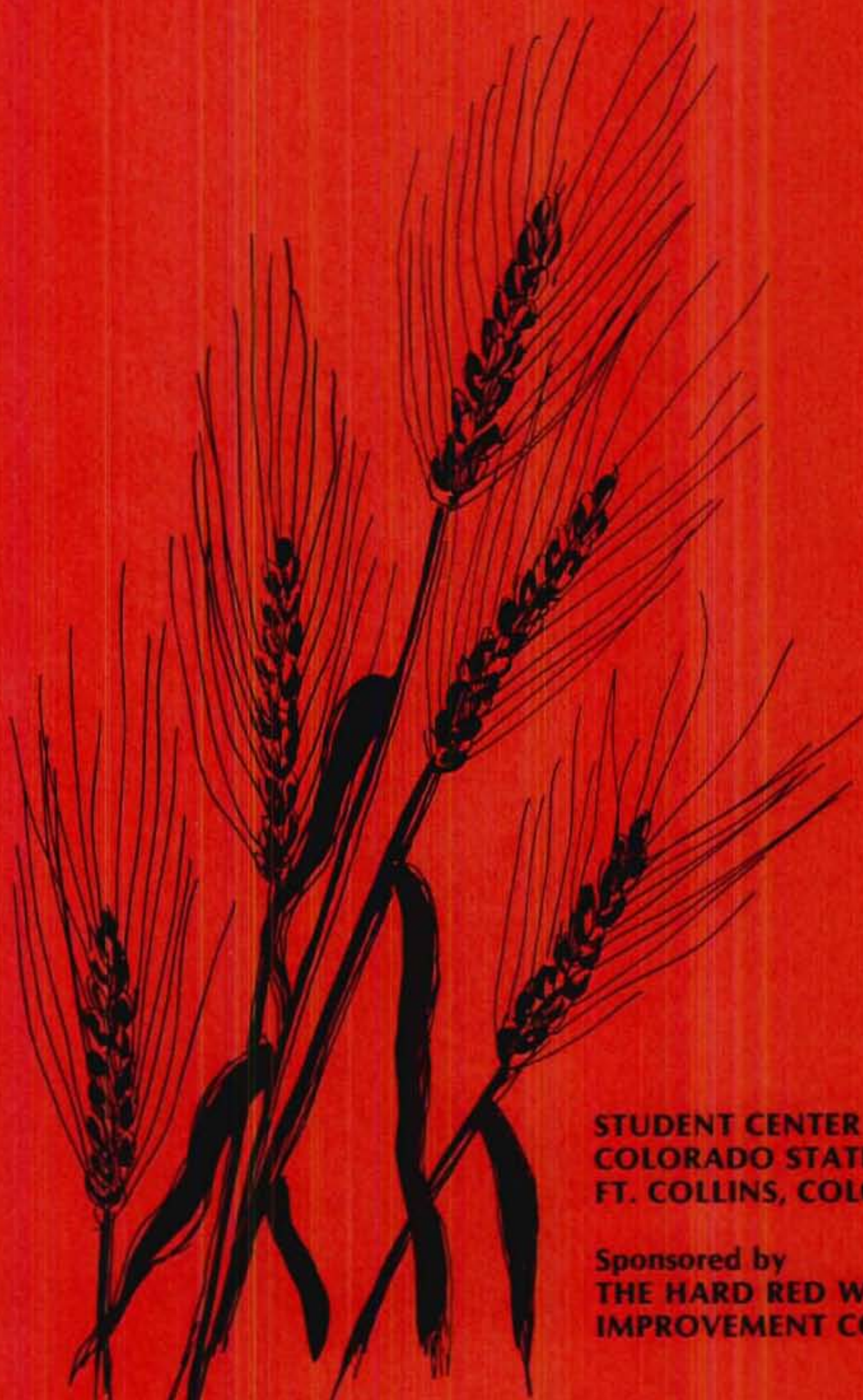
PROCEEDINGS

FIFTEENTH HARD RED WINTER WHEAT WORKERS CONFERENCE

FEBRUARY 12-14, 1980



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COLORADO STATE UNIVERSITY
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THE HARD RED WINTER WHEAT IMPROVEMENT COMMITTEE

UNITED STATES DEPARTMENT OF AGRICULTURE

Science and Education Administration
Agricultural Research

and

State Agricultural Experiment Stations

in the

Hard Red Winter Wheat Region

PROCEEDINGS

OF THE

FIFTEENTH HARD RED WINTER WHEAT WORKERS CONFERENCE

Colorado State University
Ft. Collins, Colorado
February 12-14, 1980

Report not for publication[1]

Agronomy Department
Nebraska Agricultural Experiment Station
Lincoln, Nebraska
April, 1980

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FOREWORD

This was the Fifteenth Regional Conference of workers in the hard red winter wheat region since the organization in 1929 of the cooperative state-federal regional program of hard winter wheat investigations. The conference, which usually is held at 3-year intervals, is sponsored by the Hard Red Winter Wheat Improvement Committee. Wheat workers from 20 states, 4 provinces of Canada, and 7 commercial seed companies participated.

The program of the Fifteenth Regional Conference was a departure from prior conference programs. It focused in its entirety on the problem of winter survival of winter wheat. In six sessions the nature of winter injury, the hardening process, evaluation techniques, pest interactions, breeding and genetics, and crop management in relation to winter survival were examined.

A special note of recognition and thanks goes to our Canadian colleagues who made a major contribution to the program. A special word of thanks also goes to John Erickson and members of his committee who organized the highly successful program. The excellent conference arrangements made by the local organizing committee likewise are recognized and commended.

A highlight of the conference was the special recognition of Dr. Ernie Sears for his many significant contributions to winter wheat improvement. All were delighted that Ernie and Lotti could be with us on this occasion.

This proceedings contains abstracts of most presentations made in the several sessions. It does not adequately reflect the full scope of the presentations and dialogue during the conference.

— V. A. Johnson
Secretary, HRWW Improvement Committee
and
Technical Advisor, HRWW Region

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Wichita, Kansas
John W. Schmidt
Lincoln, Nebraska
G. Allan Taylor
Bozeman, Montana
Brian Fowler
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Local Arrangements

Byrd C. Curtis
Ft. Collins, Colorado
James R. Welsh
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A TRIBUTE TO ERNIE SEARS

presented at
the Conference Banquet

Contribution from Rosalind Morris, University of Nebraska

It is a high privilege to be entrusted with this program of tribute to Dr. E. R. Sears, and at the same time a challenge to present the many facets of a brilliant career. In this challenge I am pleased to have the participation of two eminent colleagues, Dr. Gordon Kimber, University of Missouri, and Dr. Shivcharan S. Maan, North Dakota State University. We have dissected Ernie's contributions to science into three parts. I shall begin with his deeds in mapping chromosomes. Shivcharan will discuss Ernie's ideas and achievements in broadening wheat's genetic base with alien genes. Gordon will develop Ernie's concepts on the evolution of wheat and the relationships among its basic sets of chromosomes.

In the beginning there was Chinese Spring. This variety has most of the characteristics that plant breeders shy away from but it does have a propensity to cross with rye. However, when Ernie used it for this purpose in the 1930's, it refused to cross with rye but produced two puny haploids. I expect most of us would have discarded the haploids, but Ernie must have sensed a new direction in his research when a few seeds resulted from crossing one of the haploids to normal Chinese Spring. From these seeds came his first monosomics. The course was set. Ever after, there was great togetherness between Ernie and his Chinese Spring monosomics as well as their products.

In the decade of the 1940's, with insight and persistence, Ernie obtained and identified the 21 monosomics of hexaploid wheat and, through self pollination of the monosomics, the 21 nullisomics, even though they occurred with a very low frequency. In 1954, he published a cytogenetic classic, "The aneuploids of common wheat." About one-third of the bulletin involves descriptive comparisons between the nullisomics and the disomics in Chinese Spring. With his meticulous powers of observation, Ernie was able to accumulate over 100 gene-chromosome associations by attributing differences between the nullisomics and the disomics to genes on the missing pairs of chromosomes.

From the misbehavior of the monosomics, Ernie obtained one-armed chromosomes, the telochromosomes. By comparing the phenotypes of a nullisomic plant and a plant with one arm of the missing chromosome added, he could define the relationship between genes and chromosomes in terms of chromosome arms rather than whole chromosomes. In the early 1960's, Ernie suggested the use of telochromosomes to locate a gene on the physical chromosome arm in relation to the centromere. Prior to his suggestion, it had been very difficult to tie a gene to a segment of the physical chromosome in wheat. Now, a number of wheat genes have been mapped not only to chromosome arms but within arms. At this point I would like to pay tribute to Dr. Lotti Sears, who has made some valuable studies on the behavior of telochromosomes. She and Ernie have worked as an effective team. They have a significant paper in the Proceedings of the Fifth International Wheat Genetics Symposium, in which they describe the 42 identified telochromosome stocks in Chinese Spring.

In 1953, Ernie published a short paper, "Nullisomic analysis in common wheat", in the American Naturalist. In it, he outlined four methods for locating genes on wheat chromosomes. This paper has remained a standard for reference down to the present. He showed how nullisomics or, more often, monosomics could be used in crosses to associate genes for specific characters with their respective chromosomes in the second or third generation. He used his mathematical and cytological abilities to reduce progeny size to a reliable low number. One of the methods he outlined was the substitution of chromosomes between varieties. This procedure has been especially valuable in locating genes for characters with a complex type of inheritance.

A hallmark of Ernie's career has been his consistent generosity in sharing his aneuploid materials with scientists throughout the world. He is truly an international ambassador of goodwill among scientists.

Wheat Gene-Chromosome Associations

Character	Number of Studies	% with Chinese Spring Aneuploids
Awn	127	76
Culm, Height, Tiller	536	77
Disease, Insect	310	80
Enzyme	291	98
Fertility	133	66
Kernel	566	79
Leaf	164	85
Maturity	115	90
Spike	354	76
Vernalization, Cold	95	98
Yield	40	87
Miscellaneous	279	84
Total	3010	81

Years		Papers involving Aneuploids
up to 1965		56
1966 - 1970		92
1971 - 1975		209
1976 - 1980		292
	Total	649
	83% used	Chinese Spring Aneuploids

Contribution from Shivcharan S. Maan, North Dakota State University

It gives me great pride in being a part of this program honoring Dr. Ernie Sears.

One important phase of Dr. Sears' life-long research has been the study of interspecific and intergeneric hybrids involving tetraploid or hexaploid wheats and related species. Since polyploidy was already known to be a significant evolutionary process in the origin of plant species, the artificial synthesis of hexaploid wheat raised the hopes that some of the artificially produced amphiploids might prove to be useful as new crop species. A large number of amphiploids were produced in the U. S. A., Europe and the USSR with high hopes of obtaining a new crop plant species. However, none of the amphiploids proved to be directly useful, but Dr. Sears and others have used them as sources of alien chromosomes with desirable genes that could be transferred to wheat. Wheats with alien chromosome(s) also were not directly useful as wheat cultivars; the addition lines were incompletely fertile and were cytologically unstable and substitution lines were relatively more stable and fertile but neither could compete with control wheat cultivars in productivity and quality of grain. Still, the interest in possible use of wild relatives of wheat plants remained undiminished, because wild species of cultivated plants have always been considered to be the reservoirs of certain useful genes for resistance to cold, drought, and certain disease organisms. Therefore, it was considered that the transfer of a small alien chromosome segment with the desirable gene to a wheat chromosome would result in the improvement of wheat cultivars lacking these desirable traits.

This milestone was reached in 1956, when Dr. Sears demonstrated that x-rays can be used to transfer an alien chromosome segment to a wheat chromosome. At the Brookhaven Symposium in 1956, Dr. Sears presented in detail the procedures and results of several experiments in which he used x-rays to induce the transfer of a small segment of an _Ae._ _umbellulata_ chromosome having a gene for leaf rust resistance to a wheat chromosome. He had established beforehand that this alien chromosome did not pair with any of the wheat chromosomes and the male gametes with the complete alien chromosome had functional disadvantage. In these experiments, wheat plants with the Ae. umbellulata chromosome were given various x-ray treatments to induce chromosomal breaks and were allowed to have chance reunion between the broken ends of the alien and a wheat chromosome. The male gametes with the reconstituted wheat chromosome(s) having the gene for leaf rust resistance were selected by using pollen from the x-rayed plants. The expectation was that male gametes with a small alien segment would be transmitted normally, and others with a larger and less desirable segment would have functional disadvantage and would be transmitted at reduced rate. From these experiments, Dr. Sears recovered the desirable plants in which an Ae. umbellulata chromosome segment with the gene for leaf rust resistance was transferred to a wheat chromosome. Later, Dr. Sears conducted similar experiments in which a rye chromosome segment with a gene for hairy peduncle was transferred to a wheat chromosome by using x-ray treatments.

The use of x-rays to induce the alien transfer did not allow full control on the size of alien chromosome segment that was transferred to a wheat chromosome. Ideally, the transfer of only a very small alien segment with the desirable gene(s) and no other gene(s) to a homoeologous wheat chromosome should be the most desirable objective, since a larger alien segment may have undesirable gene(s) and the transfer of an alien segment to the chromosomes other than the homoeologous wheat chromosomes may have undesirable effects on wheat plants. The accomplishment of this objective became possible when another highly significant discovery was made in Dr. Sears' laboratory at Columbia, Missouri in 1957. Dr. Okamoto found that the absence of chromosome V (5B) affected meiotic pairing in wheat plants. A year later, Sears and Okamoto in the USA and Riley in UK reported that the absence of 5B induced pairing among the homoeologous chromosomes of the ABD genomes. These findings opened the way to experiments in which an alien chromosome could be induced to pair with the homeologous wheat chromosomes, either by eliminating the Ph gene on 5B or by suppressing the activity of the Ph gene in hybrids involving Ae. speltoides. Dr. Sears and others have successfully used these methods to induce the transfer of desirable genes from Ae. speltoides and Agropyron chromosomes to the wheat chromosomes.

In conclusion, I must confess that I have given a very brief account of some of Dr. Sears' accomplishments in the area of alien transfers for wheat improvement. Dr. Sears' accomplishments are truly monumental. I hope and wish that wheat cytogenetics will continue to be fun to Ernie Sears as he often says it has been, and his colleagues will continue to have the benefit of his guidance in formulating new research projects in making use of the aneuploid stocks and chromosome engineering techniques he has perfected.

Contribution from Gordon Kimber, University of Missouri

The contributions of E. R. Sears to wheat cytogenetics have been, and continue to be, both profound and prolific.

Perhaps the two most conspicuous conceptual efforts have been the recognition of the parental species that distinguish bread wheats from the macaroni wheats and the establishment of the homoeologous classification of wheat chromosomes.

The recognition of the phylogenetic history of any species as profound as wheat is of paramount importance in understanding the processes that will allow the introduction of desirable alien variation into the cultivated forms. The investigation of the evolutionary pathway is characteristically undertaken by making species hybrids and recording the chromosome pairing in the F_1. The precise identification of the D genome donor was made difficult by the barriers severely inhibiting the successful hybrid combination. Dr. Sears circumvented those difficulties by crossing the proposed species to tetraploid wheat, doubling the chromosome number of the F_1 and crossing the fertile, spelta-like amphiploid onto cultivated bread wheat. The observed chromosome pairing in this hybrid left no doubt whatsoever that the donor of the D genome was T. tauschii (Ae. squarosa). Subsequent work by several authors has, as may be anticipated, confirmed this early conclusion. Additionally, not only was this a precise proof of the phylogenetic pathway but it represented the vanguard of the use of colchicine in doubling the chromosome number of a hybrid to demonstrate species relationships.

Perhaps, initially, of a more theoretical nature but ultimately of considerable practical consequence was the fundamental conceptual contribution of the homoeologous groups and the difficult, painstaking and elegant proof by nullisomic-tetrasomic compensation. This study alone would rank Dr. Sears at the forefront of scientific endeavor.

Dr. Sears recognized early that the diploid divergence and polyploid convergence of wheat and its relatives must imply a unique genetical and cytological structure. Later it was assumed that this structure exists in other polyploid species also. The proof of this structure involved the detailed recognition of a complete range of types with varying, aneuploid constitutions. This alone could easily represent one worker's life work. After this collection and identification came the crossing and analysis of many combinations. Eventually the pattern, previously visualized, emerged of seven groups of three chromosomes, one member of each group having been derived from one of three diploid progenitors of bread wheat.

This conceptual framework and its elegant proof is unparalleled in any of the myriad of organisms studied by thousands of workers in this century. Such is the measure of the ideas, diligence and contribution of E. R. Sears.

THE NATIONAL PLANT GERMPLASM SYSTEM

Wilson H. Foote
National Plant Germplasm Committee

The NPGS is a coordinated network of institutions, agencies, research units and individuals in the United States which work cooperatively to introduce, maintain, evaluate, classify and distribute plant germplasm. Primary financial and administrative support for the System comes from the USDA-SEA and the SAES. Commercial breeding and seed trade interests also contribute and support the System.

The structure of the NPGS is best recognized by the key elements.

National Plant Genetics Resources Board
National Plant Germplasm Committee
Four Regional Plant Introduction Stations
Germplasm Resources Laboratory - Beltsville
SEA-Plant Introduction Stations
Potato Introduction Station
National Seed Storage Laboratory
National Clonal Repositories
State, Federal, and Private Plant Germplasm Curators

The function of the System is to develop and maintain a coordinated system of plant introduction, seek ways in which the introductions are evaluated and cataloged so the information on the characteristics is readily available, to store and maintain samples in a safe and viable state, and to distribute the plant germplasm to those who use it in their programs. All of these functions will lead to a more productive American agriculture.

