/pathogen pathogenicity; techniques for interspecific and intergeneric hybridization, and cytogenetic studies. Physiological and biochemical research often is involved, especially with the recent interest in "biotechnology", which has seen increased efforts in areas such as somatic hybridization, embryo culture of difficult crosses, another culture to produce "instant" inbreds, iso-enzyme work for the detection of "sibs" in hybrid breeding, DNA/RNA biochemistry of plant resistance, and male sterility. Such research is essential for the continuing success of plant breeding. In times of recession, public research programs undoubtedly suffer. Although the level of public expenditure on the breeding of horticultural crops has been roughly maintained in the United Kingdom there have been changes. Breeding research on some crops, such as glasshouse tomatoes and cucumbers, has been terminated, while fruit breeding has been reduced and field vegetable breeding slightly increased, especially studies of genetics of plant resistance to pests. Yet, compared to major crops such as cereals and potatoes, research on minor horticultural crops is still in its infancy. As private investment increases, there will be increased pressure on government institutes to provide improved techniques to speed breeding programs and to make them more efficient. Contractual service work has also been done on a small scale for private Brassica breeders by the NVRS and the SCRI. The NVRS has, using its world reference collection of S-alleles, identified incompatibility S-alleles in inbred lines of Brassica. Sengana GmbH (Federal Republic of Germany) is now being sold by NSDO to overseas firms. Such inbreds cannot be sold overseas until 3 years after the initiation of a joint program involving British companies.

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### Production of commercial varieties by government institutes

In fruit breeding, an enthusiastic and gifted amateur occasionally may produce an outstanding variety from chance seedlings as, for example, the famous 'Granny Smith' apple which was selected in the 1850s in Australia but did not become important globally until the 1950s (10). In the United Kingdom the last major success of this type was the apple 'Discovery' in the 1950s. Other exceptions to government-bred varieties of fruit are the 'Senga' series of strawberries from the private company Sengbusch (Sengana GmbH) of Hamburg, W. Germany, and the strawberry variety 'Grandee' from the German breeder Hummel. Unfortunately, Sengana GmbH recently decided to terminate their breeding activities.

Most fruit breeding in the United Kingdom is done at government institutes (Tables 3 and 4). This is also true of other western European countries. One exception is the large French nursery firm Delbard, which maintains a tree fruit breeding program.

In countries where there is little private vegetable breeding, such as Italy and Greece, government institutes breed commercial varieties. Yet growers rely mostly on imported varieties, as well as on

### Table 2: Vegetable breeding material released by INRA to French private breeders 1967–75 (H. Bannerot, personal communication).

<table>
<thead>
<tr>
<th>Crop</th>
<th>Trait(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capsicum</td>
<td>Genic male sterility</td>
</tr>
<tr>
<td>Tomato</td>
<td>Selected inbreds for hybrid breeding; genic male sterility; novel resistance to tomato mosaic virus</td>
</tr>
<tr>
<td>Phaeolus beans</td>
<td>Resistance to anthracnose and to halo blight</td>
</tr>
<tr>
<td>Carrot</td>
<td>Male sterile lines and maintainers</td>
</tr>
<tr>
<td>Lettuce</td>
<td>Resistance to lettuce mosaic virus</td>
</tr>
</tbody>
</table>

### Table 3: New top (tree) fruit cultivars bred by EMRS and released through NSDO since 1968.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Cultivar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>Malling® Kent</td>
</tr>
<tr>
<td></td>
<td>Malling' Suntan</td>
</tr>
<tr>
<td></td>
<td>Malling' Greensleeves</td>
</tr>
<tr>
<td></td>
<td>Malling' Jester</td>
</tr>
<tr>
<td></td>
<td>Malling' Jupiter</td>
</tr>
<tr>
<td>Apple Rootstock</td>
<td>M.27</td>
</tr>
<tr>
<td>Pear</td>
<td>Malling' Beth</td>
</tr>
<tr>
<td>Cherry Rootstocks</td>
<td>Malling' Cob</td>
</tr>
<tr>
<td></td>
<td>Malling' Charger</td>
</tr>
<tr>
<td>Plum Rootstock</td>
<td>Malling' Colt</td>
</tr>
<tr>
<td></td>
<td>Malling' Pixy</td>
</tr>
</tbody>
</table>

