V. A. Johnson

REPORT

of the

# SEVENTH HARD RED WINTER WHEAT IMPROVEMENT CONFERENCE

Manhattan, Kansas
January 19-21, 1955

(NOT FOR PUBLICATION WITHOUT PERMISSION) 1/

UNITED STATES DEPARTMENT OF AGRICULTURE

AGRICULTURAL RESEARCH SERVICE

Field Crops Research Branch

and cooperating

STATE AGRICULTURAL EXPERIMENT STATIONS

in the Hard Red Winter Wheat Belt

Agronomy Department
Agricultural Experiment Station
Lincoln, Nebraska
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# FOREWORD

The Seventh Hard Red Winter Wheat Improvement Conference was held at Kansas State College, Manhattan, Kansas, January 19 to 21, 1955. The conference was attended by 138 workers. Seventeen states, the U. S. Department of Agriculture, and Canada were represented. Five years had elapsed since the Sixth Hard Red Winter Wheat Conference was held at Stillwater, Oklahoma, in 1950; consequently, the three-day program was a full one.

Conference objectives included a review of research in progress or completed since 1950, the examination of current problems of wheat production, and the formulation of plans and recommendations for future research in the Hard Red Winter Wheat Region. Major topics of discussion included the wheat diseases and insects, quality, breeding techniques, wheat hardiness, genetic and physiologic studies, interspecific and intergeneric crosses in breeding, storage problems, fertilizers, and the regional testing program.

The conference was sponsored by the Hard Red Winter Wheat Improvement Committee composed of 25 members from Experiment Stations in 11 hard red winter wheat-producing states. Dr. H. H. Laude has served ably as chairman of the committee since its organization in 1945. He is succeeded as committee chairman by Dr. A. M. Schlehuber of Oklahoma Agricultural and Mechanical College, Stillwater.

This report includes abstracts of formal papers and statements presented at the conference. General discussion and informal comments made in response to questions have not been included except in the case of the round-table discussion of the regional testing program. Also included are several contributions by workers unable to attend the conference. These are indicated throughout the report by an asterisk after the abstract title. In the interest of brevity, numerous editorial changes have been made in the original abstracts submitted. It is hoped that such changes have not altered the ideas expressed.

A word of recognition and thanks is in order to Dr. Laude and the other people at Kansas State College who made such excellent preparations for the conference. I wish also to express my appreciation to the many people who participated in the conference in various ways, particularly those who organized and led the several panel discussions and ~~to~~ Dale E. Weibel and John W. Schmidt who served as conference secretaries.

V. A. Johnson
Regional Coordinator

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CONFERENCE REPORT

D. E. Weibel, J. W. Schmidt, and V. A. Johnson, Conference Secretaries

WEDNESDAY MORNING, JANUARY 19

S. M. Pady, Chairman

PANEL: RUSTS OF WHEAT
Leader, W. M. Myers, Minnesota

## SOURCES OF RESISTANCE

### PROGRESS IN BREEDING FOR LEAF AND STEM RUST RESISTANCE IN WHEATS ADAPTED TO TEXAS CONDITIONS

I. M. Atkins

Early work on breeding for rust resistance in wheat in Texas resulted in the development of the Austin, Seabreeze, Supremo, and Quanah varieties which utilized Hope wheat as a source of resistance. Westar, with resistance to prevalent races of leaf rust but not to stem rust, also was developed and distributed. More recently, Frisco, from a cross of Fronteira x Red May, was released to growers. While these varieties were improvements over those previously available to farmers, the recent changes in the prevalence of races of leaf and stem rust have reduced the effectiveness of their resistance.

During the early 1940's it was realized that a higher type of resistance than was available in the Hope derivatives was necessary for adequate protection of the crop, to prevent overwintering and to extend the usefulness of the crop into South Texas where it could well be utilized for winter pasture. At College Station, crosses were made to combine the high resistance to leaf rust of certain South American varieties, such as Renacimiento, with the stem rust resistance from several Kenya strains. The cross of Renacimiento x Kenya C10862, P.I. 118901, resulted in the new varieties Bowie and Travis but, even though these varieties were resistant to race 15B of stem rust, they lacked sufficient resistance to protect the crop from other formerly rare races, among them being races 29A, 48A, 49, 125, and 139, so they have not yet been released to growers. Crosses between Bowie or Travis and other wheats resistant to the above races are now being studied.

At the Denton Substation, the leaf and stem rust resistance of Fronteira, Sinvalocho, Marquillo-Oro strains, Hope-Cheyenne strains, the Wisconsin derivatives of Triticum timopheevi and certain Kenya strains, which later were found susceptible to race 15B, were used extensively in crosses during the same period. From this work came the variety Frisco while several other strains of outstanding quality from the crosses (Sinvalocho x Wichita) x Hope-Cheyenne; (Kanred-Hard Federation-Tenmarq x Mediterranean-Hope) x Cimarron; (Cimarron x Hope-Cheyenne) x Comanche; and Kanred-Hard Federation-Tenmarq x Marquillo-Oro are currently being seriously considered for release in the drier sections of Texas where rusts are less frequently of major importance.

Leaf rust races which attack the Hope derivatives became widely prevalent and damaged the crop during the late 1940's. At this time Exchange, Rio Negro, La Prevision 25, Frontana, Marquillo-Oro, and several spring wheats were introduced into the breeding program to bring in new sources of leaf rust resistance. In most of these crosses, the stem rust resistance of parental material was not adequate for present needs so the better selections from these crosses are being used in further breeding work.

When race 15B of stem rust became prevalent in 1950, it was again necessary to widen the base of germ plasm. The Kenya strains, 58 and 117A, were used extensively in crosses at that time as was also the Argentine strain, Sinvalocho x H44-Baja, G-1-3-3-1. Further changes in the races have made these crosses of less value, but some are being continued.

The rapid increase and threat of races 11, 29A, 48A, 49, 125, and 139, which occurred very recently, made necessary still other crosses. These new crosses are in the second and third generations and include the best commercial varieties grown in Texas with Kenya Farmer, Egypt Na 95, Egypt Na 101; the Mexican strains Yaqui-Timstein x Kenya, 2245-1y-3c, Kentana x Yaqui 48, 2585-3y-4c, and Egypt-Timstein x Mayo, 2156-6c-4y-1c; several Canadian selections from the cross Frontana-McMurachy-Exchange x Redman; several Agropyron elongatum derivatives; and selections from McFadden's derivatives of (Triticum dicoccoides x Aegilops speltoides) x Austin$^2$; as well as the better derivatives from Lee, Thatcher, Hope, and other strains developed in the spring wheat area.

There is a small acreage of durum wheat grown in the Central Blacklands and Edwards Plateau areas of Central Texas. With the increase in prevalence of race 15B, this immediately became an important factor in the overwintering and early spread of stem rust whereas, previously, the durum area was not a factor because the durums were resistant to the older races. Several crosses have been made to develop resistant durums for this area and the hybrid populations have been advanced rapidly in cooperation with workers in North Dakota. Durum strains, developed in other programs or through introductions, are also available.

Until very recently, facilities and personnel have not been available for detailed studies with pure races of rust and work was of necessity confined to field observations of reaction to natural epidemics or those developed by artificial inoculation under field conditions. Studies are now in progress on the inheritance of resistance to 15B in the Kenya-derived variety Bowie, in certain Agropyron derivatives, and in Khapli emmer crosses. Attempts are being made to recombine resistance from several sources into germ plasm having a broader base of resistance for future breeding work. A number of species derivatives developed by Dr. McFadden have been crossed with Chinese wheats in the hope that with the aid of present facilities, new sources of resistance derived from related species may be incorporated into useful germ plasm. St 464, a durum introduction from Ethiopia, has been crossed with both common wheat and durum varieties to transfer the high rust resistance of this strain into adapted material.

## COMBINATIONS OF GENES THAT RESIST THE OLD AND NEW RACES OF STEM RUST

E. S. McFadden

One of the principal objectives of the cooperative work at College Station, Texas, has been to produce wheat varieties combining all known factors for resistance to stem rust and leaf rust. During the 19 years that this work has been in progress, practically all sources of resistance to stem rust available up to 1950 have been under study. Observations made up-to-date indicate that there is one combination of source materials, and possibly only one, that will give resistance to all of the present dominant and threatening races of stem rust without bringing in objectional morphological characters.

The incorporation of genes for resistance to many races of stem rust from Hope wheat into varieties such as Austin, Seabreeze, and Supremo undoubtedly resulted in considerable reduction in overwintering of stem rust in southern Texas and Mexico, and we like to think that this was a factor of some importance in the prevention of epidemics in the winter wheat belt for several years previous to 1952 when race 15B first became widespread in southern Texas. However, the Hope derivatives never were very successful in preventing overwintering of such races as 17, 34, and the numerous biotypes of race 15.

High resistance to race 17 and 34 was later incorporated into the Hope derivatives from Thatcher and McMurachy, respectively. However, the wheats having these combinations of genes were later found to be unsatisfactory because of their high susceptibility to race 15B of stem rust and numerous races of leaf rust.

In the spring of 1938, race 49 of stem rust was isolated from McMurachy and several of the Kenya wheats grown at College Station. Seedling tests conducted in the greenhouse the following winter showed all of the 18 Kenya wheats grown in 1938 to be highly resistant to races 17, 38, and 56 but susceptible to race 49 to which Hope, Kanred, and Thatcher were immune. Later tests conducted by Stakman and co-workers showed the same Kenya varieties to have high resistance to several other races of stem rust including race 15B. Consequently, an attempt was made to combine resistance to race 49 from Hope, Kanred, and Thatcher with resistance to many races from the Kenya varieties. The success or failure of this project could never be determined because of loss of our supply of inoculum of race 49. However, none of these crosses produced segregates with sufficient resistance to leaf rust to be acceptable for conditions in southern Texas.