The Strengths of the System

Strong regional involvement of state, federal, and private individuals and agencies with financial support from state, federal and private sources.

Recognition of the importance of germplasm to a productive and permanent United States agriculture.

Permanency and continuity of the System.

International recognition as a leading System in the world.

Involvement of many dedicated scientists as curators and members of advisory committees.

Information system which provides information more accessible to the users and identify problems and opportunities to strengthen the System.

The Weaknesses of the System

Too much emphasis has been placed on maintenance of germplasm and not enough on evaluation and use.

Leadership of the System has been diffuse and no strong central administrative representation.

Inadequate funding relative to the true needs of the System.

Wide gap between the introduction of germplasm and its ultimate use in developmental breeding.

SELECTION FOR WINTERHARDINESS IN WHEAT -- RELATIONSHIP OF DESICCATION AND SEEDLING CHARACTERISTICS

G. Allan Taylor

Twelve diverse winter wheat (*Triticum aestivum* L.) cultivars and one winter rye (*Secale cereale* L.) cultivar of known winter survival were utilized to: (1) identify adverse environmental factors and cultivar seedling characteristics associated with winter survival of wheat, and, (2) develop a technique for selecting winter-hardy and non-winter-hardy wheats.

Freezing temperatures (minimum -20C) did not differentially kill the winter cereal cultivars in controlled environments. The addition of a desiccant to the controlled environment, however, dehydrated the plants, resulting in killing of top growth and in subsequent differential regrowth which correlated with field percentage of winter survival (.92** including the one rye and .90** wheats only).

Fall and spring growth habit, spring vigor, and spring plant color were associated with field percentage of winter survival and may be used for screening in breeding programs.

SOME FACTORS CONTRIBUTING TO WINTERKILL OF WHEAT IN THE INLAND PACIFIC NORTHWEST

Donald W. George

Wheat grown in the Inland Pacific Northwest encounters unusual problems of winter survival. Elevation in the producing area ranges from <100 to> 1200 meters above sea level; the length of a growing season (>-2° C) may range from <120 to> 250 days; and mean annual precipitation from <250 to> 500 mm, with the greatest amounts received in January. North-facing slopes represent a very different environment from south-facing ones and the occurrence and nature of winter injury often depends on the presence or absence of a snow cover.

Yielding ability appears to be highest in cultivars that are only marginally hardy, but these are the ones chosen by the growers, who depend upon an adequate snow cover to protect the crop. Winterkill may result from low temperature injury to the plant crowns, but other forms of injury are often noted. These include leaf tissue destruction, desiccation, frost heaving, and the separate or combined effects of several disease organisms. Accelerated soil erosion contributes to winterkill by exposing plant crowns and root systems. Some of the greatest soil losses have been from hill tops and ridges where the effects of wind and cold are most severe and the wheat in these areas is most frequently injured.

THE ROLE OF ICE ENCASEMENT IN WINTER SURVIVAL OF WHEAT IN THE NORTH EAST

C. J. Andrews

In eastern Ontario typical winter weather results in continuous snow cover from November to March with soil temperatures of about -1 C. Lower soil temperatures before snow cover are rarely damaging. Partial thaws, or rain in winter may give ice of varying severity at the soil level. Manipulations of the winter environment have shown that even with snow insulation over ice, damage to wheat plants can be severe. Ice cover results in a rapid decline in cold hardiness and a gradual decrease in survival of the plant population through winter. Ice cover does not necessarily result in damage if the underlying soil is not saturated: a threshold level of soil moisture exists below which sufficient gaseous exchange persists to preserve the viability of plants.

THE FREEZING PROCESS IN WINTER WHEATS

L. V. Gusta

Unfortunately, the mechanism of freezing damage to winter cereals is poorly understood. During the winter period plants are exposed to several different forms of freezing stresses which greatly affects the killing temperature of the winter cereals. For example, it has been shown that injury increases with the length of exposure to cold as the lethal temperature is approached. Hardened hardy cultivars can tolerate -23°C for 1 hour, whereas they can only tolerate -18°C for 24 hours and -15°C for 144 hours. Also, repeated freezing and thawing have an amplifying effect on injury, e. g. fully acclimated hardy winter wheat withstood a slow freeze to -19°C, but was killed at -12°C after two thawing and refreezing cycles. Increasing the water content of the crowns by flooding results in several degrees loss in freezing tolerance.

Under conditions of slow freezing, in hardened plants, ice first forms and grows in the extracellular air spaces of the tissue. The protoplast remains unfrozen as long as the plasma membrane partitions the ice away from the protoplast. Therefore during the freezing process water must cross the plasma membrane to reach ice in the extracellular spaces. Water freezes as "ideal solution" with not all of the water frozen at once. The amount of water that is removed from the cell is a function of the temperature. Thus the cells become progressively dehydrated because of water removal for ice growth. In winter cereals most of the freezing takes place between 0 and -10°C. Very little additional freezing occurs below -10°C.

When freezing injury occurs it is associated with a general lysis of the tissue cells. The killing temperatures are sharply defined, with more than 80% of the cellular electrolytes being lost over a narrow temperature range. At the killing temperature for hardy tissue, there is no significant change in the amount of water frozen or the consequent cellular dehydration as demonstrated by nuclear magnetic resonance and differential thermal analysis method. Therefore, the freezing of cellular water per se seems an unlikely cause of damage.

Freezing and thawing rates for winter cereals generally show a substantial increase if the tissue is freeze killed. This suggests that the plasma membrane is the rate limiting barrier for water movement during freezing and thawing under some conditions and this barrier is reduced when the differential permeability is lost. The results are consistent with either a temperature dependent and irreversible increase in water permeability of the plasma membrane, which occurs at the killing temperature, or with ice penetration of the protoplast at the killing temperature.

ROOT-INFECTING PATHOGENS THAT PREDISPOSE WINTER WHEAT TO WINTER INJURY

William W. Bockus

Autumn infections of wheat soil-borne mosaic virus and common root and crown rot have been shown to predispose winter wheat to winter injury. Although soil-borne mosaic reduces tiller number by an average of 11.8% in Kansas, plants are usually not killed by the virus. However, in 1978 there were many weedy areas in fields infested with soil-borne mosaic apparently due to decreases in the wheat stand during the winter. The winterkill and root and crown rot complex was especially severe in Kansas and Nebraska in 1979. Kansas reported a 7,704,000 bushel yield loss and Nebraska reported 5-10% of the wheat in the eastcentral and southeastern regions plowed under because of this problem. Recent evidence indicates that the role of other fungi in the winterkill complex may be underestimated. Other root-infecting pathogens such as the Take-all fungus and the Pythium root rot fungi can also weaken wheat plants and render them more prone to winter injury. In fields under continuous wheat cultivation the Take-all fungus can be isolated from a high percentage of wheat root systems collected during the winter. Although Pythium root rot has declined in recent years with the use of fertilizers, USDA research indicates that the disease is important under the direct-drilling cropping system. Low temperatures can predispose plants to attack by pathogens and vice versa, so the interplay of autumn and winter environmental conditions with pathogen activity is very important to survival of wheat during the winter. Thus, in many cases it is difficult to determine just what caused the injury to plants which are described as "winter-killed."

SNOW MOLDS OF WINTER CEREALS IN CANADA

J. Drew Smith

Cold and desiccation injury are often abiotic causes of injury and death of winter wheat and fall rye in Canada. Low-temperature-tolerant fungi, singly and in complexes also cause damage in snowy regions and seasons. They may be associated with abiotic factors. The fungi are those which also invade perennial grasses, *Fusarium nivale*, *Sclerotinia borealis*, *Typhula ishikariensis* var. *canadensis*, *T. incarnata* and the nonsclerotial low-temperature basidiomycete, LTB. The importance of *Plenodomus meliloti*, the sclerotial basidiomycete, SLTB, *Pythium* sp., and *Acremonium boreale* found on dead or damaged winter cereals is uncertain. Intraspecific and interspecific antagonism occurs between isolates of some of these fungi. This antagonism, as well as inherent differences in activity of the fungi and of host resistance, nutrient value of host tissue, prehibernal and subniveal environmental conditions are important factors determining snow mold presence, activity, and dominance.

EFFECTS OF INFECTION WITH BARLEY YELLOW DWARF AND WHEAT SPINDLE STREAK MOSAIC VIRUSES ON COLD HARDINESS OF WINTER CEREALS

Y. C. Paliwal and C. J. Andrews

Barley yellow dwarf virus (BYDV) infection greatly reduced the cold hardiness and survival after ice encasement of Dover winter barley and Coast Black winter oat but the BYDV effect was less severe in Fredrick and Kharkov winter wheats and was absent in Puma winter rye. Both wheat and rye cultivars developed relatively high virus concentrations and their fresh and dry plant weights were usually reduced by BYDV. The magnitude of BYDV effect varied mainly with the cereal species and the period of virus development to which the plants were subjected. Fredrick wheat subjected to 17 days of BYDV development followed by 33 days of cold hardening had no loss of low temperature tolerance but showed an increased survival after ice encasement. Infection with wheat spindle streak mosaic virus lowered the cold hardiness and survival after ice encasement of Fredrick and Kharkov but the effect was severe in Fredrick.

Discussion

Myron Brakke - Reported an instance in the mid-60's of wheat being predisposed to winterkill by an additive effect of leaf rust and SMB. Winterkill only occurred in the areas in which both diseases were present.

Allan Taylor - Were different fungi isolated from the healthy and dead areas of the fields you tested?

Bill Bockus - No.

Harry Young and Bill Roberts - Indicated that recovery notes were extremely important in rating damage from soil-borne wheat mosaic virus.

BREEDING AND GENETICS

John W. Schmidt

The literature regarding the genetics of winter survival is not very definitive. It suggests that it is complex. Probability of obtaining hardy segregates is highest from hardy X hardy crosses, and decreases in hardy X tender, and tender X tender crosses. Large populations are necessary if recovery of the hardy parent level is the goal in winter X spring crosses. Recovery is facilitated by backcrosses to the hardy parent. Minter wheat is a prime example of recovery of a very hardy wheat utilizing one backcross following a winter X spring cross. A suitable environment that will facilitate identification of hardiness level is critical to the breeding of winterhardy wheats.

The following traits influence the survival of winter wheat under various sets of environmental conditions:

1. Vernalization requirement:

   Five genes for vernalization requirement (Vrn 1-Vrn 5) have been identified (with possibility of alleles at each locus). A winter-tender wheat may have a longer vernalization period requirement than a winterhardy one although the reverse is the usual.

2. Cold resistance (other than vernalization requirement).

3. Light response:

   a. Photoperiodic response:

      Three genes for photoperiodic response (Ppd 1-Ppd 3) are known. Wheats with a short vernalization period requirement may need to be strongly daylength sensitive in order to prevent spike initiation during periods of abnormally high temperature during the fall or winter.

   b. Light quality (thresholds for sensitivity to red light, etc.).

4. Morphology:

   a. Prostrate versus upright growth.
   b. Leaf width (resistance to desiccation).
   c. Foliage color intensity.
   d. Crown placement (perhaps different in cold dry versus cold wet).
   e. Root.
   f. Ability to retiller and reroot after damage.

5. Interaction with diseases and insects:

   a. Winter survival decreased by presence of viruses (SBMV, WSMV, root pathogens, etc.).

   b. Winter survival decreased by fall infestation with Hessian fly, etc.

The literature suggests that the breeding of wheats with greater winterhardiness than necessary for a location may be counterproductive. Thus, a compromise is accommodated by breeding for yield at or near the minimum level of hardiness required. However, by regions, with proper testing conditions, productive lines with improved hardiness are being identified. At the University of Nebraska we believe that we can and must improve the winterhardiness level and not sacrifice yield.

BREEDING AND GENETICS OF WINTER SURVIVAL IN WHEAT

M. N. Grant

Germplasm

During the past 30 years of winter wheat breeding at Lethbridge, a large number of lines and varieties have been subjected to field tests and laboratory tests for cold hardiness. Only a few lines have shown real promise as parental material.

Among the older varieties we find superior cold hardiness in such varieties as Kharkov 22 MC, Minter, and to a lesser degree, Cheyenne. From the U. S. S. R. the best germplasm has been Alabaskaya, Ulianovka, Albidum 114, and Lutescens 329. This superior cold hardiness has been transferred to newer varieties such as Norstar, Sundance, and Roughrider. Winalta appears more cold hardy in artificial tests than it actually is in the field. A surprising level of hardiness was shown in 1979 by Jo 3057, a Finland variety. A sister line to Norstar (Winalta x Alabaskaya, 7759-8) appeared hardier than Norstar, but was of poorer quality.

Breeding Program

At Lethbridge I have relied on a bulk hybrid type of program, mainly because of a lack of sufficient technical help to maintain pedigree lines. Bulk hybrid populations are grown for several generations, and sometimes, as in 1978-79, they are subjected to severe winterkill conditions. Selected lines are grown in winterhardiness field tests at Lethbridge, Edmonton, Swift Current, Saskatoon, and Winnipeg, and usually a differential kill occurs at one or more stations.

An effort to use Gaines and other high-yield, short-strawed parents has not been successful, due to a low level of winterhardiness.

I am now moving rapidly to the use of Norstar, Sundance, Roughrider, Ulianovka, Alabaskaya, and Kharkov 22 MC as cold hardy parents and have quite a few crosses from F_2 to F_8, most of which appeared quite hardy in 1978-79.

EXOTIC SOURCES OF WINTERHARDINESS

D. G. Wells

Encouraged by a report of John Grafius that he produced a bread wheat line (subsequently lost) approaching the hardiness of perennial wheatgrass, we tested the world collection of *A. intermedium* and *A. trichophorum* for survival. The surviving collections that also were crossable with wheat were PI212230 (Afghanistan), PI223240 (Washington), and PI229917 (Iran). F_1 seed was easily obtained on wheat but we have failed in our attempts to double the chromosome number and thereby we believe ensure fertility of the hybrid. I am repeating the crosses. Translocation lines of Centurk genotype but having immunity from streak mosaic are proving to be no hardier or much less hardy than Centurk in early tests.

The world collection of the diploid progenitors of wheat was seeded in the fall at Brookings. Surviving the winter were some *boeoticums* and *monococcums*. Efforts to cross them to durum wheat have produced a few seeds but no seedlings. Efforts are continuing.

The exchange of cytoplasms may teach us something about hardiness and increase the hardiness of valuable commercial cultivars. Exchanges through 7 doses involving Pawnee and YTO-117 have shown modifications of height, heading, grass appearance, reaction to leaf rust on occasion, and hardiness at some locations. Encouraged by those results, I have begun making alloplasmic lines in these combinations: Centurk-Winoka, TX line-Roughrider, TX line-Winoka, Centurk-Bounty 309, Roughrider-Bounty 309, and Winoka-Bounty 309.

UTILIZATION OF RELATED SPECIES FOR IMPROVEMENT OF COLD HARDINESS IN WINTER WHEAT

Allen Limin

The apparent lack of genetic variability for cold hardiness in the winter wheat gene pool appears to be the limiting factor facing plant breeders who are working outside of the traditional winter wheat growing areas. This has lead to an investigation of the cold hardiness potentials of some of the wheat relatives. These species include: T. turgidum group - turgidum, dicoccon, durum and var. dicoccoides; T. monococcum; T. speltoides; T. longissimum; and T. tauschii. The most hardy of the species tested was rye (Secale cereale). This was followed in hardiness by hexaploid wheat itself (Triticum aestivum). All other species accessions tested were less hardy than the most hardy hexaploid wheat.

To determine if the superior cold tolerance genes of rye could be exploited for the improvement of wheat, several octaploid and hexaploid triticales were produced. It was found that in all cases the triticales were not significantly different in hardiness from their wheat parent, indicating that there is little hope of improving the hardiness of wheat by incorporating genes from rye.

A number of autotetraploid rye populations were also produced to investigate the effects of ploidy level on cold hardiness. In all cases the autotetraploid was found to be less hardy than the diploid from which it was derived. This reduced hardiness of the tetraploid rye may have been due to increased cell volume and water content and/or possibly due to a genetic imbalance brought about by the tetraploid state.

Although none of the wild Triticum diploids or tetraploid species exceeded the most hardy hexaploid winter wheats, it is possible that they may have evolved within their genetic constitutions, genes conferring cold hardiness which are different from those present in the corresponding genome of the present day hardy hexaploid wheats. To investigate the genetic interactions between different combinations of hardy and nonhardy related genomes, the following crosses have been made and amphiploids are being produced: T. tauschii (D genome) x several different groups of tetraploid wheat (AB or AG); T. monococcum (A); S. cereale (R). Amphiploids have also been made of reciprocal wheat-rye crosses to check the effect of cytoplasm on cold hardiness. It is hoped that some of the amphiploids produced from these interspecific crosses will provide useful new genetic variability for the winter wheat gene pool.

WINTER DURUM WINTER SURVIVAL

J. W. Schmidt

Most of the available winter durum cultivars have been grown at Lincoln, Nebraska, the past few years. Those with best survival have originated in the USSR. Data from Lincoln in 1979 and Clay Center in earlier years are shown below:

	% Winter Survival		
Cultivar	Lincoln 1979	Clay Center 1976	Clay Center 1975
Wheat check (Scout 66 or Lindon)	100	100	100
Afghan	80	90	92
DF 7/72	45	70	95
Kharkovskaya 1	65	--	90
Kharkovskaya 909	50	--	75
Michurinka	95	85	97
Novomichurinka	85	91	97
Odesskaya Yubileynaja	67	--	--
Rubezh	83	--	--

Crossing and recrossing different introductions from various locations has not improved hardiness but has resulted in much better agronomic types and the same hardiness level.

