General Discussion

Matsumoto, S. (Japan): I would like to suggest that the general discussion which will be presided by Dr. H. Hibino, International Rice Research Institute (IRRI), Dr. D.V.R. Reddy, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and Dr. H.W. Rossel, International Institute of Tropical Agriculture (IITA) be divided into two parts, rice virus diseases and virus diseases of leguminous crops.

Chairman: Hibino, H. (IRRI): I shall first summarize the main points discussed during the presentations made during these three days. As you may know, in 1976, the Tropical Agriculture Research Center organized a symposium on virus diseases of tropical crops in which rice was included. It appears that remarkable progress has been achieved during the 10-year period between the former symposium and the present one as the properties of a large number of viruses have been clarified. Through the country reports the importance of virus diseases affecting rice was underlined. Along with the improvement of and introduction of new cultural practices, many countries in Southeast Asia have reached a level of self-sufficiency in rice and the demand for varieties with better eating quality is likely to grow in future. Since most of these varieties are susceptible to the pests it is anticipated that the problems of virus diseases will become increasingly important. Although research on the viruses has made significant progress, the knowledge on the epidemiology of the diseases and the ecology of the vectors is still limited. It is also recognized that control by insecticides is difficult to achieve if the varieties cultivated are not resistant and if the disease pressure is high. Although varietal resistance is very important, after two to three years of cultivation, resistance of the varieties recommended for cultivation often breaks down. Therefore, efforts should be concentrated on studies on virus strains and insect biotypes. Also resistance itself is mostly directed against the vector rather than against the virus. Moreover, no sources of resistance are available for certain viruses such as grassy stunt, ragged stunt, gall dwarf and black-streaked dwarf viruses. For the past 10 years, progress has been made with regard to the identification and purification of a large number of rice viruses. Also diagnostic techniques have been developed and antisera have been produced in Japan mostly. The transfer of technology to national programs and scientists will become essential along with the promotion of international collaboration between scientists and institutes, as sophisticated equipment or trained researchers are often lacking in several developing countries.

During the symposium the discussions often dealt with problems relating to virus epidemiology and vector ecology which are closely linked with the shift of vectors or the adaptation of vectors to the resistant varieties. I would like to ask Dr. Kishimoto to comment on these particular aspects.

Kishimoto, R. (Japan): Although research on the virus itself has made great strides, studies on the ecology and population dynamics of the vectors are insufficient. The objective of epidemiology is to understand the density and amount of viruses in a given area from the spatial and temporal points of view. On the other hand it is difficult to estimate the density and amount of vectors in a given area. However these parameters can be estimated on the basis of the proportion of infective vectors in a local population, which is referred to as "population infectivity". Indeed the "population infectivity" is a good index of the status of an epidemic, including the fluctuations in time and space. Unfortunately, studies on population infectivity have just started in the tropics. On the other hand, such studies have been conducted in Japan for rice stripe virus which is endemic to Japan and is responsible for severe epidemics both in Hokkaido, in the northern part of Japan and in Kyushu, in the

southern part of the country. Population infectivity of the vector was traced in various areas, showing fluctuations from year to year. When the population infectivity of the vector exceeds values of 10 to 20%, measures should be taken before the migration starts. It is considered that population infectivity surveys are useful as an index of the epidemic status and a model describing the epidemic of rice stripe virus through the determination of the population infectivity and density of the vectors in a given area has been developed. To trace the population infectivity in a local area year after year and from generation to generation is useful for understanding the epidemiology of certain virus diseases for the persistent or non persistent type of transmission of the virus. For tungro disease, the understanding of population infectivity may be difficult. However it appears to be easy to understand the epidemic status through the determination of population infectivity in the case of grassy stunt or ragged stunt with a persistent type of transmission.

Chairman: Hibino, H. (IRRI): I agree with Prof. Kishimoto that studies on population infectivity are important for the persistent type of transmission but they may not be easy for the non persistent type as in the case of tungro virus. There are undoubtedly fluctuations in the incidence of virus diseases. For example, until 1978 tungro incidence was low in spite of a high population of brown planthoppers in several tropical countries. Thereafter tungro became very important. Does any one have any evidence indicating the presence of fluctuations of insect populations or virus incidence?