The failure of our early attempts, led to an entirely new approach on the problem in 1939 and 1940. The new approach was based on two new discoveries, viz. that (1) the Kenya wheats were highly resistant to all of the dominant races of stem rust except race 49, and that (2) certain "Latin American" wheats were resistant to a large number of the dominant races of leaf rust including the races that attacked the Hope derivatives. The new approach called for two series of double crosses in which (1) the genes for resistance to stem rust from the Kenya wheats would be combined with genes for resistance to many races of leaf rust from the Latin American wheats, and (2) genes for resistance to race 49 of stem rust from Hope and Thatcher would be combined with genes for resistance to other races of leaf rust from other Latin American wheats and Timstein.

The first chance to evaluate the new "double-cross approach" appeared in 1954 when four or more rare races with pathogenic characteristics similar to race 49 made their appearance in the States bordering on the Gulf of Mexico; namely, races 29A, 48A, 125, and 139. Races 29A and 48A were isolated from infection centers in our nursery at College Station while races 125 and 139 were isolated from samples collected in other Gulf Coast States. However, it appears highly probable that all four of these races could have been isolated from the hundreds of infection centers that developed at College Station following heavy spore showers out of Mexico the latter part of February 1954. It is known also that the races 17, 38, and 15B were present at College Station, and it appears highly probable that several other races reported from other parts of the South were also present before the season was over.

Probably as a result of the great diversity in pathogenic characteristics of the races present in 1954, none of the varieties among those being used as resistant parental material were entirely free from stem rust, while most of them gave completely susceptible reactions. Several selections from Bowie x Lee which had showed high resistance to races 49 and 15B in both seedling and field tests in Mexico broke out in a rash of small pustules shortly before ripening. Dr. Futrell's Khapli derivatives which had showed high resistance in 1953 and our Aegilops speltoides derivatives which had previously been highly resistant also developed numerous small pustules late in the season. Also, a large collection of Agropyron derivatives all developed considerable stem rust before the close of the growing season. Out of 70 bulk hybrids comprising various combinations of resistant vulgare parents, only one combination of genes gave any completely rust-free segregates. This combination was obtained in crosses of Kenya derivatives with Thatcher derivatives. A glance at the chart will show why this combination of genes could, theoretically, give resistance to all races now on the epidemic horizon, and why no other combination of the old standard parental material could be expected to give protection against all of the races. Thatcher not only carries resistance to all of the races to which the Kenya derivative, Bowie, is susceptible but there is a considerable overlapping of resistance to quite a number of races.

Our particular double-cross that has given outstanding results from standpoints of resistance to both stem rust and leaf rust is (Kenya-Renacimiento, Selection 131) x (Frontana-Newthatch, Selection II-46-86-2). The $F_3$ generation of this cross grown in 1954 from unselected $F_2$ plants showed a ratio of close to 1 stem rust immune plant to 3 susceptible plants. No explanation of this ratio in the $F_3$ generation will be attempted at this time, but the high number of completely immune plants in the presence of so many diverse races, and under conditions where immunity is usually recessive leads to the speculation that the obtaining of resistance to all the threatening races now on the horizon may not be a very difficult problem provided factors for resistance to the important races are used in the breeding program.

There is some evidence that the resistance in certain Kenya wheats to a large number of races is controlled by a single major factor and that the same is true for the Thatcher resistance to the remaining races. Furthermore, it appears that the important factor from Thatcher is derived from Iumillo durum rather than the Kanred parent of Thatcher, since certain crosses of Kenya and Kanred derivatives failed to give segregates with resistance to all races present in 1954. Furthermore, Iumillo itself has been reported as being immune to all five of the original biotypes of the threatening races to which most of the Kenya wheats and their derivatives are susceptible, whereas Reliance, which is supposed to carry the Kanred gene, is completely susceptible to one or more of these races.

If further studies show that only two factors are required to obtain resistance to all the present threatening races, the immediate breeding problem is indeed much simpler than is now generally assumed. However, we are assuming that Nature may be holding other races in reserve to attack wheats having the Kenya-Thatcher combination of factors. Working in accordance with this assumption, attempts will be continued to combine additional factors for resistance to both rusts with the Kenya, Thatcher, and Latin American factors.

Seedling Reactions of Parental Varieties to Individual Races of Stem Rust 1/

| Parental varieties | Kenya Resistance | | | | | | | | Overlapping Resistance | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 11 | 15B | 32 | 34 | 38 | 39 | 42 | 56 | 1 | 2 | 14 | 17 | 19 | 36? | 48 | 59 | 69 | 80 |
| Bowie 2/ | 0 1‡ | 0 1- | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 1 | 0 | 0 1 | 0 | 0 | 0 | 0 |
| Thatcher 2/ | 0 4 | 3+ 4 | X+ | 3+ | 2 4 | 2+ | 3 | 0 2+ | 0 | 0 | 0 | 0 4? | 0 | 0 3-? | 0 | 0 | 0 | 0 |
| Kanred (Reliance) 3/ | 3++ | 4 | 4= | 4- | 4- | 4= | 1± | 3+ | 0 | 2= | 1- | 0 | 0 | 4- | 0 | 0 | 0 | 0 |
| Hope 2/ | 0 4 | 3‡ 4 | 3+ | 4 | 0 3 | 2+ | 3-3± | 1 3= | 1 | 1- | 0 | 1+ 4 | 1 2 | 0 1 | 2+ | 0 | 0 | 1= |
| Kota 3/ | 3+ | 3‡? | 3+ | 4= | 3- | 3+ | 0 | 3+ | 3+ | 2= | 1++ | 3+ | 3- | 3++ | 1+ | 0 | 0 | 3- |
| Webster 5/ | 3 | 3-? | 3= | 3= | 3= | 2+ | -- | -- | 3- | -- | 3- | 2- 3- | 2 3 | 3 | 2 | -- | -- | -- |
| Frontana 2/ | 1 3+ | 1 3= | 0 1 | 2+ | 0 3+ | 1+ | 0 2 | 0 1+ | 2- | 1 | 2+ | 1‡ 3+ | 2 3 | 2 3- | 1+ | 2 | 1- | 1+ |
| McMurachy 2/ | 0 3 | 0 3+ | 0 | 0 | 0 2+ | 0 | 0 3- | 0 | 0 | 0 | X+ | 0 1+ | 0 | 0 1 | 0 | 3+ | 0 | 0 |
| Timstein (or Lee?) 2/ | 0 1‡ | 2 4 | 0 1 | 1 | 0 1 | 1 | 0 1 | 0 1 | 1= | 1- | 2+ | 0 2+ | 0 | 0 | 1- | 0 | 1- | 1= |
| Supremo 2/ | 1 4 | 3 4 | 3- | 3= | 2 3 | 2 | 1 3- | 2+ 3- | 3- | 2- | 2+ | 2- 3 | 1 2 | 2 3 | 2+ | 2 | 1= | 2+ |
| Red Egyptian 2/ | 0 1‡ | 0 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | X- | 0 1= | 0 1 | 0 1+ | 0 | 3= | 0 | 0 |
| Kenya 338.A.A.1.A.2 2/ | 0 2 | 0 3 | 2 | 1- | 0 3 | 2 | -- | 1 3= | 2- | 2- | 1= | 1 3- | 3= | 0 1 | 1+ | 0 1 | 1= | 2 |
| Kenya 338.A.C.2.E.2 2/ | 0 1 | 0 1 | 0 | 0 | 0 1 | 1- | 0 | 0 1 | 0 | 1- | 1= | 1= 1‡ | 0 | 0 1- | 0 | 0 | 0 | 1 |
| Front. x Newthatch, Sel. II-46-86-2-1 4/ | 0 1- | 0 2- | -- | 2+ | 2+ | -- | -- | 1 | -- | -- | -- | 0 | 0 | 0 | -- | 0 | -- | -- |

| Parental varieties | Thatcher Resistance | | | | |
|---|---|---|---|---|---|
| | 29A (17M) | 48A | 49 | 125 | 139 |
| Bowie 2/ | 1= 1+ | 3? | 2- 2 | 2+ | 0 3+ |
| Thatcher 2/ | 0 | 0? | 0 | 0 | 0 |
| Kanred (Reliance) 3/ | 0? | 0? | 0 | 4 | 1- |
| Hope 2/ | 4 | 2+? | 0 1+ | 0 | 0 1+ |
| Kota 3/ | 3? | 1+? | 4= | 4 | 2± |
| Webster 5/ | 3+? | 3-? | 3- | -- | -- |
| Frontana 2/ | X- | 1+? | 0 1+ | 1+ | 0 2 |
| McMurachy 2/ | 0 | 0? | 2 4 | 1+ | 0 4 |
| Timstein (or Lee?) 2/ | 0 | 1-? | 0 1‡ | 0 1 | 0 1+ |
| Supremo 2/ | 2+ | 2+? | 1+ 3- | 0 1 | 0 2 |
| Red Egyptian 2/ | 2‡ | 0? | 3= | 2+ | 0 3- |
| Kenya 338A.A.1.A2 2/ | 2+ | 1+? | 0 1+ | 2- | 0 1+ |
| Kenya 338.A.C.2.E.2 2/ | 1- | 0? | 0 1 | 0 | 0 1+ |
| Front. x Newthatch, Sel. II-46-86-2-1 4/ | 2 | 0 | 0 | 0 | 2 |

1/ Compiled from various sources.
2/ Data from 1953 elite nursery tests.
3/ Data from Paper No. 2148 by Stakman, et.al.
4/ College Station data combined with data supplied by T. Johnson.
5/ Data from Stakman, et.al.

