General Discussion

Chairman (Dr. Rao, India): Thank you very much for asking me to be the chairman of the general discussion of the symposium on methods of crop breeding. The twenty two papers presented at the symposium can be divided into 5 groups. Group I is related to rice and comprises 7 papers. Group II deals with vegetatively propagated crops. There are 5 papers referring to sweet potato, cassava, sugar cane, tea and cacao, respectively. Group III deals with oil crops and comprises three papers on oil palm, rapeseed and coconut. Group IV considers cereals and legumes and 4 papers covered forage sorghum, soybeans, legumes and wheat. Group V deals with miscellaneous crops such as tobacco, tomato and fruit trees. Group VI will review some of the techniques discussed in the course of the symposium and will pay special attention to test tube breeding, chromosome engineering, pollen, anther and cell culture and isozyme analysis.

I shall now proceed to a brief review of the papers presented at the symposium. Among the 22 papers discussed, 7 dealt with rice. There were two papers on breeding methods for rice improvement, two papers on deep water rice, one on acceleration method of generation advancement, one on classification of rice varieties, one on test tube breeding by tissue culture.

Among the papers on breeding methods for rice improvement, one of the papers by Dr. Khush from IRRI dealt with the development of varieties with multiple resistance to diseases and pests, emphasizing the development of screening methods and of germ plasm. The pedigree method was used rather than the backcross method owing to the lack of suitable reciprocal parents.

On the other hand, Dr. Fujimaki put the accent on the extensive use of the backcross method which improves specific attributes without spoiling other aspects of performance. The main problem is to evaluate and detect undesirable linkage.

Acceleration methods for generation advancement are important in countries where seasons interfere with rice growing. Suitable materials could be located in tropical areas requiring international cooperation. In Japan, artificial methods are being used such as the nursery box method and the nursery bed method, as explained by Dr. Kikuchi.

Dr. Chai from Thailand and Dr. Zaman from Bangladesh have presented interesting papers dealing with breeding of deep water rice. Emphasis is put on yield and tolerance to submergence.

The paper by Dr. Nakagahra on origin, differentiation and classification of rice varieties by the use of isozyme analysis represents an additional contribution to breeding methods.

The last paper on rice presented by Dr. Oono outlines the potential of the use of tissue culture as a means of replacing conventional methods of breeding.

In the case of vegetatively propagated crops, as these are asexually propagated, though breeding behaviour is not unimportant, knowledge of the phenotype as seen from the variations introduced and selection assume a very important role while maintenance of the genotype poses no problem. The use of wild relatives has been mentioned in the case of sugar cane, sweet potato and tea.

Dr. Kobayashi highlighted the hybridization of *Ipomoea* species with sweet potato, as the wild species provides useful genes for the improvement of sweet potato, namely yield.

Dr. Rao outlined the importance of the use of wild relatives which led to a breakthrough in the matter of yield of sugar cane and tolerance to adverse conditions as well as to diseases and pests.

Dr. Kawano pointed out that genetic improvement of cassava was of recent origin and that limited attention had been given to improving the species, although cassava is an important crop as a source of food for populations living in the developing countries located in the tropics.

In his paper on tea breeding, Dr. Kulasegaram insisted on the fact that a tea breeding programme was a very long term project owing to the time needed for the completion of the life cycle of the crop and its outbreeding nature. The use of wild genes or varieties was also mentioned in his paper.

Objectives of breeding of cacao, as indicated by Dr. Soria are to increase yield and quality.

Emphasis is placed on widening the genetic basis by means of a large germ plasm collection as tropical America offers a wide scope owing to the existence of a large wild population.

In the case of oil crops, three papers have been presented, one on palm oil, one on coconut and one on *Brassica.*

Two of the crops are of long duration and need intensive breeding work. Emphasis is placed on limiting health hazards, hence improving quality and shifting to unsaturated fatty acids, as outlined by Dr. Ooi in palm oil and by Dr. Shiga in *Brassica.*

In the case of oil palm, and coconut, it is important to dwarf the plant for easy access to breeding and fruit collection. Collection of germ plasm is also indicated. In the case of coconut, it is most important to develop varieties resistant to wilt disease whose nature remains unclear and should be investigated on a multi-disciplinary approach basis.