Disthaporn, S. (Thailand): With regard to fluctuations of disease or insect incidence I would like to emphasize that the host is as important as the vector population. By using resistant varieties, the source of virus decreases with the decrease in the inoculum. Emphasis is placed on the development of resistance genes to the vector and the virus. To alleviate the breakdown of resistance which occurs due to the adaptation of insect biotypes to the varieties, I would like to suggest that varieties be changed or that heterogeneous varieties be used for this purpose. In Thailand, fluctuations of tungro incidence are based on the host.

Chairman: Hibino, H. (IRRI): Resistant varieties may become susceptible after several seasons or years of cropping as observed in Indonesia.

Could Dr. Tantera make a few comments with regard to the situation of rice viruses in Indonesia, particularly tungro.

Tantera, D.M. (Indonesia): In relation to the incidence of rice virus diseases three points should be emphasized. First, the improvement of cultivation techniques for rice production has resulted in intensive cultivation with concomitant oversupply of rice in various countries of South and Southeast Asia. The farmers tend to cultivate susceptible varieties with the aim of achieving high yields and improving the quality of rice. Priorities for production involve seed selection, use of fertilizers, promotion of irrigation facilities and lastly plant protection measures. As a result, the risk of occurrence of virus diseases associated with insect outbreaks becomes significantly higher. In Indonesia the use of resistant varieties is being promoted as a method of control. In the case of grassy stunt and ragged stunt, varieties resistant to the virus are being cultivated through the incorporation of the resistance genes to grassy stunt or ragged stunt virus harbored by *Oryza nivara* into high-yielding varieties. In tungro, varieties harboring resistance genes to the green leafhopper are being planted. Such varieties should be further improved by the incorporation of resistance genes to the virus. Second, epidemiological studies are approached from two points of view, the population of the insect vector is monitored for the purpose of control through the application of insecticides in the form of spray. However even if the vector population is destroyed, in many instances the virus will already have penetrated and infected the plant. Therefore the concept of the relationship between the vector population and virus population should be considered carefully. Thirdly, varietal rotation is being strongly recommended. In the case of tungro the integration of control methods including

the use of resistant varieties, synchronized planting and insecticide application to seedbeds has brought about a decrease in the incidence of the disease and presently only 2,000 to 3,000 hectares are infected.

Chairman: Hibino, H. (IRRI): I would like to know how varietal rotation affects insect characteristics. Also what happens if we grow certain varieties over wide areas and then in the next season plant varieties with a different level of resistance? Is there any effect on the vector in terms of transmission efficiency?

Inoue, H. (Japan): It is difficult to answer. During the period 1966–1969 in Thailand, there was a severe outbreak of tungro disease. Thereafter for about 5 years the incidence of tungro decreased. Then farmers introduced one susceptible variety over a whole province and severe incidence of the disease was recorded, presumably because homogeneous genotypes had been spread over wide areas. The favorable effect of changes in the varieties cultivated may be associated with the fact that the donor of resistance varies with the variety.

Kishimoto, R. (Japan): Epidemiology should be analysed from the angle of the dynamics of the virus population. In the case of insects, there are three factors that control the population fluctuations, namely the initial density in a given area, the rate of increase from generation to generation and the saturation point in a given locality. By analogy, the dynamics of virus populations should be studied. In persistent transmission by leaf-or planthoppers, the analysis made in rice stripe virus may be relevant. The semi-persistent or non persistent type of transmission by aphids or in tungro is more difficult to approach. It is a well-known fact that varieties do not remain resistant for a long time. The efficiency of resistance of varieties to insects should be evaluated on the basis of the virus population dynamics. The introduction of resistant varieties affects the population infectivity which may become lower, as shown in rice stripe virus.

Chairman: Hibino, H. (IRRI): When tungro becomes epidemic it is because resistant varieties became susceptible. Then new varieties are introduced and tungro disappears. Under these conditions, there are still some insect populations that remain infective, giving rise to new epidemics.

Inoue, H. (Japan): I would like to emphasize the need for a close cooperation between entomologists, plant breeders and plant pathologists or virologists.