* Malling is a registered trademark.
In the United Kingdom, the Plant Royalty Bureau (PRB) which is a nonprofit organization, acts on behalf of its members who are holders of rights (private and public), issues licenses to produce, or to produce and sell seed of plant varieties protected by plant variety rights, and collects fees for rights (royalties) on behalf of the licensors. At present, the PRB concentrates on the major arable crops e.g., cereals, potatoes, grasses, legumes, and on soft fruit (small fruit). It does not collect royalties on vegetables. Exclusive private arrangements are made between breeders and seedsmen for royalty payments on vegetables, as well as for varieties of fruit bred by the private sector.

In France, the Caisse de Gestion des Licences Vegetables (CGLV) is similar to the PRB, but for most horticultural crops throughout western Europe, private royalty agreements are made directly between breeder and seedsmen, or breeder and propagator. The marketing of varieties bred by INRA in France is flexible, with partnerships involving private seed companies who pay royalties directly to INRA. Formerly, any company could obtain a license, but this led to excessive competition and lack of commercial success. There is now a movement in France to make exclusive agreements with single firms or groups, with a provision to revoke such agreements every 3 years if results are unsatisfactory. INRA is now empowered to create a subsidiary private company for its own varieties.

Genetic conservation

The need for genetic variability in all breeding programs is well-recognized. Peterson (13) has summarized the extensive use of plant introductions for vegetable breeding in the USA and stressed the important role played by the Plant Introduction (PI) stations. It is one thing, however, for an individual breeder or group of breeders to assemble useful genetic variation, but another to ensure that such material is preserved and made readily available to breeders everywhere.

Fortunately, methods are now available to store seed in a viable condition over a lengthy period of time (15). At present, most fruit varieties, being clonally propagated, are still maintained in "live" collections, but tissue culture and cryogenic methods of storage could lead to different methods of storing fruit germplasm. Personnel at the Kew Botanical Gardens Gene Bank in the United Kingdom currently are studying the possibility of conserving apple germplasm in the form of stored seeds.

The conservation of global genetic resources is a task beyond most individual countries’ means, so in 1974 the International Board for Plant Genetic Resources (IBPGR) was formed by the Consultative Group in Agricultural Research (CGIAR) with a mandate to promote and coordinate the collection and preservation of germplasm, and the data storage and retrieval systems that are essential to the efficiency of gene banks. In recent years, IBPGR has increased its efforts on vegetables and has published, or intends to publish, reports on the genetic resources of amaranths, cruciferous crops, tomatoes, *Allium*, *Capsicum*, okra, eggplant, and *Cucurbitaceae* (6). In addition, there is a worldwide list of vegetable germplasm collections, including small ones and those belonging to private companies (16).

Vegetable gene banks recognized by IBPGR (6) in western Europe include those at Braunschweig (Federal Republic of Germany), IVT (The Netherlands) and NVRS (UK). In addition, some vegetable germplasm is stored at Bari, Italy, and at the Nordic Gene Bank, Lund, Sweden.

Over the last few years there has been considerable activity on genetic conservation in Europe, with the Eucarpia Genetic Resources Section providing scientific links between interested parties. At an organizational level the European Cooperative Program (ECP), which is now under the aegis of IBPGR, has been financed from the United Nations Development Program (UNDP) and FAO, and has been active in coordinating European efforts through crop working groups. The European Economic Community (EEC) has actively supported the collection of endangered *Brassica* material, and a similar scheme for *Allium* crops is being organized.

