WHEAT CROP GERMPLASM COMMITTEE REPORT

1996 Update

I. INTRODUCTION

World Production:

Wheat is the leading crop in world production, with over 500 million metric tons harvested in 1995 (NAWG, 1995). World consumption continues to increase with production. Major country producers (approximately by rank in production) include China, Russia, the European Union (EU), the U.S., and India. The U.S. is the largest exporter, followed by the EU, Canada, and Australia. Regions with the largest imports are the EU, North America, and China. World stocks of wheat today are at their lowest level in many years.

U.S. Production:

U.S. production has declined steadily since the record year of 1981 when nearly 2.8 billion bushels were produced. Current production is below 2.2 billion bushels. One third of all wheat farmers harvest 85% of the wheat produced. Grain yields have averaged 37.4bu/ac so far in the 1990s, compared with 35.8 bu/ac in the 1980s. Ending Stocks of wheat have dropped from 1.9 billion bushels in 1985 to only 427 million bushels in 1995.

Domestic Use:

We consume about half of our own production, and of that 1.1 billion bushels (3 million bushels of wheat each day), approximately 80% is milled. The rest is used for livestock feed and industrial purposes. Baked goods, including bread, rolls, crackers, cookies, and other sweet goods represent the greatest value of consumption, followed by cereal, flour, and pasta products.

The current grain classification system describes 5 different classes of wheat that are roughly related to milling and baking uses. The classes are grouped according to hardness, color, and spring or winter growth habit. Hard red winter wheat accounts for the majority of the U.S. wheat crop. It has good milling and baking characteristics for making bread. Hard red spring wheat is also used for making bread but is grown primarily in the north central U.S. and often has higher protein content. Soft red winter wheat is grown in the eastern third of the U.S. and is milled and baked for a variety of uses including cakes, pastries, quick breads, and crackers, batters, and snack foods. White wheat includes subclasses of hard white, soft white, western white and white club. Except for the hard white, these subclasses are used for the pastry products and also export. Hard white wheat is used for bread. Durum wheat is milled to produce semolina for pasta products.

Exports:

Wheat is an essential export commodity for maintaining the U.S. balance of trade. U.S. wheat exports represent slightly more than 50% of our total production. Exports peaked in 1981 at about 1.8 billion bushels, with current exports estimated at 1.2 billion bushels (NAWG, 1995).

II. CURRENT GERMPLASM ACTIVITIES

Every year, a huge volume of germplasm circulates among wheat breeders and geneticists, both within the United States and internationally. The USDA-ARS National Small Grains Collection (NSGC) at Aberdeen, Idaho receives, maintains, and distributes seed of wheat cultivars, breeding lines, land races, and wild species. In addition, many wheat researchers have extensive collections of materials that are not duplicated in the NSGC, and much of this germplasm in disseminated among researchers. In response to a 1992 NPGS survey, 22 U.S.

wheat breeders and geneticists (by no means encompassing all breeding programs) reported holding in storage a total of approximately 122,000 genotypes, including breeding lines, cultivars, wild relatives, and other germplasm. Of these, only about 4.5% had been deposited in NPGS. Together, the 22 researchers reported distributing a total of about 1450 samples per year.

Wheat geneticists and breeders also are constantly developing and identifying new genetic stocks for investigating biological phenomena. These include aneuploid stocks, translocation stocks, genetic marker stocks, isolines, mutants, etc. The Annual Wheat Newsletter is an excellent resource for identifying wheat researchers and some of their current research activities.

A. Collection:

There has been considerable activity, although not all financed by the USDA. Since 1989, the following collection trips have been made:

Mexico: 8000+ single spikes from sites in 12 states-CIMMYT, 1990-95

Tibet: (But the material was not received from China- the area should be collected again through proper channels in China)-CIMMYT, U. Saskatchewan, and ICARDA 1990-95

West Asia and North Africa (WANA) region: Including Lebanon, Iraq, Iran, Turkey, Turkic Republics in Central Asia, Balkans, Southern Russia Caucasus republics-ICARDA 1990-95

Turkey: USDA (Calvin Sperling), 1989 or 1990
Endophytes and seed-Texas A&M (Dave Marshall), 1994
Hatay, Ceylanpinar State farm-Turkish gov't 1993-95
Gaziantep-ICARDA 1994-95
Western Turkey- UC Davis (Brush, Qualset), Turkish gov't 1992-93
Observations on locations of wild wheat populations in southeastern Turkey-UC Riverside (Waines), 1989-94

Italy: Especially dicoccum and einkorn- Italy and IPGRI

Albania: IPGRI 1993

Syria and Lebanon: 2000+ single heads of populations of wild wheats and *Aegilops* for population studies-ICARDA, UC Riverside (Waines), 1994

USA: Weedy species such as *Ae. cylindrica, Ae. triuncialis, Ae. ovata* and *Secale cereale* From California and Oregon- UC Riverside (Waines), 1993-1995

B. Preservation:

Currently there are over 41,000 *T. aestivum* and *T. turgidum* accessions and over 6,000 accessions of other *Triticum* species in the NSGC at Aberdeen, which is the working collection for wheat. The National Seed Storage Laboratory (NSSL) in Fort Collins, Colorado is the permanent storage facility, with little or no distribution to researchers. It holds duplicate samples of almost all accessions in the NSGC.

The Wheat Genetics Resource Center at Kansas State University maintains, evaluates, utilizes, and distributes accessions from a collection of over 2600 wild or primitive wheat accessions belonging to 45 different taxa. Many of these are also deposited in the Aberdeen collection as well, and plans include deposition of all material as seed supplies become sufficient.

Major wheat germplasm collection and conservation centers around the world (IBPGR, 1990) are listed in Appendix I.