Omura. T. (Japan): The control of virus diseases is difficult to achieve since many inter-related factors are involved, including strains for the virus, biotypes for the insect along with the changes in the transmission ability in a same species of insect depending on the regions. As for the crop, varietal differences must be considered as well as the identification of sources of resistance to produce resistant varieties which play a significant role in the control of virus diseases. The cultural conditions of crops and the environmental conditions affecting crop growth and insect migration ability and multiplication including rainfall pattern, temperature and soil conditions, fertilizer and pesticide applications, etc. are also factors associated with the incidence of virus diseases. In addition, the role of natural enemies or predators in the control of the vector and insect migrations must be considered. I also agree with Dr. Inoue that cooperation among scientists working in various disciplines and belonging to different countries is essential for the control of virus diseases. Finally I would like to emphasize the importance of field studies for gathering information on population of insects including the proportion of viruliferous insects, crop conditions, varieties used, chemicals applied and environmental conditions in relation to the incidence of virus diseases.

Anjaneyulu, A. (India): In India tungro is a disease of economic importance which occurs in cycles of three to four years depending on four factors, namely the availability of vectors, virus inoculum, stage of crop growth and varietal susceptibility which should coincide. Control of tungro disease is centered on the cultivation of resistant varieties. However to avoid the breakdown of resistance associated with the development of new biotypes of the

vector, control should integrate various measures such as cultural practices including adjustment of the planting date, spacing (closer spacing results in a decrease of the disease incidence and yield increase), and roguing of infected plants at early stages of growth as well as vector control through the use of pesticides.

Kaneda, C. (Japan): In Japan, a cooperative research project among plant pathologists, entomologists and plant breeders was undertaken during the period 1975–1979 to study the resistance of host plant to vector insect and virus, namely the green leafhopper *Nephotettix cincticeps* and dwarf virus. No new biotypes were developed but local strains were identified, i.e. the biotypes from Kyushu were found to be different from those of the Kanto region. Using these two biotypes, studies on the reaction of rice plant (including IR24) to dwarf virus were carried out. When the wild type of insect was used, several varieties were resistant but when other biotypes were tested the varieties became susceptible. It was eventually concluded that in Japan the resistance of host plant to rice dwarf is stable due to the low probability of development of biotypes of the green leafhopper.

Wakimoto, S. (Japan): The relationships between host plant, insect vector and virus are complex. Although a large number of studies have been carried out on varietal resistance, transmission ability, etc. research on virus strains is somewhat limited. I was told by Dr. Hanada that rice viruses are simple compared with viruses affecting other crops such as vegetables. If so, breeding for resistance to virus diseases should be relatively easy.

Chairman: Hibino, H. (IRRI): It is well-known that strains cause problems in grassy stunt. In the case of tungro there appear to be different reactions on the same variety in different countries. Little information is available on virus strains or insect biotypes.

Wakimoto, S. (Japan): Dr. Inoue reported that one grassy stunt isolate was transmitted by insect colonies while Philippine colonies could not transmit the isolate. The use of different isolates from various countries may give rise to differences in data.

Kishimoto, R. (Japan): Regarding the strategy for breeding resistant varieties, I wonder what is better: vector or virus resistance. In the tropics most of the resistance is concentrated on the vector. Presently attempts are being made in Japan to breed varieties resistant to rice stripe virus. These varieties are not resistant to the vector. Good results have been obtained for the past three years although new virus strains may appear in future. I believe that the variations in virus strains may be lower than those of vector biotypes as the vector has more complex enzyme systems as well as physiological and morphological characteristics enabling adaptation to new environmental conditions. Therefore virus resistance should be better than vector resistance.

Chairman: Hibino, H. (IRRI): One of the problems is the definition of the term "resistance". For example, in the case of varieties resistant to rice stripe virus although the varieties are infected the symptoms are very mild. In this instance it might be preferable to use the term "tolerance", implying that the varieties are susceptible to the virus infection but the symptoms are not pronounced and the yield loss is comparatively low. Actually varietal resistance in the case of rice follows three types, namely, resistance to the vector, resistance to the virus and tolerance to the virus.

Mochida, O. (IRRI): I would like to make a few comments. During the symposium no detailed data on the epidemiology of virus diseases of rice were supplied. Also I noticed that precise methods to detect virus diseases are lacking. It appears that under tropical conditions varieties often undergo changes. I would like to suggest that some organization provide equipment and materials for the detection of virus diseases. This may contribute to the promotion of epidemiology studies on rice viruses.