## SOURCES OF RUST RESISTANCE IN OKLAHOMA

H. C. Young, Jr.

There have been 9 races of leaf rust identified from collections made in Oklahoma during the past 4 years. They are races 5, 9, 15, 21, 32, 58, 105, 105A, and 105B. Westar is resistant to all but 58, 105A, and 105B and Concho is resistant to all but 32, 105A, and 105B. These two varieties in addition to selections of Triticum sp.-Agropyron elongatum x Pawnee, Anniversario, Wabash x American Banner, and Frondoso x Trumbull-Hope-Hussar are being used as sources of resistance to leaf rust.

Kenya Farmer and a selection of Gabo x Peru-Supremo-Peru are being used as new stem rust resistant sources.

## SOURCES OF RESISTANCE TO PHYSIOLOGIC RACES OF LEAF RUST

C. O. Johnston

Despite the fact that many physiologic races and biotypes of leaf rust are present in the hard winter wheat area, ample resistance is available for breeding programs. Excellent sources of resistance among the winter and spring wheats are shown in the accompanying table. In addition, several selections of (Chinese x A. elongatum) x Pawnee made in Oklahoma are resistant to all races with which they have been tested. Many other wheat x Agropyron hybrids apparently are resistant to most races. Several selections of (T. vulgare x T. timopheevi) x T. vulgare made in Wisconsin have high adult plant resistance to many races, although they show little seedling resistance.

Many of these sources of resistance have been used in crosses at the Kansas Station and resistant segregates are now in advanced generations. Some of the most promising material has been selected from the Mediterranean-Hope-Pawnee x Frontana cross in which leaf rust resistance from all four parents and stem rust resistance from Hope and Frontana apparently have been combined.

Some of the Better Leaf Rust-Resistant Wheat Varieties and Their Reaction to Physiologic Races of Leaf Rust

| Class and variety | C. I. No. | Reaction and races | | |
|---|---|---|---|---|
| | | High resistance | Moderate resistance | Intermediate |
| Hard Winter | | | | |
| Concho | 12517 | 1,9,10,15,19,93, 122 | 5,15,28,35 | 11,58 |
| Pawnee | 11669 | 1,9,10,11,13,19,20 | | |
| Ponca | 12128 | 1,9,10,11,15,19, 20,50,93,128 | 3,45 | 5,58,126 |
| Quanah | 12145 | 1,11 | | 5,9,35,126 |
| Sioux | 12142 | 1,9,10,11,19,93 | | |
| Westar | 12110 | 1,3,5,9,10,15,19, 20,21,45,50,58 | 93,126,128 | 11,77,105 |
| Westar sel. | 13090 | 1,3,5,6,9,15,35, 37,44,77 | 10,11,19,21, 50,58,68 | |
| Soft Winter | | | | |
| Blackhawk | 12218 | 9,11,19,45,93,105, 128 | | 15 |
| Bowie | 13146 | 1,9,10,11,19,37, 44,68,93,131 | | 6,15,28 |
| Kawvale | 8180 | 9,10,11,19,93 | | |
| Wabash x American Banner | 12992 | 1,5,6,9,11,15,37, 58,105 | | 35 |
| Well Medit. sel. 40 | | 1,5,9,11,15,58, 122 | 6 | |
| Spring | | | | |
| Aniversario | 12587 | 1,5,6,9,10,11,15, 19,20,35,37,58, 93,105,126 | | |
| Frontana* | 12470 | 1,11,15,58,93 | 105 | 5,9,10,20,35 |
| Gabo* | 11795 | 1,5,9,10,15,19,20, 35,93 | 105 | 11,58 |
| Kenya Farmer* (338AC.2.E.2) | | 1,5,9,10,35,58,93, 122 | | |
| La Prevision 25 | 12956 | 1,9,10,11,19,20, 58,93,105 | 5,15 | |
| Lee* | 12488 | 1,5,9,10,15,19, 58,93,122,126 | 6,11,28,37, 105 | 131 |
| Renacimiento | 12002 | 1,9,11,15,58,93, 105 | 35 | |
| Rio Negro | 12469 | 1,11,15,58,93 | 5,9,105 | |
| Selkirk* | 13100 | 1,5,9,10,15,19, 58,93,122,126 | 6,11,28,105 | 131 |

* Variety has considerable resistance to stem rust.

## SOURCES OF RESISTANCE TO WHEAT STEM RUST IN KANSAS

W. C. Haskett

At the present time there are no commercial varieties of hard red winter wheat grown in Kansas resistant to race 15B of stem rust. Pawnee and Comanche have shown some degree of tolerance to stem rust in the field. Triumph is able to escape damaging infection by early maturity. Concho and Cheyenne have been particularly heavy rusting varieties in the field.

Seedling resistance to various races is shown in the following table:

| Variety | Race of stem rust and reaction | | | | | |
|---|---|---|---|---|---|---|
| | 15B | 49 | 29 | 48A | 56 | 17 |
| Cheyenne | 4 | 0; | 0; | 0; | 3+ | 3+ |
| Nebred | 4 | 2+ | 3 | 3 | 3 | 2 |
| Sioux | 4 | 1-2 | - | - | 4 | 2 |
| Comanche | 3+ | 0; | 0; | 0; | 3+ | 1-2 |
| Tenmarq | 3+ | 0;? | 3+ | 3+ | 3+ | 3+ |

These varieties will be tested in the mature stage this year.

The following sources of stem rust resistance are being used in the Kansas breeding program: Timstein; Frontana; McMurachy; Red Egyptian; Kenya, RL 1373; Kenya 117A; Kenya Farmer (338AC.2.E.2); Kentana; Gaza; Hope; and Egypt Na 101. In addition, certain timopheevi hybrids and Agropyron sources have been used.

The combination of two or more sources of resistance in many hybrids has given a broad base of resistance to many races including race 15B. The following data show the relative field resistance and seedling resistance to certain races. These hybrids are representative of the stem rust-resistant material being developed at this Station.

Field and Seedling Reaction of Winter Wheat Hybrids to Stem Rust, 1954

Manhattan, Kansas

| Hybrid | Field reaction | Seedling reaction to races | | | | |
|---|---|---|---|---|---|---|
| | | 15B | 49 | 29 | 48A | 56 |
| Frontana x M. H. P. | 2 R | 1+ | 0; | 2 | 2 | 1 |
| Kv. Mqo. x Clarkan x R. E. | 10 R | 0-1 | 1 | 1 | 2 | 1 |
| Egypt Na 101 x Hope-Chey. | 20 MR | 0-1 | 0; | 0; | 0; | 1 |
| Bobin-Bobin-Gaza x Pn. | 20 MS | 1 | 0; | 1- | 1= | 1= |
| Med-Hope-Tq. x McMur. | 20 MS | 4 | 0; | 0; | 0; | 0; |
| Com. Med. Hope x Com. | 15 MR | 3+ | 1 | 0; | 2 | 1 |
| Kenya x Hope-Turkey | 10 R | 1+ | 4 | 4 | 4 | 1 |

The most outstanding lines are from Frontana x Med.-Hope-Pawnee crosses. They possess a high level of resistance to both stem and leaf rust.

Early generation hybrids involving Shands 473 and Kenya Farmer possess a very high type of field resistance.

## BREEDING FOR RUST RESISTANCE IN NEBRASKA

V. A. Johnson

Rust resistance is a major objective in the winter wheat breeding program at Nebraska. Some of the sources of leaf and stem rust resistance which have been utilized are as follows:

| Variety | C. I. or sel. no. | Hybrid material |
|---|---|---|
| Kenya 58 | 12471 | $F_5$ |
| Kenya 117A | 12568 | $F_5$ |
| Mida x Kenya 117A | II-44-2 and II-44-22 | $F_5$ |
| Kenya 58 x Newthatch | II-44-29 | $F_5$ |
| Red Egyptian | 12345 | $F_5$ |
| Ill. 1-Chinese x T. timopheevi | 12633 | $F_5$ |
| (T. timopheevi x T. vulgare) 473 x Cheyenne | 13005 | $F_3$ |
| McMurachy-Exchange x Redman | 187166 | $F_5$ |
| Webster | 3780 | $F_3$ |
| Frontana | 12470 | $F_5$ |
| T. vulgare volunteer | Sando No. 60 | $F_1$ |

Potential stem rust-resistant material has been screened through seedling tests in the last three years to stem rust races 15B, 11, 139, and 48A and in the adult stage to 15B, 56, 38, and 17. Segregates from crosses of winter wheats with Mida-Kenya 117A and Kenya 58-Newthatch have shown the highest type of seedling resistance to the races used. $F_3$ material of the first back-crosses of resistant segregates to winter wheats represents the present stage of the second breeding cycle.

# PROGRESS IN BREEDING WINTER WHEAT IN MINNESOTA

E. R. Ausemus, D. W. Sunderman, K. J. Hsu
(Presented by D. W. Sunderman)

Winter hardiness and rust resistance are two of the most important problems in winter wheat breeding at Minnesota. In the last 12 years, 100 percent winterkilling occurred four times at St. Paul, almost a complete failure of the crop once in every 3 years. Minturki, Minter, and Minhardi have been the most winter-hardy varieties. Crosses have been made with these and with derivatives from such varieties as Minhardi, Marmin, and Cheyenne, but none of the selected lines have exceeded the winter hardiness of Minturki and Minter. All the older varieties are susceptible to stem rust race 15B.

In breeding for rust resistance, the selections are grown in a field rust nursery at St. Paul where a mixture of leaf and stem rust races are used in creating the epiphytotic. Sixty races and biotypes of stem rust and 14 races of leaf rust comprised the mixture used in 1953 and 1954.