C. Evaluation:

There are two principle areas of evaluation of wheat germplasm. One is the formal evaluation and accessions in the NSGC that began in 1983. Eventually, each accession will be evaluated for the selected plant descriptors and the data entered into the GRIN system. The systematic evaluation of wheat accessions in the National Small Grains Collections (NSGC) and other elite germplasm is coordinated or conducted by National Small Grains Germplasm Research Facility (NSGGRF) staff at Aberdeen, Idaho (Appendices II-III). Cooperative NSGC wheat evaluations in recent years has included reaction to Russian wheat aphid; Hessian fly; barley yellow dwarf virus; stripe, leaf, and stem rust; powdery mildew; dwarf bunt; and ploidy analysis of *Triticum* species. The evaluations identified resistance to dwarf and common bunt of wheat as well as resistance to Russian wheat aphid in wheat. The Aberdeen staff has been directly involved in the entry of NSGC evaluation data into the GRIN system and the evaluation of growth habit and NSGC wheat accessions.

Under the direction of H.E. Bockelman, the NSGC staff distributed an average of over 34,000 accessions on the years 1993 to 1995. Maintenance and evaluation of NSGC small grains germplasm, including quarantine entries, also continues at Maricopa, Arizona under the supervision of S. Nieto. Experiments coordinated form Aberdeen by B.J. Goates have included three field locations to determine the relationship of inoculum levels on seed or in soil on dwarf bunt incidence. Fumigation of soil with methyl bromide at three field locations killed teliospores of *Tilletia controversa.*

Another effort in the past several years has included the increase and cooperative evaluation of a wheat germplasm collection derived from a series of interspecific crosses completed by W.J. Sando in the 1930s and previously last grown in the 1960s. Cooperative evaluation of this germplasm collection included characters such as reaction to barley yellow dwarf virus, leaf rust, stripe rust, powdery mildew, Hessian fly, and Russian wheat aphid. Specific Cooperative Agreements or within ARS Fund transfers involving cooperative evaluations and related research for all small grains involve over 29 University and ARS projects in at least 17 states. Recent fund transfers concerned with wheat germplasm evaluations involve Pullman, WA (Line), West Lafayette, IN (Ratcliffe), Manhattan, KS (Hatchett & Eversmeyer), Davis, CA (Qualset), Stillwater, OK (Webster), Columbia, MO (Kimber), and Lincoln, NE (Peterson).

Core Subsets

A core subset (10-15%) of the *T. aestivum* collection is being developed, based primarily on geographic origin and morphological characters. The core will be useful in responding to general requests to evaluate diversity in the collection for new traits, such as nutritional factors or physiological traits, for which there is little existing information. For several years, the CGC has struggled with the idea of forming a core subset for evaluation. For several reasons, we have recommended that a single core *not* be designated to be screened first for resistances and other traits needed by wheat breeders. A different order of screening should be set up for each trait, based on wheat researchers' knowledge of the trait and its environment context; geographical and climatic information that will enrich the first-screened sets for desired genes; and desired background traits. Fortunately, screening of wheat for many of the resistance traits is fast and inexpensive, relative to other crops, making it possible to screen the whole collection even though it is large. In fact, for some resistances, we are close to having screened all current accessions.

Data management

Descriptors appropriate for wheat have been established. Field evaluation data are recorded on such descriptors as growth habit, number of days from planting to anthesis (heading), plant height, spike of panicle density, lodging, straw breakage, shattering, and awn and glume characteristics, including color. Data on field descriptors have been obtained on approximately 35,500 wheat accessions during the 1983-95 period. Special nurseries are grown for that purpose at Aberdeen, Idaho and Maricopa, Arizona, with grain being harvested from each field evaluation nursery to replenish NSGC seed stocks. Triticum descriptors with data currently on the GRIN system are summarized in Appendix III.

Data obtained from evaluations of NSGC germplasm are entered in the Germplasm Resources Information Network (GRIN) system by the NSGGRF staff in cooperation with the ARS National Germplasm Resources Laboratory, Beltsville, Maryland. GRIN is a database containing all the characteristics and availability of all genetics resources included in the National Plant Germplasm System. The database manager is J.D. Mowder, Beltsville, Maryland. The NSGGRF staff interacts with the GRIN system in recording NSGC orders (seed requests), entering a variety of data, and conducting information searches. No evaluations have been conducted to date for descriptors such as drought tolerance, salt tolerance, winterhardiness, Cephalosporium stripe, flag smut, leaf blight, loose smut, snow mold, take-all, tan spot, wheat streak mosaic, green bug, cereal leaf beetle, and protein.

We wish to acknowledge the important contributions of the NSGGRF staff in this effort, with special thanks to Glenda B. Rutger, John F. Connett, Kathy E. Burrup, Kay B. Calzada, Vicki Gamble, Evalyne McLean, Judy Bradley, Carol S. Truman, Fawn R. Buffi, Sharon Klassen, and M.A. Bohning.

D. Enhancement:

Wheat germplasm enhancement is being conducted at many sites by identifying and introgressing genes relevant to wheat improvement. Tools once considered novel, such as marker-based selection and utilization of related species, wild or domesticated are now considered routine in most programs. The Annual Wheat Newsletter is an excellent resource for identifying researchers involved in germplasm enhancement.

