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Genetic Resources Conservation and Maintenance in the Former Soviet Union

by

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in the Former Soviet Union

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Preface

Armineh Zohrabian is currently a graduate student in the Department of Animal and Dairy Sciences at Auburn University (Auburn, Alabama). During the summer and fall of 1994 she pursued research and was enrolled in the graduate program in the Department of Agricultural and Applied Economics at the University of Minnesota. During the 1993-1994 academic year she was enrolled in the professional development program at the University of Minnesota in Hubert H. Humphrey Institute of Public Affairs.

Ms. Zohrabian has a diploma (equivalent to M.S.) in biophysics from Yerevan State University (Armenia, former Soviet Union), where she was enrolled in research related to molecular genetics of plants. She also worked in the Pure-Line Animal Breeding Scientific-Research Institute of Armenia in the laboratory of genetic engineering. Later she worked in the Ministry of Agriculture of the Republic of Armenia as a policy consultant.

The research on which this report is based was supported through a cooperative agreement between the Economic Research Service (ERS) of the United States Department of Agriculture and the Department of Agricultural and Applied Economics of the University of Minnesota. Ms. Zohrabian spent the summer of 1994 in the Land and Natural Global Resources Division of the ERS where she utilized the resources of USDA Library, National Agricultural Library and Library of Congress pursuing research on a project entitled "Genetic Resources Conservation And Maintenance System In The Former Soviet Union".

George Frisvold
Economic Research Service

Vernon Ruttan
University of Minnesota

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The advice and guidance of Henry Shands of the U.S. Department of Agriculture's Agricultural Research Service (ARS) was particularly valuable. He provided me with information about the cooperation between the United States and Russia in the field of germplasm conservation and maintenance and made important comments and suggestions on the draft of the report. I am also thankful to James Elgin of the ARS, to Dr. Sergey Alexanian of the Vavilov Institute of Plant Industry in St. Petersburg and Jacqueline Gallagher of the Diversity journal. They provided me with important information and materials related to this project.

Armineh Zohrabian
University of Minnesota

Prologue

This report discusses the development and current status of the plant genetic resources conservation and maintenance system in the former Soviet Union as of mid 1994. Information and data were based on published and unpublished reports and documents available as of that time and were supplemented by personal interviews and correspondence with numerous individuals knowledgeable about various aspects of the Vavilov Institute program and about recent developments in the field of genetic resources conservation and maintenance.

Many activities related to this system and its present and proposed interrelationships with international plant genetic resources activities are ongoing and situations change frequently. Thus many questions either cannot be answered at this time or the answers must necessarily be vague. This report, however, attempts to pull together and summarize what is known at this particular time. It attempts to identify current problems, activities, and fruitful avenues for further exploration and to emphasize the extreme importance of assistance to support the plant genetic resources system of the former USSR.

Genetic Resources Conservation And Maintenance

In The Former Soviet Union

Introduction

Due to outbreaks of pest or pathogens (such as the southern corn leafblight outbreak), and to environmental changes (such as ozone depletion or climate change), there is a constant need to develop new agricultural varieties with higher resistance to diseases and better adaptation to specific climatic conditions. Thus the capacity of national agricultural research systems to respond to such circumstances is dependent on the ability to draw on genetic materials available in breeders working collections, in national collections and in collections at the international agricultural research institutes. Thus it is necessary to have access to the widest possible diversity of germ plasm including varieties and their wild relatives.

For thousands of years people have made selections of crops, replacing wild species with improved types that contain increasingly narrow ranges of germ plasm. Wild species of crops may contain genes with resistance to different harmful conditions, as many of them have to survive drought, flood, hot or cold conditions on their own and only the fittest survive in nature, it has become obvious that the number of wild plants and animals has been and continues to decrease dramatically. This is why systematic and widespread accessions to the world germplasm banks represent progressively greater value for mankind.

There is need to mention the peculiarity of the interpretation of biodiversity in agriculture. In general biology the term biodiversity is typically used to refer to the diversity of species. But in agriculture it is traditionally used to refer to diversity within species - the diversity of varieties, including various commercial crops, their wild relatives and landraces (Evenson, 1994). We live in a world where fewer than 20 plant species produce 90 percent of world's food supply (Buffet, 1994). However, due to the significant improvement on breeding methods it has become possible to use genetic diversity in other species in the same genus.

Recently the topic of the potential of world agriculture to provide sufficient food for a growing world population is being questioned. According to G. Edward Schuh, the Dean of the Hubert H. Humphrey Institute of Public Affairs at the University of Minnesota, "the potential of the miracle wheats and rices of Green Revolution fame is rapidly being exhausted, and nothing is in line to replace them" (Stuart, 1994). Other scholars have raised the question of whether growth in demand, generated by population and income growth, will outpace growth in the world's food supply (Brown, 1994; Miller, 1994).

During the last several years the topic of genetic resources conservation and maintenance has become one of the most important issues on the agenda of international agricultural research institutions. A number of rules, protocols and agreements have been established related to the ownership and exchange of genetic resources (Barton and Siebeck, 1994). Significant attention is being paid to the improvement of already existing systems of genetic resource conservation and maintenance in developed countries and to establishing systems in developing countries. One of the most noticeable is the new relationship between the germplasm conservation institutions in the West and those of the former Soviet Union.

The former USSR, which occupies one sixth of the world's land, has a large diversity of natural resources. It also has inherited from the past scientific world of Russia one of the largest plant gene banks in the world - the N. I. Vavilov Institute of Plant Breeding with its unique collection. However, one may notice that in spite of the development of this powerful potential, during the Soviet era Russia changed from one of the world's major grain exporters to a net importer. The potential contribution of the Vavilov Institute, and more generally of the capacity of the Soviet agricultural research system to contribute to agricultural production was substantially underutilized. (Virginia Tech Leadership Forum, 1991; Strauss and Thompson, 1993).

With breakup of the communist system, the former USSR agricultural research system became more open to the West. This openness makes possible a fuller contribution from that invaluable genetic resource heritage to the international agricultural research community for the ultimate benefit of the world's agriculture. Meanwhile, the former Soviet research institutions now have access to technical and financial support from the West to modernize their research facilities and technical abilities in accordance with current international standards. However, because of current economic difficulties being faced by Russia and former member republics, this valuable collection has experienced substantial deterioration. Unless immediate steps are taken to remedy the situation irreplaceable plant genetic materials may be lost.

The purposes of this paper are to describe the status of the genetic resource conservation and maintenance system of the USSR and constituent republics prior to the breakup of the Soviet system, and to characterize the changes in the capacity of the system since the mid-1980s. Special attention is paid to the current financial and physical constraints and organizational issues that will have to be addressed if that genetic conservation and maintenance system is to effectively serve the research and plant breeding needs of the successor states of the USSR and wider cooperation with foreign nations.

Based on reports, articles and missions related to assistance to former USSR germplasm conservation institutes, it is clear that a lot of study has already been done and, hopefully, from action upon the recommendations of these and subsequent missions and investigations, through mutual efforts and cooperation, the germplasm resources on that part of the world will be better maintained.