INHERITANCE OF WINTERHARDINESS

John R. Erickson

Bulk populations

Several parents, encompassing a wide range of winterhardiness, and their F_2 and F_3 bulk populations were grown at Williston, North Dakota in 1977-78. Each plot contained both parents and the bulk generations seeded at 50 lbs/A. Each entry was seeded in a single 10-foot row with two replications. A duplicate trial at Casselton, North Dakota was winterkilled completely. Winter survival was recorded in late April and the two replicates were averaged. No statistical analysis was done, but similar trials have indicated about a 15% difference to be significant. Quite consistent results were obtained and the parents survived as expected.

The first set of crosses involved two Russian introductions crossed to several northern plains wheats. The crosses with CI11879 were very similar to one another. Winoka was less winterhardy than the other parents, but its bulk hybrids equalled or exceeded the expected mid-parent value. The same group of parents were crossed to each other and then to Centurk. The three-way hybrid populations all equalled or exceeded their mid-parent values.

The next group of crosses were between the same northern plains wheats and two Nebraska cultivars. There was a large difference in survival between the two sets of parents. The bulk hybrid populations again equalled or exceeded their mid-parent values.

Two spring wheats were crossed to Froid and Minter and then backcrossed to the winter parent. The bulk hybrid populations on the average were similar to the mid-parent calculated on the basis of two doses of the winter parent. Previous experience with winter/spring single crosses had been a large loss of population due to spring growth habit and poor winterhardiness.

The last group of crosses involved several medium to low winterhardy types. In almost all cases the bulk hybrid populations equalled or slightly exceeded their mid-parent values. Over all combinations the more winterhardy parent averaged 74% survival, the less winterhardy parent 43%, the mid-parent value 50%, the F_2 bulk 67%, and the F_3 bulk 61% average survival. The consistent improvement of F_2 over mid-parent is an indication of partial dominance for winterhardiness.

F_1 Hybrids

A set of restorer lines, varying greatly for winterhardiness, was crossed to two common male-sterile lines. The hybrids and parents were grown in 4-row plots 8 ft. long in four replications at five locations in Montana and Nebraska in 1978. Differential survival was recorded on a scale of 1-5 with 1 indicating full survival and 5 very poor survival.

Winter survival of parents and bulk hybrids.

P_2	P_1				
	Froid	Hume	Minter	Winoka	$\bar{x}$
	P_1 90	P_1 80	P_1 85		85
CI11879	P_2 85	P_2 85	P_2 85		85
	mp 88	mp 83	mp 85		85
	F_2 90	F_2 75	F_2 90		85
	F_3 90	F_3 80	F_3 80		83
		P_1 75	P_1 70	P_1 40	62
Gorkowtschanka		P_2 80	P_2 80	P_2 75	78
		mp 78	mp 75	mp 58	70
		F_2 85	F_2 75	F_2 65	75
		F_3 80	F_3 80	F_3 65	75

P_2	P_1 = Centurk//				
	Froid	Hume	Minter	Winoka	$\bar{x}$
	P_1 65	P_1 55	P_1 55		58
CI11879	P_2 85	P_2 85	P_2 85		85
	mp 75	mp 70	mp 70		72
	F_2 80	F_2 70	F_2 75		75
	F_3 75	F_3 75	F_3 70		73
		P_1 40	P_1 35	P_1 55	43
Gorkowtschanka		P_2 70	P_2 75	P_2 85	77
		mp 55	mp 55	mp 70	60
		F_2 65	F_2 70	F_2 65	67
		F_3 65	F_3 43	F_3 60	56

P_2	P_1				
	Froid	Hume	Minter	Winoka	$\bar{x}$
	P_1 75	P_1 75	P_1 80	P_1 50	70
Agate	P_2 31	P_2 20	P_2 35	P_2 25	28
	mp 53	mp 48	mp 58	mp 38	49
	F_2 75	F_2 60	F_2 75	F_2 45	64
	F_3 50	F_3 60	F_3 65	F_3 35	53
	P_1 90	P_1 65	P_1 50	P_1 70	69
Centurk 78	P_2 60	P_2 20	P_2 3	P_2 55	35
	mp 75	mp 43	mp 27	mp 63	52
	F_2 80	F_2 65	F_2 40	F_2 75	65
	F_3 75	F_3 55	F_3 40	F_3 65	59

Winter survival of parents and bulk hybrids

P_2	P_1: Froid	Minter	Winoka	Sundance	$\bar{x}$
	P_1 70 *2	P_1 75 *2			73
ND522 (HRS)	P_2 0	P_2 0			0
	mp 47	mp 50			49
	F_2 35	F_2 50			43
	F_3 35	F_3 60			48
	P_1 90 *2	P_1 70 *2			80
Kitt (HRS)	P_2 0	P_2 0			0
	mp 60	mp 47			54
	F_2 60	F_2 55			58
	F_3 55	F_3 45			50
	P_1 85		P_1 55	P_1 70	70
Mironovskaya 808	P_2 75		P_2 60	P_2 60	65
	mp 80		mp 58	mp 65	68
	F_2 95		F_2 65	F_2 70	77
	F_3 75		F_3 50	F_3 65	63
	P_1 85		P_1 50		68
Lancota	P_2 35		P_2 23		29
	mp 60		mp 37		49
	F_2 70		F_2 45		58
	F_3 55		F_3 45		50
	P_1 60		P_1 50		55
MT7115	P_2 35		P_2 35		35
	mp 48		mp 43		45
	F_2 60		F_2 45		53
	F_3 55		F_3 45		50
			P_1 70	P_1 85	78
Gent			P_2 40	P_2 50	45
			mp 55	mp 68	62
			F_2 55	F_2 80	68
			F_3 45	F_3 75	60

$\bar{x}$ = P_1 = 74; P_2 = 43; mp = 60; F_2 = 67; F_3 = 61.

Both general and specific combining ability values were calculated. The g.c.a. values for the female parents were quite small because of the similarity of the parents themselves and the fact that they were averaged over a larger number of male parents. The g.c.a. values for male parents were greater due to the diversity of the male parents themselves and the fact that they were averaged over only two female parents. In general the g.c.a. values were related to parental values.

The analysis of variance showed the male parents were highly significantly different, while the female parents and the male x female interaction were not different. The mean squares for males and females are a measurement of g.c.a. and the male x female interaction is a measurement of s.c.a. In this group of lines, g.c.a. was 20.7 times more important than s.c.a. or 95.4% of the variation was due to g.c.a. The relative importance of g.c.a. is indicative of additive gene action. This means that parental performance *per se* was a good indicator of hybrid performance.

Comparison of hybrid values with their mid-parent values indicates that most hybrids were more winterhardy than their mid-parent values and a few were equivalent to their better parent. Averaged over all combinations, the hybrids were 10% greater than their mid-parent values, indicating partial dominance for winterhardiness.

Combining ability analysis for winter survival

♂	♀ AI24 $\bar{x}$ = 1.80			AB116 $\bar{x}$ = 2.0			Combined			
	$\bar{x}$	m.p.	% m.p.	$\bar{x}$	m.p.	% m.p.	$\bar{x}$	m.p.	% m.p.	$\hat{G}_m$
NR 125-1-1-1	3.60	3.05	84.7	2.45	3.15	106.8	3.28	3.10	94.5	-1.41
$\bar{x}$ = 4.3	$\hat{S}_{mf}$ = 0.3			$\hat{S}_{mf}$ = 0.3						
A62-NR10	2.65	2.83	106.8	2.60	2.93	112.7	2.63	2.88	109.5	-0.76
$\bar{x}$ = 3.85	$\hat{S}_{mf}$ = 0.0			$\hat{S}_{mf}$ = 0.0						
AI24-4510-NR8	1.70	1.73	101.8	1.60	1.83	114.4	1.65	1.78	107.9	0.22
$\bar{x}$ = 1.65	$\hat{S}_{mf}$ = 0.03			$\hat{S}_{mf}$ = 0.02						
NR26-NR34	1.40	1.60	114.3	1.65	1.70	103.0	1.53	1.65	107.8	0.34
$\bar{x}$ = 1.40	$\hat{S}_{mf}$ = 0.15			$\hat{S}_{mf}$ = -0.15						
R332T41	1.40	1.53	109.3	1.55	1.63	105.2	1.48	1.58	106.8	0.39
$\bar{x}$ = 1.25	$\hat{S}_{mf}$ = 0.1			$\hat{S}_{mf}$ = -0.1						
A62-NR3	1.40	1.63	116.4	1.65	1.73	104.8	1.53	1.68	109.8	0.34
$\bar{x}$ = 1.45	$\hat{S}_{mf}$ = 0.15			$\hat{S}_{mf}$ = -0.15						
A62-NR15	1.75	2.08	118.9	1.75	2.18	124.5	1.75	2.13	121.7	0.12
$\bar{x}$ = 2.35	$\hat{S}_{mf}$ = 0.02			$\hat{S}_{mf}$ = 0.03						
R108	1.55			1.55			1.55			0.32
	$\hat{S}_{mf}$ = 0.02			$\hat{S}_{mf}$ = -0.03						
R210T42	1.55	1.55	100.0	1.25	1.65	132.0	1.40	1.60	114.3	0.47
$\bar{x}$ = 1.30	$\hat{S}_{mf}$ = -0.13			$\hat{S}_{mf}$ = 0.12						L.S.D.$_{.05}$=0.40
Combined	1.89			1.84			1.87			
$\hat{G}_f$	-0.02			0.03	L.S.D.$_{.05}$ = 0.18					

Source	D.F.	S.S.	M.S.		
Replicates (Location)	4	27.8152	6.9538**		
Treatment (gene)	17	34.9201	2.0541**		
Males	8	33.2389		4.1549**	
Females	1	0.0562	20.7	0.0562$^{n.s.}$	.954
M x F	8	1.625		0.2031$^{n.s.}$	
Error	68	13.5352	0.1990		
Total	89	76.2705			

POTENTIAL FOR THE IMPROVEMENT OF COLD HARDINESS IN WINTER WHEAT

Brian Fowler

A large number of winter wheat introductions have been screened in field survival trials in Saskatchewan during the period 1972 to 1979. Many of these introductions were selected because they had shown promise in cold hardiness screens conducted out of Fargo, North Dakota and Lethbridge, Alberta.

Differences in field survival of these genotypes demonstrated that a wide range of cold hardiness potentials exists in the winter wheat gene pool. In addition, the field survival ratings suggest that most successful winter wheat cultivars have only marginally greater winterhardiness than the minimum required for the area in which they are produced. Certainly for most production areas there would appear to be plenty of opportunity for improvement in cold hardiness potential of adapted cultivars. It was also apparent from this study that recent improvements in cold hardiness have been small and in most of the traditional winter wheat producing areas, if anything, new variety releases have reduced cold hardiness.

While there should be a general optimism that much could be done to improve the cold hardiness potential of cultivars for the traditional winter wheat producing areas, there is little evidence that super-hardy winter wheats can be produced. The Crimean varieties introduced from the USSR in the late 1880's provided the basic germplasm for successful production of hard red winter wheat in the Great Plains of North America. Although most of the early introductions and selections are no longer of commercial importance, Quisenberry and Reitz have noted that prior to 1969 nearly all the new strains of hard red winter wheat grown in the Great Plains were developed from hybrids involving selected Crimean cultivars. Clark, Martin and Parker reported on an extensive evaluation of winter wheat cultivars in the Great Plains region during the period 1920 to 1925. They found that Minhardi and a MacDonald College selection from Kharkov were among the hardiest cultivars available at that time. The ancestry of both cultivars can be traced to the early USSR introductions. It is noteworthy that the same material still ranks with the hardiest cultivars available today. It is, therefore, apparent that without new sources of genetic variability the opportunity for large improvements in cold hardiness through plant breeding has been limited. In this regard the more recent USSR introductions, Alabaskaja and Ulianovkia, have significantly greater cold hardiness than Kharkov 22MC and Minhardi. With release of the cultivar Norstar, which was selected at Lethbridge, Alberta, from a cross between Winalta and Alabaskaja, they have become proven sources of additional genetic variability for winterhardiness in the American Great Plains. However, the information on these two introductions suggests that they have been available in the USSR for many years and while they represent exploitable genetic variability, it is doubtful that the additional improvement would provide the necessary winterhardiness to greatly expand the present winter wheat production area.

Two other factors that have hindered the plant breeders' efforts to improve the cold hardiness of winter wheat are the lack of effective selection methods and limited information on its genetic control. The limitations imposed by selection methods have been discussed earlier. It suffices here to emphasize that no simple, reliable method has yet been developed to evaluate the cold hardiness potential of winter cereals on a single plant basis. This problem is complicated because the genetic system is inducible and hardiness is not always expressed to the same level in comparable plant parts, e.g., tillers. In spite of these limitations, several genetic studies have been attempted. These studies have indicated that winterhardiness is a heritable but complex quantitative character. Genetic control was mainly additive, but nonadditive, recessive and dominant genes have also been implicated. Results from reciprocal crosses have demonstrated that the influence of cytoplasm on the expression of cold hardiness is minimal.

CURRENT USSR CULTIVARS

J. W. Schmidt

Wheat breeders in the USSR believe that the currently-grown winter wheat cultivars are improved for winterhardiness in comparison to Bezostaya 1 but none appear to be superior to Mironovskaya 808. Thus, across the forest-type area of European USSR, Mironovskaya 808 continues as the predominant winter wheat cultivar. A new cultivar, Mironovskaya 25, similar to 808 in hardiness was being increased. In the western Ukraine, Odesskaya 51 is now the predominant cultivar. Others seen in 1979 in the Kiev area were Polesskaya 70, Achtyrchanka (or Aktyrchanka), Dnieprovskaya 775, and Ilychovka. In the Krasnodar area, Bezostaya 1, Krasnodarskaya 39, and Krasnodarskaya 46 are being grown, with the latter increasing rapidly. In the Rostov area, Bezostaya 1 has been replaced with Rostovchanka, Severodonskaya, and Odesskaya 51. Experimentals from the Zernograd Breeding Station were being field tested.

THE HARDENING PROCESS IN WINTER CEREALS

L. V. Gusta

Winter cereals exposed to temperatures below 10°C and above 0°C are capable of acclimating to freezing. This ability to cold acclimate is under the control of a genetic system induced by low temperatures. It is, however, a metabolic process which requires energy. Energy is supplied through photosynthesis and in the case of seedlings, from energy reserves in the seed. Because the development of frost tolerance is dependent on energy and cold temperatures, its expression can be modified by factors such as nutrition, temperature, date and method of seeding, physiological development, humidity, rate of growth, and moisture content of tissue and soil.

Under artificial conditions winter wheats can acclimate up to 10°C in one week, depending upon the hardiness potential of the cultivar. Under natural conditions the process can be drawn out, but the first period of acclimation is the most active. Under both natural and artificial environments a minimum of approximately 4 to 6 weeks is required for full development of the hardiness potential, and in both instances a period of continuous frost (-2 to -3°C) is required at the end of this stage.

When fully acclimated, cultivars of rye can tolerate the lowest temperatures (ca. -30°C) of the winter cereals. Cultivars of winter wheat are next in line (ca. -21°C) followed by barley (ca. -14°C) and then oats (ca. -10°C). Within the fully acclimated plant the roots have a higher moisture content and are generally considered to be the least hardy tissue, with the crown next and the herbage the hardiest.

Fully acclimated hardy winter wheat cultivars such as Kharkov, Sundance, and Winalta can be maintained several months at -3 to -5°C, with little or no loss of hardiness. Less winterhardy cultivars such as Richmond and Rideau may tolerate very low temperatures (-19 to -20°C) in the late fall, but readily deharden after a few months when stored at -3° to -5°C. In both cases fully hardened winter wheat plants maintained for eight or more weeks at temperatures just above freezing rapidly lose their hardiness and eventually senesce.

Winter cereals collected in the fall prior to freeze-up and exposed to temperatures above 10°C rapidly deharden but at this stage, when returned to near-freezing temperatures, they still have the ability to quickly reharden. However, crowns that have dehardened the most require a longer period to reharden.

Even fully acclimated winter cereals do not necessarily maintain one cold hardiness level for the entire winter. In natural environments the cumulated effect of the factors that influence cold hardiness at this stage often results in a large reduction in the hardiness of the overwintered cereals.

Exposure to warm spring temperatures will eventually result in a complete dehardening of winter cereals. Studies conducted in artificial environments have demonstrated that once spring dehardening has been initiated in winter wheat and rye, returning plants to conditions for cold acclimation will not reverse the dehardening process and loss of cold hardiness will result even during storage at temperatures below freezing.

THE FREEZING PROCESS IN WINTER WHEATS

L. V. Gusta

Unfortunately, the mechanism of freezing damage to winter cereals is poorly understood. During the winter period plants are exposed to several different forms of freezing stresses which greatly affects the killing temperature of the winter cereals. For example, it has been shown that injury increases with the length of exposure to cold as the lethal temperature is approached. Hardened hardy cultivars can tolerate -23°C for one hour, whereas they can only tolerate -18°C for 24 hours and -15°C for 144 hours. Also, repeated freezing and thawing have an amplifying effect on injury, e.g., fully acclimated hardy winter wheat withstood a slow freeze to -19°C, but was killed at -12°C after two thawing and refreezing cycles. Increasing the water content of the crowns by flooding results in several degrees loss in freezing tolerance.