A group of varieties now being grown in rod-row trials are resistant to both leaf and stem rust in the Rust Nursery and in field trials throughout the State. The parentages of these strains are:

| | |
|---|---|
| H255-49-5-1-4 x Blackhawk | H255 = Minturki x [(Ill.-Chinese x T. timopheevi) x Red Turkey] |
| H227-10-3-1-1 x H255-49-5-1-3 | H227 = Fultz-Hungarian x Forward-Hope-Hussar x Minhardi-Fulhio |
| H207-1-6-3-1 x H255-49-5-1-3 | H207 = Wabash-Hope-Hussar x Minhardi-Fulhio |

The crosses were made by Dr. R. G. Shands of Wisconsin and $F_2$ to $F_5$ selections have been made at St. Paul in years when plants survived the winters. The winter hardiness of these newer strains remains to be seen. Some of the best rust-resistant strains have been used to cross with Minter, Minturki, and other varieties for the purpose of obtaining a variety that has winter hardiness, rust resistance, and other desirable characters.

The program of incorporating the resistance to rust from spring wheats to winter wheats has been continued. Frontana and Klein Titan, resistant to leaf rust, and Kenya 117A and Kenya 58, resistant to stem rust, have been used as the non-recurrent parents in backcrosses with Minter and Minturki. The progenies of second backcross have been tested in the rust nurseries. Lines resistant to leaf rust are being crossed with the selections resistant to stem rust in an attempt to produce a rust-resistant variety with the winter hardiness and quality of the recurrent parent.

Other sources of resistance to rust have also been used, among which are the selections of Agropyron-wheat and T. orientale-Agropyron, P.I. 201821. The latter, P.I. 201821, is highly resistant to both stem rust and leaf rust, late in maturity, and has long, bearded heads and produces slender kernels more like rye than wheat. It has 21 pairs of chromosomes and crosses readily with wheat. In many crosses with wheat, the $F_1$ plants are dwarf or, if not dwarf, partially sterile. Backcrosses are being made to wheat.

The future plans of winter wheat breeding at Minnesota include (1) to seek new sources of winter hardiness and new sources of resistance to stem and leaf rust, (2) to continue and intensify the backcross programs, (3) to breed for stiff straw and good quality, and (4) to continue irradiation studies to obtain new, desirable characters.

## SOURCES OF RESISTANCE TO LEAF AND STEM RUST USED IN COLORADO

T. E. Haus

Races 17, 38, and 56 of stem rust have been prevalent in Colorado with occasional reports of other races since 1934 and in recent years race 15B has also been reported yearly. Prior to the occurrence of race 15B, the Hope type of resistance seemed to offer good control of the disease. With the appearance of race 15B, new sources have been sought. The following selections have been used:

| Variety | C. I., P. I., or sel. no. |
|---|---|
| Gabo x (Peru-Supremo) Peru | 185905-1 |
| Maria Escobar x Newthatch-Peru | 185907-1 |
| Mayo x (Peru-Supremo) x (Peru-Kenya) | 185918-3 |
| Newthatch-Marroqui x (Peru-Supremo) Peru | 185955-1 |
| Kenya 117A | 12568 |
| Kenya Farmer | 187165 |
| Egypt Na 101 x Timstein | 704-1y-5y-2c-1c-1c-1y-1c |
| Frontana x II-44-29 | II-50-18 |
| Do. | II-50-25 |
| Do. | 13155 |
| Do. | II-50-71 |

## SOURCES OF RUST RESISTANCE USED AT WISCONSIN*

H. L. Shands

Over the years, leaf rust probably has been more damaging than stem rust in Wisconsin. Recently race 15B threatens more than leaf rust since the latter is fairly well under control by use of Blackhawk.

Leaf rust resistance is being supplied by Blackhawk, Knox, Shansi 480, and timopheevi derivatives.

Stem rust resistance is being provided by timopheevi derivatives; McMurachy-Exchange-Redman3 x winter wheats (stocks from Kansas); and the following spring wheat varieties: Kenya Farmer, C.I. 12880; Veadeiro, P.I. 192475; and Yaqui (Timstein-Kenya), 2245-1c-3y-3c. They have been crossed with H410-7-1-1-2, H409-15-5-4-3, H483a-1-1-5, and C.I. 12658. The parents of H483a are C.I. 12662 x Blackhawk.

## "BREAKDOWN" AND BUILDING OF RESISTANCE TO LEAF RUST OF WHEAT

R. M. Caldwell, L. E. Compton, F. L. Patterson, and J. F. Schafer
(Presented by R. M. Caldwell)

Several selections of the family 3369-61-1 from the cross Wabash x American Banner, including C.I. 12879 and C.I. 12992, have been highly resistant to a very considerable number of races of leaf rust in tests in Indiana, Kansas, Minnesota, and Canada. Collections of races 35 and 45 have now been obtained that produce four type reactions on these lines. Warden x Leap, C.I. 12660, is highly resistant to these two races although susceptible to races 89 and 104B to which C.I. 12992 is highly resistant.

Derivatives of a cross between 3369-61-1-1-2-3 and C.I. 12660 have been obtained giving highly resistant reaction to all four of these races as well as to four other races to which tested thus far. (See accompanying table). Genetic studies of the resistance of C.I. 12992 by Fitzgerald, Caldwell, and Nelson indicate that resistance to leaf rust races 5, 15, 9, and 76 is governed by dominant genes at four different loci, and that resistance to race 65 is governed by duplicate recessive genes. Genes for resistance to races 15 and 76 are closely linked.

Derivatives of Agropyron elongatum having characteristic vulgare type, grain quality, and promising performance have given an "O" type seedling reaction to all leaf rust races to which tested thus far. This resistance is considered to present a good possibility of providing a type of protection from leaf rust that may be more "stable" than that derived from Triticum species. This type of resistance has been readily transferred in breeding operations. Limited studies of the inheritance of the leaf rust resistance of the Agropyron derivative, Purdue 39120A5-3-1-1-1, indicate a segregation in approximately a 1:1 ratio in backcrosses, although some as yet unexplained deviations have occurred.

Winter-hardy derivatives of Aniversario have been found to be highly resistant to five races of leaf rust in seedling tests. In the field in 1954 several lines showing such highly resistant seedling reactions developed infection of 35 percent severity of an intermediate type. Aniversario itself developed field infection of 50 percent severity of an intermediate type.

The mature plant resistance of the spring wheat, Chinese, C.I. 6223, has been utilized in a commercial wheat for the first time in the production and release of the Knox variety. Thus far in nursery trials under inoculation with a array of virulent races this resistance has held rust infection to the 0 to trace level. Some reports of higher infection have come from uniform nursery trials.

Kenya Farmer has been highly resistant to leaf rust throughout the hemisphere. It has shown high seedling resistance to a number of races but is susceptible as a seedling to those cultures of leaf rust found also to be virulent on Warden-Leap, C.I. 12660.

| Variety | C. I. no. | Race or biotype and reaction 35 | 45 | 89 | 104B | 104 |
|---|---|---|---|---|---|---|
| Malakof | 4898 | 4 | 0 | 4 | 4 | 4 |
| Hussar | 4843 | 1 3+ | 1+ 2- | 4 | 1- 3 | 1- 3 |
| 3848-36 | 12530 | 1= 3- | 1- 1+ | 4 | 1= 1 | 1- 1+ |
| Wabash-American Banner | 12992 | 4 | 4 | 0 1 | 0 X | 0 |
| Warden-Leap | 12660 | 0 1- | 0 | 4 | 4 | 0 |
| Kenya Farmer | 12880 | 0 1+ | 0 1= | 2- 3+ | 4 | 0 1- |
| Warden-Leap x Wabash-American Banner | | 0 | 0 | 1- | 0 | 0 |
| Purdue 39120A5-3-1-1-1 | | 0 | 0 | 0 | 0 | 0 |
| Aniversario | 12578 | 0 1= | 0 1= | 1 X | 0 2- | 0 1- |

## BREEDING WHEAT FOR RESISTANCE TO STEM AND LEAF RUST*

A. B. Campbell
Cereal Breeding Laboratory, Winnipeg

In 1951 we started a backcrossing program with the purpose of producing high-quality hard red spring wheats with a broader base of stem rust and leaf rust resistance than possessed by varieties then in use. The backcross method appeared to hold the greatest promise at that time, all things considered. The recommended varieties for Manitoba were Lee, Redman, and Thatcher; consequently, these three varieties were used as recurrent parents. Since that time Chinook, a sawfly-resistant variety, and Selkirk have been added to the list. Selkirk itself is almost a backcross variety, having three doses of Redman in it. These recurrent parents include a number of notable sources of stem rust resistance, Thatcher, Hope, H-44-24, Timstein, and McMurachy. Kenya Farmer is the only donor parent being used for additional stem rust resistance. We are searching for additional sources to use in this program, but have not been successful to date in locating new ones.

The recurrent parents mentioned above also include several notable sources of leaf rust resistance, Hope, H-44-24, Timstein, and Exchange. For additional leaf rust resistance we have been using the donor parent Frontana chiefly; also, some Lee and a line of Klein Titan x Thatcher3 obtained from Dr. E. R. Ausemus. Recently we have started using Exchange again and Maria Escobar.

Our progress in this program is indicated by the material we now have on hand:

| Recurrent parent | Doses | | Donor parent | Generation |
|---|---|---|---|---|
| Thatcher | 6 | x | Kenya Farmer | $F_5$ |
| Thatcher | 7 | x | Kenya Farmer | $F_2$ |
| Thatcher | 7 | x | Frontana | $F_1$ |
| Thatcher | 6 | x | Klein Titan | $F_1$ |
| Lee | 6 | x | Kenya Farmer | $F_5$ |
| Lee | 7 | x | Kenya Farmer | $F_2$ |
| Lee | 7 | x | Frontana | $F_1$ |
| Redman | 7 | x | Kenya Farmer | $F_2$ |
| Redman | 6 | x | Frontana | $F_1$ |
| Selkirk | 3 | x | Kenya Farmer | $F_2$ |
| Selkirk | 3 | x | Frontana | $F_1$ |
| Selkirk | 2 | x | Exchange | $F_1$ |
| Chinook | 2 | x | Kenya Farmer | $F_1$ |
| Chinook | 1 | x | Maria Escobar | $F_1$ |

We have already made some of the crosses necessary to combine both leaf and stem rust resistance in Thatcher and in Lee, but have not tested any of the progeny as yet. We intend to make crosses among the different derivatives in the hope of improving yield and other agronomic characters, while maintaining stem and leaf rust resistance.