Among the four papers on cereals and legumes, one dealt with the breeding of forage sorghum in using male sterile lines, as suggested by Dr. Tarumoto. Emphasis was placed on the need to develop forage crops as feed for cattle so as to increase production of meat and milk.

As leaf rust is a serious disease in wheat, the paper presented by Dr. Mukade in which he indicated the use of chromosome engineering to transfer leaf rust resistance from rye to wheat is quite interesting. The use of acceleration of generation advancement was also suggested.

Dr. Arwooth emphasized the increasing importance of breeding soybeans owing to their high protein content. As this crop which was chiefly cultivated in cool temperate zones is now moving to the humid tropics, it will become necessary to develop new techniques to breed varieties resistant to diseases.

As outlined by Dr. Ramirez, legumes can be bred through conventional methods and screening for diseases and desirable agronomic characteristics is most important in the case of mungbeans, soybeans and peanuts.

As for the miscellaneous crops discussed at the symposium, in the case of tobacco, the new technique of production of haploid plants by anther culture has been presented by Dr. Oinuma. Such technique is suitable for breeding programs involving a small number of segregating genes.

As outlined by Dr. Yamakawa, the breeding of tomatoes in Japan has to meet definite marketing requirements depending on consumers demands such as color preference. Also it is important to develop varieties resistant to a large number of diseases.

Dr. Yamaguchi highlighted some of the virus diseases affecting fruit trees, insisting on the need for grafting virus free materials. The use of heat treatment seems the easiest way of inactivating or eliminating the viruses.

I would now like to ask Dr. Khush from IRRI (Philippines) to discuss with some detail the methods currently applied for the breeding of rice.

Dr. Khush (IRRI): Thank you very much. I decided to list on the blackboard methods commonly used for rice improvement (Fig. 1). Most of these methods are not particularly new and are well known. They depend on the situation, the objectives of the breeding programme and the type of material used.

Methods of rice breeding

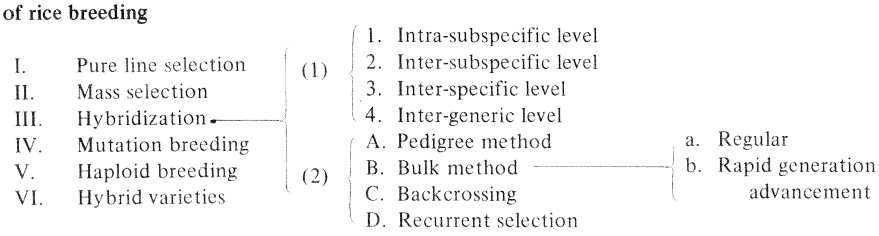

Fig. 1. Methods commonly used for rice improvement

The pure line method has been widely used in the beginning of the century and has enabled the development of more than 200 varieties. This method was extensively applied in Thailand in the 1950's and the 1960's.

Mass selection method is mainly used in crossing programs.

Hybridization is one of the most important technique for rice breeding and it takes place at various levels.

It can be said that 90% of the hybridizations involve the intrasubspecific level leading to the development of *japonica-indica* cross, for example. However as it is limited in the case of hybridization between *javanica* and *japonica* varieties, the inter-subspecific level is preferred for these varieties. This method applies to the varieties developed in the southern part of the U.S.A. Also germ plasm of *indica* is used for blast resistance in Japan. One should mention FAO programmes emphasizing hybridization at the inter-subspecific level for breeding of *japonica* which has been successfully conducted in Indonesia, Manchuria and Malaysia. In China, hybrids are being developed between *japonica* and *indica* so as to benefit by the cold resistance character present in *japonica.*

Hybridization at the inter-specific level is limited in the case of rice, although it could increase the variability of cultivated species by use of wild varieties. This method is applied to develop varieties resistant to diseases such as blast. It will become increasingly important owing to the possibility of using wild relatives in hybridization programmes.

Hybridization at the inter-generic level is known in many species, as it enables to increase genetic variability from distant relatives. One of the examples is provided by Dr. Mukade's paper who is currently breeding leaf resistant wheat cultivars by the use of inter-specific and inter-generic crosses to transfer leaf resistance from rye to wheat. Such method is not often applied in the case of rice.

As for the breeding procedures, the pedigree method is used for the development of resistance to diseases as a record of the parental lines can be kept.

The bulk method has been illustrated by Dr. Kikuchi in his paper on acceleration methods for advancement generation of rice as it enables to shorten the breeding cycle. Several modifications have been developed in Japan.