Cox (1991) documented the role of wild species, land races, and other introduced germplasm in the percentage of all U.S. wheat cultivars released before 1990. Use of exotic germplasm has accelerated since then. Resistance genes derived from wild species or rye are present in several of the most widely grown wheat varieties in the country. For example 'Madsen', the most widely grown variety in the Pacific Northwest, carries a gene *Pchl*, which confers resistance to eyespot derived from *Triticum ventricosum* (Allan 1989). This gene has saved growers over $15,000,000 in reduced fungicide application each year since 1991

Benefits of similar magnitude have been obtained from other genes that originated in wild or exotic germplasm, e.g., the T1AL·1RS and T1BL·1RS wheat rye translocations; the *Sr2* gene for stem rust resistance from *T. turgidum*, the *Lr24* gene for leaf rust resistance from *Agropyron elongatum*; and bunt, stripe rust, and snow mold resistance genes from the land race pI178383 (Cox, 1991).

III. STATUS OF CROP VULNERABILITY

A. The original genetic base

Cultivated wheat is believed to have evolved about 10,000 years ago- relatively recently compared to many other crops (Clark et al. 1922). Because of having evolved through two hybridization bottlenecks, hexaploid wheat exhibits very low genetic polymorphism at the molecular level. Genetic variability in U.S. wheats is further restricted because of the narrow cultivar base on which our wheat industry was founded (Cox, 1991). Mediterranean was introduced in the early 1800's from Italy and accounts for much of the genetic background of soft red winter wheat cultivars. Mennonite immigrants from the Ukraine introduced Turkey wheat into the U.S. about 1873, laying the genetic foundation of today's hard winter wheats. Genes from the original hard red spring wheat cultivars Red Fife and its progeny Marquis make up a major portion of the gene pool in that class.

B. Trends in genetic diversity of the U.S. wheat crop:

The total number of cultivars grown in the U.S., as well as the number of cultivars within each market class, increased substantially since the first survey in 1990 (Clark et al., 1922). In 1924, 152 cultivars were reported (Clark et al., 1929) and in 1984 there were 429 cultivars reported (Siegenthaler et al., 1986). (Comparable figures are not available for more recent years, because the national wheat cultivar survey was discontinued.) This suggests that genetic diversity of the U.S. wheat crop is gradually increasing over time. Increased cultivar development by private industry in recent decades has contributed significantly to the number of cultivars in production (especially since the Plant Variety Protection Act of 1970).

In the hard and soft red winter wheat classes, the trend toward increasing genetic diversity by the total number of cultivars is consistent with statistics indicating 1) an increased cultivar turnover rate, 2) an increased number of cultivars comprising 50% of the production in each market class, and 3) a smaller percentage of production accounted for by the dominant cultivars in each market class (Cox et al., 1986).

In general, hard red spring wheats have had a fairly high by slowly decreasing interrelatedness (coefficient of percentage = 0.22) among modern cultivars, with some regional differences (Von Bueningen and Busch, Crop Sci., in press). Chen et al. (1994), studying variation for molecular markers, concluded that genetic variation is more restricted among hard red spring wheat cultivars that it is among cultivars of other classes. Diversity in the hard red spring wheat region had been restricted by quality considerations, but has tended to ebb and flow. For instance, stem rust in the 50s opened up the gene fool for a time. With increased breeding for scab resistance, introduction of Chinese and other Asian types, as well as wheats from Europe and South America may broaden the future genetic base.

The white-wheat germplasm is relatively broad based. The soft white springs have a degree of infusion from the CIMMYT and Australian germplasm, while the soft white winter wheats are heavily intermated with European germplasm. The club wheats are still very narrow in their genetic composition. Rayfuse and Jones (1993) uniformity in farmers' fields is much higher, because a small number of cultivars are deployed. There are many cultivars available, but few dominate. For example, in 1995, nearly 80% of Idaho's white wheat production was planted to Stephens and Penawawa. Washington's production is dominated by Madsen, with Eltan and Stephens also occupying substantial acreages.

Genetic diversity is usually thought of as the amount of genetic variability among individuals of a cultivar, population, or species (Brown, 1983). Although genetic vulnerability may result from a reduction in genetic variability, it is known that genetic diversity per se does not prevent vulnerability unless that diversity includes genetic resistance to the particular pathogen or stress causing the problem. This does not mean breeders should not strive for genetic diversity in cultivars released; however, in the absence of unusual disease or environmental stress, breeders tend to concentrate on crosses of elite lines and cultivars, thus reducing genetic diversity of newly released cultivars. Breeders utilize only a small portion of the vast germplasm resources available because of a lack of information about the characteristics of accessions in the collections and because of the difficulty of transferring some of the traits from an exotic genotype to cultivated wheat.

C. Impediments to Maintaining and Augmenting Genetic Diversity:

There are several factors that restrict genetic diversity of U.S. wheat cultivars. Our 1989 CAC report cited as one factor the current grain classification system that uses morphological characteristics of kernels to classify wheat. Development of the automated single-kernel grain classification system and other new methodologies promises partially to alleviate this restriction on germplasm use. In 1989, we also mentioned " the lack of efficient techniques for the transfer of genes from one species to another" as a restriction on " the use of new genetic variation for germplasm enhancement activities." Today, the routine use of techniques such as embryo rescue, manipulation of chromosome pairing, molecular cytogenetics, and molecular mapping is increasing the rate at which introgression is producing useful germplasm.

Quarantine restrictions on 'flag smut' and 'Karnal bunt' countries continues to place severe limits on the flow of germplasm between the U.S. and those countries. The problem is exacerbated by the current lack of research on smut diseases of wheat on the U.S. Some of the most valuable germplasm in the world is virtually ignored by the U.S. wheat breeders due to the difficulty of satisfying important requirements.

The CGC has conducted lengthy discussions regarding our potential role in encouraging and/or facilitating US breeders' success to elite international germplasm. The primary motivation has been the demise of several international nurseries that once served this function. Wheat breeders also requested our assistance (Peterson and Busch, 1994; Appendix V). We considered a range of options, from soliciting foreign breeding lines that would be deposited temporarily (3 years) in NPGS and distributed to breeding programs, to setting up a "listserv" system on the Internet, through which individual breeders could notify others when that obtained new germplasm, and offer to share it.