The Fruit Section of Eucarpia has received funds from IBPGR to improve the coordination of national fruit collections throughout

Table 4: Successful soft (small) fruit cultivars protected by plant variety rights bred by Government institutes in the UK.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Cultivar*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raspberry</td>
<td>Glen Cova (1)</td>
</tr>
<tr>
<td></td>
<td>Glen Moy (1)</td>
</tr>
<tr>
<td></td>
<td>Glen Pros (1)</td>
</tr>
<tr>
<td></td>
<td>Malling Admiral (2)</td>
</tr>
<tr>
<td></td>
<td>Malling Delight (2)</td>
</tr>
<tr>
<td></td>
<td>Leo (2)</td>
</tr>
<tr>
<td></td>
<td>Joy (2)</td>
</tr>
<tr>
<td>Strawberry</td>
<td>Harvester (3)</td>
</tr>
<tr>
<td></td>
<td>Saladin (1)</td>
</tr>
<tr>
<td></td>
<td>Silver Jubilee (1)</td>
</tr>
<tr>
<td></td>
<td>Tantallon (1)</td>
</tr>
<tr>
<td></td>
<td>Troubadour (1)</td>
</tr>
<tr>
<td></td>
<td>Ben Lomond (1)</td>
</tr>
<tr>
<td></td>
<td>Ben More (1)</td>
</tr>
<tr>
<td></td>
<td>Ben Nenis (1)</td>
</tr>
<tr>
<td></td>
<td>Jet (2)</td>
</tr>
<tr>
<td></td>
<td>Blackdown (4)</td>
</tr>
<tr>
<td>Blackcurrant</td>
<td>Invicta (2)</td>
</tr>
</tbody>
</table>

*There are no rights schemes for redcurrants for which NSDO markets Redstart (2), nor for the blackberry x raspberry hybrids Tayberry (1) and Sunberry (2) which are gaining in popularity.

*The most popular variety is 'Cambridge Favourite' bred at the State Horticultural Research Unit at Cambridge prior to the introduction of Plant Variety Rights in 1964.

1. Scottish Crop Research Institute, 2. East Malling Research Station, 3. John Innes Institute, and 4. Long Ashton Research Station.
Europe, and there is an EEC committee, with several subcommittees for specific fruit crops, to coordinate genetic conservation in the EEC.

Material in western European gene banks usually is freely available to bona fide breeders throughout the world with no discrimination between public and private plant breeders.

Although moves to ensure conservation of valuable germplasm have undoubtedly been partially successful, there is still no room for complacency. Much genetic material still needs to be collected, multiplied, characterized, and stored. Data storage and retrieval systems need to be devised that make known to potential users the useful characters of such material.

Training of plant breeders

At a time when plant breeding is becoming increasingly scientific, calling for highly specialized knowledge and expertise in diverse areas of biology, the training of young plant breeders and technicians is of paramount importance. In several countries, experienced staff from public institutes have transferred to the private sector, but private breeding companies are looking more and more to university graduates to staff their expanding programs.

The involvement of universities, public research institutes, and private companies in training varies from country to country. In a number of European countries there are agricultural universities which specialize in the training of scientists for agricultural and horticultural research and development, but in the United Kingdom, agricultural and horticultural scientists graduate from agricultural or horticultural departments at universities which also emphasize other subjects. No United Kingdom university produces graduates with BS degrees in plant breeding, although plant breeding is covered in courses in genetics, and students often spend part of their vacations working at government institutes. Usually botanists, biologists, or geneticists follow a general curriculum at the undergraduate level in the United Kingdom and subsequently specialize in plant breeding at a MS or PhD degree level. There are now a number of MS courses on plant breeding in which much of the curriculum concentrates on lectures and practicals, and project work forms only part of the syllabus. Private companies usually employ BS graduates as plant breeders for "in-house" training, and such staff rarely pursue higher degrees. In the United Kingdom, the government provides financial support to PhD students on joint projects between university departments and private companies, and in projects involving universities and government institutes. Over the last few years, NVRS has had several joint PhD projects in plant breeding with the Genetics Dept. of Birmingham Univ., and joint projects with other universities in more specialized areas such as protoplast cloning and the biochemistry of plant resistance to diseases (2).