The Establishment Of Genetic Resources Conservation and Maintenance System in the Former Soviet Union.

In Russia a plant gene bank was established around one hundred years ago under the authority of the Bureau of Applied Botany. The Bureau was organized in 1894, in Petrograd (St. Petersburg). It started collecting seeds within Russia and neighboring regions (Caucasus, Asia). The first paid worker of the Bureau of Applied Botany, R. Regel, requested experimental institutions, schools and individual landowners to send at least a quarter of pound (slightly over 100 grams) of the seeds and spikes of barley they grew and to describe them using a special questionnaire. In response to this initial request 302 specimens were received during the first year (Table 1). The Bureau also purchased samples from Canada and Sweden. (Lenin All-Union Academy of Agricultural Science, 1987).

The decisive factor in the establishment of the former Soviet Union agricultural research system was V. I. Lenin's positive attitude toward science. He emphasized the need for an organized agricultural science system and the necessity for establishing an Agricultural Academy.

In 1924 the Bureau for Applied Botany was converted to the All-Union Institute of Applied Botany And New Cultures (it is currently called N. I. Vavilov Research Institute of Plant Industry). Some years later the Lenin All-Union Academy Of Agricultural Sciences was organized with N. Vavilov as its first President (1929-1935). The Academy's principle goals were the improvement and development of the crop, livestock, soil and other productive resources in the USSR; the generalization of the advanced practices in Soviet agriculture and the utilization of the world's experience; and the training of personnel qualified to carry out agricultural research. In addition to the Institute of Applied Botany and New Cultures, 10 other institutes including organizations for economic survey and management were established throughout the Soviet Union.

By the end of 1920s Soviet Russia was a center of outstanding genetics research. The work of Nikolai Ivanovich Vavilov is well-known to world geneticists and agricultural scientists for both his collection of plant specimens and his establishment of a network of research institutions. Vavilov's scientific contribution included the elaboration of a theory for collecting plants based on their centres of origin and the utilization of genetic diversity in the breeding of agricultural crops. In 1921 he closely studied the work of the USDA's Bureau of Plant Introduction, was familiar with the history of world farming and the crop exploration work of the world's botanists. He made several expeditions across the Soviet Union and to neighboring countries, investigating many varieties of crops. Vavilov emphasized the necessity for identifying the plant resources available on each continent and in each region, to establish the basic rules governing the development of the taxons of the plant kingdom, and stressed the importance of paying significant attention to the agricultural value of each group.

During 1920's and 1930's he conducted lengthy expeditions throughout the USSR and in over fifty countries in Asia, North-Eastern Africa, Europe, the Mediterranean and the Americas. This, along with exchanges from other institutions, resulted in the collection of 50,000 seed samples of grains and lentils, which provided the foundation for the establishment of modern gene banks in the Soviet Union. Based on the studies of the variation of characteristics in plants, Vavilov discovered the law of homologous series in hereditary variation. His concept of species was used for predicting the plant forms missing in a gene pool collection but occurring in nature or that can be produced experimentally. He also paid great attention to the economic potential of germplasm collections, particularly with regard to adaptation and disease resistance, and he emphasized sampling the entire range of species in order to gather as much genetic diversity as possible (Krivchenko, 1988).

The Structure Of The N. I. Vavilov Institute (VIR) As An All-Union Plant Research Institute.

In 1930 the All-Union Institute of Applied Botany and New Crops was renamed the N. I. Vavilov Institute of Plant Industry (VIR) with N. I. Vavilov as its director (1921-1940). During the period from 1921 to 1940 more than 180 collecting missions were organized all over the world. As a result of those expeditions the existing collection (302) was expanded by more than 160,000 samples of various agricultural crops and their wild relatives. Thus the plant breeding institutions of the Soviet Union received the most valuable initial material which then became the basis for developing over 500 varieties of new agricultural crops. Soon these varieties occupied one fifth of all the crop land of the USSR (Krivchenko, 1988).

It is generally believed that in 1988 the germplasm collection of VIR held more than 330,000 samples relating to 155 botanical families, 304 genera and 2,539 species (Krivchenko, 1988). [The estimates of the number of specimens vary from 330,000 up to 375,000 which may be explained by the absence of complete database and imprecise registration]. The collection represents more than 10 percent of the world's cultivated crops (Possehl, 1993) and is one of the largest of the 120 major gene banks in the world (Table 2).

At the VIR there are three types of collections where each accession is preserved: working, duplicate, and base. The working collection is preserved at room temperature and humidity. This is used for breeding and research purposes, as well as for educational institutions. The duplicate collections are preserved at the experiment stations. The seeds of these collection are reproduced for renewing the working collection, as well as for replacing old accessions in the duplicate collections. The base collection is intended to be kept for a long period (theoretically, from 30 to 100 years). The seeds are kept in a controlled environment, under special temperature and humidity conditions (Kuban seed storage).

Today the largest collection at VIR gene bank is the collection of wheat and its wild relatives (Aegilops). Started in 1907, a systematic collection of wheats was carried out in over 70 countries including the primary center for wheat species and their rare endangered relatives - western Asia and Transcaucasus (Armenia, Azerbaijan, Georgia). This collection represents the widest array of diversity for wheat. Among VIR's accessions of wheat and its wild relatives are initial materials that may be used in the world for solving almost any imaginable breeding problem connected with wheat varieties. Over 80 percent of the wheat varieties cultivated in Russia have been developed on the basis of the VIR collection. This collection is used not only for the benefit of Russian breeding programs, but for those of the international community as well. Recently the Vavilov Institute provided the US collection in Aberdeen, Idaho, with several dozen old American varieties that were missing from the U.S. collection. Those samples can be used as sources of resistance to the Russian wheat aphid which has been damaging commercial wheat fields in the United States during recent years (Merezhko, 1994).

The VIR has also played an important role in collecting, preserving and studying potato germplasm as well. Numerous expeditions to Central and South America, which are considered to be the centers of origin for potatoes, have been organized. In mid-1991, the collection housed 9,700 samples from all over the world (Budin, 1992). VIR scientists identified forms with high pathogen and pest-resistance, and created high- and low-temperature tolerant varieties of potato.

The theoretical and practical basis for the Institute's activities was worked out by N. I. Vavilov, who determined its structure and working principles. Its main tasks and objectives were outlined in the Statute of the All-Union Institute of Applied Botany and New Crops adopted by Enactment no.39 of the USSR Council of People's Commissaries (Vavilov Institute, 1994). The objectives of the Institute have been (and are):

- **(1) collecting the world's plant resources,**
- **(2) preserving the collected material in a viable state,**
- **(3) studying the collected material,**
- **(4) supplying breeding centers with the initial material for plant breeding,**
- **(5) conducting theoretical and methodological research.**

As one may notice, practical plant breeding is not VIR's direct responsibility. The Institute provides initial material to breeding centers organized within the Soviet agricultural research system especially for this purpose.