Under conditions of slow freezing, in hardened plants, ice first forms and grows in the extracellular air spaces of the tissue. The protoplast remains unfrozen as long as the plasma membrane partitions the ice away from the protoplast. Therefore, during the freezing process water must cross the plasma membrane to reach ice in the extracellular spaces. Water freezes as "ideal solution" with not all of the water frozen at once. The amount of water that is removed from the cell is a function of the temperature. Thus the cells become progressively dehydrated because of water removal for ice growth. In winter cereals most of the freezing takes place between 0 and -10°C. Very little additional freezing occurs below -10°C.

When freezing injury occurs it is associated with a general lysis of the tissue cells. The killing temperatures are sharply defined, with more than 80% of the cellular electrolytes being lost over a narrow temperature range. At the killing temperature for hardy tissue, there is no significant change in the amount of water frozen or the consequent cellular dehydration as demonstrated by nuclear magnetic resonance and differential thermal analysis method. Therefore, the freezing of cellular water per se seems an unlikely cause of damage.

Freezing and thawing rates for winter cereals generally show a substantial increase if the tissue is freeze-killed. This suggests that the plasma membrane is the rate limiting barrier for water movement during freezing and thawing under some conditions and this barrier is reduced when the differential permeability is lost. The results are consistent with either a temperature dependent and irreversible increase in water permeability of the plasma membrane, which occurs at the killing temperature, or with ice penetration of the protoplast at the killing temperature.

ENVIRONMENTAL EFFECTS ON COLD HARDINESS AND WINTER SURVIVAL IN THE EASTERN WINTER WHEAT AREA

C. J. Andrews

Growth of winter wheat plants at low temperature increases both their resistance to freezing stress and their tolerance to ice encasement. The association is demonstrated as a correlation between LD_{50} and ice tolerance in a range of red wheats, but independent selection for ice tolerance could be valuable, particularly among eastern wheats. Ice encasement is accompanied by accumulations of ethanol and CO_2 which reduce plant survival and are toxic to cellular membranes.

Low temperature flooding to soil level during hardening of wheat has little effect on hardiness levels. Cold hardiness of fully hardened plants is appreciably reduced by total flooding for six weeks, and these levels are closely correlated with the increased moisture content of the plant crowns. Plants flooded for two and four weeks are more resistant to subsequent ice encasement than non-flooded plants. The response has been shown to exist in 8 wheat cultivars.

Evaluation of winter survival potential proceeds on 3 lines:

1) LD_{50} determinations in a 1° per hour temperature decrease;
2) tolerance of total ice encasement at -1° for one week;
3) tolerance of field ice encasement, prepared in January each year.

CHARACTERIZATION OF SYSTEMS THAT HAVE EVOLVED IN PLANTS TO PROTECT THEM FROM FREEZE INJURY

C. R. Olien

Stress analysis was reviewed as a basis for defining systems that have evolved in plants to protect them from cold-induced injury. These systems can be assayed as component traits in breeding hardy cultivars.

Freezing and melting are processes catalyzed by ice-liquid interface. Both phases can exist below 0°C. The balance shifts toward ice as the temperature decreases. This shift is partly determined by the colligative effect of solute concentration, but it also is determined by constitutive properties of hydrophilic substances that cause them to compete with ice by retention of water. The pattern of liquid transition to ice as a function of temperature is more abrupt in root tissues than in leaves. Liquid water of plants is located in many different sites and associations, and the shift in distribution as freezing progresses is not simply proportional. Liquid of the outer free space can be studied by several techniques that measure the mobility of indicators. The proportion of the total water frozen can be assayed by NMR. Total liquid water is a sigmoid function of liquid remaining in the outer free space. Freezing is considered to be an equilibrium process when no significant displacement from the equilibrium redistribution pattern occurs. Heritable traits that affect the origin and shape of this pattern greatly affect freezing stress.

Nonequilibrium freezing has two stages. If there is no catalytic interface, liquid water supercools. This is a protective mechanism in some woody plants. The free energy of ice formation is a function of the displacement of temperature from equilibrium. In the first stage of freezing a supercooled system, the temperature rapidly rises. Cells of tender tissue can survive freezing from a few degrees of supercooling. Hardening increases the supercooling required to cause ice crystals to grow across the plasmalemma into the protoplast, which is lethal. In the second stage of nonequilibrium freezing the temperature returns to that of the environment. Less displacement from equilibrium but more water is involved, so high energies of freezing can develop and cause histological disruption. The second stage of nonequilibrium freezing typically injures the fibrous tissues of lower crown and roots where the transition pattern is abrupt, especially when the tissue moisture content is high. Inhibitors of freezing kinetics reduce the rate of crystal growth by a "skin" of polymer which forms on the surface of the crystal as it grows. The polymers are certain xylan mucigels produced by hardy genotypes that give these plants control over freezing.

We distinguish freezing from desiccation by whether ice actively contributes to injurious stress or only passively accumulates water. These effects can be evaluated by vector analysis. The vapor pressure in frozen tissue is determined by ice. Normal cold tests follow the resultant of a temperature (kinetic energy) vector and a vapor pressure (density) vector. These vectors can be manipulated independently, and we find that freezing stress injures at a higher temperature than desiccation.

Equilibrium freezing is more subtle than nonequilibrium freezing and required analysis of freezing dynamics. Gibbs chemical potential is zero for ice and liquid at equilibrium, but recrystallization continually causes ice crystals to change shape indicating that there must be a chemical potential for freezing that is balanced by another for melting. By partitioning the net chemical potential on a basis of frequency distribution of exchangeable kinetic energy over activation limits, we calculated free energies of freezing and melting. This also required measuring the latent heat that separates the activation limits. This latent heat shifts as freezing progresses and was measured by coordinating transition and thermal analysis. Equilibrium freezing, where ice and plant polymers compete for intervening liquid water, maintains a balanced condition by shifts in the activation limits as freezing progresses. This is distinctly different from osmotic or vapor desiccation in which equilibrium is maintained by shifts in water density through concentration of solutes and decrease in vapor pressure respectively. The shift in activation energy in equilibrium freezing causes an energy of adhesion to develop between hydrophilic polymers and ice. Adhesive interaction between the plasmalemma and ice results in stress that becomes increasingly severe with decreasing temperature. Hardened cereal plants are killed in the range between effects of nonequilibrium freezing (-4°C for stage 1, -8°C for stage 2) and of desiccation (-16°C for osmotic and -20°C for vapor). Hardy plants produce adhesion inhibitors, soluble substances which maintain a liquid barrier that prevents direct interaction between ice and the plasmalemma. This liquid capsule surrounding each protoplast causes osmotic desiccation as freezing withdraws liquid water concentrating the solute. The temperature at which injury occurs can approach the vapor desiccation limit if the solutes have no toxic effect.

Each type of plant tissue has a unique set of protective systems. Differences between similar tissues of different genotypes are heritable traits -- components of hardiness.

MORPHO-DEVELOPMENTAL FACTORS RELATED TO WINTER SURVIVAL OF WHEAT -- ASSOCIATION OF CHARACTERISTICS OF GROWTH CHAMBER AND FIELD GROWN SEEDINGS WITH WINTER SURVIVAL

G. Allan Taylor

We studied the relationship between morpho-developmental characteristics and winter wheat (Triticum aestivum L.) survival of six diverse cultivars planted at five depths in a growth chamber and one depth in the field.

Cultivars and planting depths differed significantly for crown node depth, emergence rate index (ERI), seedling height, adventitious root length and number, tiller number, and seedling foliar dry weight. The cultivar X depth interactions were significant for all characteristics except ERI and seedling height. 'Froid' and 'Yogo' developed the shallowest crown nodes followed by 'Cheyenne', MT 6928, 'Itana' and 'Crest' in that order. Froid and Yogo had the longest adventitious roots and the most adventitious roots and tillers. Shallow planting depths resulted in high ERIs, tall seedlings, shallow crowns, long adventitious roots, more adventitious roots and tillers, and high foliar dry weights.

All characteristics were significantly correlated. Crown node depth was negatively associated with adventitious root length and number, tiller number, and foliar dry weight. Adventitious root length was positively associated with number of roots and tillers, ERI, and foliar dry weight. Growth chamber and field crown node depths and adventitious dry lengths were significantly correlated (.90* and .90*, respectively).

Shallow crowns were associated with increased winter survival. The negative correlation of adventitious root length with crown node depth ($r = -.58^{**}$) and the positive correlation of root length with winter survival ($r = .99^{**}$) further emphasize the importance of the winter wheat crown region relative to winterhardiness.

The identification of genotypes with shallow crown nodes, high adventitious root lengths and ERI should enhance selection for winter survival in winter wheat breeding programs functioning in environments similar to Montana.

WINTERHARDINESS IN NORTHERN AND SOUTHERN REGIONAL PERFORMANCE NURSERIES, 1959-1970

G. Allan Taylor

Winter injury has been an important Great Plains winter wheat production problem for more than the 100 years that hard red winter wheats have been grown from Texas to Canada. High levels of winterhardiness are necessary in the more northern areas of the Great Plains. Severe winterkill during several recent years from Nebraska northward into Alberta has resulted in questions being raised as to the level of winterhardiness in wheats which are being tested in the Northern Regional Performance Nursery (NRPN) and the Southern Regional Performance Nursery (SRPN) and subsequently released as varieties.

The winterhardiness levels of NRPN and SRPN entries and the winterhardiness level of entries according to state of origin were examined for the 1959-1978 time period. The NRPN (47 locations) and the SRPN (40 locations) as we now know them, originated in 1957. It is from these nurseries which new Great Plains HRWW varieties originate.

The winter survival of NRPN and SRPN entries were examined as a percent of the long-time check variety 'Kharkof' by 4-year periods from 1959-1978 with the check varieties excluded. Only those locations where "reasonable" differential winterkill occurred were used.

The winterhardiness level in the NRPN measured as a percent winter survival and expressed as a percentage of the winterhardy check cultivar Kharkof decreased from 116% to 95%, 89%, 94%, and 86% from the 4-year periods of 1959-1962, 1963-1966, 1967-1970, 1971-1974, and 1975-1978, respectively. Likewise, the average of the SRPN entries, calculated in the same manner, decreased from 89% to 85%, 82%, 75%, and 67% of Kharkof, respectively, for the same time periods.

Since individual states contribute lines to both the NRPN and SRPN, the question arises as to how the states fare with respect to the average level of winterhardiness for their entries during the same 1959-1978 time period. As with the previous data, the winterhardiness level of the experimental lines was examined as a percent of the long-time winterhardy check Kharkof.

In the NRPN, Alberta, Montana, South Dakota, and Nebraska consistently have entries in this nursery. The Montana breeding program has maintained a relatively high, stable level of hardiness in its lines, ranging from 103% to 114% of Kharkof. The same is true of Alberta, with 107% to 128% of the check. Although the hardiness of the Nebraska entries remained fairly stable from 1959-1978, its entries were lowest in hardiness with a range of 76% to 95% of the winterhardy Kharkof check. The average hardiness of South Dakota lines decreased drastically from 146% of Kharkof in 1959-1962 to 101% in 1967-1970, and 86% in 1975-1978.

In the SRPN, Nebraska, Kansas, Colorado, Oklahoma, and Texas regularly had entries during 1959-1978. The Kansas entries, starting high with an average of 105% of Kharkof in 1959-1962, declined to 50% in 1975-1978. Colorado entries averaged only 65% of Kharkof in 1959-1962, peaked at 100% in 1967-1970, and decreased to 61% of Kharkof in 1975-1978. The average winterhardiness of the Nebraska lines was stable, ranging from 81% to 98% of the check. Although the entries from Oklahoma averaged a few percentage points higher than Texas, both states had similar decreases from 1959-1962 (Oklahoma 86%, Texas 78) to 1975-1978 (Oklahoma and Texas 67%).

Several interesting conclusions are apparent in this examination of NRPN and SRPN cultivars with respect to winterhardiness levels. First, winterhardiness levels have declined since 1959 in both regional hard red winter wheat nurseries. Second, state programs certainly vary with respect to the level of hardiness they're willing to accept. In the NRPN, the South Dakota entries have drastically declined when their winterhardiness is compared to the long-time hardy Kharkof check from 1959 to 1978. During this same time period in the SRPN, both Kansas and Colorado entries have also declined when winterhardiness levels were examined.

Although it is generally thought that yield and winterhardiness are negatively related, this relationship should be examined, utilizing both winterhardiness and yield data from the NRPN and SRPN.

Current mobility of varieties developed in one state and grown in another state or area emphasizes the importance of maintaining adequate levels of winterhardiness. The severe winterkill experienced in Montana during the winter of 1978-1979 is, to some extent, a result of a variety with low levels of winterhardiness being introduced and widely grown in the state. It is suggested that cultivars should be evaluated for winterhardiness in areas with more severe winters than those areas cultivars are expected to be used as varieties, if released.

DURATION OF HARDENING AND COLD HARDINESS IN WINTER WHEAT

D. W. A. Roberts

At the Lethbridge Research Station, work on the relationship of environmental factors affecting cold hardiness in wheat to winter survival in the field is in progress. One of the environmental factors under study is duration of exposure to hardening conditions.

In growth cabinets the cold hardiness of winter wheats changes in a characteristic manner with progressively longer hardening treatments at 3-5°C. Dry seeds are very cold-resistant. As the seeds take up moisture their cold hardiness drops (for approximately 2 to 3 weeks). About 3 weeks after moistening, the cold hardiness of the germinating seed starts to rise to a plateau which lasts from approximately the seventh to eleventh week after seeding. Starting about 11 to 13 weeks after seeding, cold hardiness enters a slow decline.

Data from plants removed from the field at different times during the winter and transferred to hardening conditions for different lengths of time indicate that wheat plants go through the same series of changes in cold hardiness in the field as they do under artificial hardening conditions in a growth cabinet. Consequently, if plants are exposed to long enough periods of warm temperatures (above freezing) in the late winter or early spring they will lose hardiness and will not regain it if temperatures fall. This partly explains why winter wheat is more severely damaged by low temperatures in the spring than in the autumn. Another probable reason is that the plant's food reserves, especially soluble sugars, are lower in the spring than in the autumn.

TECHNIQUES FOR EVALUATING WINTER SURVIVAL POTENTIAL IN WHEAT

Brian Fowler

There are two primary methods for evaluating the winter hardiness potential of wheat. These are survival under field conditions and laboratory prediction tests.

Field survival is considered to be the ultimate test of a cultivar's winterhardiness. The main limitation to this method is the lack of control that the researcher has over the level of stress which test sites experience.

Researchers have reported that test winters which produce differential winterkill occur as infrequently as once every 10 years. However, the frequency of differential winterkilling of cultivars of a particular winterhardiness class can be increased greatly by selecting sites which have a history of providing the desired levels of stress. This can usually be accomplished by growing trials at or outside the margin of the winter wheat producing area for which the plant breeder is selecting.

Variation in stress levels within field trials makes it difficult to identify small but important differences among cultivars even when differential winterkill does result. To minimize errors resulting from this variation, comparisons should be restricted to plots that are in close proximity to one another. Use of a moving average in estimating stress levels may assist in overcoming part of these limitations. The periodic inclusion of control plots of known winter survival ability should also assist in initial estimates of stress levels experienced within and between field trials.

Because of the limitations inherent in field trials there has been a continuing search for rapid and efficient laboratory methods for testing cold resistance of cultivars. However, the development and maintenance of cold tolerance in winter cereals and the consequences of interactions with environment makes for a very complex situation which the researcher must attempt to duplicate and evaluate under artificial conditions.

Just about every biochemical and physiological process changes in the plant during cold acclimation and based on these changes, a large number of prediction tests have evolved. We have considered 41 variables, which have been implicated in winter survival of plants, to determine their usefulness in prediction tests. In these evaluations we have asked the following questions:

1. Do fully acclimated plants from genotypes with a range of cold-hardiness potential show significant differences for these variables?

2. Are measurements of these variables sufficiently repeatable?

3. Are the differences detected heritable?

4. What is the relationship of these differences to differences in field survival?

All experiments are not complete but to date we have found:

1. That significant differences among fully acclimated cultivars do occur for most of these variables.

2. The experimental error for measurements of many of these variables was high, i.e., repeatabilities were low.

3. Highest heritabilities were found for LT_{50} (.82), crown and leaf water content, plant height and plant erectness.

4. LT_{50} gave the highest correlation with field survival ($r= -.94$). Measures of plant erectness provided additional information on field survival. Tissue moisture content and LT_{50} ($r=.86$) explained similar variability in field survival.

Our conclusion from these studies is that where differences in winter-hardiness potential are large, there are a number of prediction tests which can be utilized as a supplement to field survival trials. However, at best, these tests provide very coarse screens and, where differences are small, there are limitations to their usefulness in estimating field survival potential. For example, to be of any practical use to the plant breeder, prediction tests should be able to detect differences of less than 15 percent in field survival. Studies have shown that for LT_{50}, the best prediction test, 1°C difference in a cultivar's survival temperature is equal to approximately 30 percent difference in field survival. The unit of measurement in most artificial freeze tests is 2°C and, for this reason, ability to detect small, but important differences among cultivars is limited. In addition, for differences this small, the limitations imposed by experimental error mean that a large number of replicates is required.