In the Netherlands, the Agricultural Univ. at Wageningen has a specialized Plant Breeding Department (IVP) which undertakes fundamental plant breeding research as well as the education of plant breeders. During their plant breeding courses, students spend at least 6 months on a practical project, very often in one of the large Dutch private breeding companies. Training of technical horticultural staff is done at IVP in a special course lasting 2 years during which participants attend one day per week for about 35 weeks per year, receiving an official certificate after an examination.

Variations on the Dutch and British systems are found in other countries with a trend toward formal courses at government institutes for the training of private plant breeders. Both private and public sector must collaborate closely to ensure a continuing supply of high quality breeders with appropriate experience.

National societies covering biology, genetics, and biometrics encourage a free exchange of ideas and technical know-how between private and public breeders. Eucarpia (the European Association of Plant Breeding), which has over 1000 members, organizes congresses every 3 years in a different European country, whereas Eucarpia Crop Groups meet more regularly to discuss special topics.

Discussion

The relationship between public and private plant breeders in western Europe varies between countries and to some extent is influenced by the political philosophy of the elected government. However, the trend for vegetables is one in which the breeding of commercial varieties is being left more and more to private companies or individuals, and government institutes are concentrating on fundamental and strategic research. One exception concerns the breeding of minor vegetable crops with small seed sales. Although public breeders will probably have to continue breeding commercial varieties of such crops, there are signs that small private breeding companies are beginning to specialize in a few of the minor vegetables. The situation for fruit is different, for although there is some private breeding in soft small fruit, top (tree) fruit breeding is almost exclusively done by public breeders. With the availability of tissue culture techniques and other forms of cell reproduction, time scales in fruit breeding and multiplication of elite clones may be reduced significantly, and it is possible that private fruit breeding, especially for soft, (small) fruit, will increase over the next decade.

The program in the United Kingdom for joint hybrid vegetable breeding programs between private and public plant breeders is one that deserves increased attention. When started with Brussells sprouts (8), there was a certain nervousness among the participants about protecting their inbred lines, and the initial exchange was only of pollen for hybridization. Subsequently, a strong trust has developed, and there is a readiness to exchange inbred plants. This scheme is clearly one that could involve private/private as well as private/public exchanges, thus maximizing the usefulness of costly inbred lines. The involvement of both public and private breeders has served to highlight a number of technological problems which can be investigated speedily by public research workers. Moreover, this joint enterprise appeals to politicians and the public alike in that they can see readily the benefits accruing from investment in public research.

The training role of university departments and government institutes is a key to the we-being of plant breeding, and it is gratifying that private companies are now more involved in the training of graduate and postgraduate students. There also is an increase in specialized training courses for private breeders or technicians at government institutes and evidence that such institutes are more aware of the need to make known advances in breeding technology quickly to private breeders. For example, private breeders in the BAPB receive abstracts of scientific papers written by public scientists as soon as a journal accepts a paper for publication.

Although the need for genetic conservation and full utilization of genetic resources has been recognized, and national and international efforts have been made to meet requirements in this sphere, there is still a need for improved integrated efforts. The last few years have seen a considerable improvement in the coordination of genetic conservation in western Europe, and it is encouraging to note that IBPGR is now involved on the European scene so that global, as well as regional, requirements are met. Apart from temporary embargoes of a relatively minor and infrequent nature, most European gene banks make germplasm readily and freely available to breeders throughout the world. Although I do not expect private breeders to make available to gene banks advanced breeding material or potential new varieties, I believe unfortunately, that private breeders may allow a considerable amount of useful materials to be lost because of the trouble and cost in sorting out material for dispatch to an appropriate gene bank.

It is interesting to consider the 5 recommendations made at the 1982 Plant Breeding Forum at Des Moines, Iowa, sponsored by Pioneer Hi-bred International Inc., (14): 1) improving coordination of private and public plant breeding, 2) increasing cooperation between public and private sector, 3) providing more public funds for plant breeding research, 4) encouraging incentives for greater private investment, and 5) preserving and utilizing exotic germplasm. I am proud to report that in field vegetable breeding in the United Kingdom, and in particular at the National Vegetable Research Station, we have adopted all 5 recommendations, over the last few years, albeit somewhat earlier than the meeting at Des Moines!