Unfortunately, our plans have foundered on the shoals of intellectual property rights. There is considerable apprehension that materials would be distributed without originators' permission, or that distribution will require complicated arrangements. However, feeling that encouragement of germplasm exchange is needed now more that ever, the CGC is still looking for a workable system. Probably the ideal situation would be to revive and expand the international nurseries (Peterson and Busch, 1994; Appendix V), but long-term commitment of resources would be necessary.

Ultimately, the growing controversy regarding germplasm ownership by public and private institutions as well as countries, and the resulting reluctance to share germplasm resources, could become the most serious of any that stands in that way of increasing diversity of the US wheat gene pool. Intellectual property rights issues will become even more complex as transgenic wheat germplasm becomes more commonplace. It is not clear whether biotechnology will increase or decrease the incentive to collect, preserve and evaluate wheat germplasm.

IV. GERMPLASM NEEDS

A. Collection Needs:

There is a need for stable nomenclature and a modern taxonomic monograph of *Triticum*, including wild but especially cultivated wheats. This is particularly so since the monograph *Wild wheats: a monograph of* Aegilops *L. and* Amblyopyrum (*Jaub and Spach)* Eig (*Poaceae)* by M.W. van Slageren (1994), was published by ICARDA and Wangeningen Agricultural University (excerpt in Appendix IV).

The germplasm system of the USDA has always recognized *Aegilops* (goat grasses) as a genus separate from *Triticum* (wild wheats *sensu strictu*). In this it mirrors the treatment in the botanical floras in countries (including the United States and Canada) in which goat grasses of wild wheats grow wild. There is a need for the wheat geneticists and biotechnologists to reassess their position of calling everything *Triticum*, now that the new taxonomic treatment by van Slageren retains *Aegilops* and *Amblyopyrum* as distinct from *Triticum.*

The recommended new monograph of *Triticum,* the need for which was stressed at the Nomenclature Workshop at the International Wheat Genetics Symposium, in Beijing, China, in 1993, should deal with hundreds and thousands of cultivated forms recognized by European, Russian, and other taxonomists, mostly described in this century since the pioneering studies of Vavilov.

Russian scientists recognize eight or more morphotypes that might make a useful system to handle cultivated material. This system needs to be translated and assessed. There is a need to encourage managers of local germplasm databases to continue or start computerizing their records. Then there is a need for a global database. There are still many large, local germplasm collections whose records are not on computer or are incomplete.

Use of geographic information system (GIS) in germplasm collections should be encouraged; this will be especially useful for a global database.

There is a need to collect indigenous knowledge and knowledge of how and why farmers grow landraces and primitive wheats. This can be considered ethnoargriculture, ethnobiology, or ethnobotany. We need to understand what selection procedures, if any (and many farmers may not be practicing conscious selection), are being undertaken by farmers for plants, spikes or seed.

Although considerable wild and landrace wheat germplasm was collected since 1989, especially by agencies not involved with the USDA, there are still large gaps in the world collections. The reasons why Croston and Williams (1981) assigned first priority to wheat among all crops for collection and preservation still pertain. Wild wheats and landraces, especially material adapted to microhabitats, are rapidly disappearing because of the introduction of agronomically superior new cultivars. Severe overgrazing by huge flocks of sheep and goats in the Near East can in a very few years wipe out later flowering *Aegilops* and *Triticum* species in preference to earlier-flowering, wild, annual barley, perennial barley (*Hordeum bulbosum*), and wild oats, which are less affected by animal grazing. Moreover, the direct wild ancestors of cultivated wheats, namely *Aegilops speltoides, Triticum urartu, T. monococcum* ssp. *aegilopoides, T. turgidum* ssp. *dicoccoides* and *T. timopheevii* ssp. *armeniacum* are especially susceptible to overgrazing and to increased cultivation of previously seasonal grasslands. We still need to preserve as much of the existing genetic variation as possible for future breeders and consumers to ensure availability of genes for yield and tolerance to environmental and biological stresses.

There are still three major and critical collections needs for wheat germplasm. The first is continued collection of wild relatives of wheats on the regions where they are native. The second need is for landraces in places such as Guatemala, where these have not been collected before. The third need is for the acquisition of improved germplasm from breeding programs in the United States and new cultivars from foreign countries.

The center of variation for wild wheat relatives includes Egypt, Israel, Jordan, Lebanon, Syria, Turkey, Armenia, Azerbaijan, Iraq, Iran, Afghanistan, and the Turkic Republics of Central Asia. Some of these countries are not easily accessible to U.S. citizens. However, they might be accessible to people of other nationalities. The range of distribution of wheat relatives occurs from the Canary Islands to Western China, and from southern Russia to Northern Pakistan and India (van Slageren, 1994). One potentially effective way of obtaining germplasm from countries with which free exchange is difficult might be to offer assistance with biotechnology (e.g., probes, recombinant libraries, and technological assistance).

The principal regions that are accessible to U.S. And are considered high priority for collection include the following:

1. **Former Yugoslavia, Albania, and Greece:** Countries relatively accessible and which contain 13 species of wild wheat relatives such as *Aegilops uniaristata* and associate

species, some of which possess heavy metal tolerance. The original collection site of *Ae. uniaristata* in Turkey is now absorbed into the suburbs of Istanbul. However, effort should be made to find this taxon at other adjacent locations in European and Asiatic Turkey.