Chairman: Hibino, H. (IRRI): I understand that the Japan Plant Protection Association has a program to promote the production of antisera against rice viruses occurring in the tropics and to develop techniques for the detection of viruses.

Anjaneyulu, A. (India): We have studied the relation between virus resistance and vector resist-

ance in the plant. When reference is made to vector resistance of the plant, what does it mean and how is it related to virus resistance? Vector resistance can be divided into three types, namely antibiosis, tolerance and non preference. In the case of tolerance, the plant may be susceptible but it is not significantly affected by insect attacks. However transmission of the virus will take place if the vector is viruliferous. In the case of antibiosis, the vector may die within two to three days but it will transmit the virus if it is viruliferous. The most important type of resistance is the non preference one as the plant is likely to escape virus infection. The non preference type of vector resistance is the most important aspect for virus transmission to the plant.

Dollet, M. (CIRAD)*: It appears that the control of virus diseases can be best achieved by the integration of various measures including the use of varieties resistant to the vector or the virus and the adoption of cultural practices, among which insecticide applications play a major role. However it was indicated that the application of these methods is not always successful. Therefore I would like to know if efforts are being made to develop methods of biological control against the two major vectors occurring in Asia, namely the leaf- and brown planthoppers.

Chairman: Hibino, H. (IRRI): Actually few applicable techniques have been developed although it is obvious that nature itself has a control ability against these vectors through the activities of natural enemies succh as fungal or bacterial pathogens.

Chairman: D.V.R. Reddy: (ICRISAT): We shall now discuss some aspects relating to legume virus diseases.

In the case of legume viruses, a large number of viruses occur in the tropics involving a large variety of crops among which soybean, peanut, mungbean and various *Phaseolus* species are widely grown.

I would like to draw your attention to several aspects. First, the identification of the viruses may be difficult but it is a prerequisite to any further research. Secondly, once the virus is identified, methods of detection can be developed. Thirdly, the control of a disease, which is mot important, requires a better understanding of the epidemiology of the disease, the ecology of the vector and the identification of sources of resistance. In this regard the term "resistance" requires some precision in the definition. I would like to refer to a "Letter to the Editor" which was published by Jones and Cooper in the journal "Phytopathology" in 1983. In this article resistance was defined this way: "The virus will not multiply in the plant, even if it invades it and it will not be possible to detect the virus in the plant." Resistance is different from immunity as in such a case the virus will not penetrate into the plant. The term "tolerance" refers to a situation in which the virus penetrates into the plant and multiplies in it although the plant does not exhibit severe symptoms and no significant yield reduction is observed. In some instances only a small percentage of the plants is infected, suggesting that the host has no inherent resistance to the virus and that the reaction observed is presumably related to dosage response or vector non preference. For example in the case of bud necrosis, under field conditions in certain lines few plants are infected although they are susceptible if inoculated in the laboratory or exposed to thrips. It appears that under field conditions, the vector does not colonize the plant as much as a susceptible one. Such plants can not be called resistant, they are indeed field-tolerant. Finally I would like to emphasize the need for promoting international cooperation to assist the developing countries with the identification of the viruses. The supply of antisera and diagnostic hosts is also of paramount importance in order to remove the confusion about the characterization of a large number of virus diseases.

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Chairman: Rossel, H.W. (IITA): In Africa there are three centers where virus research is concentrated and which can act as service centers, namely in Kenya, in the Ivory Coast (ORSTOM) and in Nigeria (IITA). These centers are responsible for extending assistance in simple procedures. The international centers where facilities and expertise are concentrated are concerned with breeding programs aiming at the improvement of crops through the introduction of resistance based on multi-locational testing. There is a need for exchange of information on a regional basis and for the creation of a network for the comparison of viruses to devise control measures. In the developing countries, the use of genetic variability should be maximized for control through the development of resistant varieties as insecticide application is not practical. Emphasis should be placed on the prevention of accidental introduction of infected materials to various areas, particularly in the case of vegetatively-propagated crops. Some viruses are crop-specific and wide intercontinental spread is uncommon except for hoja blanca which was introduced to Asia from Latin America. I believe that although virus diseases can not be cured they can be prevented and their control may not be particularly difficult. Variability is a cause for concern as it is related to the identification of the strains. Moreover the definition of a virus strain is one of the major problems due to the lack of definite criteria. Judging from the presentations made during the symposium it appears that the nomenclature of the legume viruses is somewhat confusing with direct implications for the control of the diseases. In this regard I would like to ask Dr. Makkouk to comment on this particular aspect.