DIFFERENTIAL SURVIVAL AMONG WINTER WHEATS IN THE FIELD

M. N. Grant

As a positive introductory statement I would say that we can still make advances in the development of hardier varieties of winter wheat through the use of field tests. I am not casting doubt on artificial tests or laboratory tests, and I encourage the proponents of such tests to continue their research one hundred percent. In my own work with winter wheat I have used the germinating seed techniques of Dr. J. E. Andrews, and the crown freezing method developed by Dr. H. G. Marshall. However, for various reasons, in my breeding and testing program I have gone back to differential survival in field tests.

In order to have reliable field tests you have to reduce or eliminate certain variables. We believe that for good survival of winter wheat you have to seed shallowly into a firm seedbed. Also, you have to insure uniform packing among the rows, and I am sure many of you have seen the differential effect on survival from the packing effect of tractor wheels.

At Lethbridge we have done considerable work on the development of a seeder which gives uniform packing for every row, and for this reason we have a high level of confidence in the differences that show up in our field tests.

One thing that you can't control is the weather. However, you can get a better range of weather conditions by growing your winterhardiness tests at several locations. When I first started testing winter wheats I tried to grow yield tests at several locations in western Canada. Over several years I found that I was almost always getting good yield tests at Lethbridge; I would occasionally get good tests at Edmonton and Lacombe; and I was wasting my time and that of my cooperator at the Swift Current location. The test there was always lost to winterkill.

The reason for this difference in survival became apparent when we looked at the soil temperature data from the different locations. For example, during 1977-1978, the temperature at 5 cm below the soil surface at Lethbridge dropped down to -5°C for 19 days during the winter months. It never did go down to -10°C. However, at Swift Current the soil temperature was at -5°C for 86 days; it was at -10°C for 37 days; and it was at -15°C for 2 days. And this was not a severe winter. We have seen winters at Swift Current where the soil temperature has been down to -20°C for several days.

We can look at these soil temperatures in a different way by observing the mean temperature for January in 1978. At Lethbridge the mean temperature for January at 5 cm below the soil surface was -4.5°C, while at Swift Current the mean for the month was -11.6°C.

On the basis of my experience attempting to grow yield tests, and taking into account the soil temperature data available to us, I now make use of four locations for winterhardiness tests. Lethbridge is the mildest location and usually gives almost complete survival. Swift Current is the most severe and often the whole test is lost. Edmonton and Winnipeg have more snow cover and give an intermediate reaction. Saskatoon is being added this year as a fifth test site. The important point about these locations is that there is always at least one where I get a good differential winterkill -- and that is what I am looking for.

Up to now the use of field tests to identify superior levels of winterhardiness has been successful, as exemplified by the release of varieties like Sundance and Norstar. Maybe we have gone as far as we can in identifying superior varieties, using this method, and in the future we will have to rely more on research in physiology and pathology, accompanied by more precise techniques for measuring fine differences in cold hardiness. For myself, the field tests have served me well, and in the long run, no matter how many laboratory tests we apply in screening out more cold hardy types, the ultimate test is still going to be survival in the field.

In summary I would say that it is possible to distinguish varieties and lines of superior winterhardiness by growing them in field trials at several locations. I have come to certain conclusions as to the relative levels of winterhardiness among many varieties, and perhaps this information can be brought out in more detail in Session V, when Dr. Schmidt will be askins us about sources of breeding material.

WINTERHARDINESS -- FIELD EVALUATION TECHNIQUES AND PROCEDURES

John R. Erickson

Test Locations

Because of variability in climatic conditions from year to year, it is difficult to predict when and where differential survival will occur. Previous experience and weather records may indicate suitable testing sites. If an area has infrequent winter damage it may be necessary to make a cooperative arrangement with someone in another region. The Uniform Winterhardiness Nurseries handled by Dr. Johnson are an example of this type of cooperation.

Testing should be done in an area which slightly exceeds the normal requirements for your area. This will permit expression of real differences that exist. Ideally, 50% average survival of tested material would allow maximum expression of real winterhardiness differences.

Testing for several years may be necessary to have the right conditions occur for maximum differential.

Land Preparation

A firm, smooth seedbed with soil moisture within seeding depth is essential for uniform stand establishment. Uneven emergence within a plot gives an effect similar to different seeding dates. Using a rod weeded for the final two tillage operations usually will result in a firm seedbed with moisture near the surface.

Another option to obtain differential survival is to seed between barriers for additional protection if prevailing conditions result in excessive winterkill. If moisture is adequate, plots can be established on stubble with duplicate plots on fallow to provide different levels of protection. Soybean stubble provides some protection with little crop residue. A thin seeding of flax planted one month before plot establishment is another means to provide additional protection.

Seeding Equipment

Any plot equipment that will give uniform stand establishment can be used for seeding winterhardiness tests. Some modifications may be necessary to improve precision. Wheel track effects can be significant in adjacent rows so rows should not be seeded in previous wheel tracks nor be driven on after seeding. Wheels should be set out at least 3-4 inches from the row to minimize effects.

Various types of openers can be used, depending on soil type, moisture content and amount of ridging desired. Disc or very narrow shovel openers will leave the surface relatively smooth and work best in heavy soil and wet conditions. Three to 5-inch wide shovels will make higher ridges and permit deeper planting without covering the seed too deeply and provide more protection. An essential feature for all planting systems is an effective set of press wheels to firm the soil around the seed. This promotes good stand establishment and helps prevent soil movement during the winter and spring.

Seeding Rate

Rate of seeding is a variable that can be adjusted to compensate for lack of winterhardiness. Heavy seeding rates may mask real survival differences, while low rates of seeding may result in excessive winterkill.

Minimum seeding rates to achieve optimum yields in an area probably are best for winterhardiness testing. Uniform stands with 60%-70% survival will achieve yields comparable to complete survival.

Seeding rates may be lowered to put additional stress on a test or raised to prevent excessive winter damage. Duplicate sets of entries seeded at different rates may achieve optimum differential survival.

Seeding Date

Seeding date can have a major effect on winter survival. Very early seeding may result in infections with wheat streak mosaic and/or foot rot organisms which can confound survival differences. Delayed seeding results in small plants with insufficient reserves for over-wintering.

Genotype by seeding date interactions are significant with more winterhardy cultivars maintaining better survival for later dates than less winterhardy cultivars.

Two or more seeding dates will provide greater possibility of encountering differential survival. A single seeding date, somewhat later than optimum for yield, may impose enough additional stress to differentiate among some genotypes.

Plot Size

Winter survival data may be obtained from various plot sizes, depending on uniformity of winter damage. Plots should be large enough to obtain an accurate estimate of survival, but small enough to sample the variability encountered in field survival. Long, narrow plots offer a better chance to avoid problems caused by minor variations in topography.

Minimum plot size for a relatively accurate assessment of survival is about 10 sq. ft. A single-row plot 10 ft. long is acceptable, but a single rod row may give more reliable readings. If seeder wheel track variability is a problem, 2-row plots 8 ft. long may be used. Head rows generally are too short for accurate assessment, but may be useful for screening purposes. If suitable checks are planted every tenth row, relative comparisons can be made.

Number of Replications

Increased replication improves precision of a test and reduces error variance. The number of treatments affects the degrees of freedom associated with the error variance, a minimum of 30 d.f. is desirable. Practical considerations such as amount of seed available, number of entries tested, etc., often restrict the amount of replication. Winter survival is often highly variable so as many replications as feasible are desirable.

A minimum of two replications is necessary to obtain an estimate of error variance. It also is a practical minimum to sample some of the gross variation encountered in a field test. Three or four replications will improve accuracy. Additional locations are another form of replication and it probably is more desirable to have two or more locations rather than increased replication at a single location. Testing for two or more years is another form of replication and is normally encountered as more advanced testing occurs.

Check Entries

The choice of suitable check entries is essential for relating winterhardiness levels. A minimum of three checks to encompass the range of acceptable winterhardiness should be used. Additional checks with higher and/or lower winterhardiness than desired may be used to detect the full expression of winter damage.

Check entries seeded every tenth row, alternating among high, medium and low winterhardiness types, permit valid comparisons. Each row is within five feet of a check and can be related to both adjacent checks.

Rating Systems

Any system of rating that adequately differentiates among entries and can be applied consistently and accurately is satisfactory. Actual stand counts are very laborious and probably unnecessary for most purposes. Visual ratings are much more rapid and sufficiently accurate (± 5%-10%) for most purposes.

An essential step in evaluating winterhardiness is taking fall stand notes. This should be done relatively late in the fall growth cycle. Spring observations should be delayed until the plants have resumed active growth as winter damage differences often are magnified. Spring vigor differences often may be related to winter injury.

Scores may be based on the percentage of surviving plants or the degree of winter damage. Scores to the nearest 10th percentile probably are about as accurate as visual observations can be realistically made.

INDIVIDUAL PLANT SELECTION WITH A CONTROLLED FREEZING TEST

H. G. Marshall

Freezing resistance is a principal component of winterhardiness in cereal crops and is, therefore, the basis of controlled freezing tests. Although many scientists have reported good correlations between winterhardiness and freezing resistance, freezing tests have not provided the needed panacea for the prediction of winterhardiness and the selection of superior genotypes. Among several reasons for this are the following: 1) precision has not been good enough to efficiently separate lines within a narrow genetic range, 2) techniques have not facilitated individual plant selection, and 3) poor control over several distinct forms of freezing stress.

In general, the differentiation of lines for resistance to freezing stress has been dependent upon the use of many replications. The use of techniques like LD_{50} (determination of the temperature at which 50% of the plants are killed) has been necessary because of uncontrolled variability, either genetic or environmental or both, in the expression and measurement of freezing resistance. Theoretically, all plants in a homogeneous population (pure-line) should respond alike to absolutely uniform conditions during the plant growth, hardening, freezing, and recovery stages of a freezing test. Under absolutely uniform experimental conditions, differences in plant response should be caused by genetic variation and not environmental variation. The ultimate freezing test should facilitate essentially error-free individual plant selection or, at least, progeny selection based on a few plants. While absolute environmental control probably is impossible and impractical, effective plant selection programs should be structured around this goal.

Recovery of winter cereals in the spring depends on survival of crown meristems from which all parts of the plant can be regenerated. For several years, I have used crown freezing tests in my winter oat program to classify lines for resistance to freezing stress. Differentiation has been based on experiments involving several plants and replications. Recently, we have been extracting individual plants in recurrent mass selection programs and in experiments to transfer genes from wild to domestic oat backgrounds.

Individual plants are grown in a semi-nutriculture system. De-hulled, pre-sprouted seeds (sorted for uniformity) are planted 3 cm deep in plastic tubes (2.5 x 11.5 cm) filled with a finely ground and thoroughly mixed medium of 1/2 sand:1/2 peat moss. Small holes in the bottoms of the tubes allow nutrient solution to enter. The tubes are placed in racks with a spacing of 4.5 cm between tube centers and suspended in plastic pans. Nutrient solution (1/2 strength Bell's or Hoagland's) is added to the pans and maintained so as to immerse the lower half of the tubes. The solutions are completely renewed every 7 to 10 days. During three weeks of pre-hardening growth, the plants receive a daily treatment of 12 hours light (20,000 lux) at 20°C and 12 hours darkness at 10°C. This is followed by one week of hardening with daily treatments of 11 hours light at 13°C and 13 hours darkness at 1°C. This hardening treatment develops a level of freeze resistance similar to that of naturally hardened plants. Growth habit, tiller number, and crown size of the plants will be similar to these traits in field-grown and hardened plants.

For the freezing treatment, the general procedure is to cut off the leaves and roots and to place the crowns in capped, clear plastic vials. The vials of crowns are placed around the perimeter of a circular turntable in a freezing chamber. Beginning at 2°C, the temperature is lowered at 1.5°C per hour to the final temperature (in the 22° to 26°C range for oats) and held for 8 hours. The temperature is then raised at the same rate to 2°C for an 8-hour thaw treatment. After thawing, the crowns are slowly warmed to 20°C over a 24-hour period. After warming, a small amount of water is added to each vial, and they are transferred to a lighted bench at about 20°C. After a 72-hour recovery period, crowns that have not made top growth similar to that of check crowns that were not frozen are discarded. The remaining crowns are held in the capped vials for 6 to 10 days and then those with new roots are transplanted to pots and grown to maturity. The crowns can be transplanted after the initial 72-hour recovery period, but this has not given any significant increase in the percentage of crowns that initiate roots.

Based on progeny tests, about 75% of the winter oat lines we have extracted from heterogeneous populations by crown freezing have been equal to the hardy parent for freezing resistance. Using a bulk population constituted from four varieties with winterhardiness ranging from moderate to high, a single cycle of mass selection for freeze survival (84% elimination) brought the population to 95% of the most hardy component variety.

The individual crown freezing technique is being used to search for plants with transgressive levels of resistance to freezing stress and to select individuals for sib-crossing in programs to improve winterhardiness in oats.

INDICATORS OF WINTER SURVIVAL ABILITY OF WHEAT GROWN IN THE PACIFIC NORTHWEST

Donald W. George

The infrequency of "test winters" at any given nursery site in the PNW and the relatively poor hardiness of many parental lines in the breeding programs make it necessary to seed alternative techniques to field testing for the evaluation of winterhardiness. A modification of the Marshall crown freezing technique has provided the most reliable indications of coldhardiness but its use depends on field conditions. Other indications of superior survival ability have been recognized. These include prostrate vs. upright growth habit, deeply placed crowns, resistance to foliage injury by freezing, and dark green narrow leaves. These characteristics have all been shown to correlate with winter survival but the winterhardiness nursery is still regarded as the definitive test of field performance.

THE CARGILL WHEAT RESEARCH EVALUATION PROGRAM FOR WINTERHARDINESS

B. J. Roberts, D. R. Johnston, and B. C. Curtis

Cargill winter wheats are evaluated for winterhardiness at Seward, Nebraska and Brookings, South Dakota. Data from these nurseries are used to identify the more winter-hardy selections and populations planted in the breeding nurseries at Spearman, Texas and Winfield, Kansas. The following describes the current procedures used:

F_2 Observation Nursery: Single replication grown at 4 locations; a check variety planted every 25th plot; a 15 gm/plot seeding rate.

Locations:

Spearman, Texas	-- 4-row plot 5' x 13' seeded. Breeding nursery.
Winfield, Kansas	-- 4-row plot 5' x 13' seeded. Breeding nursery for resistance to SBMV.
Brookings, South Dakota	-- 2-row plot 2.5' x 13'. Winterhardiness.
Seward, Nebraska	-- 2-row plot 2.5' x 13'. Winterhardiness.

F_2 Regular Nursery: Best populations from the F_2 Observation Nursery from the previous year are grown at Ft. Collins from reserve F_2 grain. Approximately 700 to 1,400 seeds are space-planted with a Milton planter. Individual plants are selected for a plant to plot evaluation in the F_3 generation. Generally, a single F_2 plant produces a sufficient quantity of seed to plant the progeny at four locations. (Two- or 4-row observation plots of the F_2 regulars are again planted at the four locations to confirm previous observations -- if there is sufficient seed.)

F_3's from F_2 Regulars: Grown at 4 locations; single replication; 10 to 15 gms/plot; 2-row plot 2.5' x 13' seeded.

Locations:

Spearman, Winfield, Seward, and Brookings.
Only F_3's from SBMV-resistant F_2's are grown at Winfield.

F_4's from F_3 Regulars: A modified bulk system is used in harvesting selected F_3 plots. Approximately 50 heads are taken and bulk threshed to provide enough seed to plant the two winter-hardy observation nurseries and continue the F_4 plot at the breeding nursery.

Advanced Lines: Two replications of all B-lines and hybrids entered in the yield trials are grown at Seward and Brookings during all test years. Restorers are grown in a single replication.

Starting with the F_3 generation, a check variety is planted in all plots with a number ending in 01, 02, 03, 04, 05, 20, 40, 60, and 80. They generally include Trapper, Centurk, Scout 66, Triumph 64, Vona, TAM 101, Payne, Newton and other new lines. A scale of 1 to 9 is used to rate each plot for winterhardiness (1 is best, and 9 segregating). The rating is usually a combination of percent of survival, severity of damage and/or vigor depending upon the severity of damage to the nursery. The response of varieties Vona, Triumph 64, and TAM 101 is generally used to establish the minimal level of acceptable winterhardiness.

The winterhardiness nurseries at Seward and Brookings are "plow down" nurseries. A contract is made with a wheat producer for land and preparation of seed bed. The contract extends from September 15, approximate date of seeding, to April 15 or until land preparation begins for a spring crop. These nurseries are used only for evaluating winterhardiness; not for seed production. All materials planted in these nurseries are grown in breeding or yield nurseries at other locations. The "plow down" feature greatly reduces the cost of our test program. In 1977 a total of 12,108 plots (5,778 at Brookings and 6,330 at Seward) were evaluated for winterhardiness at an approximate cost of $0.167 per plot. Fifty percent of this cost is for land rental and the other fifty percent is for "associated expenses".

WINTERHARDINESS EVALUATION IN FLATS

D. G. Wells and C. L. Lay

In the early part of my program on winter wheat in the 1960's, we made tests of hardiness in wooden flats or plastic trays using suggestions in published papers. A useful differential in survival occurred among varieties seeded in flats, hardened outside until December, then frozen at 5°F for one or two days. Results resembled those occurring in field plots. Since field testing was then so reliable, indoor tests were not continued. The recent occurrence of excessive winter injury in succeeding years and the possibility of refined techniques able to distinguish between varieties at the upper levels of hardiness encourage the use of new artificial procedures.