2. **Western Mediterranean:** The countries include Portugal, Spain, Southern France, Morocco (Algeria), and Tunisia. Most are accessible, and they harbor eight or more species. In northern Portugal, there are landraces of wheat and rye adapted to unidentified soil problems. There are also primitive wheats such as spelt, dococcum, and monococcum that are still grown in Spain for specific culinary or animal uses. In North Africa, there are landraces of diploid, tetraploid, and hexaploid wheats that may exhibit physical environmental stress tolerances. Collections of *Ae. bicornis* from coastal areas of Egypt and Cyprus, in the Eastern Mediterranean, might be useful as a source of salt tolerance.
3. *Ae. tauschii* is the donor of the DD genome to bread wheat. Its chromosomes have already been connected with several genes for physical and biological stress tolerance, as well as flour-quality characteristics. Recently, agronomists working out of ICARDA found Ae. *tauschii* var. *meyerii* growing in the **Syrian desert** in the area near Rasafa. It grows as a weed in wheat and Barley fields to receive runoff during winter rains. Temperatures in this area rise quickly in mid to late spring. It is important to determine the extent of the two tetraploid companion species *Ae. crassa* and *Ae. vavilovii. Ae. tauschii* also grows in more mesic areas in **southeastern Turkey, the northern regions of Iraq, Iran, and Afghanistan, and into western China.** It may follow the so-called Silk Road form India to China. However, the most drought- and heat-stressed of these areas appear to by the Syrian Desert.
4. **Outer Mongolia, Tibet, Nepal:** Keith Briggs reported early maturing wheats from Mongolia. Are these landraces or improved Soviet wheats?
   Tibet: the landraces of wheats and barley in Tibet should be re-collected through the proper channels in China. The seed from the original collection in the 1990s, by CIMMYT, ICARDA and Canada, has never been received. The seed was to be grown out at Beijing first. Nepal: there are landraces of wheats and barley in the foothills of the Himalayas that have never been collected.
5. **Guatemala, Honduras, Peru, Bolivia:** There are landraces in wheats on all of countries that should be colleted. They may date from early introductions by the Spanish.
6. **Eritrea:** There are landraces of durum and possibly bread wheats in this area of northeastern Africa.
7. **Niger:** Wheats reported to be grown as paddy systems in the Niger river basin. This system needs to by checked out and germplasm collected to ascertain whether it is useful in areas with a high water table.
8. A very important area that in not accessible to the U.S. citizens is **Iran** with 17 species. Although Many landraces of wheats were collected in Iran and were available before and after the Islamic revolution, wild wheats and *Aegilops* from Iran are still largely uncollected and unknown. There is no botanist in Iran who is known to have a major interest in wild *Triticum* and *Aegilops.* Few agronomists in Iran have an interest in collecting wheats outside of farmers' fields. The USDA collection has one accession of *Triticum urartu,* the A-genome donor to durum and bread wheat from the mountains near Isfahan, and one collection from the Mountains near Shiraz. So the material is known to be there. The mountainous area between Kerman Shah, Isfahan, and Shiraz needs to be collected for *Aegilops, speltoides, T. urartu, T. monococcum* ssp. *aegilopoides, T. turgidum* ssp. *dicoccoides and T. timopheevii* ssp. *armeniacum*, as well as other species of *Aegilops.* We do not know how far wild wheats extend south of Shiraz. In the Iranian desert east of the Zagros mountains there are drought-tolerant and salt-tolerant goat

grasses that have been little collected. Another promising area is the mountain chain that runs from Isfahan to Yazd to Kerman to Bam.

B. Preservation Needs:

Storage facilities at Aberdeen and Ft. Collins are adequate for the foreseeable future. Several upright freezers will be utilized at Aberdeen to store certain on the Triticum species to prolong storage for the more difficult -to-grow and less-requested accessions.

C. Evaluation Needs:

The systematic evaluation of accessions in the NSGC should continue at the present pace (at least) until all accessions are evaluated for each of the descriptors. The descriptors are reviewed annually by the Wheat CGC, and occasionally a descriptor may be added. In some cases, the data are already available; however, some may require some additional evaluation. As an example , if a new disease or race of a pathogen appeared and resistance was unknown or rare, it would be important to identify resistant accessions. Screening of the entire collection for powdery mildew has been initiated by ARS, Raleigh, NC, and should continue to be funded until completed. Other screenings that are at a more advanced stage also should be completed.

There is a need to assess wild, primitive, and landrace material for a range of physical and biological stresses, and agronomic and product-related characters. We will continue to work toward standardization of evaluation-trial methodology so that data from different trials will be comparable. There are gaps in descriptors for many lines, sometimes for some basic traits such as head type. A priority is to complete data collection on such basic agronomic and plant descriptors. We also need development of an image database of spikes and seeds. This would be placed on the GRIN computer and viewable via the WWW.

D. Enhancement Needs:

The need for increased efforts in wheat germplasm enhancement is strong and well-documented. In 1995, the national Wheat Improvement Committee sent a survey to state experiment stations and private firms involved in wheat research, in order to determine the highest priorities for future research. One questionnaire was sent to each state or firm, asking for a ranking of the top six priority research areas out of 22, according to the consensus of wheat workers in that organization. The category “genetics and breeding of germplasm” ranked among the top six priorities for 24 out of 27 responding organizations. For organizations identifying this area as a priority, the average rank was number 2 out of 22 items.

The most critical need for alien genetic sources is in providing resistance to diseases for which the range naturally occurring variation in common wheat is extremely narrow. These diseases include Fusarium head scab, take-all, Stagonospora glume blotch, tan spot, Cephalosporium stripe, eyespot, barley yellow dwarf, wheat streak mosaic virus, and dryland footrot.