Makkouk, K.M. (ICARDA)*: I would like to make a few general remarks. I agree with Dr. Reddy on the need to prepare high quality antisera which could be made available to the researchers working in the developing countries. Some strategy should be developed to meet these requirements. Indeed cost is not a problem since capital investment is already made when the virus is indentified, propagated and purified. It is chiefly a matter of coordination of effors. With regard to the artificial inoculation of soybean dwarf virus presented by Dr. Banba, bulk harvesting of viruliferous aphids by shaking virus-infected plants with aphids on them over trays with talcum powder would be preferable to the transfer of individual viruliferous insects with a brush. This way thousands of aphids are harvested in a short period of time. The talcum powder prevents aphids from sticking together and permits adding them to plants quickly and easily. When hundreds of lines have to be screened for virus resistance, such a procedure is extremely useful.

Green, S.K. (AVRDC)**: I would like to make a few comments. With regard to the description of strains reacting to antisera, original strains often get lost. In a recent letter to the editor published in Phytopathology, the author suggested that every virus or strain described should be handed over to a reference center for collection and propagation for future use in comparison studies. I sometimes wonder if by screening in the field in releasing viruliferous insects there is no danger of building up virus inoculum in nature. As far as I am concerned I feel that the concept of tolerance may not be practical for screening as tolerance can be expressed by a great variability in the manifestation of the symptoms and yield. Also I believe that disease incidence may not be a reliable method to quantify resistance. Indeed when screening under field conditions problems may arise and even after artificial inoculation the rate of infection may vary. Latent infection that can be checked by ELISA may depend on the inoculum concentration. The mechanism underlying the expression of symptoms may be difficult to understand and interpret.

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Chairman: Rossel, H.W. (IITA): In this regard I would like to present two examples: One deals with rice yellow mottle and the resistance to rice yellow mottle (RYMV). There are only a few *Oryza sativa* varieties of Southeast Asian origin that are tolerant to RYMV, among the more tolerant varieties that are cultivated in Africa, including landraces which are fairly to highly tolerant. The concentration of virus is low and symptoms mild and under field conditions or upon inoculation symptom expression takes a longer time than in the susceptible varieties. Field resistance may be based on the same mechanism and dose dependency is observed when the genetic background is such that a form of resistance against the virus is present. The other example concerns maize streak. Severe epidemics have occurred in Africa. It is interesting to mention that open-pollinated progenies of plants which had escaped the infection also showed resistance to the disease. I believe that resistance may exist in a dilute form and that control may be achieved by making the best use of host plant conditions and natural epidemics as well as by pursuing these forms of resistance when encountering variability within breeding lines and germplasm accessions.

Inouye, T. (Japan): It appears that the terminology and classification of potyviruses infecting legumes is somewhat confusing. Although this problem cannot be solved immediately, there is a need for a better classification based on comparative studies from the standpoint of serological relationships and seed transmission.

Iwaki, M. (Japan): In the past ten years a large number of viruses and virus diseases affecting legumes have been identified. However, I believe that in future studies on the epidemiology of viruses and vectors should be further promoted along with the need for developing resistant varieties.

Iizuka, N. (Japan): Judging from the presentations made by Dr. Makkouk and Dr. Green the identification of potyviruses may give rise to confusion, as there may be subgroups or strains of the same virus. There is a need for further characterization of the viruses based on their serological or physico-chemical properties, as new viruses are likely to occur. Presently the control of legume virus diseases is best achieved by the use of resistant varieties which are available in the case of soybean dwarf and soybean mosaic for example. I believe that it is possible to breed a larger number of resistant varieties.

Deema, N. (Thailand): The main problems we face in Thailand are as follows: how to protect plants from serious diseases and how to get antisera for the identification of the viruses.

Tantera, D.M. (Indonesia): The identification of legume viruses is difficult due to the wide range of host plants. In the case of resistance, the reaction is directed to a population of individual plants which are heterogeneous. Therefore resistance is a relative figure. In future, emphasis should be placed on the identification of resistant donors since many legume viruses, unlike rice viruses, do not require transmission through a vector but can be inoculated mechanically.