Several genetic studies are being conducted jointly by our Laboratory and the Plant Pathology Laboratory, Winnipeg. One involves diallel crosses among the varieties Garnet, McMurachy, Kenya 122.D.I.T. (L) (R.L. 1373), Timstein, and Gabo. The purpose of this study is to distinguish as many different stem rust genes as possible. Tests of seedling resistance have almost been completed with race 15B. Tests with race 56 will be made this winter. A final check of adult plant resistance will be made in the field in 1955.

A similar leaf rust study involves the varieties Garnet, Exchange, Frontana, Klein Titan, and Timstein. $F_3$ lines of most of the crosses are available and seedling tests will be made with races 5a and 15a. The "a" signifies that these races attack Hope, H-44-24, and their derivatives.

Another study is under way to evaluate the leaf rust resistance of Rio Negro and Maria Escobar. These varieties have been crossed with Frontana, Klein Titan, and Lee. Adult plant tests will be made in the hope of finding another outstanding source of leaf rust resistance for use in our backcrossing program.

## CURRENT PREVALENCE AND DISTRIBUTION OF RACES

### THE STEM RUST RACE SITUATION AND ITS RELATION TO BREEDING

E. C. Stakman, E. B. Hayden, and D. M. Stewart, Minnesota
(Presented by E. C. Stakman)

The trend toward turbulence in the physiologic race situation of wheat stem rust that started in 1950 has continued, and still further continuance seems probable. The situation in the United States can hardly be considered apart from that in Mexico and the situation in Guatemala may have to be considered also.

Since 1950 when race 15B became prevalent, there have been a number of important developments. The first was the increase of the race 49-139 complex in Mexico with subsequent subsidence. The second and most recent change has been the increase in prevalence of the race 17-37-29 complex and of the 48 complex, both in Mexico and in the United States in 1954 with preliminary indications earlier. A high percentage of the race 17-37-29 complex is race 29 and a high percentage of the race 48 complex, in Mexico at least, is race 48A. Races 29 and 48A each comprised about 35 percent of the total number of isolates in Mexico in 1954, together making up about 70 percent of all Mexican isolates. Both were widely distributed in the United States and, according to Canadian reports, in Canada also. Along with the increase of races 29 and 48A in Mexico was a decrease in prevalence of race 15B.

Several late collections of rusted material from Mexico have not been identified, but so far the following races have been found: 9, 11, 15, 15B, 29, 38, 48A, 49, 56, and 139. There were only a few isolates of races 9, 11, 49, and 139. There were a number of isolates of race 15, all from one place.

Among the approximately 1,100 isolates identified in the United States, races 15B, 56, the 38-48 complex, the 17-37-29 complex together comprise upwards of 90 percent of the isolates. Other races identified are 1, 11, 15, 19, 32, 59, 59A, 59B, 59C, 95, 125, and 139.

From barberry the following races have been isolated: 11, 15, 15B, 17-37-29 complex, 32, 33, 38-48 complex, 56, 57, 59, 59A, 59B, 59C, 98, 102, 111, and 139.

Some of the races are very difficult to identify without making trials both at moderate and at high temperatures. This is conspicuously true of the 17-37-29 group. Race 29, which appears to be most prevalent in this group, may look like 17 at high temperatures as the infection type X is not clear on the durums. At temperatures of 65° F. to 70° F., however, it is perfectly clear. There are no facilities for maintaining low temperatures during the summer and many collections, therefore, have to be rerun in the fall. It has been pointed out frequently that races 49 and 139 are quite distinct at temperatures up to about 75°, but so far they are indistinguishable at 85°. There is similar difficulty with the 38-48 group. There appear to be biotypes that are intermediate between 38 and 48. Extensive studies are being made to determine the range in variability of infection types produced on the standard differentials and on a group of potentially supplemental differentials.

During the past summer the following varieties were tested extensively to determine their suitability as additional differentials: Willet, Selkirk, Newthatch, Frontana x (K58-Newthatch) II-50-25 (C.I. 13155), Kentana 52 (C.I. 13085), Gabo 54, Yaqui 53, Mayo 54, Yaktana 53, Kenya Farmer, Bowie, Travis, and "durum" C.I. 3255; barley varieties Kindred (C.I. 6969) and Montcalm (C.I. 7149); and Emerald rye. So far none has proved to be a good differential for identifying races, although Bowie and Travis are very useful in detecting mixtures of race 29 in cultures of 15B.

There are a number of biotypes of several races such as 48, 59, 15B, and others. It has been shown conclusively that there are biotypes of races 29 and 139 also. A number of special studies, principally by graduate students, are now being made in an attempt to lay a sound basis for distinguishing between these biotypes. As there are important differences between some of them, both with respect to the varieties they attack under a fairly wide range of conditions and with respect to the difference in their ability to attack certain varieties at different temperatures, the problem of classifying them on the basis of their practical importance is not simple.

Because of the present complexity of the race situation and the fact that the virulence of certain races or the resistance of certain varieties, or both, can vary so much with temperature, tests of varietal resistance should be made against a composite sample of each of the important races. Moreover, the tests should be made at about 85° F. if they are made at one temperature only. Rust epidemics are much more likely to occur when temperatures are high, provided there is adequate moisture, than when temperatures are low. Many varieties will escape damage in moderately cool seasons regardless of the degree of their resistance. The resistance is really needed when conditions are most favorable for rust development; therefore, varieties should be tested at high temperatures.

The fact that a number of races are still being produced on barberries and that they become widespread and prevalent from time to time suggests that the broadest possible base for resistance be established. There should be incorporated into individual varieties as many factors for resistance as possible, both physiologic and morphologic. It is clear that some varieties are not as easily infected as others, that the rust does not develop rapidly on them in the field, and that they seem to have some degree of tolerance to a given amount of infection. They seem to have a combination of characters that make them less liable to rust than many other varieties, even though they may rust heavily under some conditions. A comprehensive and detailed study of all of the characters involved is needed and is now being only partly met.

Finally, it is evident that barberry eradication should be prosecuted vigorously to reduce still further the number of races that are formed or that persist by means of the alternate host. More studies are needed also on the extent to which new races may arise by mutation or heterocaryosis. Historically, however, it is demonstrable that the races which disturbed the status quo in the past were produced on barberry and were known for a number of years before they became widespread.

Predictions cannot be made with respect to the rapidity with which new or unusual races may become widespread and prevalent. Past history shows that the process may be either gradual or sudden.

Every effort should be made in breeding work to retain resistance to so-called old races as well as to develop resistance to "new races." The history of races indicates clearly that "new races" may become old and that old ones may become new. Races may virtually disappear from sight, but not from the face of the earth. The same race obviously may be produced a number of different times and in a number of different places by recombinations on the barberry. Races that decrease greatly in prevalence, or even some that never were prevalent so far as is known, may flare up if host plants and weather conditions become favorable. There should be the broadest possible base of resistance to as many races as possible and every attempt should be made to identify characters that confer a certain degree of generalized resistance and try to combine them in individual varieties. This will take much study and considerable time, but it should be one of the broader objectives in breeding.

The situation with respect to races and varieties is confused at present. It is perfectly evident that the complexity of the problem is such as to require more manpower and more physical facilties than are now available.

## OVERWINTERING OF FOUR RACES OF STEM RUST IN FOUR WHEAT VARIETIES IN TEXAS

M. C. Futrell and A. J. Pilgrim
(Presented by M. C. Futrell)

In the fall of 1954, races 15B, 17, 38, and 56 of stem rust were inoculated into plots of Concho, Knox, Bowie, and Nugget wheats at seven locations from Denton south to Beeville, Texas, to determine where stem rust overwinters in Texas. Good fall infections were established in the College Station and Prairie View tests. Dry weather retarded establishment of good fall infection centers at Temple, McGregor, Beeville, and Refugio.

Preliminary observations at College Station and Prairie View revealed that Knox was susceptible to all four races; Concho was resistant to race 17 and susceptible to races 15B, 38, and 56; Nugget was highly susceptible to race 15B and resistant to 17, 38, and 56; and Bowie was resistant to all of these races.

The period from December 25, 1954, to January 7, 1955, was characterized by cloudy, humid, foggy weather in the area around College Station and Prairie View. First generation stem rust pustules had just become well established and were sporulating vigorously when the muggy weather started. Bacteria and/or other microorganisms invaded the rust pustules and partially destroyed primary infections. Race 15B was most nearly destroyed by microorgansims on the Nugget and Knox varieties, race 17 was reduced on the Knox variety, and race 56 was reduced most on Concho. The destruction was the least pronounced with race 38 on Concho and Knox.

At this time it does not appear that the infection centers are completely destroyed because second generation pustules are appearing slowly especially on the Concho variety. From these preliminary data it appears that in winters like the current one, stem rust may be reduced or destroyed in overwintering centers by invasion of microorganisms in humid areas of South Texas. It is possible that on certain years the invasion of microorganisms may be a larger factor than low temperatures in destroying stem rust overwintering centers in South Texas.

## CURRENT PREVALENCE AND DISTRIBUTION OF WHEAT STEM RUST RACES IN KANSAS

W. C. Haskett

The races of wheat stem rust occurring in Kansas may be summarized in one brief statement. From 140 isolates made in 1953 and 1954, 136 were identified as race 15B. One collection of race 56 was identified in 1953 and two isolates of 56 and one of 11 was made in 1954.

Approximately 90 percent of these collections were made from Pawnee, Wichita, Triumph, and Red Chief wheats. The collections were made over the entire State with the largest numbers from the south and north central and the southeastern areas of the State.