At present, the work with plant genetic diversity is regulated by the scientific program "Plant Genetic Diversity" and the Institute's Charter, and coordinated by "The Status of Global Collections", "The Guidelines for the Work with the VIR's World Collection" and the Resolution of the Inter-Department Coordination Commission concerning the status of the Institute as a Federal Scientific Centre.

Before the breakup of the Soviet Union the Institute consisted of 18 experiment stations (Figure 1), and 30 specialized departments and laboratories.

The experiment stations are spread from the polar region to the subtropics and from the European part of the USSR to the Far East. This makes it possible to study materials from various countries in conditions that resemble more or less the natural, indigenous conditions of those plants. The collected materials are studied in two stages: field assessment and laboratory assessment. In the final stage of study each of the collection accessions acquire an identification document--passport, where its important biological characteristics and peculiarities are recorded.

The major units in the Vavilov Institute are:

Department of Plant Introduction

The Department of Plant Introduction is responsible for organizing exploration and collection of plants and for quarantine testing of the received material. There are groups within this department divided accordingly to specific regions of the world: European, American, African, Asian, and Oceanian countries. This makes the expeditions and studies more systematic. Materials that come from abroad pass their quarantine testing at one of the seven introduction quarantine nurseries.

All the germplasm materials entering the Institute undergo registration in this department where each accession acquires its permanent introduction number in this process.

Departments of Plant Resources

From the Department of Plant Introduction the germplasm materials go to one of the nine Departments of Plant Resources. These are organized on the basis of closely related crops, such as the Department of Wheat, the Department of Maize and Small Grains, the Department of Fodder Crops, the Department of Industrial and Oil Crops, Department of Vegetables and Melons and others. In these departments researchers carry out comprehensive encyclopedic study of the crops. As N.I Vavilov would say, they study the crops on world-wide scale, i.e., knowing the characteristics and status of each crop in each place where it is grown.

Methodological Departments and Laboratories

In these laboratories more thorough study is done using different biological methods and levels. There are Departments and Laboratories of Biochemistry, Molecular Biology, Cell Engineering and Tissue Culture, Plant Physiology, Genetic Cytology and Anatomy, and others. As a result of these studies the original passport data, determined by the experts from the Department of Plant

Resources, are expanded. Ultimately the donors and bearers of particular traits or of a complex of them are selected here. This is necessary for determining the potential of each accession in agriculture and plant breeding.

The Special Seed Testing Laboratory and Storehouse

The Special Laboratory of Seed Testing tests acquisitions for seed germination and viability. In the Seed Storehouse at the Kuban Experiment Station portions of seeds are kept for long-term preservation. Also there are ten experiment stations within the network of the Institute, located in diverse climatic zones throughout the former USSR that are engaged in the preservation of fruits and berries.

Long-term Seed Storage in the Former USSR

Long-term seed storage assumes preservation of seeds for 30 to 100 years. The main factors affecting the longevity of seeds are temperature and moisture content. The collections are supposed to be kept under conditions of low relative seed moisture (6-8 percent) and at subfreezing(-10 to -20 degrees C), or cryogenic (-150 to -195 degrees C) temperatures (Committee on Managing Global Genetic Resources, 1993).

The N. I. Vavilov Institute of Plant Industry is the only seed repository in the former Soviet Union. For almost 50 years the plant germplasm collection was preserved through frequent renewal and harvesting. This method has not only carried much risk for genetic integrity of the plant, but was also not economically effective. From 1946-1951 E. I. Yakusheva (VIR) conducted special experiments to find out the optimal conditions for long-term storage of various seeds. As a result, it became obvious that seeds remained in better conditions in sealed containers with low-moisture content. Hence, in 1969 the Institute organized controlled-environment storage of more than 120,000 duplicate samples from the VIR collection.

In 1976 a long-term seed storage facility for the VIR collection was built in the Kuban, Krasnodar region, 600 miles south of St. Petersburg. It is a three-story building, with storage underground. There are 24 seed storage chambers on the two lower floors (12 on each). Chambers differ in size: each may contain from 15-20,000 accessions. In total there are 220,000 plant varieties preserved there at present (Strobel, 1993).

In terms of climatic conditions, the Krasnodar region was not a very convenient area to build such a storage. In summer the temperature goes up to 30-40 degrees C (80-104 degrees F). For minimizing the negative impact of warm air, the walls of two lower levels are protected from the outside warm air by an earth embankment. In addition to that, the blocks of the 12 chambers on the first floor are isolated from outer walls with a through passage along the perimeter. However,

the facility does not have freezing equipment.There are four cooling units. According to US specialists, who visited VIR in 1993, (USDA ARS, Beltsville, MD) only one fan was working. If it were to become inoperative, the whole preserved material there would be in danger of spoiling. During the summer of 1994 the temperature inside the chambers ranged from +3 to +5 degrees C. Obviously this was not a satisfactory condition for long-term preservation. In St. Petersburg seeds are stored in even worse conditions - under room temperature and without air conditioning.

With the help of international funds, raised to improve conditions for maintaining genetic resources in Russia, work has started to replace the old cooling units in Kuban with more modern ones. This is expected to lower temperature in the storage rooms to -2 degrees C. In addition to this 10 to 12 automatic climatic chambers are going to be installed. They will have temperature from -10 to -12 degrees C. They have capacity for 80,000 accessions.

Sampling Seed and Preparing it for Storage

It is important that the samples chosen for long-term storage be genetically representative of the original population. During experiments conducted by Yakusheva in 1946-1951 it was noticed that samples of seed of the same variety but from different climatic zones have different seed longevity in storage. This is why it is necessary to obtain high quality seed from the most favorable climatic zones (Zaitsev, 1990).

The size of accessions varies from 500 to 12,000, depending on seed species, 100-seed weight, seed expense for control tests, and other factors determined by the International Seed Testers Association. In cases where there is not enough seed available, the accession is being multiplied up to the necessary amount.

Seeds intended for long-term storage must be absolutely sound, without mechanical damage, and with high viability and vigor. There are several techniques applied for drying seeds - forced-air ventilation and chemical methods (silica gel). However, seed dehydration is a very prolonged process and it may well cause a decrease in seed viability. The moisture content recommended for long-term preservation in the State Storage at Kuban Experiment Station is 2 to 9 percent (Zaitsev, 1990). The American specialists, after their visits to VIR, recommended that obtaining drying equipment must be included in the priority list of the Institute's needs.

There are specific sanitation measures for accessions coming from abroad. They undergo quarantine examination and fumigation. Although fumigation seems to be essential for preventing diseases and pests, until recently there have been no available data on long-term storage of fumigated seed. Therefore, to avoid risk, workers preserve non-fumigated seed. However, recently, Bulgarian specialists discovered that storage of fumigated seed under sub-zero temperatures did not affect its germination ability (Zaitsev, 1990).
In the VIR, for hermetically sealed storage of seed, wide-mouth glass bottles are used. They are

of different capacity: from 50 to 500 cubic centimeters. Complete hermetical sealing is secured by an aluminum cap tightly pressed on a silicon stopper. There are various types of containers for preserving seeds (bags of aluminum foil, plastic polytene, paper). One of the advantages of glass bottles is that they are transparent. It makes possible to have visual control of seeds in storage (Zaitsev, 1990).