Kassim, A. (Malaysia): In Malaysia the problems we face are of two types, namely the large number of viruses that occur and the lack of trained researchers working on virus diseases. I also agree that there is a need for the standardization of methods for host range and test plants in the tropics. I would appreciate receiving lines that are considered to be resistant to viruses occurring in Malaysia in order to test them.

Green, S.K. (AVRDC): It would be important to exchange resistant cultivars, depending on the quarantine regulations in the respective countries, in order to obtain information as to whether there are different strains of a given virus or if the virus dealt with is a different virus. Also there should be a centralized organization where antisera could be supplied and where research on the molecular characterization of certain viruses is carried out. This would be particularly suitable for the potyviruses such as bean common mosaic virus, blackeye cowpea mosaic virus and azuki bean mosaic virus. Finally I would like to emphasize that international cooperation should be promoted to solve these problems and that developed countries such as Japan and Australia could make a great contribution in

this regard.

Hayashi, K. (Japan): I agree with the proposal of Dr. Green and I believe that the international agriculture research centers could take the initial steps to create a new organization or initiate the mechanism for this specialized research. Thereafter national organizations such as the Tropical Agriculture Research Center which is one of the twenty institutes affiliated to the Ministry of Agriculture, Forestry and Fisheries of Japan could consider to extend a form of cooperation in this project.

Kajiwara, T. (Japan): I understand that the classification of legume viruses is difficult. It is also obvious that the control of the diseases caused by these viruses can be best obtained by the use of resistant varieties, which implies a close cooperation between plant pathologists and plant breeders. In future it will be essential that the most important viruses prevailing in the respective countries be identified along with the development of improved methods for testing the viruses.

Green, S. K. (AVRDC): It would be difficult for the international centers to undertake the type of research I mentioned previously. Indeed these centers have mandate crops, research is regulated according to priorities defined in the charter, the countries where they are located adopt strict quarantine regulations and equipment, facilities and the number of qualified researchers in this particular field are limited. I believe that Japan would be in a better position to extend assistance in this project particularly in the Tsukuba area where there is a large concentration of well-equiped institutes with researchers well-trained in both theoretical and applied aspects of virology.

Chairman: Reddy, D.V.R. (ICRISAT): To help scientists who find it difficult to identify a particular virus, antisera could be produced in the country of origin and the materials could be purified and inactivated prior to sending them to a reference center.

Dollet, M. (CIRAD): I agree that quarantine problems are difficult to solve. For example in spite of the existence of very strict quarantine regulations peanut stripe was able to spread over wide areas of the United States. Also since viruses propagate on various plants, the exchange of seeds and materials is fraught with the risk of dissemination of the viruses. A special effort should be made to control seed-transmitted viruses. Indeed diseases caused by such viruses can be propagated rapidly. For example peanut clump virus which is transmitted through soil and seed by the ubiquitous fungus *Polymyxa graminis* has been found to occur over wide areas in West Africa as well as in India. Moreover peanut clump virus also occurs on sorghum although the symptoms are difficult to detect. With regard to ELISA, the application of this method is often associated with errors. There is a need for improving diagnostic tests as well as developing more sensitive ones.

Chairman: Reddy, D.V.R. (ICRISAT): I agree with you and I also believe that a spectrun of tests should be used and the data confirmed in any identification scheme.

Kassim, A. (Malaysia): Could you describe the activities of the international working group on legume viruses of which you are a member?

Chairman: Reddy, D.V.R. (ICRISAT): The members of this group join international meetings of virology. They send a questionnaire which contains the summary of the work done on legume viruses by the various groups. They also publish a newsletter outlining the activities of other members.

Chairman: Hibino, H. (IRRI): I would like to make a few comments on the problems of quarantine and international cooperation. As far as rice viruses are concerned, strain problems are important and in the case of IRRI which is located in the Philippines, the quarantine regulations are very strict. With regard to cooperation, I believe that Japan would be in the best position to help and support the program of the international research centers and the national programs since Japan is the only country which has most of the rice viruses and the vectors transmitting these viruses, namely leaf- and brown planthoppers in addition to excellent facilities to keep these materials safely in greenhouses.