The backcross method is of limited use unless recurrent parents are available. Modifications of the method illustrating the use of genetic male sterility has been reported by Dr. Fujimaki.

Recurrent selection method is particularly suitable for the traits of polygenic inheritance or quantitative traits in which selection through backcross or pedigree methods is not effective. It is also used to enhance protein content and to develop stem borer resistance. Several genes of parents which influence variability in the crosses can be transmitted to progenies. When hybrid progeny is crossed in diallelic manner, one can set up a breeding population and introduce male sterility genes so as to continuously promote outcrosses in this breeding population, as highlighted by Dr. Fujimaki.

Mutation breeding has contributed to the development of a large number of varieties. It is particularly useful for changing one gene in a combination of several genes.

Haploid breeding methods are now becoming increasingly popular, for example anther culture which has been presented by Dr. Oono. It can be applied to rice and an improved variety has been developed in Taiwan, although the method remains very difficult for practical breeding. Another method of haploid breeding is represented by distant hybridization. It consists of making crosses between two distant species and has been applied to potato. After pollination, crossing takes place and the alien chromosome of the male parent is taken out because of incompatibility of the cytoplasm of the female parent. As a result only the genes of the female remain and hybrids can be obtained by crossing through distant hybrids.

Chairman: Thank you very much for your nice presentation on breeding methods of rice and for outlining future possibilities which might enable to improve yield and quality.

Dr. Zaman (Bangladesh): Very often sterility problems occur when breeders attempt to develop varieties with photo-sensitivity or flood resistance and then try to incorporate genes from high-yielding varieties such as *japonica,* for instance. If instead of going through screening process one uses as parents IR 20, Mahsuri or IR 5, certain relatives develop to receive genes from *japonica* types without any sterility. When photosensitive varieties are crossed to some of these lines, the sterility is markedly reduced and selection is very efficient. Also, I would like to add that as many rice-growing countries encounter salinity problems due to lack of germ plasm resistant to salinity, development of varieties by countries such as India, Bangladesh, China and Thailand could cover those areas which are quite suitable for rice production.

Dr. Fujimaki (Japan): I would like to ask Dr. Khush if it is true that in developing diploid plants through anther culture hybrid sterility is not likely to occur.

Dr. Khush (IRRI): Yes.

Dr. Fujimaki (Japan): Also in using the bridge method as outlined by Dr. Zaman, is it possible that sterility could disappear?

Dr. Khush (IRRI): If one cultivates anthers from hybrids between *indica* and *japonica* and pursues regular breeding with such plants, incompatibility of sterility is not seen any longer because sterility genes are eliminated.

Dr. Chai (Thailand): With Dr. Kawai we were able to develop through mutation a glutinous variety of rice. Such procedure is being used in deep water rice on a small scale.

Chairman: I would like to sum up what has been said about methods of rice breeding. It is obvious that earlier selection methods have been replaced by hybridization methods, namely at the inter-specific sub-level in the case of *japonica* and *indica* and other excellent varieties.

However, the time may come when one may be faced with loss in variation when crossing within this group. Also, it might become necessary to develop resistance to new diseases and pests. For such purpose, breeding programmes will have to expand and hybridization at the intra-specific level will become more important, in making use of the wild relatives. Moreover, the use of intra-generic hybridization as practiced in China should enable to develop more variation, while enhancing yield, quality and resistance to diseases and pests. Finally, as pointed out by Dr. Zaman, salinity, due to lack of germ plasm for this particular characteristic, is an important problem. Attention should concentrate on collecting wild plants resistant to salinity.

I am now requesting Dr. Soria to lead the discussion on vegetatively propagated crops, namely sweet potato, cassava, sugar cane, tea and cacao.

Dr. Soria (Costa Rica): Vegetatively propagated crops can be divided into two groups, those which are obligate vegetatively propagated crops, such as cassava and sweet potato and those which in addition to being vegetatively propagated crops for commercial use also have seedling progenies, such as cacao and tea.

Breeding procedures involve germ plasm collections in order to attain variability through the use of wild relatives, for instance. There is a need for more germ plasm collections. However, maintenance of collections requires large areas. Also, these are sensitive to pests and diseases and must be continuously renewed. To overcome these difficulties tissue culture could be used to maintain large germ plasm collections in a small area.