Gene development and race-nonspecific resistances are short lived, necessitating constant replacement of otherwise highly desirable varieties. Although disease resistance is paramount in most breeding programs nation-wide, other factors such as insects , abiotic stresses, grain yield, adaptability and end-use quality are also being studied and improved.

V. RECOMMENDATIONS

Priorities assume the continuation of support of existing germplasm activities at the current level or higher. In addition, portions of the priority activities listed below should be carried out simultaneously rather that successively.

A. Priorities:

1. Collection and evaluation of wild relatives.
2. Encouragement of international germplasm exchange, especially of elite material
3. Germplasm enhancement

B. Type and level of support:

Collection:

Wild relatives: a minimum of six trips, of 3 to 4 weeks' duration each, would be required to sample the indicated regions. The total cost of these trips would be approximately $12,000 to $15,000 each. That would include two scientists, local expenses, shipping, airfare, etc. Of course a smaller number of the most critical countries could be visited at a lower expense.

Germplasm exchange:

The best mechanisms to foster free germplasm exchange are international evaluation nurseries. We recommend renewal of the International Winter Wheat Performance Nursery (IWWPN), terminated in 1991, and initiation of an analogous nursery for spring wheats (the later would increase germplasm circulation where it is now restricted because of Karnal bunt-inspired quarantine). The annual cost of operating these nurseries currently would be approximately $250,000.

Germplasm enhancement

Continued or increased funding of germplasm enhancement is critical to carrying out a nation wide mandate of wheat production and use that requires fewer inputs and moves toward sustainability. NPGS has not directly funded enhancement in the past. However, the intense interest of the wheat-improvement community in germplasm enhancement (see Section IV. D.) justifies funding of such efforts, via a mechanism similar to that used to fund evaluation.

REFERENCES

Allan, R.E., C.J. Peterson, Jr., G.L. Rubenthaler, R.F. Line, and D.E. Roberts. 1989. Registration of 'Madsen' wheat. Crop Sci. 29:1575-1576.

Brown, W.L. 1983. Genetic diversity and genetic vulnerability-An appraisal. Econ. Bot. 37:4-12.

Chen, H.B., J.M. Martin, M. Lavin, and L.E. Talbert.1994. Genetic diversity in hard red spring wheat based on sequence-tagged-site PCR markers. Crop Sci. 34:1628-1632.

Clark, J.A., J.H. Martin, and C.R. Ball. 1992. Classification of American wheat varieties. USDA Bul. 1074, 238 pp.

Clark, J.A., J.H. Martin, and K.S. Quisenberry.1929. Distribution of the varieties and classes of wheat in the United States. U.S.D.A. Bul. 1498, 68 pp.

Cox, T.S. 1991. The contribution of introduced germplasm to the development of U.S. wheat cultivars. p. 114-144 *In* H.L. Shands and L. Wiesner (eds.) *The Use of Plant Introductions in Cultivar Development,* Crop Science Society of America. Madison, WI.

Cox, T.S., J.P. Murphy, and D.M. Rogers. 1986. Changes in genetic diversity in the red winter wheat regions of the United States. Proc. Natl. Acad. Sci. USA 83:5583-5586.

Croston, R.P. and J.T. Williams (eds.) 1991. A world survey of wheat genetic resources. IBPGR, FAO, Rome.

International Board of Plant Genetic Resources. 1990. Directory of Germplasm Collections:3. Cereals.

Kimber, G. and M. Feldman. 1987. Wild Wheat: An Introduction. Spec. Rpt. No.353, Univ. of Mess. Agric. Expt. Sta., 150 pp.

National Association of Wheat Growers. 1995. Wheat Facts. NAWG.

Peterson, C.J., and R.H. Busch. 1995. International wheat germplasm exchange: status and future. In C.J. Peterson(ed.) Proceeding of the North American Wheat Workers' Workshop. Mar. 7-9, 1994, Kansas City, MO. Natl. Wheat Improvement Committee.

Rayfuse, L.M. and S.S. Jones. 1993. Variation at the *Glu-1*lici in club wheats. Plant Breeding 111-89-98.

Siegenthaler, V.L., J.E. Stepanich, and L.W. Briggle. 1986. Distribution of the varieties and classes of wheat in the United States, 1984. U.S.D.A. Statistical Bulletin No. 739.

Vavilov, N.I. 1926. Studies on the origins of cultivated plants. Bull. Appl. Bot. Plant Breed. 16:1-245.

van Slageren, M.W. 1994. *Wild wheats: a monograph of* Aegilops L. *and* Amblyopyrum (*Jaub and Spach) Eig (Poaceae).* ICARDA and Wangeningen Agricultural University. Papers 94-7.

APPENDIX I
Wheat Germplasm Collections Worldwide
(Intl. Board Plant Genet. Resources, 1990)

Country	Location	Approx. no. accessions
Australia	Aus.W. Cereal Coll.	22,686
Brazil	EMBRAPA-CNPT	9000+
Bulgaria	IIPGR “K Malkov	7388
Canada	PGRC	7500+
China	CAAS-ICGR	9400+
Czech Rep	RIPP	7900+
Ethiopia	PGRC	10,745
France	INRA	3000+
Germany	Gatersleben-IPK	16,990
	Braunschweig	15,839
Hungary	RCA Tapioszele	7500+
India	NBPGR	16,440
Israel	Volcani	14,150
Italy	Bari	32,000
Japan	NIAR Tsukuba	7000+
	Kyoto	4378
Netherlands	Wageningen	6200
Nordic Gene Bank	?	
Poland	Warsaw	7500
Russia	VIR	50000+
Turkey	Izmir	4186
UK	AFRC	9817