Conservation of Genetic Resources In Nature (In Situ)

Besides the gene banks (ex situ), genetic resources can be conserved in nature (in situ). The institutions for nature conservation are represented as special protected areas, such as nature reserves and national parks. These two methods (in situ and ex situ conservation) have to complement each other. Seed banks and field banks may be damaged because of natural disasters and technical problems such as electrical power cuts, fires, war or political problems (as with some stations of the Vavilov Institute). The availability of in situ genetic resources may enable replenishment of some such damaged resources.

Although real efforts in the world at in situ conservation have been slow to emerge, 127 reserves for the protection of wild relatives of crops have been established in the former Soviet Union (Committee on Conserving Global Genetic Resources, 1993). Wild relatives of wheat and fruit trees are maintained in the protected area of the Caucasus Mountains, between the Black Sea and the Caspian Sea. In the Kopet Mountains, just north of the Iranian border, east of the Caspian Sea, the Soviet Union has established a reserve for wild pistachio, apricot and almond trees, and for wild fodder grasses.

Another significant area is the 23,868 hectare Sary-Chelek reserve in Kyrgystan, near the western China border, where wild relatives of various nut trees (especially walnuts) and fruit (apples, pears, some prunus) and others are preserved (Hoyt, 1992).

The Russian Far East (RFE) territories of Khabarovsk and Primorye in particular-- an area larger than California , Washington and Oregon combined-are approximately 75% forested (Gore-Chernomyrdin working group, 1994). These tremendous resources are not only of great value as timber reserves, but are a critical global resource to buffer the effects of global climate change: they take up vast amounts of carbon dioxide (carbon sink). It is as well a valuable forest habitat for several endangered species including 200 remaining Amur Tigers. The Sikotin-Alin Mountain region is considered to be biologically the most diverse terrestrial region of Russia. However, because of insufficient and weak management of natural resources in Russia, the existence of these unique, endangered species is threatened.

The draft of report for the Gore-Chernomyrdin working group indicates that with no reliable sources of financing protected resources are collapsing. Habitat loss and poaching are serious

problems. Very little has been done to protect endangered species outside the formal reserves. High rates of unemployment and low wages increase poaching and other anticonservation encroachment in and around protected areas. The federal and regional agencies that manage formal protected reserves lack funding to carry out even basic anti-poaching or anti-encroachment activities. Nor are they able even to collect, organize, and disseminate data to manage the preserves and educate the public on the value of the resources. Long-term funding mechanisms that are independent of Russian government budgets are lacking. In addition,there is no financing source to support habitat protection and restoration, biodiversity research, and employment generation for communities adjacent to protected areas.

Recently American plant explorers undertook a survey investigation of the Kazakhstan and Kirgistan former Soviet republics. These regions are known for their high quality fruits and large forests with wild fruit plants, which are very valuable germplasm for horticulture. However, the explorers were told that nearly 80 percent of the forests have disappeared during the last 30 years, due to human pressure in areas close to the major population centers or the capitals (Diversity, 1994).

Changes In The Capacity Of The Germplasm Conservation and Maintenance System Since The Mid-1980s

After the collapse of the Soviet Union genetic resource conservation and maintenance, both in nature and off-site (in situ and ex situ), became disordered and disorganized. It suffered not only from adverse economic conditions and lack of funds, but from political problems as well.

After the disintegration of the Union, six experiment stations of the Vavilov Institute came under the control of the newly emerged independent republics: Ukraine, Turkmenistan, Kazakhstan, Uzbekistan and Georgia (Figure 1). Facing more basic social and structural problems, and having critical financial difficulties, the new governments gave little attention to agricultural research. The state budget allocations for all sciences were greatly reduced.

Seed multiplication and hybrid testing at the stations, situated in the territory of these republics, were virtually stopped and new projects were started "in line with national interests". Thus, 25 percent of the entire Vavilov collection is "in danger of going stale" (Possehl, 1993). Recently VIR has signed an agreement with the Uzbek Research Institute of Plant Industry (the former Central Asia Branch of VIR) on cooperation in the sphere of maintenance and study of the collection inherited from VIR. Therefore this collection can be regarded as still associated with the N. I. Vavilov Institute.

The Russian government did not allow the Vavilov Institute to allot any of its 1993 budget of 337 million rubles (US $504,491 using the official exchange rate of 668 rubles to a dollar as of

February-March 1993) to these stations. The administration of VIR from its headquarters in St. Petersburg, tried "to negotiate the transfer of unique germ plasm stored there and duplicate it in Russia". According to recent information obtained from Dr. Sergey Alexanian, head of the Department of Foreign Relations at the Vavilov Institute (September 1994), the larger part of those collections is currently being duplicated at other locations in Russia.

In 1993 one of the stations, the Sukhumi station in Georgia, was destroyed in the civil war in that republic. Although five botanists succeeded in evacuating 226 precious samples of subtropical fruit plants and almost the whole lemon collection from that dangerous zone, 2,000 samples were left behind in Sukhumi (Strobel, 1993). Fortunately the damage appeared to be less than expected: only some trees were injured (Shands, 1994).

Another problem is the dramatic reduction of funds for salaries. Since 1991 at the St. Petersburg Institute the staff has been cut from 700 to 400 personnel. Soon another 10 percent reduction has been announced. Scientists are being asked to take early retirement. However, losing the experienced specialists hasn't freed enough funds for attracting and permanently engaging younger talented experts, "because commercial structures can entice young researchers with incomparably higher wages, prospects of training abroad, and better labor conditions " (Dragavtsev and Alexanian, 1993).

Because the Institute had no hard currency in 1992, it canceled 15 subscriptions to foreign journals. However, Sergey Alexanian reported that "despite poor pay and work conditions, we have not experienced a (serious) brain drain yet. The scientists are very loyal."

In a document prepared by N.I. Vavilov Institute of Plant Industry (November 1994), there is a table illustrating the constraints faced by the Institute (Table 3). According to that table, among the biggest constraints are: deteriorated/poor facilities lack of appropriate/necessary equipment, and operational inputs. A five year plan has been outlined to accomplish a series of measures aimed at enhancing the methods and technologies of plant genetic resource activities. The priorities of the plan will be: integration of the Institute and its experimental network into the international cooperation system, modernization of the Kuban seed storage facility with its transformation into a medium-term seed-storage facility; construction of a new long-term storage repository (with temperature below -20 degree C); establishment of a genebank facility for vegetative propagation of plants (in vitro); and development of a compatible international database on the VIR's global collection. Additional priorities include creation of different forms of training with the purpose of qualification, improvement, and specialization for the Institute's staff and experimental stations' personnel, furnishing of the experimental stations with the seed drying equipment and freezing facilities for the collection samples, and refurbishing of the Pushkin Fundamental Laboratories of VIR.