TILLAGE MANAGEMENT FOR HARD RED WINTER WHEAT PRODUCTION

B. W. Greb

Climate largely determines the cropping system of winter wheat in the Central and Southern Great Plains of the United States into three categories:

Rainfed summer fallow rotations in semiarid areas of 12 to 22 inches (305 to 560 mm) annual precipitation and the 22 to 25 inch (560 to 635 mm) fringe of subhumid climate.

Continuously cropped winter wheat in rainfed subhumid areas of 25 to 32 inches (635 to 810 mm).

Irrigated wheat.

Regardless of cropping system, the objective is to satisfy the water requirement needed for economic production. It takes about 8.3 to 9.0 inches (21 to 23 cm) water-use by winter wheat to produce the first unit of grain. Production proceeds thereafter at 4 to 7 bushels/acre-inch water supply as shown in Figure 1.

At crop harvest, the soil is generally dry to several feet depth. The business of harvest to planting tillage systems is to enhance soil water storage, especially of rainfed systems, and also provide a firm moist seedbed for rapid wheat seed germination. Choice of tillage is dictated by the type of cropping system, volume of crop residue, weed infestation, and to a lesser extent, the soil texture ranging from loose sand to tight clay loam.

The ramifications of tillage are much too complex to be given here. Only an outline of basic principles and a few tillage options are presented for the three categories of winter wheat production.

Summer Fallow Rotations

With alternate fallow-wheat, the fallow season is 13½ to 15 months. In fallow-wheat-sorghum (corn or millet), the fallow season is 10½ to 11 months. Both these rotations include an important overwinter period. The objectives of good fallow include: (1) maximize soil water storage; (2) maintain available N supply; (3) minimize soil erosion; and (4) minimize production costs.

Research and experience shows that the above objectives are best achieved with the following five point program: (1) weed-free stubble by tillage and/or herbicide control during the entire fallow period; (2) keep stubble upright over winter to catch snow, suppress evaporation, and moderate raindrop impact of heavy rain; (3) maintain a straw mulch the last 2½ months prior to planting; (4) maintain hard soil clods ½- to 3-inch (1.3

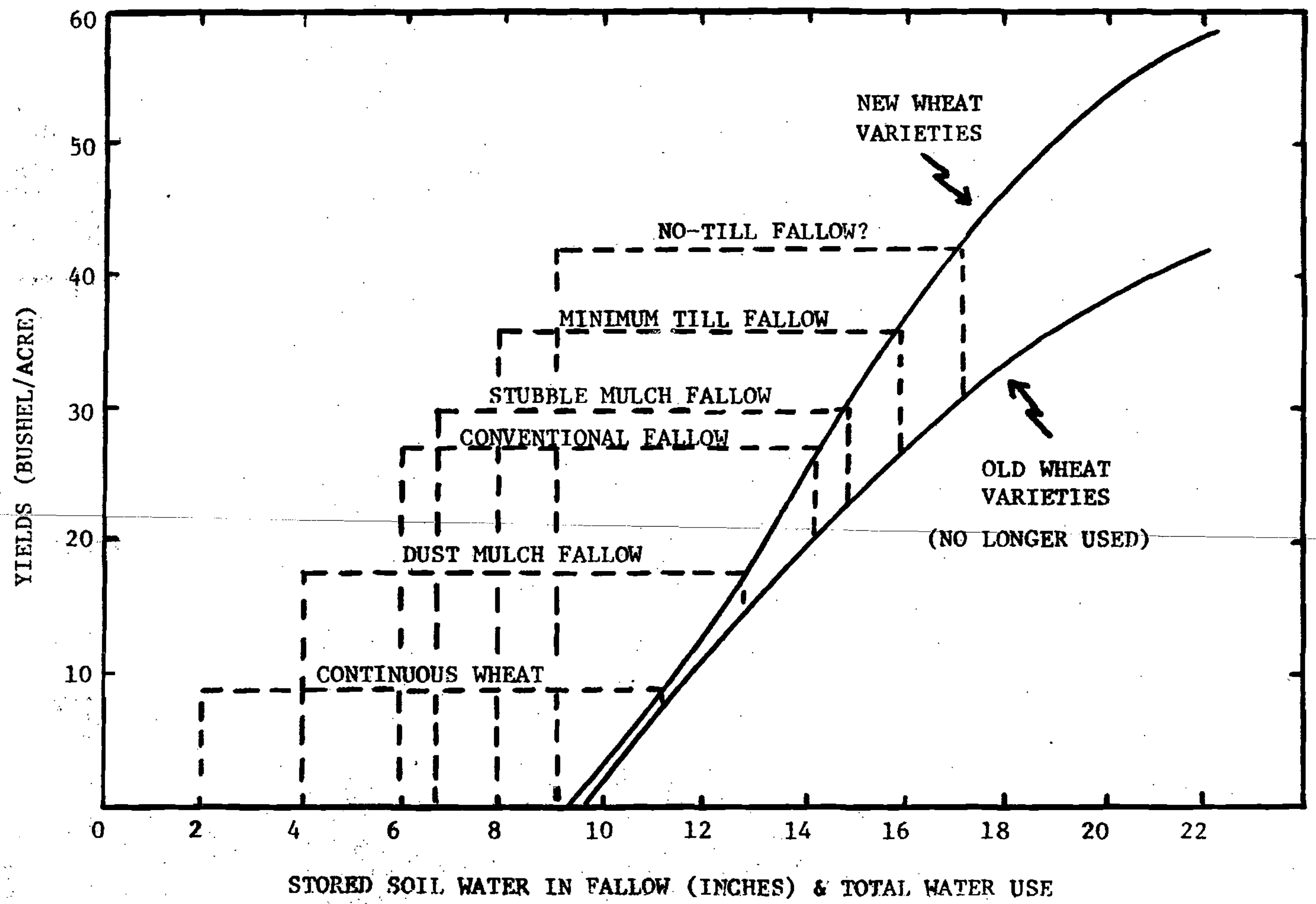

FIGURE 1 - PROGRESS OF WINTER WHEAT YIELDS TO AVAILABLE SOIL WATER AT SEEDING TIME AND WHEAT VARIETIES AT AKRON, COLORADO.

to 7.6 cm) diameter for erosion control; and (5) moist soil near soil surface for seedbed. The three most used tillage systems for fallow include those shown below:

Fallow Systems

Time	Conventional	Stubble Mulch	Minimum Tillage
Fall	--	Sweep	Herbicides
Mid-Spring	Disk (deep)	Disk (shallow)	--
Late Spring	Disk (shallow)	Sweep	Sweep
Summer	Duckfoot chisel Rod-weed Rod-weed	Rod-weed Rod-weed	Rod-weed Rod-weed?

A history of fallow efficiency and resulting wheat yields under these and other systems at Akron, Colorado is given in Figure 1. Yields from North Platte, Nebraska and Colby, Kansas would be somewhat higher than at Akron because of higher annual precipitation.

Fuel costs and technology suggest that minimum tillage fallow will be of greater importance in the near future. No-till fallow is on the drawing boards pending herbicide experimentation and development of new planting equipment needed for heavy stubble conditions.

Continuous Wheat

The time lag from harvest to planting for continuous winter wheat ranges from 3 to 4½ months. It is imperative that 7 to 9 inches (180 to 230 mm) rainfall be received during this period to assure some stored soil water and seedbed moisture. Fall rains after seeding are also needed to promote root extension deeper into the soil.

Tillage options for continuous wheat include at least four systems as follows:

Operations	A	B	C	D
1	Plow (grassy weed control)	Disk (heavy stubble)	Sweep (light stubble)	Herbicide
2	Disk (weed and soil packing)	Rod-weed	Rod-weed	Sweep or Disk (stubble factor)
3	--	Rod-weed?	Rod-weed?	Rod-weed?

There is a trend toward greater use of herbicides. No-till is also a possibility for continuous winter wheat. In both fallow and continuous wheat, the rod-weeder with tongs attached is the standard seedbed tillage operation.

Irrigated Wheat

There should be little difference in tillage and/or herbicide use between irrigated and continuous rainfed wheat. Fresh thick stubble lends itself well to post-harvest weed control if succeeded by full irrigated corn or partial irrigated sorghum or millet. The water requirement for irrigated wheat is little different from fallowed wheat. Assuming a water saturated soil profile to six foot depth containing 8 to 11 inches (20 to 28 cm) available water at seeding time, irrigation can be limited to only about 4 to 6 (10 to 15 cm) inches at the late-flowering stage to achieve high yield. Abundant early spring irrigation tends to elongate stems and leaves at the expense of grain yields later.

Summary

The modern concept for all winter wheat culture during the period from the harvest of a crop (wheat or otherwise) to wheat planting is a weed-free upright stubble maintained as long as possible. This is best achieved with herbicide combinations.

CONTROL OF WINTER ANNUAL, PERENNIAL, AND ANNUAL WEEDS IN WINTER WHEAT

R. L. Zimdahl

Because the title assigned for this paper was so broad, certain assumptions were made. These included that those present knew the usual broadleaf and grass weed problems encountered in winter wheat and could distinguish between them. I further assumed that people understood local weed control recommendations and consulted them when appropriate.

Colorado's recommendations for weed control in winter wheat include only four herbicides (2,4-D, MCPA, Dicamba, and Bromoxynil). The characteristics and uses of 2,4-D and MCPA are familiar to wheat workers. Bromoxynil is a contact herbicide which is superior to phenoxy acids for control of some winter annual weeds such as tansy or blue mustard. It does have good selectivity in wheat and can be used in the fall or early spring without the crop injury often associated with phenoxy acids. Dicamba will control several difficult annual broadleaved species such as kochia and wild buckwheat which are often resistant to 2,4-D. It does not control perennial weeds at rates recommended for selective use in small grains although it will give some suppression in combination with 2,4-D.

Among the important unsolved problems in winter wheat are jointed goatgrass, an annual; downy bromegrass, normally a winter annual although it often behaves as a spring annual; cultivated rye, an annual; field bindweed, a perennial; and Canada thistle, a perennial. The problem with these weeds is not that they cannot be controlled, it's that they cannot be controlled selectively with presently available technology.

Downy bromegrass is a good example of a problem we have helped to create by solving other problems. The way in which we culture wheat and our ability to control broadleaf species have created an environment in which downy bromegrass does well. We know that delaying planting until mid-October will help control this weed. Cultivation associated with planting and soil preparation eliminates early germinating plants and the weed is not as able to germinate later in the fall. The method, of course, will not work if downy bromegrass behaves as a spring annual. Cultivation during fallow will also help but if it is improperly done, it can spread and increase the problem. Plowing will control downy bromegrass because the seeds only germinate in the upper few inches of the soil and do not survive burial. Each of these practices has obvious disadvantages which may preclude use in a given farming operation but they should not be dismissed as trivial control measures.

The same cultural techniques work for jointed goatgrass which is becoming an increasingly serious problem in Colorado. We are creating the conditions for its perpetuation and are often not willing to change or find it economically difficult to change present cultural patterns to effect cultural control. The additional problem with jointed goatgrass is that, to date, there are no acceptable herbicides for it.

There are a few developing chemical controls for downy bromegrass, although they have not received widespread commercial acceptance as yet. They include metribuzin, trifluralin, and diclofop. Metribuzin has given good control of downy bromegrass and other annual grass weeds but usually has reduced crop vigor. The rate which has given good control has often been very close to the rate which begins to injure the crop. Incorporation is essential for weed control with trifluralin. Incorporation to one inch has given control with good crop tolerance. Deeper incorporation has resulted in crop injury although any level of incorporation gave weed control. Diclofop has exhibited excellent crop tolerance and control of downy bromegrass. It offers great promise for control of downy bromegrass and several other annual grassy weeds including wild oats in small grains.

Field bindweed is a vigorous perennial broadleaved species which is a problem in wheat and on fallow land. Glyphosate at a minimum of 2 lbs. of active ingredient per acre has given good results in most trials. Fall application or application after bloom have given best results. Combination of glyphosate with 2,4-D or dicamba has not been advantageous.

Canada thistle can be controlled with 2,4-D but control requires repeated applications in one year and applications over successive years. Combination of 2,4-D with dicamb provides better suppression of Canada thistle. Picloram works well for control of Canada thistle and field bindweed but environmental side effects and crop sensitivity have precluded its use in most situations. Glyphosate has given variable results. Fall application is almost always better and application at the budding stage or later has given better results than application during the spring or in the rosette stage of growth.

NITROGEN AND PHOSPHORUS RELATIONSHIPS IN COLORADO DRYLAND WINTER WHEAT

A. E. Ludwick

A series of field experiments are conducted annually in Colorado to evaluate fertilizer relationships in dryland winter wheat production. This program began in 1977. Nitrogen nutrition and management have been emphasized each year of this program. Phosphorus was introduced as a nutrient variable in 1979.

Nitrogen

Thirty-nine percent of the field sites (11 of 28) were shown to be nitrogen deficient. Yield responses ranged up to 20 bu/A. In general, the magnitude of yield response was inversely related to soil nitrate content. Grain protein consistently increased with nitrogen fertilization; the increase averaged approximately 1% protein per 35 lbs N/A and was independent of soil nitrate content. Present information indicates that a reliable fertilizer recommendation for nitrogen can be made, based on the yield goal of the crop and a soil nitrate test to at least two feet deep.

Three wheat varieties (Scout 66, Centurk and Vona) were evaluated in relation to their response to nitrogen fertilization. Each responded in a similar fashion indicating that there is no need to develop separate nitrogen recommendations based on crop variety.

Sources of nitrogen evaluated included anhydrous ammonia, ammonium nitrate, urea, nitrogen solution (28% N), and ammonium sulfate. In general, these materials performed equally well over the three-year study period. In two cases the nitrogen solution produced greater grain protein than the other materials at an equal rate of nitrogen. This appears to be the exception rather than the rule. Time of nitrogen application was not a significant factor affecting yields comparing preplant incorporation and fall versus spring topdressing of ammonium nitrate.

Phosphorus

In the first season of evaluating phosphorus as a potential limiting nutrient for wheat production in eastern Colorado, three yield responses were observed out of seven locations. The maximum yield response was 4.0 bu/A.

Additional research will be conducted on a range of soils during the next few seasons to determine the extent (frequency and severity) of phosphorus deficiency. Additionally, dual nitrogen-phosphorus application methods will be evaluated for potential positive interactions as have been observed in research by Kansas State University personnel on dryland winter wheat.

AGRONOMIC PRACTICES FOR WINTER SURVIVAL OF WINTER WHEAT

J. K. Aase

The winter of 1978-79 proved to be a severe test for winter wheat survival in the Great Plains of Canada and the northern United States. "Time tested" cultural practices failed and thousands of acres of winter wheat did not survive -- although some cultivars survived better than others.

Survival of winter wheat is influenced by environmental and genetic factors. Some environmental factors causing winterkill include: freezing, desiccation, suffocation, ice crust formation, and soil heaving.

The environmental conditions to which winter wheat is exposed directly affect the rate of hardening and the cold hardiness levels that are attained. Prerequisites for a high level of cold hardiness are well established plants and proper hardening temperatures. If the proper conditions are met, hardy cultivars can withstand soil temperatures at the crown node (ca. 3-cm depth) of -20 to -22°C; less hardy cultivars, -15 to -16°C.

To aid in achieving maximum cold hardiness levels, close attention must be given to management practices. Since winter wheat can regenerate from the undamaged crown node, the temperature to which the crown node is exposed is critical for winter survival. Should the temperature fall below the minimum survival temperature at any time during winter, death of the crown node will result. Therefore, to protect the crown, it is important that proper seeding techniques be employed. Deep furrow drills form furrows about 5 cm deep, providing some protection, and also create uniform roughness for trapping snow. Snow cover is very important -- a uniform snow cover of about 7 cm is probably sufficient to protect the crown when air temperatures occasionally drop to -40°C. Seeding at the proper depth (about 4 cm) into a firm, moist seedbed is important as is time of seeding. A well-developed plant is needed for proper hardening. Early seeding causes too much growth, usually resulting in plants susceptible to disease and injury. Late seeding does not provide enough time for the plant to develop and accumulate enough reserves.

Probably an optimum management practice would be to seed with a zero tillage drill or deep furrow drill directly into standing stubble. Conditions would be that weeds are controlled, soil water is adequate, and proper attention paid to fertilizer needs. The stubble greatly aids in trapping and holding snow and also in itself has an ameliorating effect on soil temperatures and desiccating winds.

Proper attention must be given to P and K fertilizer levels to insure adequacy. Large kernels seem to be advantageous, and uniform seed size will aid in even germination and emergence which in turn will insure better probability of a uniform, well-developed and hardy field of winter wheat before freeze-up.

EFFECT OF CULTURAL PRACTICES ON COLD HARDINESS AND SURVIVAL OF WINTER WHEAT

S. Freyman

Low temperatures during the winter of 1978-79 along with little snow cover, followed by warm weather in early spring and then a cold snap, provided a severe test for winter wheat survival in southern Alberta.

Winterkill was extensive and occurred in patches, with the most severe damage on knolls wind-swept clear of snow. In some cases, winterkill occurred despite the use of recommended varieties and good agronomic practices. However, in many cases, where recommended practices were followed, the wheat survived even though there was little or no snow cover.