Appendix II
NSGC DISEASE EVALUATIONS ON GRIN-WHEAT

Character	Years	Location	Number of Accessions
Barley Yellow Dwarf Virus	1985-92	Davis, CA	2,287
Barley Yellow Dwarf Virus	1988-94	Urbana, IL	17,517
Soilborne Mosaic Virus	1985-89	Urbana, IL	6,587
Leaf Rust	1983-89, 91-95	Manhattan, KS	38,753
Stripe Rust – Adult	1984-94	Mt.Vernon, WA	30,525
Stripe Rust – Adult	1984-95	Pullman, WA	21,803
Stripe Rust – Cdl 17	1984-95	Pullman, WA	15,455
Stripe Rust – Cdl 20	1984-95	Pullman, WA	12,508
Stripe Rust – Cdl 25	1984-95	Pullman, WA	1,682
Stripe Rust – Cdl 27	1984-95	Pullman, WA	14,511
Stripe Rust – Cdl 29	1984-95	Pullman, WA	14,259
Stripe Rust – Cdl 37	1984-95	Pullman, WA	1,851
Stripe Rust – Cdl 43	1984-95	Pullman, WA	1,805

Stripe Rust – Cdl 45	1984-95	Pullman, WA	1,880
Rust – Adult	1987-94	Rosemount, MN	8,078
Stem Rust – Adult	Stem 1987-94	St. Paul, MN	19,141
Stem Rust – HJCS	1987-92	St.Paul, MN	4,342
Stem Rust – QFBS	1987-92	St.Paul, MN	8,639
Stem Rust – QSHS	1987-92	St.Paul, MN	4,455
Stem Rust – RHRS	1987-92	St.Paul, MN	4,312
Stem Rust – RTQQ	1987-92	St.Paul, MN	8,973
Stem Rust – TNMH	1987-92	St.Paul, MN	4,402
Stem Rust – TNMK	1987-92	St.Paul, MN	8,938
Stem Rust – HNLQ	1987-92	St.Paul, MN	4,705
Stem Rust – RKQS	1987-92	St.Paul, MN	4,682
Stem Rust – Genes	1987-92	St.Paul, MN	1,018
Common Bunt – R36	1981-92	Aberdeen, ID*	74
Common Bunt – R39	1981-92	Aberdeen, ID*	1,422
Common Bunt – R43	1981-92	Aberdeen, ID*	318
Common Bunt – T-1	1981-92	Aberdeen, ID*	6,301
Common Bunt – Multiple	1981-95	Aberdeen, ID*	11,093
Dwarf Bunt	1978-95	Aberdeen, ID+	9,033
Septoria nodorum	1970-78	Bozeman, MT	8,095

* 1985-86 Pendleton, OR.

+ Field tests are conducted at Logan, UT by Aberdeen ARS staff.

Appendix III

NSGC INSECT EVALUATIONS ON GRIN – WHEAT

Character	Years	Location	Number of Accessions
Hessian Fly – B	1983-94	West Lafayette, IN	449
Hessian Fly – C	1983-94	West Lafayette, IN	24,165
Hessian Fly – E	1983-94	West Lafayette, IN	24,149
Hessian Fly – GP	1983-94	West Lafayette, IN	14,441
Hessian Fly – L	1983-94	West Lafayette, IN	5,864
Russian Wheat Aphid (RWA)	1988-95	Stillwater, OK	40,475

NSGC AGRONOMIC, TAXONOMIC, & QUALITY EVALUATIONS ON GRI –WHEAT

Character	Years	Location	Number of Accessions
Growth Habit	1987-94	Aberdeen, ID	37,992

Chromosome Number	1988-91	Columbia, MO	519
Market Class			921
Lysine Content	1966-69	Lincoln, NE	10,367
Awn Color	1983-94	Aberdeen, ID & Maricopa AZ	20,477
Awn Type	1983-94	Aberdeen, ID & Maricopa AZ	24,614
Glume Color	1983-94	Aberdeen, ID & Maricopa AZ	20,521
Glume Pubescence	1983-94	Aberdeen, ID & Maricopa AZ	22,329
Heading Date	1983-94	Aberdeen, ID & Maricopa AZ	16,018
Kernel Color	1983-94	Aberdeen, ID & Maricopa AZ	19,993
Leaf Pubescence	1983-94	Aberdeen, ID & Maricopa AZ	20,890
Plant Height	1983-94	Aberdeen, ID & Maricopa AZ	19,508
Shattering	1983-94	Aberdeen, ID & Maricopa AZ	10,637
Spike Density	1983-94	Aberdeen, ID & Maricopa AZ	13,681
Spike Type	1983-94	Aberdeen, ID & Maricopa AZ	13,498
Straw Breakage	1983-94	Aberdeen, ID & Maricopa AZ	16,831
Straw Color	1983-94	Aberdeen, ID & Maricopa AZ	19,624
Straw Lodging	1983-94	Aberdeen, ID & Maricopa AZ	23,077

APPENDIX IV

Tables 1 to 3 from *Wild wheats: a monograph of* Aegilops *L. and* Amblyopyrum (*Jaub and Spach) Eig (Poaceae)* by M.W. van Slageren; attached

APPENDIX V

copy of Peterson & Busch (1994); attached

APPENDIX IV

Table 1. Summary of accepted taxa in the primary and (partially secondary gene pools of cultivated wheat.

Aegilops L. (1753)
--Ploidy level: diploid, tetraploid, hexaploid; genome types: C, D, M, N, S, U
--22 species, 5 autonym varieties, 5 nontypical varieties
--Type species: *Aegilops triuncialis* L.