The losses from 1953 and 1954 due to stem rust were estimated at approximately 1 to 2 percent. Only the development of extremely hot weather with strong drying winds prevented major stem rust epiphytotics in these years.

Isolates of wheat stem rust races made in Kansas in 1953-54 were as follows:

| Year | Season | 15B | 56 | 11 |
|---|---|---|---|---|
| 1953 | Summer | 15 | 0 | 0 |
| 1953 | Fall | 21 | 1 | 0 |
| 1954 | Summer | 26 | 1 | 0 |
| 1954 | Fall | 74 | 1 | 1 |

# PHYSIOLOGIC RACES OF WHEAT STEM RUST IN CANADA IN 1954*

T. Johnson and G. J. Green
Plant Pathology Laboratory, Winnipeg, Manitoba

In 1954 Western Canada experienced the most widespread and severe wheat rust epidemic in its history. An unusual feature of this epidemic is the fact that the greatest severity of infection and damage occurred in central Saskatchewan, about 200 to 300 miles farther west than is usual. The initial source of infection for both stem rust and leaf rust was windborne spores carried northwestwards from the Kansas area by strong winds in the first week of June. Rust infections broke out simultaneously over the whole area from eastern Manitoba to North Battleford, Saskatchewan, more than 500 miles northwest of Winnipeg, and initial infections were most numerous in the Saskatoon-Battleford area. The intensity of the subsequent rust epidemic was closely related to the amount of initial infection.

The stem rust survey in 1954 included 361 isolates. The following races were isolated (the number of isolates of each in brackets): race 10 (1); race 11 (1); race 15 (2); race 15B, including three distinct biotypes, (283); race 29, including three distinct biotypes (30); race 37 (1); race 38 (5); race 48 (14); race 56 (15); race 59, including two distinct biotypes (6); race 87 (2); and race 139 (1).

Race 15B was the predominant race in both Eastern Canada and the Prairie Provinces, accounting for 77 percent of all isolates. Most of the isolates of this race were of the type prevalent since 1950, but two of the other biotypes, distinguishable by means of the accessory varieties Golden Ball and Selkirk, were found in small amounts. Six isolates were found of the biotype virulent to Selkirk, which was discovered in 1952, and three isolates of the one virulent to Golden Ball.

Race 29 was next after race 15B in order of prevalence, accounting for about 8 percent of all isolates. In this race, three biotypes were distinguished by means of accessory varieties: race 29-1 virulent on Golden Ball and Selkirk; race 29-2 non-virulent on Golden Ball but virulent on Selkirk; and race 29-3 virulent on Golden Ball but not on Selkirk. The two biotypes virulent on Selkirk are the most common of the rust strains known to be pathogenic to that variety.

Race 56, the predominant race for many years prior to 1950, was reduced to the low ebb of 4 percent of the isolates.

The rather wide distribution of race 48 in Eastern Canada is of interest. This race had a wide distribution in the southern United States in 1954, but occurred only to a slight extent in the Prairie Provinces presumably because it had little opportunity to get established on account of the resistance to it of the wheat varieties grown there. In Eastern Canada, it was widespread and was responsible for severe rusting of McMurachy wheat in several of the Uniform Rust Nurseries. It is of interest that in the same nurseries, Selkirk, which is a descendant of McMurachy, was virtually free from stem rust. This is the first time that McMurachy has shown any appreciable amount of stem rust in the Uniform Rust Nurseries in Canada. This strain of race 48 is pathogenically distinct from isolates of that race found in earlier years. It is probably identical with the one described as race 48A in the United States.

## PREVALENCE AND DISTRIBUTION OF PHYSIOLOGIC RACES OF LEAF RUST IN THE HARD RED WINTER WHEAT AREA

C. O. Johnston

A total of 37 physiologic races of leaf rust were isolated from collections made in 10 states of the hard red winter wheat area during the period 1949-1953, inclusive. Ten races were isolated only once each and 9 others averaged 1 percent or less of the total number of isolates. Only 6 races were abundant and widely distributed, being isolated in each of the years and appearing in isolates from nearly every state. These were races 5, 9, 15, 58, 105, and 126, representing in all 78.1 percent of all isolates.

Many of the races appearing in only minor amounts are very similar to various major races. When these minor races are included with the proper major races, it is revealed that the six major races and race 11 comprised an average of 97.1 percent of all races for the 5-year period, as shown in the following table:

| | Average percent of all isolates, major race, and similar races | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 5 | 9 | 11 | 15 | 35 | 58 | 105 | |
| Year | (52) | (10,13,19, 20,31) | (131) | (2) | (21,114, 115,122) | (44) | (6,28, 126) | |
| 1949 | 33.6 | 29.9 | | 4.2 | 2.5 | 2.3 | 25.3 | |
| 1950 | 29.6 | 26.2 | | 7.9 | 3.1 | 3.5 | 27.5 | |
| 1951 | 43.0 | 14.4 | | 15.1 | 1.8 | 1.6 | 24.9 | |
| 1952 | 28.1 | 6.2 | 1.9 | 26.5 | 6.5 | 2.8 | 18.6 | |
| 1953 | 31.1 | 5.7 | 3.1 | 23.3 | 14.6 | 3.4 | 17.1 | |
| Average | 33.1 | 16.5 | 1.0 | 15.4 | 5.7 | 2.7 | 22.7 | Total: 97.1 |

It is clear that race 5 and its companion races are by far the most abundant group of races in the hard red winter wheat area. Race 105 and its companion races are the second most abundant group, followed by races 9 and 15 and their companion races in the order named.

One of the most striking features of these data is the rapid decline in abundance of race 9 during the 5-year period. This race was for many years the most abundant and widely distributed one in the hard winter wheat area. Race 9 itself represented only 1.4 percent of all isolates in 1953, although the inclusion of its satelites brings the figure up to 5.7 percent.

Just as striking as the decline in abundance of race 9 has been the increase in abundance and importance of races 15 and 35, including their respective satelites. Both of these groups were relatively unimportant in 1949, but were very important in 1953. These races must receive careful attention in any breeding program. The increase in race 35 and its companion races 54 and 122 is particularly disturbing because they are virulent races. None of these are new races but are old, well-known races which have increased in abundance. Fortunately, however, good resistance to them is available in Concho and Westar selections.

Another interesting feature of these studies has been the increase in prevalence of race 11 in recent years. This race has long been the most abundant one in Mexico and in the Pacific Coast States of the United States. Until very recently there has been little evidence that it was moving from either of those areas into the hard red winter wheat area of the central United States. Before 1949 it was isolated only a few times from collections made in the central United States and from 1949 to 1951, inclusive, not at all. However, in 1952 it represented 1.9 percent of all isolates from the hard winter wheat area and increased to 3.1 percent in 1953. It, therefore, seems likely that leaf rust races may now be moving from Mexico into the United States. Insofar as race 11 is concerned, that is not important since many varieties including Pawnee, Ponca, and Concho are highly resistant, but, if a virulent race arose in Mexico, it could be a definite threat to wheat production in the hard red winter wheat area of the United States.

In addition to a rather extensive list of physiologic races, there are biotypes of some races which are virulent on certain varieties otherwise known to be resistant. For example, at least one biotype each of races 5 and 11 are virulent on Westar. Thus far, such biotypes have not proved to be widespread in distribution nor have they increased rapidly, although they have been known for some time.

## CURRENT PREVALENCE AND DISTRIBUTION OF LEAF RUST RACES IN OKLAHOMA

H. C. Young, Jr.

Isolations from rather numerous collections of leaf rust in Oklahoma indicate that there are local race prevalence and distribution patterns which are not evident from the results of the Federal Rust Survey (Table 1). The collections identified in Oklahoma were taken from specific varieties (Table 2) and the results indicate that certain supposedly susceptible varieties seem to have an influence upon the prevalence and distribution of races. For instance, the varieties Cheyenne, Comanche, Kiowa, Tenmarq, Triumph, and Wichita are all considered susceptible, yet there was a much higher percentage of race 15 isolated from Kiowa, Tenmarq, and Triumph than from Cheyenne, Comanche, and Wichita. The acreage devoted to these varieties in different areas of the State is reflected in the leaf rust race populations (Table 2). In the eastern section of the State where the varieties Pawnee and Triumph predominate race 15 was most often isolated. at the expense of races 5 and 9. On the other hand, in the northwest where the varieties Comanche and Wichita predominate the percent of isolates of races 5 and 9 were higher at the expense of race 15.

It is believed that studies of this nature will give further knowledge on race survival, and perhaps enhance the ability to predict the longevity of resistance of new varieties being released.

Table 1. A comparison of wheat leaf rust race isolations found in the Federal Rust Survey and in a state survey in Oklahoma in the 1951, 1952, and 1953 crop years.

| | | Percent of race group | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| Year | Type of survey | 5 | 9 | 15 | 21 | 32 | 58 | 105-126 1/ | no. of isolates |
| 1951 | Federal survey for entire U. S. | 27 | 6 | 13 | - | - | 19 | 32 | 286 |
| | Federal survey, Oklahoma isolates only | 5 | 5 | - | - | - | - | 85 2/ | 20 |
| | Oklahoma survey | 27 | 11 | 29 | - | - | 1 | 32 | 66 |
| 1952 | Federal survey for entire U. S. | 22 | 9 | 16 | - | 1 | 12 | 20 | 432 |
| | Federal survey, Oklahoma isolates only | 21 | 11 | 13 | - | - | - | 46 | 53 |
| | Oklahoma survey | 24 | 14 | 41 | - | - | - | 21 | 190 |
| 1953 | Federal survey for entire U. S. | 31 | 6 | 13 | 1 | - | 6 | 22 | 392 |
| | Federal survey, Oklahoma isolates only | 12 | 27 | 3 | - | - | - | 48 | 33 |
| | Oklahoma survey | 20 | 3 | 72 | - | - | - | 5 | 79 |

1/ Including biotypes 105A and 105B.
2/ Abnormally high number of collections from the variety Westar.