As for the methods of breeding, one should mention individual plant selection which is the most important one. Selection can be made from local or introduced varieties, for specific characteristics or for a combination of characteristics such as yield, quality, resistance to diseases and pests and tolerance to adverse environmental factors. Once selection is made,

plants are propagated vegetatively, put into replicated trials to test their value and later on, to be released to the farmers. Despite the existence of a large number of clones, as pointed out by Dr. Kawano in cassava, there is a need for the combination of different characteristics and for increasing variability or recombinations. Therefore, other methods must be used such as inter-specific crossing which can be applied in sweet potato.

Hybridization can also be applied at various levels. For instance, inter-varietal or inter-clonal crosses have been used for obtaining varieties or combinations to give the opportunity to the breeder of selecting the best plants for propagation and further testing. Inter-specific crossing programmes involve sugar cane and sweet potato. Also inter-generic and inter-subspecific crosses can be performed. The objective of breeding programmes is to rectify characteristics or combination of characters which are desirable for use by the farmers.

In the case of tea and cacao, individual plant selection has been used. The best plants are tested in replicated trials and thereafter distributed as clones. Also the use of sexual families has been promoted by testing the performance of progenies of selected plants or clones by open pollinated materials or by hybridization (cacao) in looking for general or specific combining ability, particularly clonal crosses. Selection of best progenies for distribution to the farmers applies to tea.

In the case of cassava, in addition to individual selection of plants coming from inter-clonal crosses, the use of inter-specific crossing has been stepped up as characteristics looked for may be available in related species.

In the case of sugar cane, species are difficult to cross owing to their high ploidy. Therefore, selection of haploids has been attempted.

Dr. Kawai (Japan): Tissue culture methods have some limitations related to genetic stability which varies depending on the species. The passage to callus may affect variability of cultured cells. Regarding the problem of genetic instability, selection procedures at several levels may be important. However, the most important thing is to establish effective methods of selection for calluses and cells. In that respect, expression of genes at the cellular level or at the callus level is very important in using this technique.

Dr. Hojo (Japan): The influence of root rate for improvement of properties of root and production process is important for getting a high yield. Harvest index has been proposed by Dr. Kawano as a measure of efficiency of plant production and harvest index is a suitable parameter to screen for yield in breeding programmes. Harvest index is based on the relation between root weight and total plant weight. High yields of root crops may be obtained by high harvest index which is based on high level of total plant weight.

Dr. Kobayashi (Japan): I would like to comment on the use of interspecific crosses for yield improvement. In the case of sweet potato, as wild species are heterozygous, direct selection of useful genes is difficult. As for yield improvement, wild species cannot be screened directly. Therefore, hybrids must be made through backcrossing progenies to select high-yielding strains. Also it is necessary to make some hybrids between cultivars and wild species and then select.

Chairman: To conclude, I would like to say that breeding methods for vegetatively propagated crops are different from those applied to sexually propagated ones. Vegetatively propagated crops are highly heterozygous and polyploid. Also the phenotype is important as the genotype can be maintained once a good phenotype with desirable characters is obtained. Efficient selection procedures are more important than breeding methods themselves. As vegetatively propagated crops are long duration crops, efficient correlation factors at the juvenile stage should be set up as regards quality, yield and resistance so as to select or reject at an earlier stage the varieties. The aspect of going beyond the individual plant selection even

at the inter-specific or inter-generic level will depend on the cytological particularities of the plant. In the case of sugar cane, the phenomenon of autosyndesis helps in making inter-specific and inter-generic plants fertile.

I would like to ask Dr. Ooi to proceed to the discussion on oil crops, namely oil palm, coconut and rapeseed.

Dr. Ooi (Malaysia): Among the oil crops which have been presented at the symposium some are legumes. In the case of soybean in particular, emphasis is now being shifted to its high protein content.

Two other oil crops, oil palm and coconut are perennial crops in contrast to rapeseed. This distinction is important for the approach to breeding programs.

Coconut is a long term crop with a low reproductive rate. Therefore, breeding methods have to take into account yield improvement and multiplication of the material. As indicated by Dr. Carlos, emphasis should be placed on hybrid programs involving populations rather than individuals to improve characters. However, pure populations are difficult to identify so as to use them for seed production owing to the wide distribution of coconuts.