For an example, one field had an excellent stand in the corners where the field was 'seeded-out', while plants in the rest of the field were dead or weak. After digging the plants up, it became evident that the most severe damage occurred where the crop was seeded too deep (±7 cm or 3 inches) into a loose seedbed and that healthy plants resulted from shallow seeding (±3 cm or 1 inch) into a firm seedbed. A similar situation was observed in another field where a discer-seeder was used. The best stands were found in the wheel tracks, where compaction prevented the seed from being placed too deep into loose soil. The importance of shallow seeding into a firm seedbed for winter survival has been recognized by Andrews et al. (1959b) and Freyman (1978) and has been a recommended practice for a number of years (Andrews et al. 1959a; Grant et al. 1968, 1974).

Another contributing factor to the widespread winterkill was that most fields were seeded in the third week of September or even later. This was due to unusually heavy precipitation in the late summer of 1978. Studies on the effect of date of seeding winter wheat at Lethbridge showed that the optimum seeding time for maximum winter survival is from September 1 to September 15 (Pittman and Andrews 1960). It was found that there is a rapid reduction in winter survival of wheat seeded earlier or later than this period.

The wheat that survived the winter most consistently had a protective snow cover. Such covers were found in low spots, along roadside embankments, and on fields with stubble. A striking example of the benefit of seeding directly into stubble was found near Medicine Hat, where a farmer seeded his fallow and then, because of excellent soil moisture conditions, decided to continue seeding into stubble of a crop harvested only 3 weeks earlier. The stubble acted as a snow trap, offering complete protection to the over-wintering winter wheat, while plants on fallow with limited or no snow cover were badly damaged and had to be cultivated out.

The climate of southern Alberta is such that in some years it is not possible to seed into stubble. Consequently, I have been studying the use of tall wheatgrass as a means of providing a protective blanket of snow to winter wheat seeded into land that had been fallowed and has little or no stubble. The use of grass barriers to trap snow has been studied extensively in Montana (Aase and Siddoway 1976) but mainly as a means of recharging soil water.

The winter of 1978-79 provided an excellent test for the barriers. Three varieties [Thatcher (spring wheat), Capelle, and Norstar] were grown in consecutive 1.4-m widths between the grass strips. Half of each of the four grass strips was cut (check) while the remainder was left standing to trap snow to the east of each grass barrier.

Soil temperatures were taken at the 2.5-cm depth on mornings following the 6 coldest nights of the winter. Thermocouples were located 1 m, 8 m, and 15 m to the east of the tall wheatgrass strips. Soil temperatures averaged for the six readings and four replicates are shown in Table 1.

Table 1. Soil Temperature, 2.5-cm depth (°C)†.

Distance from strip (m)	Wheatgrass Cut	Wheatgrass Uncut
1	-11.0	- 5.3
8	-10.8	-10.8
15	-11.0	-11.5

†Average of 4 reps on 6 coldest days.

The lowest temperature recorded was -15°C on December 29, 1978. Trapped snow was deepest close to the strips and tapered off to a light skiff 5m away. This light snow cover had no effect on soil temperatures and consequently offered little or no protection to the wheat. Check plots were essentially free of snow. About 10% of Capelle and 5% of Thatcher survived within 2 m of standing wheatgrass but these varieties were completely killed elsewhere. Norstar survived regardless of the presence of a snow cover. Furthermore, distance from, or presence or absence of wheatgrass strips, had no effect on the yield of Norstar. These plots are being continued; however, judging from the experience of the past winter, tall wheatgrass barriers hold little promise as a means of offering protection against winterkill.

Another method of trapping snow in fallowed land is to use furrow-forming drills such as the Noble. My experience so far has been that the snow in the furrows does not persist and consequently offers little protection to the winter wheat.

In controlled environment experiments, I have found that fertilizer and herbicides affect cold hardiness.

The effect of fertilizers on cold hardiness has been known for many years and the reported work has been reviewed (Dexter 1956; Alden and Hermann

1971; Single 1971). It has generally been found that applied N reduces cold hardiness while K increases it, but the effect of P has been variable. We conducted controlled environment experiments on the effect of fertilizers on cold hardiness (Freyman and Kaldy 1979) because no studies had been done on a calcareous Dark Brown Chernozem. This soil is typical of those on which a large portion of the winter wheat on the Canadian prairies is grown and is normally low in N and P and high in K. The effect of applied fertilizers on cold hardiness of winter wheat is presented in Table 2.

Table 2. Cold hardiness of two winter wheats.

NPK fertilizer (kg/ha)	LT 50 (°C)	
	Kharkov 22 MC	Sundance
0-0-0	-16.0 a	-15.7 ab
90-0-0	-13.9 d	-14.1 cd
180-0-0	-13.9 d	-14.2 cd
0-40-0	-15.5 ab	-15.3 ab
0-80-0	-15.4 ab	-15.3 ab
90-40-0	-15.7 ab	-14.9 bc
180-80-0	-15.9 a	-15.9 a

Applied N decreased cold hardiness in the absence of P, while P applied in the absence of N had little effect. When applied together, P counteracted the effect of N, resulting in a significant N x P interaction. The soil was rich in K, and application of additional amounts (in another experiment) had no effect on cold hardiness. These results suggest that, in soils deficient in P, K alone does not counteract the effect of N and that P and, presumably, K are needed to attain a high degree of hardiness when winter wheat is grown on a soil rich in N.

Phenoxy herbicides are occasionally used in the fall to control winter annual weeds such as stinkweed and tansy mustard. We studied the effect of this practice on cold hardiness in a controlled environment experiment (Freyman and Hamman 1979) and found that all the herbicides tested, except diclofop methyl at the lower rate, significantly reduced the cold hardiness (Table 3). Reduction in cold hardiness was greater at the higher rates of application than at the lower rates. The greatest reduction in cold hardiness was caused by MCPA. No reduction in cold hardiness was detected in a field test with the same herbicides in 1978-79.

Table 3. Cold hardiness of Norstar winter wheat.

Herbicide	LT 50 (°C) Low rate†	High rate†
Check	-16.6 g	
Diclofop methyl	-15.9 g	-15.1 f
MCPA amine	-13.1 cd	-11.4 a
2,4-D ester	-14.3 e	-12.6 bc
2,4-DB	-14.1 e	-12.1 b
2,4-D amine	-13.7 de	-12.5 b

†Low rate = 0.5 kg/ha; high rate = 1.0 kg/ha for all herbicides except 2,4-DB, where low and high rates = 1.0 and 2.0 kg/ha, respectively.

In summary, on the basis of observations and research at Lethbridge, the following cultural practices should be followed to minimize the risk of winterkill:

- Seed recommended winter-hardy varieties.
- Seed between September 1 and September 15.
- Seed into stubble. Stubble is the most effective way of trapping snow that will protect the wheat regardless of the severity of the winter.
- Use plump kernels and seed shallow into a firm seedbed.
- If N fertilizer is applied in the fall, the soil P content should also be high.
- Spray phenoxy herbicides in the spring instead of in the fall.

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THE EFFECT OF MANAGEMENT PRACTICES ON WINTER SURVIVAL OF WHEAT

Brian Fowler

The ability of wheat cultivars to survive the extremes of winter can be greatly influenced by management practices. The closer the minimum cold hardiness requirement for a production area is to the cold hardiness potential of a cultivar, the more critical management becomes. Therefore, in our efforts to overwinter wheat under the extreme conditions experienced in Saskatchewan, we have given special emphasis to the role of management.

Seedbed preparation

Seedbed preparation is one of the most important factors affecting winter wheat survival. Hot, dry weather, which often occurs in the late summer, quickly dries out loose, open soils. The result is usually uneven germination and weak seedlings which are extremely prone to winterkilling. Under Saskatchewan conditions this will essentially guarantee a winter wheat failure.

Stubble seeding can result in successful winter wheat stands where the previous crop has been harvested at an early date and where moisture conditions are adequate to permit good plant establishment before freeze-up. The standing stubble assists in trapping snow and a very firm seedbed is provided. No seedbed preparation is necessary; however, good drill penetration is required. The hoe press drill or zero tillage drills will provide the best stands under these conditions.

On both summerfallow and stubble, the optimum seeding depth is less than 4 cm. into firm, moist soil. Deeper seeding often results in delayed emergence and weak plants which are susceptible to winterkilling.

Date of seeding

Winter wheat should be seeded early enough to allow for the establishment of a healthy, vigorous plant before freeze-up. However, seeding too early will result in excessive growth in the fall and plants which are usually less resistant to injury and disease. Generally recommended seeding dates in Saskatchewan are around August 25 for the north and September 7 for the extreme south of the agriculture area.

Snow trapping

Given the extremes of Saskatchewan winters, snow cover becomes a critical factor in winter cereal production. Snow usually arrives earlier and stays later in the Black and Gray soil zones (Parkland) than in the Brown. For this reason, outside of the Chinook area in the extreme southwest of Saskatchewan, the greatest potential for winter wheat production lies in the northern part of the agricultural area. However, even in the Parkland, it is extremely difficult to maintain adequate snow cover for acceptable winter wheat survival on summer fallow fields. This means that some form of snow trapping is necessary in most of Saskatchewan to ensure the successful overwintering of wheat.

Several means of snow trapping have been considered. These include:

(a) Thin stands of rape, flax or other summer annual grown as a companion crop with the winter wheat. To be effective, this method of snow trapping usually requires the companion crop be seeded earlier than the winter wheat.

(b) Trap strips of summer annual crops or perennial grasses sown at intervals across the wheat field perpendicular to the prevailing winter winds. This method also requires two seeding operations. In addition, where perennial grasses are utilized the strips interfere with normal tillage operations.

(c) Tree shelterbelts. Shelterbelts have been utilized effectively to reduce soil erosion by wind. Similarly, they can be effective in trapping and reducing the drifting of snow. However, where there are only a few shelterbelts, most of the snow will collect in or adjacent to the trees leaving the area between the shelterbelts free of snow. A further problem arises in that snow banking of this nature often produces an ideal environment for snow moulds.

(d) Direct seeding into standing stubble or "zero till" cropping. Where "zero till" summerfallow is practiced, there may be some difficulty in maintaining standing stubble until the spring of the winter wheat crop year, i.e. for two winters. Where stubble land is seeded to winter wheat on the same year that it was cropped, there must be sufficient moisture for germination, the recommended seeding date must be adhered to, weeds must be controlled and adequate fertilizer must be provided. Where these requirements have been met, this method of snow trapping has shown the most promise in Saskatchewan.

VALUE OF STUBBLE TO ENHANCE SURVIVAL

D. G. Wells

Stubble of small grain and flax, even in small amounts, protects winter wheat surprisingly well apparently by retarding rates of cooling and warming of the crowns. Tests of varieties, kinds of stubble, methods of preparation of stubble land for seeding, methods of seeding, kinds and rates of fertilizer and placement of fertilizer have been made for many years by Quentin Kingsley at the Watertown and Garden City stations in northeast South Dakota. Lancer and Minter in 1967, surviving 48% and 80% respectively, yielded 46 and 45 bushels per acre at Watertown. Survival on fall plowing was 0 and 5% respectively. Winoka and Hume in the same test yielded 47 and 45 bushels. Handled the same way at Garden City, the four varieties yielded from 45 to 52 bushels. The fields in both cases were bladed first to loosen the soil and diminish growth of weeds. At Watertown in 1968, 30-15-0 fertilizer applied with the seed of Lancer in a press drill or a deep furrow drill produced the highest yields of all treatments, 23 bushels per acre. Waldron spring wheat yielded 38 bushels the same year.

At Garden City, Lancer seed mixed with 50-15-0 fertilizer and seeded with a press drill on bladed stubble yielded 54 bushels. Yields were severely depressed from using a deep furrow drill. Duckfooting plus discing of stubble and chisel plowing of stubble were effective procedures in 1972.

ZERO TILLAGE WINTER WHEAT PRODUCTION IN MANITOBA

E. H. Stobbe

Early reports have suggested that winter wheat survival was improved under zero tillage.

How does zero tillage affect winter wheat production?

1. Better snow retention means warmer soil temperatures. North Dakota studies have shown that snow cover is usually as deep as the height of the stubble. Our results in Manitoba have shown that soil temperatures can be up to 10°C warmer under zero tillage, never allowing the soil temperature at the crown zone to reach -16°C, considered to be critical temperatures for the killing of winter wheat. Winter wheat survival appears to be assured under zero tillage. Although the previous crop stubble may have an effect on the amount of snow retained under zero tillage, rapeseed stubble at Homewood resulted in sufficient snow retention to allow for the temperature differences reported above.

2. Better snow retention results in more moisture for the crop in spring. Results from North Dakota have shown that tall stubble can dramatically increase the moisture available to the plants. Tall stubble would be particularly important in the drier areas of the province.

3. Snow mold. To date we have not noted any snow mold in our winter wheat plots or on farmers' fields. However, due to the more snow cover, snow mold may be a more serious problem under zero tillage. Also, under zero tillage, trash on the soil surface provides an excellent medium on which snow mold can grow, thus increasing the problem compared to conventional tillage.

4. If the winter is severe, even though the winter wheat plants are not killed, under conventional tillage, crop growth and development can be slowed down. In comparison trials on farmers' fields in Dauphin and St. Rose in 1978-79, winter wheat on conventional tillage was 7-10 days behind the wheat grown under zero tillage.

Growing Winter Wheat under Zero Tillage

Seeding Date:

In 1977-78 our trials at Minnedosa suggested that winter wheat could be harvested with respectable yields when the crop was seeded as late as October 26. However, in 1978-79, winter wheat seeded after October 1 was not worth harvesting. Our recommendations would, therefore, agree with those of Alberta where seeding is recommended before September 15.

Seeding Rate:

Our trials comparing seeding rates of 50-100 kg/ha in 1977-78 suggested that winter wheat yields were higher with the higher seeding rates. However, in 1978-79, with seeding dates in mid-August to early September, seeding rate (50-100 kg/A) had little effect on final wheat yield. Our results would suggest that when winter wheat is seeded in mid-September, the seeding rate should be higher than when seeded before September 1.

Seeding Depth:

Under zero tillage deep seeding is difficult since the soil is firm in the fall. Ideally, the seed should be placed into moist soil.

Seeding Equipment:

In our own trials we have seeded our crop with a Melroe triple-disc drill with satisfactory results. In Alberta, trials with a narrow shoe drill have also given good results.

SEEDING OPERATIONS

D. E. Smika

Successful winter wheat seeding occurs when the seed is placed firmly into moist soil with a covering of firm, preferably moist, soil about 1 to 1½ inches thick to keep the seed from drying out before it has time to germinate and establish roots for self-sustained growth. This is not difficult in humid areas where the soil is rewet by frequent rains. However, in the semiarid Great Plains where the surface 3 to 5 inches of soil is frequently dry and will remain in that condition for much of the time, successful seeding may be difficult to achieve.

Another problem frequently associated with seeding in the semiarid Great Plains is the presence of large quantities of residue from the previous crop. This is especially true where minimum or no-till fallow methods were used and residue quantity frequently exceeds 2,000 lb/ac at the end of fallow. Seeding in such conditions is extremely difficult with existing commercially available drills. The residue may be loose and fluffy and may contain large dead weeds, both of which are difficult to get to pass through drills. Best results to date have been obtained with hoe-type drills modified to have a rolling coulter placed in front of each hoe opener. For the coulter to operate properly, they must penetrate the soil so that all trash and residue is cut, not just pushed into the soil. To get proper penetration, each coulter requires about 300 pounds. For sufficient clearance for the trash, the hoe openers should have a minimum working clearance of at least 24 inches in all directions. Hoe openers pass trash best when they are narrow, smooth, and straight.

Minimum and no-till fallow usually provide adequate soil water within the surface 3 inches of soil. But the surface soil is often cloddy and care has to be taken to avoid excessive air pockets in the seed zone, therefore a positive action seed firming wheel or press wheel is a necessity. A second necessity is that the seed dispersing device be such that the seed is dropped no more than one-half inch from the bottom of the slot made by the hoe and as close to the back of the opener as possible. This is necessary to insure that the seed is dropped on moist soil and is pressed into moist soil regardless of whether dry soil falls on top of the seed when being pressed into the moist soil. If the distance from the seed dispensing device and the bottom of the slot exceeds one-half inch and there is any distance between the seed dispensing device and the back of the hoe opener, dry soil will flow into the furrow before the seed can be dropped on the moist soil and poor germination results.

Disk-type drills, single, double, and triple disk, have not been successful because of their lack of ability to penetrate soil to depths necessary to reach the moist soil line. A second disadvantage to disk drills is the fact that they cut and destroy clods which are necessary for wind erosion control.

REGIONAL BUSINESS MEETING

Hard Red Winter Wheat Improvement Committee
February 14, 1980
Ft. Collins, Colorado

Minutes

The meeting was called to order by Chairman Welsh at 8:15 a.m. Committee members in attendance were:

M. K. Brakke, Nebraska (USDA)
L. E. Browder, Kansas (USDA)
L. I. Croy, Oklahoma
B. C. Curtis, Cargill (Colorado)
A. L. Diehl, Northrup-King (Nebraska)
J. R. Erickson, DeKalb (Kansas)
R. E. Finkner, New Mexico
J. H. Gardenhire, Texas
E. C. Gilmore, Texas
V. A. Johnson, Nebraska (USDA)
B. J. Kolp, Wyoming
P. J. Mattern, Nebraska
O. G. Merkle, Oklahoma (USDA)
M. R. Morris, Nebraska
K. B. Porter, Texas
J. W. Schmidt, Nebraska
E. L. Smith, Oklahoma
V. R. Stewart, Montana
G. A. Taylor, Montana
D. G. Wells, South Dakota
J. R. Welsh, Colorado
H. C. Young, Jr., Oklahoma

T. J. Martin read the following tribute to Dr. Ron Livers prepared by him and K. B. Porter:

Recognition of
Dr. Ronald W. Livers

Ron Livers was born and raised in Waterville, Kansas. He received his B.S. degree in agriculture and his M.S. in plant breeding from Kansas State University. He was granted his Ph.D. from the University of Minnesota in 1957. Ron then spent 10 years as a plant breeder at the Clovis Branch of New Mexico's Agricultural Experiment Station.