Table 2. A comparison of the wheat leaf rust races isolated from specific varieties and areas in Oklahoma in the 1951, 1952, and 1953 crop years

| | Race and percent of isolates | | | | | | | Total no. of isolates |
|---|---|---|---|---|---|---|---|---|
| | 5 | 9 | 15 | 58 | 105 | 105A | 105B | |
| **Variety** | | | | | | | | |
| Cheyenne | 33 | 36 | 26 | - | 5 | - | - | 42 |
| Comanche | 24 | 24 | 41 | - | 3 | 8 | - | 37 |
| Concho | 5 | 10 | 10 | - | 13 | 57 | 5 | 21 |
| Kiowa | 18 | 15 | 64 | - | - | 3 | - | 33 |
| Pawnee | 34 | - | 60 | - | 6 | - | - | 35 |
| Ponca | 33 | 4 | 52 | - | - | 7 | 4 | 27 |
| Tenmarq | 18 | 15 | 55 | - | 4 | 4 | 4 | 27 |
| Triumph | 15 | 10 | 62 | - | 7 | 3 | 3 | 40 |
| Westar | 14 | 3 | 3 | - | 30 | 47 | 3 | 30 |
| Wichita | 29 | 12 | 47 | - | 3 | 9 | - | 34 |
| Clarkan | 33 | - | 67 | - | - | - | - | 3 |
| Quanah | 40 | - | 40 | 20 | - | - | - | 5 |
| Total | 24 | 13 | 43 | 1 | 7 | 11 | 1 | 334 |
| **Division of State** | | | | | | | | |
| East 1/ | 21 | 2 | 57 | - | 7 | 11 | 2 | 44 |
| Southwest 2/ | 32 | 10 | 42 | - | 6 | 9 | 1 | 120 |
| North Central 3/ | 13 | 8 | 55 | 1 | 8 | 13 | 2 | 86 |
| Northwest 4/ | 29 | 20 | 37 | - | 4 | 9 | 1 | 70 |
| Panhandle 5/ | 13 | 13 | 34 | - | 13 | 27 | - | 15 |
| Entire State | 24 | 11 | 46 | 1 | 6 | 11 | 1 | 335 |

1/ Predominant variety is Pawnee, some Triumph.
2/ Predominant variety is Comanche, some Triumph.
3/ Predominant variety is Triumph.
4/ Predominant varieties are Wichita and Comanche.
5/ Predominant varieties are Comanche and Westar.

# PHYSIOLOGIC RACES OF LEAF RUST OF WHEAT IN CANADA IN 1954*

T. Johnson and A. M. Brown
Plant Pathology Laboratory, Winnipeg, Manitoba

Leaf rust caused more yield reduction in wheat in Western Canada in 1954 than in any previous year. This is due to the susceptibility of the varieties chiefly grown such as Thatcher and Redman, the extreme lateness of the crop, and the unusually early arrival of inoculum. Initial infection, caused by spores blown in from the south in the first week of June, was heaviest in the Saskatoon-North Battleford area in Saskatchewan. The subsequent epidemic developed most rapidly where initial infection was heaviest. It is considered that leaf rust generally did more damage than stem rust.

## Distribution of Physiologic Races

Race identification was carried out by use of the varieties Malakof, Webster, Loros, Mediterranean, and Democrat, with the addition of Brevit and Renown. The varieties Carina and Hussar were added when it was considered necessary. Furthermore, following increase on Little Club, all rust collections were inoculated to a screening set composed of Exchange, Lee, Kenya Farmer, and Selkirk.

Altogether, 342 isolates were studied and identified as follows (number of isolates in brackets): race 1 (11); races 3 and 58 (66); race 5 (96); race 9 (5); race 11 (7); race 15 (105); race 35 (2); race 93 (2); and race 126 (48).

The race distribution in 1954 was rather similar to that of 1953. Race 58 was predominant in Eastern Canada, especially in Ontario, and races 5 and 15 comprised most of the rust in the Prairie Provinces. Race 1 was found only in British Columbia and Quebec while race 11 was found in Ontario, Saskatchewan, and Alberta. Race 126 was more common in the Prairie Provinces than in the preceding year. This race is probably a complex, including race 105 which has never been readily distinguishable from it under Winnipeg greenhouse conditions. This complex is of particular interest because some elements of it show evidence of pathogenicity to the rust resistant variety Lee. Selkirk and Exchange are only moderately resistant to this race.

In greenhouse tests, it was noted that Rosen rye in the seedling stage proved to be a congenial host to races 5, 11, 15, and 126. To these races, however, Prolific spring rye was resistant. As Rosen is a winter rye, its ability to harbor leaf rust of wheat raises the question of whether or not varieties of winter rye could play any part in the overwintering of this rust in areas north of the winter wheat belt.

## RUST CHEMOTHERAPY

### EFFICACY AND FEASIBILITY OF FUNGICIDES FOR CEREAL RUST CONTROL*

M. N. Levine, Minnesota

The results obtained in 1954 with several fungicides tested in experimental field plots at St. Paul, Minnesota, were in several respects more striking than at any previous time. The fungicides used were: Sulforon, Zineb, Manzate, and Karathane. Sulforon was used as a dust and was applied at the rate of 40 and 30 pounds per acre, respectively. Each of these dosages was applied 3 and 5 times during the growing season. The other fungicides were used as sprays; Zineb and Manzate at the rate of 1-1/2 pounds per acre, diluted in 5 gallons and 100 gallons of water, respectively; Karathane at the rate of 1-1/2 quarts per acre, diluted in the same manner as Zineb and Manzate. Each of the sprays was in some instances applied only once during the growing season; in other instances 3 times. The wheat variety used in the test was Marquis, C.I. 3641. The treatments were applied in randomized fashion, and each was replicated 4 times. There were quadruplicated untreated plots used as controls.

Similar controls of both stem rust and leaf rust were obtained with any 1 of the 3 sprays whether applied in 5-gallon or 100-gallon dilutions. Nor were there significant differences in the effect produced by these sprays on yield and quality. Inasmuch as the 100-gallon per acre applications are altogether impractical, the results obtained from their usage were not included in the accompanying table. It will be seen from the data presented that whatever the fungicide used, and regardless of the manner in which it was applied, there was some reduction in the severity of infection, although in several instances it was disappointingly very little. Dusting with Sulforon was on the whole more effective in controlling the epidemics than spraying once or even 3 times in 1954.

A comparison of variants stemming from diverse treatments employed during the past 2 years is also presented in the accompanying table. The return per acre was determined on the basis of the market quotations as of the middle of September of each year. The results of the spray treatments are to some extent hypothetical as regards the year 1953. The gallonages used that year were actually 100 instead of 5 gallons per acre; but in the light of the results obtained in 1954, it seemed reasonable to assume that the end results in 1953 might not have differed very much from those shown in the table. Whereas in 1954 Sulforon dust treatments applied 5 times at either 40 or 30 pounds per acre were most profitable, in 1953 Zineb spray applied 5 times during the growing season appeared to be most economical. There is still no evidence that the above experimental results could be duplicated year in and year out, where wheat and other small grains are grown extensively. There is still need for more sure fire means.

Comparison of Some Notable Results Obtained from Experimental Use of Several Fungicidal Dusts and Sprays in an Attempt to Control Rust Epidemics on Marquis Wheat Grown in Field Plots at St. Paul, Minnesota, 1953 and 1954

| Treatments | Leaf rust load | Stem rust load | Bu/a mean-yield | Lbs/bu test weight | Pct. protein | Net return /a | Overall cost | Gain or loss |
|---|---|---|---|---|---|---|---|---|
| 1953 | | | | | | | | |
| Untreated plots | 64.8 | 54.6 | 15.8 | 50.6 | 13.0 | $30.73 | $27.56 | +3.17 |
| Treated plots | | | | | | | | |
| Dust treatments | | | | | | | | |
| 40 lbs/a | | | | | | | | |
| 5 times | | | | | | | | |
| Sulforon | 24.2 | 21.2 | 26.4 | 58.3 | 15.1 | 60.98 | 53.06 | +7.92 |
| Zineb | 17.1 | 18.2 | 24.3 | 58.2 | 15.1 | 56.13 | 53.00 | +3.13 |
| Manzate | 18.8 | 24.2 | 24.8 | 57.2 | 14.6 | 55.92 | 54.90 | +1.02 |
| Sulfamate | 9.6 | 23.0 | 18.2 | 51.9 | 15.6 | 39.49 | 47.72 | -8.23 |
| Spray treatments | | | | | | | | |
| 5 gal/a | | | | | | | | |
| Zineb | | | | | | | | |
| 5 times | 7.6 | 13.0 | 24.2 | 58.0 | 15.3 | 56.26 | 40.88 | +15.38 |
| Manzate | | | | | | | | |
| 5 times | 16.1 | 22.2 | 23.8 | 57.4 | 14.0 | 52.96 | 42.31 | +10.65 |
| Sulfamate | | | | | | | | |
| 5 times | 13.3 | 33.3 | 13.8 | 49.5 | | 26.91 | 44.31 | -17.40 |
| 3 times | 16.3 | 34.6 | 18.4 | 51.9 | 14.1 | 38.09 | 37.61 | +0.48 |
| 1 time | 27.5 | 47.5 | 19.8 | 51.5 | | 40.19 | 30.91 | +9.28 |
| 1954 | | | | | | | | |
| Untreated plots | 77.7 | 47.3 | 8.7 | 45.2 | 15.9 | $17.14 | $27.56 | -10.42 |
| Treated plots | | | | | | | | |
| Dust treatments | | | | | | | | |
| Sulforon | | | | | | | | |
| 40 lbs/a | | | | | | | | |
| 5 times | 13.2 | 1.8 | 28.9 | 58.8 | 17.1 | 78.61 | 53.06 | +25.55 |
| 3 times | 22.4 | 14.7 | 23.2 | 56.6 | 16.3 | 61.02 | 42.86 | +18.16 |
| 30 lbs/a | | | | | | | | |
| 5 times | 21.2 | 6.4 | 26.9 | 58.0 | 16.0 | 72.36 | 46.69 | +25.67 |
| 3 times | 44.7 | 27.8 | 16.4 | 51.5 | 16.2 | 39.03 | 39.03 | |
| Spray treatments | | | | | | | | |
| 5 gal/a | | | | | | | | |
| Zineb | | | | | | | | |
| 3 times | 21.2 | 28.4 | 15.4 | 52.0 | 15.5 | 36.65 | 35.56 | +1.09 |
| 1 time | 48.8 | 37.4 | 11.0 | 47.5 | 15.3 | 22.55 | 30.23 | -7.68 |
| Manzate | | | | | | | | |
| 3 times | 23.6 | 24.5 | 16.9 | 52.8 | 14.8 | 39.21 | 36.41 | +2.80 |
| 1 time | 51.0 | 39.0 | 10.1 | 45.8 | 15.6 | 19.59 | 30.51 | -10.92 |
| Karathane | | | | | | | | |
| 3 times | 59.9 | 32.5 | 12.0 | 49.3 | 15.5 | 26.52 | 39.11 | -12.59 |
| 1 time | 62.7 | 37.2 | 10.4 | 47.7 | 16.1 | 22.05 | 31.41 | -9.36 |