Amblyopyrum (Jaub. & Spach) Eig. (1929)
-- Ploidy level: diploid; genome types: T
--1 species, 1 autonym variety, 5 nontypical varieties
--Type species: *Amblyopyrum muticum* (Boiss.) EIG

Triticum L. (1753)
-- Ploidy level: diploid, tetraploid, hexaploid; genome types: A, B, D, G
--6 species, 4 autonym varieties, 13 nontypical varieties
--Type species: *Triticum aestivum* L.

Table 2. Taxa recognized in the genera ***Aegilops*** and ***Amblyopyrum*** and their basionyms or most widely knows synonyms.

Taxon	Basionym (B) and/or most common synonym
Genus ***Aegilops*** L.	S: *Triticum* L. *pro parte*
Sections of ***Aegilops***	
1. Sect. *Aegilops*	S: *Aegilops* L. sect. *Surculosa* Zhuk.
2. Sect. *Comopyrum* (Jaub. & Spach) Zhuk.	B: *Aegilops* L. subg. *Comopyrum* Jaub. & Spach
3. Sect. *Cylindropyrum* (Jaub. & Spach) Zhuk.	B: *Aegilops* L. subg. *Cylindropyrum* Jaub. & Spach
4. Sect. Sitopsis (Jaub. & Spach) Zhuk.	B: *Aegilops* L. subg. *Sitopsis* Jaub. & Spach
5. Sect. *Vertebrata* Zhuk. emend. Kihara	(no basionym. Emendation of sect. Vertebrata Zhuk.
Species of ***Aegilops***	
1. *Aegilops bicornis* (Forssk.) Juab. & Spach	B: *Triticum bicome* Forssk.
var. *bicornis*	
var. *anathera* Eig	S: *Aegilops bicornis* (Forssk.) Juab. & Spach var. *millica* (Asch.) Eig
2. *Aegilops biuncialis* Vis.	S: *Aegilops lorentii* Hochst.
3. *Aegilops caudata* L.	S: *Aegilops markgrafii* (Greuter) Hammer S: *Aegilops dichasians* (Bowden) Humphries
4. *Aegilops columnaris* Zhuk.	--

As *Aegilops* has been considered frequently, both in floristic treatments and especially in (cyto-)genetic studies as a part of an emendated genus *Triticum*, the correct names under both genera are presented (Table 3.).

The separate generic status of *Aegilops* is both practical and also in accordance with the 'Gene pool concept of Harlan & de Wet (1971). In this concept, *Aegilops* and *Amblyopyrum* constitute most of the secondary gene pool (or GP-2) of wheat.

Wageningen Agric. Univ. Papers 94-7 (1994)

Table 3. Genomic formula and synonyms when *Aegilops* and *Amblyopyrum* are placed with *Triticum* emend.

1. *Aegilops bicornis* (Forssk.) Juab and Spach	$\mathbf{S^b}$	*Triticum bicome* Forssk.
2. *Aegilops biuncialis* Vis.	**UM**	*Triticum macrochaetum* (Shuttlew. & A.Huet ex Duval-Jouve) K.Richt..
3. *Aegilops caudata* L.	**C**	*Triticum dichasians* Bowden
4. *Aegilops columnaris* Zhuk.	**UM**	*Triticum coulumnare* (Zhuk.) Morris & Sears, comb. Nov.
5. *Aegilops comosa* Sm. In Sibth. & Sm.	**M**	*Triticum comosum* (Sm. In sibth. & Sm.) K. Richt.
6. *Aegilops crassa* Boiss. (4x)	**DM**	*Triticum crassum* (Boiss.) Aitch. &

	DDM	Hemsl.
7. *Aegilops cylindrica* Host	**DC**	*Triticum cylindricum* (Host) Ces., Pass. & Gibelli
8. *Aegilops geniculata* Roth	**MU**	*Triticum ovatum* (L.) Raspail
9. *Aegilops juvenalis* (Thell.) Eig	**DMU**	*Triticum juvenale* Thell.
10. *Aegilops kotschyi* Boiss.	**SU**	*Triticum kotschyi* (Boiss.) Bowden
11. *Aegilops longissima* Schweinf. & Muschl	**S^l**	*Triticum longissimum* (Schweinf. & Muschl) Bowden
12. *Aegilops neglecta* Req. ex Bertol (6x)	**UM**	*Triticum neglectum* (Req. Ex Bertol.) Greuter
	UMN	*Triticum recta* (Zhuk.) Chennav.
13. *Aegilops peregrina* (Hack. In J. Fraser) Maire & Weiller	**SU**	*Triticum pereginum* Hack. in J. Fraser
14. *Aegilops searsii* Feldman &Kislev ex Hammer	**S^s**	*Triticum searsii* (Feldman and Kislev) Feldman, *comb. nov.*
15. *Aegilops sharonensis* Eig	**S**	*Triticum longissimum* (Schweinf. & Muschl) Bowden ssp. *sharonense* (Eig) Chennav.
16. *Aegilops speltoides* Tausch	**S**	*Triticum speltoides* (Tausch) Gren. Ex K.Richt.
17. *Aegilops tauschii* Coss.	**D**	*Triticum aegilops* P.Beauv. ex Roem. & Schult.
18. *Aegilops triuncialis* L.	**UC**	*Triticum triunciale* (1.) Rasp. (var. *triunciale)*
19. *Aegilops umbellulata* Zhuk.	**U**	*Triticum umbellulatum* (Zhuk.) Bowden
20. *Aegilops uniaristata* Vis.	**N**	*Triticum uniaristata* (Vis.)K.Richt.
21. *Aegilops vavilovii* (Zhuk.) Chennav. (6x)	**DMS**	*Triticum syriacum* Bowden (6x)
22. *Aegilops ventricosa* Tausch	**DN**	*Triticum ventricosum* (Tausch) Ces., Pass. & Gibelli