Summary

In western Europe most government agencies concerned with agriculture and horticulture are rationalizing their research programs to meet national needs. Although funds for public research are decreasing, there is an increasing collaboration between private and
public vegetable breeders. Efforts to maximize returns from highly bred gene pools are likely to increase, with private companies entering into joint breeding agreements, either with public breeders or other private breeders, especially in the breeding of hybrid varieties. Breeding material from public funded programs probably will be made more readily available to private breeders. The main function of the public element related to vegetable breeding may well become the provision of a better understanding of biological-processes, accompanied by the provision of techniques to speed up breeding programs and to make them more efficient. In fruit breeding, top (tree) fruit is likely to continue to depend on public effort for new varieties, whereas there may be more private investment in soft fruit (small fruit) breeding. Genetic conservation and utilization is at last being given the attention it deserves, but private breeders should contribute more to national and international gene banks. The training of plant breeders is likely to become more specialised and universities, government, and private breeders must collaborate more closely to provide high quality training.

Literature Cited


The Art and Science of Plant Breeding in the Modern World of Research Management

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Although plant breeding is very old, it has, at least during recorded history, seldom been short of new ideas and concepts that have made breeding procedures more and more powerful and effective. It is reasonable to speculate that the first act of plant breeding was the use of seeds from superior plants for the next year’s crop. Development of new technologies in the intervening years, has added to the power and versatility of the plant breeder’s art. Some of these changes have been spectacular, others rather modest.

New ideas in plant breeding

One of the earliest, and most spectacular, additions was the technique of hybridization, largely based upon the work of Kolreuter in the 1760s, which freed the breeder from the severe constraint of working within a limited population, enabling him to bring together useful traits from 2 or more sources. Nearly all modern plant breeding involves some use of hybridization.

Equally spectacular was the development of the F1 hybrid concept through the work of Shull, East, and Jones in the early 20th Century (9). This development, too, has influenced plant breeding greatly, although not as much as hybridization.

In the late 1920s, Muller and Stadler discovered that mutations could be induced by X-irradiation (4, 10). Blakeslee and Avery demonstrated in 1937 the usefulness of colchicine in the induction of polyploidy (2). There was a surge of interest in the use of these techniques in plant breeding. Great expectations were raised in the 40s and 50s that these techniques would revolutionize plant breeding. These expectations were only partly realized, as each technique has found a small place in plant breeding, but certainly has not transformed it (3).

In the modern world, our ability to assess the ultimate worth of new ideas and concepts, which is difficult enough, is complicated often by our enhanced ability to communicate with each other, instantly, in living color, and in great volume. This communication sometimes takes a form known as "media hype", which can easily obscure the true worth and potential scope of many of the new phenomena that keep cropping up in our society, such as the computer revolution.

In our own field of plant breeding, we are being asked to deal with several new ideas, concepts, and technologies, the virtues of which are being extolled before they have made actual, substantial contributions to plant breeding. Of particular concern are 2 phenomena: genetic engineering and germplasm enhancement.

Genetic engineering

The field of genetic engineering is surrounded by a heady mixture of venture capital, legal and economic concerns, political oversight, and an extraordinary volume of publicity. It is somewhat difficult to separate the DNA fragments from the dollar signs. It is extremely difficult to distinguish between appearance and substance in order to answer the question: What can we expect genetic engineering to contribute to plant breeding? The truth is that we don’t know and we won’t know until the contributions have in fact been made. I suspect that there will be contributions, and perhaps very substantial ones. It is well to remember that plant breeding is a long and complex series of steps, however, with many looping and branching sequences, towards the ultimate goal of permanent crop improvement. It is much more than the transfer of exotic but desirable genes from one organism to another. It is becoming apparent, from their recent writings and talks, that the genetic engineers themselves are, to their credit, beginning to recognize this fact. The question may be asked whether substantial changes will be made in the structure of existing research systems that are based upon realistic expectation.