According to a joint FAO-IPGRI report of October 1994, the Baltic Republics, especially

Lithuania, want to establish their own national plant genetic resources programs. In the past they maintained only working collections as all genetic resources were provided to breeders by the VIR. Now steps have been taken to request repatriation of germplasm of Baltic origin. In addition, the three Baltic Republics are very interested in establishing a new mode of collaboration with VIR and other former Soviet republics' germplasm research institutions. They have already worked out a very progressive cooperative plan with the Nordic Genebank, and are exploring participation in other international collaborative programs (Frison and Serwinski, 1994).

International Cooperation And The Former Soviet Union.

The world's largest international collection of genetic resources is collectively maintained by the centres of the Consultative Group on International Agricultural Research (CGIAR), established in 1971. It is an informal association of 40 public and private sector donors that supports a network of 18 international agricultural research centres (Figure 2). As this has been assembled in cooperation with countries and institutions worldwide, the centres do not claim ownership of the materials: they are held in trust for the world community. Meanwhile the Convention on Biological Diversity of 1992 provides incentives for countries to exercise sovereign rights over genetic resources in their territories. Mechanisms are being worked out for facilitating the unhindered movement of genetic resources and the fair and equitable sharing of benefits derived from their use (Barton and Siebeck, 1994).

Representatives of the N. I. Vavilov Institute insist that the VIR has always been guided by the conviction: "Plant genetic resources are the heritage of the world community, not of one country" (Dragavtsev and Alexanian, 1993). As evidence of this conviction, when in 1984 the U.S. soybean crop was being damaged, researchers from VIR supplied their U.S. colleagues soybeans with genetic materials with the desired resistance (Strobel, 1993). Also recently the Vavilov Institute was able to provide the U.S. collection in Aberdeen, (Idaho) with several dozen old American wheat varieties which were not in the U.S. collection (Merezhko, 1994). The significance of diverse agricultural crop exchange becomes more clear when we recognize the fact that in the United States 99 percent of the commercial crop acres is planted with plant varieties introduced from foreign countries (Buffet, 1994).

For the purpose of exchanging materials with collections of other countries, every three years the Vavilov Institute has published a seed exchange catalogue, <u>Delectus Seminum,</u> and receives similar catalogues from the former Soviet republics, botanical gardens and foreign institutions. The VIR also satisfies, whenever possible, requests for plant samples in addition to those offered in the exchange catalogue. Data indicate that in

1989 9,013 samples from the VIR collection were sent to 45 countries, while the Institute received 9,418 samples from 45 countries. If we compare this with the number of seed samples that the United States dispatches each year (Committee on Managing Global Genetic Resources provides the figure of more than 230,000 samples to over 100 countries), it seems less impressive, but it does serve to indicate that the desire to exchange materials with the international community is real. More recently, on June 4 1990, in St. Petersburg the Vavilov Institute has signed a landmark agreement (Memorandum of Understanding) with the International Board for Plant Genetic Resources (IBPGR) which now is called International Plant Genetic Resources Institute (IPGRI), a member of CGIAR.

The USDA and the All-Union Academy of Agricultural Sciences engaged in several personnel exchanges under the Memorandum of Understanding (June 4, 1994) developed for their mutual benefit. Both administrators and scientists visited institutions and collaborating scientists in the other country over several years. Plant collecting trips in both countries, exchange of germplasm, and scientific visits to research institutions of interest have been conducted since 1986 onward. By the time of collapse of the USSR, both ARS and VIR had gone far beyond the formalities of cold war exchange and were engaged in close collaboration with strong friendships developing between the scientists involved. James Elgin, Paul Fitzgerald, Henry Shands, Calvin Sperling, V. I. Krivchenko, Victor Dragavtsev, Sergey Shuvalov, and Sergey Alexanian were among the key scientists. In the scientific press Diversity magazine's Deborah Srauss was a catalyst, leading to articles in the New York Times and the Washington Post and others. As the efforts to strengthen the Vavilov Institute materialized, ARS was ready to assist in a limited but significant effort to supply computers to help establish a database for the VIR collection (Shands, 1994).

All these have lead to the establishment of a comprehensive program of collaboration, joint collecting missions and research projects, and sharing of information on all relevant activities. As IBPGR Acting Director D. H. van Sloten said, with the signing of this Memorandum of Understanding, the (former) USSR has now fully opened its doors for international cooperation. Simultaneously it became a Member of the European Cooperative Programme on Crop Genetic Resources Network (ECP/GR), which is operated in cooperation with the IBPGR. At the end of 1989 there were 25 European Members of this network. "Upon signing the IBPGR-VIR Memorandum", according to Sergey Alexanian, VIR Director of Foreign Relations, "...VIR legally became one of the links in the global network of genebanks. As a part of the expected activities, VIR will organize advanced courses for Third World specialists."

In June of the same year (1990), at Beltsville, Maryland, a joint communique was issued by United States and Soviet Union germplasm leaders. It was signed by Vladimir Krivchenko, Director of VIR, Sergey Alexanian, head of the VIR Department of Foreign Relations, Waldemar Klassen, Associate Deputy Administrator, National Program Staff, USDA, and Paul Fitzgerald, the ARS Agricultural Science Advisor for germplasm. The Communique expresses the firm decision of plant genetic resources experts from both countries to seek the approval of appropriate

authorities of the two governments for a long-term arrangement to assure maximum effectiveness in the development and use of plant genetic resources of the USA and the USSR. It was stressed at the signing ceremony that the intention of the signatories was to assure that plant genetic resources provide major benefits not only to the people of the USA and the USSR, but to all humanity (Diversity, 1990). "We need each other as sources for new varieties. That's what their and our germ plasm collections are all about", says Dr. Henry Shands from USDA Agricultural Research Service, Beltsville, Maryland.

From 1986 onward the American specialists gained access to resources and areas which were not available to them before. An example is the territory in Kazakhstan where a unique crested wheat variety which gives an outstanding growth in a low rain-fall areas with saline soil is bred. Before it was considered to be within the limits of a military restricted area and was closed to outsiders. That was a crested wheat variety which gives an outstanding growth in a low rain-fall areas with saline soil. Another interesting genetic resource is in the fruit area. Dr. Shands mentioned special peach varieties whose skin does not have fuzz, as most peach varieties do.

One of the articles in Diversity (from the series on to the former Soviet plant genetics) is devoted to the expedition of American and New Zealand explorers who went to Kazakhstan and Kyrgystan to collect germplasm of apples and grapes in September 1993. The team traversed seven unique ecosystems during the exploration and identified significant genetic diversity in apples, which will greatly expand the genetic diversity of the United States apple germplasm collection. It is not surprising as N. I. Vavilov considered the Kyrgystan region as one of the sites of the origin of the cultivated apple. Explorers also found an abundance of wild grapes - black, red, and white types, which had excellent flavor and important characteristics for disease resistance which have great potential for improving grape varieties in both America and New Zealand.