In 1962, Ron accepted the wheat breeder's position at the Fort Hays Branch Experiment Station, where he resided until his death in November of 1979.

Ron was not only a dedicated Wheat Breeder but also dedicated himself to serving his family and his community. Ron helped raise 4 children, and was still an extremely active Lions Club member for many years. Ron held many offices in local Lions Clubs plus several district and state offices.

In preparing this tribute, Ken Porter and myself talked to a number of people who knew Ron during various stages of his career. The following are but a few of the typical responses we obtained about Ron:

----- Ron was studious and an individual thinker.
----- Ron was a totally responsible researcher and wasn't a fly-by-nighter.
----- Ron had a great deal of curiosity and certainly was determined to know the details of a scientific process and was unwilling to accept a professor's lecture as the gospel truth.

The true measure of Ron's success can best be seen by the grower acceptance of the wheat varieties he released. From 1972 to 1979, over 24 million Kansas acres were planted with his varieties. An additional 5 million acres were planted in the fall of 1979. With the improved bread making qualities of Eagle and the yield advantages of Sage and Larned, it is not difficult to substantiate Ron's influence on wheat production in Kansas.

I feel that the editor of the Hays Daily News probably summed it up best in an editorial in tribute to Ron:

"Too often there is a temptation to focus on the ephemeral. We watch politicians and others of momentary fame come and go, hang on their words, track their arguments - as if, somehow, it was all holy writ.

The loss of someone like Ron Livers, however, shows where the true substance of our culture actually is.

These things are difficult for most of us to measure, yet there is little question that his accomplishments were extraordinary in scale.

Wheat quality and yields once thought to be uncommon now are common.

To say this has affected agriculture is an understatement. It may fit better to say Livers had more of an impact than a mere effect."

Today we pay tribute to Ron Livers and his accomplishments. I believe that Ron would have found it extremely satisfying if this group merely said, 'a job well done'.

Joe Martin
Ken Porter

Members voted to dispense with the reading of the minutes of the last meeting held at Lincoln, Nebraska on February 10, 1977. The minutes are printed in the Proceedings of the Fourteenth Hard Red Winter Wheat Workers Conference, February 8-10, Lincoln, Nebraska.

K. B. Porter reported on the funding status of the Wheat Newsletter as follows:

Balance in Fund May 15, 1979	$1871.52
Expenditures Volume XXV	
Printing	1440.00
Postage	207.50
Bank charges	5.78
Receipts since May 15, 1979	1643.75
Balance in Fund February 9, 1980	1861.99

V. A. Johnson reported briefly on the recent merger of the Wheat Improvement Association with the Hard Winter Wheat Quality Advisory Council. The merger occurred on January 17, 1980 at the annual meeting of the Advisory Council in Manhattan, Kansas. The new organization will operate under the name Wheat Quality Council, Inc. Tom C. Roberts was named Executive Vice-President. Members of a 9-person Board of Trustees were named. State Experiment Stations in the region and USDA/SEA-AR are not represented on the Board. Collaborative large-scale testing of new experimental hard winter wheat varieties will continue to be a central activity of the new organization. T. C. Roberts and a secretary will be full-time paid employees of the new organization. Activities of the organization are intended to be region-wide. R. E. Heiner, named a member to the Board of Trustees, reported that the Board had met and that a Technical Committee to oversee collaborative testing had been named.

E. C. Gilmore reported for E. G. Heyne on the deliberations of a sub-committee on regional nursery distribution and data handling appointed in 1977. Sub-committee members are E. G. Heyne (chairman), E. C. Gilmore, L. E. Briggle, J. R. Erickson, and C. Hayward. The sub-committee report which appears below was adopted.

REPORT OF THE AD HOC COMMITTEE ON GUIDELINES FOR REGIONAL NURSERIES OF THE HARD RED WINTER WHEAT IMPROVEMENT COMMITTEE

Committee Members: Lee Briggle, John Erickson, Charles Hayward, Earl Gilmore, and E. G. Heyne.

The Hard Red Winter Wheat Improvement Committee (HRWWIC) was established by the state experiment stations to foster cooperative research on wheat improvement among the experiment stations in the Great Plains. Over the years, several regional nurseries which are coordinated by the USDA have developed out of this cooperative effort.

Regional nurseries are based on the concept that there are substantial benefits to be derived from cooperative attacks on problems of wheat improvement. The cooperative program in the hard red winter wheat region dates to 1931 and has included testing of new experimental varieties for yield, adaptation, reaction to diseases, insects, and adverse weather, and milling and baking characteristics. Currently, there are six regional nurseries, three of which are replicated performance nurseries (SRPN, NRPN, Hybrids), two concerned with winter-hardiness evaluation (southern, northern), and one for assessment of resistance to wheat soil-borne mosaic. The SRPN and NRPN have effectively aided in the early identification of cultivars with broad adaptation and relatively stable and superior performance in a wide array of production situations. The validity of regional nursery performance as a basis for predicted commercial performance and grower acceptance is attested by such varieties as Pawnee, Scout and Tam 105 - to name only three. Equally important is the contribution of regional testing to determination of limits of acceptable adaptation of cultivars based on disease reaction, winterhardiness, etc. These regional cooperative studies have been profitable to wheat production and should be continued on a broad cooperative base.

The advent of hybrid wheat and the passage of the Plant Variety Protection Acts in recent years have increased the involvement of commercial companies in wheat variety development, which formerly was almost exclusively the domain of public institutions. The HRWWIC first invited research workers of the commercial companies to attend conferences of the committee to foster better communication among all segments of the wheat improvement industry. Later, the commercial representatives were invited to participate in deliberations of the committee and to submit entries for the various regional nurseries, which were distributed to the state experiment stations for testing.

The participation of commercial companies in activities of the HRWWIC led to questions of policy regarding distribution and use of the regional nurseries, and the Regional Coordinator asked the HRWWIC in 1977 for guidelines to follow in administering these nurseries. A committee was appointed to develop these guidelines, and this is a report of that committee.

The guidelines submitted in this report were developed with the objective of offering the commercial companies the maximum participation possible within the constraints dictated by the policies of the various state experiment stations and the USDA. The HRWWIC has neither the authority nor the intention to interfere with or contradict policies of the various state experiment stations, USDA and commercial companies.

Guidelines

1. <u>Source of entries</u>
   Any organization that operates a permanent wheat breeding program, research, and testing facility located in the HWW area may submit entries. The entries submitted would be respected according to the National Wheat Improvement Committee's statement of 27 October 1976 on "Wheat Workers Code of Ethics" (attached).

2. <u>Selection of entries</u>
   Each participant should list proposed entries in order of priority, and the coordinator should select the highest priority entries when necessary to reduce the number of submitted entries to the number established in these guidelines.

3. Size of nurseries

The SRPN, NRPN, and similar nurseries should not exceed 40 entries in any one year.

The Southern Hardiness Nursery should be approximately 300 entries and the Northern Hardiness Nursery approximately 200 entries.

The WSBM nursery should not exceed 200 entries.

All entries should have had adequate local screening and testing before they are submitted as possible entries.

4. Test sites

Public Agencies -- Performance nurseries will be distributed by the Regional Coordinator to state experiment stations for testing in Texas, New Mexico, Oklahoma, Kansas, Colorado, Missouri, Illinois, Iowa, Nebraska, Wyoming, South Dakota, North Dakota, Minnesota, Montana, Washington, Idaho, and Canada. The hardiness nurseries will be distributed by the Regional Coordinator to at least four sites in the northern region of South Dakota, North Dakota, Minnesota, Montana, Canada, and Nebraska.

The wheat soil-borne mosaic virus nursery will be distributed by the Regional Coordinator to at least one site in Kansas and one site in Illinois.

Commercial Companies -- The Regional Coordinator will publish a list of entries in each nursery and distribute these lists to all commercial companies which request them. Any company which desires to grow the nursery will contact each state experiment station or commercial company and request seed for the nursery. The experiment stations and companies submitting entries to the nurseries then may respond according to the policies of their respective organizations regarding distribution of seed.

5. Distribution of data

The Regional Coordinator will collect all data from each nursery, make appropriate summaries and distribute them.

6. Use of the data

Public institutions may refer to data from the nurseries in providing information to the public regarding performance of any entry in a nursery. Reference to overall means of entries in a nursery may be used by public institutions without permission from the various participants in the nursery, but permission must be requested from a participant to utilize data with specific reference to a location or state.

Commercial companies may utilize overall means from the nursery for advertising as long as reference is not made specifically to the name of the nursery, the USDA or an experiment station. Each state experiment station may, if it so chooses, give permission to a company to utilize the experiment station name in advertising but may not give permission to use the name of the nursery. To use data from specific locations in advertising, a company must secure permission from the participant originating the data.

WHEAT WORKERS CODE OF ETHICS

"This seed is being distributed in accordance with the 'Wheat Workers Code of Ethics for Distribution of Germplasm' developed by The National Wheat Improvement Committee 10/27/76. Acceptance of this seed constitutes Agreement."

The originating breeder, station, or company has certain rights to the unreleased material. These rights are not waived with the distribution of seeds or plant materials but remain with the originator for disposal at his initiative.

The recipient of unreleased seeds or plant material shall make no secondary distributions of the germplasm without the permission of the owner/breeder.

The owner/breeder in distributing unreleased seeds or other propagating material, grants permission for use (1) in tests under the recipient's control, (2) as a parent for making crosses from which selections will be made, and (3) for induction of mutations. All other uses, such as testing in regional nurseries, increase and release as a cultivar, selection from the stock, use as parents in commercial F_1 hybrids or synthetic or multiline cultivars, require the written approval of the owner/breeder.

Plant materials of this nature entered in crop cultivar trials shall not be used for seed increase. Reasonable precautions to insure retention or recovery of plant materials at harvest shall be taken.

The distributor of wheat germplasm stocks may impose additional restrictions on use or may waive any of the above.

It was agreed that the regional coordinator at the time he calls for candidate varieties and lines for the SRPN and NRPN will request cooperators to indicate their willingness to have candidate varieties tested by private seed companies. This information will be made a part of nursery lists and will guide private seed companies in making requests for seed from the originating states. Seed of SRPN and NRPN entries will not be distributed to seed companies by the regional office.

It was moved that the Hard Red Winter Wheat Improvement Committee go on record as favoring revision and update of the ASA Wheat Monograph. It was agreed that some sections will need major revision; others only minimal changes. Motion passed.

B. C. Curtis, Lee Briggle, and J. R. Welsh reported on the activities of the National Wheat Improvement Committee. A major activity of the committee in the last two years has been preparation and support of a small grains germplasm proposal calling for expanded facilities and improved support to enable better management and characterization of small grains germplasm. The proposal was cut from the FY1980 and FY1981 SEA budgets. It will be re-submitted for FY1982. There now is strong support for the germplasm proposal from the National Wheat Growers Association, Crop Quality Council, and several other small grains commodity organizations.

The editor of the "Wheat Grower", a national magazine published monthly by the NWGA, has requested short articles from wheat researchers for inclusion in the magazine as space permits. The 60,000 circulation of the magazine, mostly to wheat growers, provides an effective vehicle for communicating wheat findings and activities to growers. The Regional Wheat Improvement Committee Chairman and Secretary will assist in getting articles from cooperators for submission to L. E. Briggle, Secretary of the National Wheat Committee.

E. L. Smith reported on activities of his sub-committee for organization of a Symposium on Yield of Wheat. Following recommendation of the NWIC that consideration be given to making the symposium an activity at an ASA meeting, Dr. Smith proposed that a 1-day symposium be organized at the 1981 ASA meetings in Atlanta, Georgia. He has contacted ASA about this and suggested that the Symposium might be sponsored jointly by Divisions C-1 and C-3.

B. C. Curtis discussed a possible workshop on the "Tan Spot" disease of wheat. A number of workers have indicated their interest in such a meeting. Some have suggested that other similar diseases might also be included in the workshop. There was general agreement that the workshop be organized in the next 12 months. A site for the workshop was not recommended although Fargo, North Dakota was mentioned as a possibility.

V. A. Johnson led a discussion of hard winter wheat regional nurseries. It was agreed that, beginning in 1980, untreated seed would be required from cooperators for regional nurseries. This is to avoid problems caused by seed treatments in various special disease evaluations of entries in the nurseries.

The hard winter varieties Centurk, Parker and Sage exhibit tolerance to barley yellow dwarf. Many current experimental lines have these varieties in their pedigrees. Dr. Henry Jedlinski, SEA/AR at Urbana, Illinois has indicated the desirability of evaluating a limited number of hard winter wheats for reaction to BYD at Urbana. This possibility will be pursued in 1980 with Dr. Jedlinski.

No changes were made in the organization of existing regional nurseries. Conferees expressed their desire for continuation of the breeders field day which, in 1980, is scheduled for Brookings, South Dakota with Lincoln, Nebraska as a back-up site.

Invitations to host the next regional conference were received from Kansas, Montana, and New Mexico. Las Cruces, New Mexico was selected in a close vote. Regional committee members also favored a February date for the 1983 conference. It was suggested that we check with the Canadian cooperators prior to fixing a date to avoid conflicts with several meetings scheduled in February in Canada.

The kind of program for the next conference was discussed. It was moved by E. L. Smith that the next conference program should include a minimum of three topical areas. The motion was seconded and passed. Other suggestions included imposing a one-day limit for each topic; use of discussion panels; and consideration of alternating general conferences with specific topic conferences in the future. Action was not taken on these suggestions.

The following resolutions prepared by E. C. Gilmore and R. E. Heiner were adopted unanimously:

1. <u>Whereas</u>, the Small Grains Germplasm Collections maintained by SEA at Beltsville, Maryland contain invaluable germplasm which has been collected over many years at considerable expense and effort; and

   <u>Whereas</u>, these collections cannot now be replaced because of unavailability of the germplasm or inaccessibility to areas of collection; and

   <u>Whereas</u>, the maintenance of an adequate supply of these collections in a viable condition is extremely important for future development of small grain varieties; therefore,

   <u>Be it resolved</u>, that public and private scientists of the Hard Red Winter Wheat Improvement Committee meeting at Ft. Collins, Colorado recommend to Dr. A. R. Bertrand, Director, SEA and to Dr. T. E. Edminister, Administrator, SEA-AR, that immediate steps be taken to improve the physical facilities housing the small grain collections to assure their maintenance in a viable and accessible condition; and

   <u>Be it further resolved</u>, that adequate funds be made available to systematically describe entries in these collections for use in future breeding programs.

2. Whereas, Dr. E. R. Sears has distinguished himself through scientific achievements in the field of wheat cytogenetics over the past 45 years; and

   Whereas, these achievements have contributed substantially to an understanding of the genetic relationships of wheat and its relatives; and

   Whereas, knowledge and techniques of genetic analysis developed by Dr. Sears has led to improvement of wheat varieties and formed the basis for future scientific programs of wheat improvement; and

   Whereas, Dr. Sears has generously shared his knowledge and techniques with plant breeders; therefore,

   Be it resolved, that the Hard Red Winter Wheat Workers express to Dr. Ernie Sears their admiration for the excellence of his scientific achievements in wheat cytogenetics and their deepest appreciation for his cooperative attitude in assisting wheat scientists in utilization of his techniques and genetic stocks in the development of improved wheat varieties.

3. Whereas, the highlight of this conference was the tribute to Ernie Sears; and

   Whereas, all wheat workers appreciated the opportunity to recognize Dr. Sears, and

   Whereas, Northrup-King Seed Company, Cargill Seed Company, DeKalb AgResearch, North American Plant Breeders, and Seed Research Associates provided funds to bring Ernie and Lotti to this conference to receive our tribute; therefore,

   Be it resolved, that the Hard Red Winter Wheat Workers express their gratitude for the generosity of these companies in supporting this conference.

4. Whereas, the Fifteenth Hard Red Winter Wheat Workers Conference has been an informative and enjoyable conference and has been conducted in an efficient manner; therefore,

   Be it resolved, that the Hard Red Winter Wheat Workers express their appreciation to Dr. Don Johnson, Dean, College of Agricultural Sciences, Colorado State University and Dr. W. F. Keim, Head of the Department of Agronomy, Colorado State University for use of their facilities and for serving as hosts of this conference; to Dr. Byrd Curtis, Ron Norman, and Gerald Ellis for making local arrangements; to Dr. John Erickson and the program committee for developing an interesting and informative program; and to the discussion leader for effectively carrying out the theme of this conference.

Be it further resolved, that the Hard Red Winter Wheat Workers commend Dr. Jim Welsh and express their appreciation to him for his effective leadership during the past three years.

Submitted by Robert Heiner
Earl Gilmore

Dr. E. G. Heyne was elected Chairman of the Hard Red Winter Wheat Improvement Committee for the next three years. V. A. Johnson will continue as Secretary.

E. L. Smith and J. R. Welsh were elected as members-at-large to the National Wheat Committee from the hard red winter wheat region. They, together with the Regional Committee Chairman and Secretary, will represent the hard red winter wheat region on the national committee in addition to B. C. Curtis, who currently serves as chairman of the national committee.

V. A. Johnson
Secretary

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