In the case of oil palm, as it has a higher reproductive rate, individual plant selection is possible as a means of future breeding for obtaining next generation breeding material as well as for producing seeds for commercial exploitation. Early selection at the seedling stage would be important to realise. This is difficult in the case of coconut and palm owing to reproductive factors. Also, only morphological characters can be identified at the seedling stage but correlation of physiological characters between generations is low. The long term character of the crop makes it difficult to proceed to early selection and to fix combinations. Tissue culture might enable to identify correlations particularly in the case of coconut.

Rapeseed oil poses the problem of high erucic acid content which exerts deleterious effects on health. Fortunately the incorporation into Asian lines of rapeseed with low erucic acid content which was introduced from Canada should enable the development of species producing oil with better quality.

Presently, emphasis is being placed on producing oil with low level of saturated fatty acids. The importance of this problem has perhaps been exaggerated to the point of producing undesirable effects in the oils.

Dr. Arwooth (Thailand): What is the difference between palm oil and palm kernel oil? Is it possible to maximize both characters?

Dr. Ooi (Malaysia): Palm kernel oil and coconut oil are identical. Palm oil is a high palmitic and high oleic acid oil. Palm oil production is being emphasized for economic reasons but maximization of characters is related to reduction of shell component.

Dr. Carlos (The Philippines): Indeed palm kernel oil and coconut oil are the same and kernel oil is mainly used in the industry.

Chairman: As far as perennial crops are concerned, yield factors are most important in the case of palm and coconut. However more recently the improvement of the quality of edible oils has taken the precedence over the achievement of high yields, particularly regarding the content in saturated and unsaturated fatty acids, which has a definite bearing on health.

In that respect, saffron oil contains probably the lowest amount of saturated fatty acids, immediately followed by sunflower oil. Coconut oil is the least popular among consumers, in India for example. Moreover, it is of poor quality and has a high content in saturated acids. In the future emphasis will be increasingly placed on quality improvement.

I would now like to ask Dr. Arwooth to proceed with the discussion on cereals and legumes, namely forage sorghum, soybean, legumes and wheat.

Dr. Arwooth (Thailand): Cereals and legumes are fast-growing annual crops and also short-season crops. As illustrated by Dr. Mukade, in wheat six generations can be obtained within a year. However when such crops are being cultivated in the tropical areas, limitations are observed dealing chiefly with the presence of pests and diseases and the low fertility of the soil. As outlined by Dr. Khush, it will become increasingly important to develop varieties resistant to multiple diseases and pests and some of the problems faced may require the development of new technologies. In the case of soybean, breeding procedures should satisfy genetic systems, mainly rhizobium systems which have to be compatible in order to get good yields. Also one must be aware of the properties of the plant to fix nitrogen from the soil through the rhizobium systems, as seen in soybeans.

Hybridization makes use of single seed descent method because in the case of soybeans, high yield and good performance result from interactions of additive introductions. When one breeds for disease resistance, backcross and pedigree methods can be used. Interspecific hybridization has been considered as it was impossible to find a cultivar which would be resistant for certain types of diseases observed in mungbean. By crossing mungbean to a resistant variety of rice bean it was thought that this problem might be solved. However, so far little success has been achieved. I would also like to mention that instead of spending large sums of money trying to develop a variety of wheat with higher protein content (1, 2%) as it is being attempted in the U.S.A., it would be more desirable to put emphasis on yield and quality and spread peanut butter on bread to increase the protein content.

Dr. Mochizuki (Japan): It is important to use major genes for improvement of quality, for instance digestibility in the case of forage sorghum.

Dr. Hashimoto (Japan): Regarding the use of interspecific hybridization to achieve nodulation, an other approach could consist of improving the soil conditions by inoculation and selecting for nitrogen.

Chairman: A lot of work has been done on cereals and legumes. Also a large number of breeding methods are available, some peculiar to the crop itself and high-yielding varieties have been successfully developed. The main problem seems to be related to the development of varieties resistant to diseases and pests as well as to increase the productivity.

I would like now to ask Dr. Carlos to take part in the discussion on miscellaneous crops, tobacco, tomatoes and fruit trees.

Dr. Carlos (The Philippines): Breeding techniques for tobacco and tomatoes follow the line of those applied to annual crops. However, there are special requirements peculiar to each group.

In the case of tobacco, the most important requirement deals with the improvement of the burning quality, whereas in the case of tomatoes, bacterial wilt disease is the most important problem in tropical countries as this disease is responsible for great fluctuations in production.