The collaboration between the Soviet and the other formerly centrally planned economies' germplasm resource scientists has comparably long history. Several articles on this subject published in Diversity, document the history of this collaboration between the Soviet and other socialist countries in the sphere of genetic resources and plant breeding. In 1962 at the 5th Conference of the Council for Mutual Economic Aid (included the Soviet Union, Bulgaria, the Hungarian People's Republic, the German Democratic Republic, the Mongolian People's Republic, Poland, and the Czechoslovak Socialist Republic), it was decided that a Session was needed to discuss the possibilities of expanding the collaboration in the sphere of research and exchange of genetic resources. The first Session devoted to that subject was held in 1964, in Leningrad (St. Petersburg). At that time the national collections of participating countries were rather insignificant. Even the Vavilov Institute couldn't completely provide the breeders with the valuable base material they required for their countries. But the results of the cooperation were quite noticeable: by 1974 almost 200,000 accessions of diverse agricultural crops had been added to the national collections of the partner countries. Recently the common fund of these national collections numbered more than 700,000 samples (Alexanian and Heintz, 1989).

The Economic Value Of Genetic Resources And The Utilization Of The Vavilov Collection

Traditionally genetic resources have been considered to be public or nonmarketed goods. In the past they were seldom traded in the marketplace. This causes difficulties in valuing them. However, there are a few methods for placing value on such nonmarketed goods. One of them is the hedonic pricing (productivity) method (Committee on Managing Global Genetic Resources, 1993). By this method the value of the nonmarketed good (in this case, of germplasm) is estimated from the economic value of the marketed good (plants or animals) to which it contributed.

However, there are no accurate data illustrating the economic value of the material conserved in the world's gene banks. Because it is not possible to foresee new pests, diseases or difficulties that breeders may face in the future, it is hard to estimate the potential usefulness of any particular element. One thing is clear: germplasm collections are an insurance against future threats, and from the past experience of the world agriculture, it is obvious that investment in the collection, preservation and management of genetic resources provides a very good return.

One of the main factors determining the phenomenal productivity of the U.S. agriculture between 1930 and 1980 was the genetic improvement of crops. During this period yields of corn, potatoes and wheat increased 333%, nearly 300%, and 136%, respectively. Roughly half of these increases was due to the use of improved germplasm. It allowed scientists to create better quality varieties with higher resistance to environmental stresses and with higher yields. Obviously this increase in agricultural production has contributed significantly to the U.S. economy.

A detailed economic analysis, the first of its type, was done using Indian rice production as an example (Committee on Managing Global Genetic Resources, 1993; Evenson, 1994). This analysis showed that the returns to be reasonably expected from genetic resource contributions to future crop yields dwarf the relatively small amounts of funds invested in maintaining these collections. Based on this study it is estimated that the result of using genetically improved rice varieties in world agriculture has produced an annual benefit stream of US $594 million (using a 10% discount rate). These figures can be compared with the current annual costs of global rice germplasm maintenance of around US$10 million.

One of the conclusions derived from this analysis is that it is very efficient to strive for a near-complete collection. There are quite reasonable presumptions that the value of a nearly complete collection relative to its cost is probably higher than the value of a smaller collection relative to its cost. Such a "complete" collection will be more effective in providing plant breeders with the tools to overcome natural threats to crops at a very low cost. The collections of the United States

and the former Soviet Union are considered to be very close to complete. This is a good reason to expect that more complete utilization of the former Soviet Union collection should generate a high rate of return.

During the last 15 years, more than 1,500 commercial varieties have been bred using materials from the Vavilov Institute collection. These varieties occupy 60 million hectares of cultivated lands (Report by Victor Dragavtsev, VIR director, at the Centennial Conference, August 1994). However it seems there is no estimate of how much of the Russian yield increase has been due to the genetic improvement of crops. It's also obvious that former Soviet agricultural production has lagged behind that of the other developed countries. The rate of productivity growth has been slow (Wong, 1985), but for reasons apparently unrelated to the genetic improvement of crops. There are data indicating that fully 80 percent of the research generated was never applied in the agricultural sector. Some 30-40 percent of fruits, vegetables and even grain was usually lost because of inadequate post-harvest agricultural transportation, storage and marketing (A Virginia Tech Leadership Forum, 1991).

In 1993 the cost of operating the Vavilov Institute of Plant Industry was around US $504,491. This is not a large amount for such a huge and unique gene bank (Possehl, 1993). For the first half of 1994, allocations from the state budget were made 820 million rubles, and 800 million rubles were scheduled for the second half. This is around US $704,000 using the current US dollar/ruble exchange rate as $1=2300 rubles (as of August-September 1994) (based on information provided by Sergey Alexanian). We may mention here that the US plant germplasm research funding for 1993 was more than US $20 million (Shands, 1994). However such comparisons are not very meaningful. The expenses of Vavilov Institute are changing (generally increasing) constantly because of technological change, increases in wages and salaries, changing economic conditions (affecting Institute's budget), and for other reasons. Because of the extremely high rates of inflation in Russia presently, comparisons with previous years' do not mean much.

American experts from USDA Agricultural Research Service are convinced that access to the former Soviet Union gene bank would be of great value to the United States. Thus, taking into account the estimates from the above described analysis, any reasonable investment in preservation and access to the germplasm collection of the former USSR will yield great value to world agriculture.

Assistance To The Former Soviet Union Genetic Resources Conservation and Maintenance System

During the last two years the international agricultural research community has paid considerable attention to the situation of the former USSR genetic resource conservation and maintenance system. In 1992 a special account was established at The World Bank for emergency donations to rescue genetic resources in Eastern Europe. This account is administered by International Plant Genetic Resources Institute (IPGRI).

According to USDA and World Bank estimates, around US $2 million is needed from international agencies to secure the maintenance of valuable genetic material in the former Soviet Union - about $500,000 for annual operational expenses and $1.5 million to provide repair and replacement of medium-to-long-term storage facilities (World Bank Proposal, 1992).

In August 1994 the World Bank and USDA Agricultural Research Service representatives visited Vavilov Institute. They were invited to participate in and address an international conference on genetic resources being organized by the Institute to commemorate the Vavilov Institute's 100th anniversary. Reportedly they also discussed the possibility of including the Vavilov Institute in the project which has been proposed by The World Bank to support agricultural research in Russia. The improvement of Vavilov Institute's ability to maintain its collections is going very well, according to a World Bank representative who has visited the Institute recently. The establishment of the computer database and the repair of refrigeration equipment of the long-term storage facility are in process and the assistance will be continued in the future.

In 1993 the United States Agency for International Development (USAID) approved a grant of US $400,000 for support of the Vavilov Institute plant collection (IPGRI Annual Report 1993). The United Nations Development Programme (UNDP) also contributed US $25,000 for that purpose. The United States Department of Agriculture, at the cost of US $30,000, provided computer hardware for a database system compatible with that used to manage its own gene bank (Aldhouse and Dorozynsky, 1994). There was also a very warm response from the American people, (52 different sources including both individuals and groups), who contributed US $18,000 to the trust fund established by the Agricultural Research Institute for the Vavilov germplasm collection last year.

In 1994 USAID allocated US $500,000 for the total germplasm maintenance system of the former Soviet Union, which included botanical gardens and herbariums as well. In this regard Mr. Rob Bertram from USAID mentioned the Komarov Botanical Institute which possesses a herbarium containing some 6 million dried plant specimens. It is one of the world-leading resources in the field of plant taxonomy. "It's the Kew of Russia"' says botanist Charles Jeffrey from the Royal Botanical garden's at Kew, London, "but it has been considerably underused". However, the building housing this world renowned resource is in terrible condition (Aldhous and Dorozynski, 1994).

USAID had prepared a project for promotion of sustainable, multiple-use forest management as well as for biodiversity protection in Khabarovsk and Primorye territories. The proposed life-of-program budget is $16.7 million (Draft Report for the Gore-Chernomyrdin Working Group, September 1994). One of the three objectives of this project is Biodiversity Conservation Management. The other two are Building a Strong Institutional Framework for Sustainable Natural Resources Management and Sustainable Forest Management.

It is expected that within three years the project will have succeeded in overcoming many of the more immediate problems facing the natural resources in these territories. Policy, legal, and institutional barriers to private sector-led sustainable forest management and biological diversity conservation will be significantly reduced. Immediate threats to endangered species and habitats will be reduced. A conservation trust fund for long-term conservation will also be established.

In January 1994 the World Wildlife Fund (WWF) released a report, "Conserving Russia's Biological Diversity - An Analytical Framework and Initial Investment Portfolio' which examines the famous Russian protected areas. The report calls for funding to rescue those areas. According to the estimates of WWF's Russia Project coordinator, US $17 million is required to put these protected areas "on a sustainable footing." "Russia is the best conservation bargain on the map today," said Eric Dinerstein, of WWF-US. "The United States has pledged $400 million to assist Russia's space program over four years. For less than twentieth of that, we can safeguard some of the earth's last true wilderness" (Diversity, 1993, 1994).

Summary

The systematic collection of plant genetic materials in Russia began about 100 years ago and was expanded under the leadership of N. I. Vavilov to one of the largest banks of plant genetic materials in the world today. In recent years economic and political instability associated with the dissolution of the Soviet Union and the emergence of independent republics has adversely affected this valuable collection. The events have occurred almost simultaneously with the increased access of the United States and the rest of the world to the Vavilov collection.

Although techniques for the economic evaluation of plant genetic resources is still in the early stages of development, the few available economic studies indicate benefits substantially exceeding costs for maintaining and exchanging genetic materials from these collections. In addition it is extremely difficult to place a monetary value on germplasm collections as insurance against future threats - plant pests, diseases, climatic change - to world food supply. In the United States, 99 percent of commercial crop acres are planted to plant varieties introduced from other countries.

During the last two years the United States and the international agricultural community has paid increasing attention to the status of genetic resources conservation and maintenance in the former Soviet Union. Various estimates indicate the need for approximately U.S. $2 million to restore and maintain the Vavilov collection with about US $500,000 needed for annual expenses. On another front, an estimated US $17 million is required to place in situ "collections" of both plants and animals on a sustainable footing.

Some financial assistance has been provided and more is in the planning stages. The United States and the other developed countries of the world have a major stake in closely monitoring the status of these plans and pressing for their implementation.

TABLE 1. Number of Specimens in the Collections of the Bureau of Applied Botany and VIR up to 1985.

Year	Number of specimens	
1901	302	
1902	626	
1903	674	
1904	991	
1905	1,091	
1906	1,142	
1907	1,535	
1908	2,156	
1909	3,748	
1910	5,715	
1915	13,891	
1940	187,500	
1950	118,203	(Following the
1960	154,684	inventory
1970	184,300	made
1980	298,268	from 1946 to
1981	310,357	1950)
1982	326,197	
1983	340,415	
1984	350,060	
1985	362,011	

Source: V.I Lenin All-Union Academy of Agricultural Sciences. 1987. Advances in Agricultural Science. Moscow. Academy Press. p. 24.

TABLE 2. Estimates of Germplasm Holdings in the Five Largest National Plant Germplasm Systems and Major International Centers.

Country/Center	Categories Concerned	Total
United States	All crops	557,000
China	All crops	400,000
Former Soviet Union	All crops	375,000
IRRI	Rice	86,000
ICRISAT	Sorghum, millet, chickpea, peanut, pigeon pea	86,000
ICARDA	Cereals, legumes, forages	77,000
India	All crops	76,800
CIMMYT	Wheat, maize	75,000
CIAT	Common bean, cassava forages	66,000
Japan	All crops	60,000
IITA	Cowpea, rice, root crops	40,000
AVRDC	Alliums (onion, garlic, shallot), Chinese cabbage, common cabbage, eggplant, mungbean, pepper, soybean, tomato, other vegetables of regional importance	38,500
CIP	Potato, sweet potato	12,000

NOTES: IRRI, International Rice Research Institute; ICRISAT, International Crops Institute for the Semi-Arid Tropics; ICARDA, International Center for Agricultural Research in the Dry Areas; CIMMYT, Centro Internacional de Mejoramiento de Maiz y Trigo; CIAT, Centro Internacional de Agricultura Tropical; IITA, International Institute for Tropical Agriculture; Avcrdc, Asian Vegetable Research and Development Center; CIP, Centro Internacional de la Papa.