Fruit crops are perennial crops requiring long breeding time. A large number of these crops are cross-pollinated and so far they have not been the object of much work as regards breeding techniques. Coconut has probably the most primitive breeding methods. Most of these crops can be propagated asexually and show a marked decrease in developing mutants, for instance citrus.

In Japan, breeding methods consist of isolating mutants and propagating them rather than of hybridization. In the U.S.A. it is the reverse. In fact a lot can be done by selecting the mutants. Once isolated, they can be vegetatively propagated either with classical methods like budding, grafting or through new techniques such as tissue culture.

Biochemical methods can also be used. In rubber, for instance, young seedlings can be classified as for their usefulness through establishing the value of mevalonic acid. Dr. Tanaka,

in Japan, has also attempted to differentiate species of citrus by biochemical methods so as to develop materials for quality and productivity. This seems to be a promising method.

Dr. Yamakawa (Japan): The most important criteria for breeding tomatoes are yield, quality and tolerance to environment, such as high temperature and humidity in summer open culture and cold in the winter. It would be particularly desirable to develop varieties resistant to cold so as to save fuel.

An other aspect related to the breeding of tomatoes is that almost all commercial varieties present in Japan are F_1 hybrids. Parental lines should have superior combining ability along with disease resistance. However such objective is difficult to realize.

Chairman: We will now consider a separate group dealing with new techniques involved in plant breeding. These are test tube breeding, chromosome engineering, pollen, anther and cell culture and isozyme analysis.

We are particularly fortunate to have among us Professor Tsunoda of Tohoku University who has accepted to discuss these techniques.

Dr. Tsunoda (Japan): Aspects including various advantages and limitations of so-called new methods of breeding have already been discussed. Now, I would like to make additional comments concerning the haploid method of breeding and the method of generation advancement under artificially controlled conditions.

I am afraid of the limitation of the population size usually adopted or adoptable in these methods, at present.

In the case of the haploid method, gene recombination occurs only in meiosis of F_1. It means that if the size of population of doubled haploid plants is not large, one cannot expect a genotype with desirable characters.

In the case of the generation advancement method in early generations, with a limited population and without any selection, a genotype with desirable characters will not be obtained if the number of genes concerned is large and/or if there is a close linkage between genes concerned, as pointed out by Dr. Iyama.

In the case of the pedigree method, many F_2 plants can be grown. If proper selection is made, regarding for example heading date, plant type, harvest index and disease resistance, it is possible to grow many plants and restrict the number of progenies.

If one combines the bulk method to the acceleration of generation advancement method, the most important problem lies in the population size.

Dr. Kikuchi (Japan): The problem of efficiency of various selection methods is difficult to compare between each other. Acceleration of generation advancement methods are being used in Japan and many promising lines are being developed. Although one cannot deny that random genetic shift occurs during the acceleration period, as breeders in Japan use a narrow base of genetic resources, a lot of combinations are quite similar. The problem is that in a limited area of greenhouse, in order to accommodate as many plants as possible in a cross, many crosses have to be grown.

Selection in early generation is sometimes dangerous. For instance, in Tohoku, breeders crossed varieties with high cold resistance and high quality. When such populations were submitted to natural selection, in the following generations, the populations became increasingly resistant to cold damage. However, in later generations, the breeders could not select types with good quality and cold resistance. On the other hand, good genotypes could be obtained when the populations grew without selection.

Dr. Sakai (Japan): Adaptability of plants to the environment, for instance temperature, soil conditions, humidity is very important. Therefore, it would be desirable to conduct

ecological and genetical studies in association with plant breeding.

Dr. Y. Yamada (Japan): I would like to ask Dr. N. Yamada to make a few comments on international cooperation in agricultural research, as he was the first Director of the TARC and was so instrumental in enhancing cooperation projects between tropical countries and Japan.

Dr. N. Yamada (Japan): When I first heard that the TARC was going to organize a symposium on methods of crop breeding, I wondered whether such an undertaking would be successful owing to the wide diversity of the crops to be discussed in such a short time. However, after listening to the papers presented, I thought that the symposium was quite successful. There were certain basic denominators common to the various crops. I believe that the exchange of information and shared experiences was quite valuable and useful for everyone.

In the future, international cooperation between scientists could expand and involve exchange of publications, of materials along with the undertaking of joint research projects.