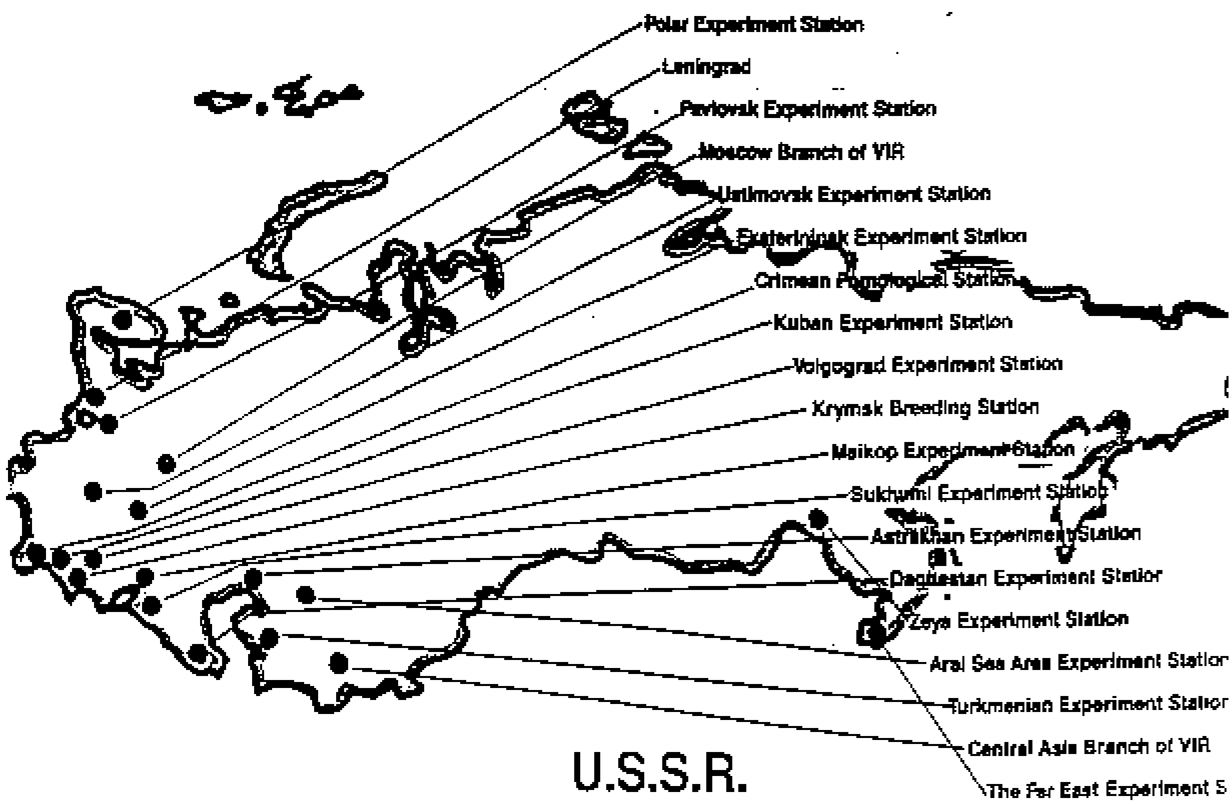
SOURCES: Asian Vegetable Research and Development Center. 1992. 1991 Progress Report. Shanhua, Taiwan: Asian Vegetable Research and Development Center; Chang, T. T. 1992. Availability of plant germplasm for use in crop improvement. pp. 17-35 in Plant Breeding in the 1990s, H. T. Stalker and J. P. Murphy, eds. Wallingford, U.K.: CAB International; Vitkovskij, V. L., and S. V. Kuznetsov. 1990. The N. I. Vavilov All Union Research Institute of Plant Industry. Diversity 6(1):15-1

TABLE 3. Constraints faced by Vavilov Institute.

Constraints	**Scale 0 to 9**
Unclear research priorities	**1**
Inefficient research/fund management	**1/1**
Lack of incentives and motivations	**5**
Deteriorated/poor facilities	**8**
Lack of appropriate/necessary equipment	**8**
Lack of operational inputs	**9**
Lack of funds for carrying out research	**7**
Limited access to national and international	**4**
Too much emphasis on Income generating activities	**1**
Poor links with research beneficiaries	**1**
Lack of opportunities for training domestically/abroad	**3**
Other: low salaries	**6**

Source: Russian Federation: Agricultural Research Project: VIR Component. 1994.

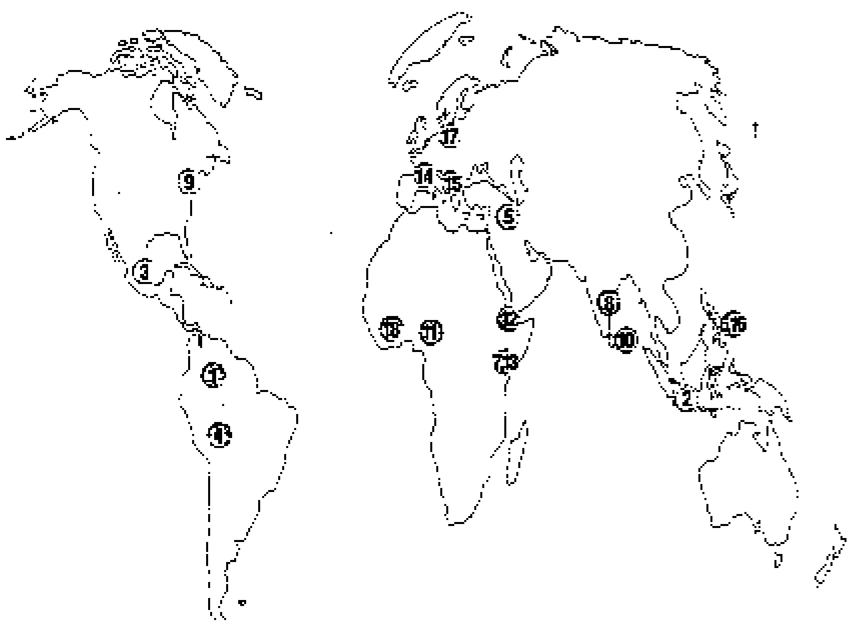
FIGURE 1. The Vavilov Institute consists of 18 experiment stations. They are spread from polar region to the subtropics and from European part of the USSR to the Far East.



Six of these stations have now become national institutes (or stations) in the respective newly emerged republic.

1) Ustimovskaya Experiment Station, Ustimovka, Ukraine
2) Crimean Pomological Station, Sevastopol, Ukraine
3) Sukhumi Experiment Station, Sukhumi, Georgia
4) Aral Sea experiment Station, Chelkar, Kazakhstan
5) Turkmenistan Experiment Station, Kara Kala, Turkmenistan
6) Central Asia Branch Institute, Tashkent, Uzbekistan

FIGURE 2. The Consultative Group on International Agricultural Research (CGIAR) is a network of 18 international agricultural research centres, including International Plant Genetic Resources Institute (IPGRI).



1	CIAT	Centro Internacional de Agricultura Tropical, Cali, Colombia
2	CIFOR	Centre for International Forestry Research, Bogor, Indonesia
3	CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo, Mexico D.F., Mexico
4	CIP	Centro Internacional de la Papa, Lima, Peru
5	ICARDA	International Center for Agricultural Research in the Dry Areas, Aleppo, Syria
6	ICLARM	International Center for Living Aquatic Resources Management, Metro Manila, Philippines
7	ICRAF	International Centre for Research on Agroforestry, Nairobi, Kenya
8	ICRISAT	International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India
9	IFPRI	International Food Policy Research Institute, Washington DC. USA
10	IIMI	International Irrigation Management Institute, Colombo. Sri Lanka
11	IITA	International Institute of Tropical Agriculture, Ibadan, Nigeria
12	ILCA	International Livestock Center for Africa, Addis Ababa, Ethiopia
13	ILRAD	International Laboratory for Research on Animal Diseases, Nairobi, Kenya
14	INIBAP	International Network for the Improvement of Banana and Plantain, Montpellier, France
15	IPGRI	International Plant Genetic Resources Institute (formerly IBPGR), Rome, Italy
16	IRRI	International Rice Research Institute, Los Baños, Philippines
17	ISNAR	International Service for National Agricultural Research, The Hague, Netherlands
18	WARDA	West Africa Rice Development Association, Bouaké, Côte d'Ivoire

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