## PROGRESS IN CHEMOTHERAPY OF WHEAT RUSTS IN KANSAS

C. O. Johnston and W. C. Haskett
(Presented by W. C. Haskett)

Experiments to date indicate that certain chemicals will give good control of leaf and stem rust with a resulting increase in yield and test weight over the untreated plots. However, the cost of material and application would not warrant their use in Kansas at the present time. The following data from the 1954 experiments indicate the control obtained:

Effect of Two Applications of Fungicides on Wheat Rusts.
Manhattan, Kansas, 1954

| Treatment | Rate | Stem rust | Leaf rust | Yield | Test weight |
|---|---|---|---|---|---|
| | | Pct. | Pct. | | |
| Check | | 47 | 63 | 32.9 | 55.1 |
| Sulfur dust | 40 lb/a | 44 | 55 | 32.2 | 54.6 |
| Ca sulfamate | 12.5 lb/10 gal/a | 12 | 4 | 29.8 | 54.4 |
| Karathane | 5 lb/10 gal/a | 21 | 36 | 37.1 | 54.0 |
| Zineb | 5 lb/10 gal/a | 14 | 28 | 35.2 | 56.9 |
| Manzate | 5 lb/10 gal/a | 18 | 11 | 36.6 | 57.7 |

Milling and baking tests on wheat from plots treated with Zineb, Karathane, and Manzate revealed no detrimental effect on the grain or flour. However, Ca sulfamate treated wheat was greatly affected in that loaf volume was reduced and mixing time was reduced by one half. The bread from the sulfamate treated wheat also had a very offensive odor.

Further field trials will be made in 1955 with an entirely new group of compounds. Greenhouse studies are being conducted with a group of hydrazine compounds at the present time. To date only a few of these chemicals have given moderate control with some indication of systemic action.

## CONTROL OF CEREAL RUSTS BY FUNGICIDES*

B. Peturson, F. R. Forsyth, and W. A. F. Hagborg
Plant Pathology Laboratory, Winnipeg, Manitoba

The advent of race 15B of stem rust of wheat revived an interest in the control of cereal rusts by means of fungicides and tests have been carried out at the Plant Pathology Laboratory, Winnipeg, Manitoba, during the past several years to study this matter further.

In these tests the following materials were tried for rust control purposes: acti-dione, ammonium sulfamate, calcium sulfamate, sodium sulfanilate, CMU, Fermate, Karathane, Manzate, Phygon, sulfur, and Zineb. All the fungicides tested except CMU, acti-dione, and calcium sulfamate are protective fungicides. CMU and acti-dione may be regarded as systemic fungicides and calcium sulfamate both as a protective and eradicant fungicide. All the fungicides except CMU were tested both in greenhouse and field experiments. CMU was used in field tests only.

## Results of Tests with Protective Fungicides

The fungicides afforded various degrees of protection from rust if applied several times during the season. Of the ones tested colloidal, sulfur and Zineb were by far the most effective.

When applied in dust form it was found necessary to apply about 40 pounds of dust per acre to obtain thorough coverage of the plants. In spray form Zineb (65 percent technical) was used at the rate of 1-1/2 pounds per acre per treatment. As the protective fungicides tend to be washed off by rain, they must be applied several times during the season. In Western Canada rust usually appears about five weeks before the crop ripens and it, therefore, is necessary to apply a fungicide from three to five times during this period, depending on the frequency and intensity of precipitation, to control rust effectively.

In a test carried out at Winnipeg in 1952, Zineb, colloidal sulfur, Manzate, Phygon XL, and calcium sulfamate were used. Zineb, Manzate, and Phygon were used in both dust and spray form, but the remaining two fungicides were used in dust form only. The check plots in this test yielded at the rate of 15.4 bushels per acre and the ones treated with Zineb dust, Zineb spray, and colloidal sulfur yielded, respectively, at the rate of 36.9, 35.7, and 32.1 bushels per acre (Table 1). The per acre costs of the fungicidal materials for the five applications amounted approximately to $32.00 for Zineb dust, $10.00 for Zineb spray, and $14.00 for sulfur (sulfur in carload lots estimated to cost $.07 per pound).

CMU (p-chlorophenyl dimethylurea), Karathane, calcium sulfamate, and sodium sulfanilate were tested in the 1954 experiments for rust control purposes. CMU was used at the rate of one pound and two pounds per acre and applied to the soil when the plants were in the 4-leaf stage. Karathane was used in spray form and calcium sulfamate and sodium sulfanilate were used individually and in conjunction with each other. The results of this test (Table 2) show that Karathane gave the best results but it did not increase yields sufficiently to warrant its use at present day costs.

Table 1. The effect of fungicidal treatments for rust control on Red Bobs wheat at Winnipeg in 1952

| Treatment | Rust intensity: August 5 when treatments were discontinued | Rust intensity: August 17 when crop was ripe | Date Ripe | Yield per acre | Weight per 1,000 kernels | Weight per bushel |
|---|---|---|---|---|---|---|
| | | | Aug. | Bu. | Gm. | Lb. |
| Zineb dust | Very light | Heavy | 25 | 36.9 | 33.3 | 59.8 |
| Zineb spray | do. | do. | 27 | 35.7 | 31.0 | 60.0 |
| Sulforon dust | do. | do. | 25 | 32.1 | 28.9 | 59.0 |
| Manzate dust | Light | do. | 23 | 28.6 | 23.9 | 57.0 |
| Manzate spray | do. | do. | 23 | 27.1 | 22.3 | 54.0 |
| Phygon dust | Mod. heavy | do. | 23. | 26.2 | 23.1 | 54.6 |
| Phygon spray | do. | do. | 20 | 20.9 | 18.0 | 51.2 |
| Calcium sulfamate | Light | do. | 26 | 15.2 | 24.4 | 52.8 |
| Check | Heavy | do. | 17 | 15.4 | 14.7 | 51.0 |

Table 2. Field tests of fungicides for the control of cereal rusts in 1954

| Treatment | Avg. lb./bu. of check and diff. from check 1 | Avg. bu./a. and diff. from check 2 | Value of increase at $2.00/bu. 3 | Cost of chemical per acre 4 | Diff./a. 3 - 4 5 | Pct. rust 6 |
|---|---|---|---|---|---|---|
| | | | $ | $ | $ | |
| Check | 59.5 | 22.1 | 0.0 | 0.0 | 0.0 | 59 |
| CMU, 1 lb. | -0.6 | +1.3 | 2.60 | - | - | 59 |
| CMU, 2 lb. | +0.2 | +1.4 | 2.80 | - | - | 62 |
| Cal. sulf., 2 appl. | -3.9 | -1.9 | -3.80 | - | - | 30 |
| Karathane, 2 qt.* | +1.3 | +5.5 | 11.00 | 12.80 | -1.80 | 50 |
| Karathane, 1½ qt.** | +1.4 | +4.1 | 8.20 | 14.40 | -6.20 | 52 |
| Karathane, 1 qt.** | +1.3 | +7.4 | 15.80 | 9.60 | 6.20 | 47 |
| Cal. sulf. + sod. sulfan., 1 appl. | +0.9 | +3.9 | 7.80 | - | - | 53 |
| Cal. sulf. + sod. sulfan., 2 appl. | -3.1 | +2.5 | 5.00 | - | - | 37 |
| Cal. sulf., 2 appl. | -3.9 | -1.9 | -3.80 | - | - | 30 |
| Sod. sulfan., 2 appl. | +0.7 | +1.9 | 3.80 | - | - | 50 |
| Cal. sulf. then sod. sulfan. | -1.1 | -0.1 | -0.20 | - | - | 39 |
| Sod. sulfan. then cal. sulf. | -4.5 | +0.9 | 1.80 | - | - | 57 |

* Applied July 27 and August 5.
** Applied July 12, 23, and 30.

## Results of Tests with Eradicant Fungicides

The only fungicide used in these tests that may be classed as an eradicant fungicide is calcium sulfamate. The calcium sulfamate treatments in field tests checked the increase of the rust after applications were commenced both in 1952 and in 1954 (see Tables 1 and 2). However, the yield from the treated plots was not sufficiently increased over the controls to indicate that use of this chemical would be advisable on an economic basis. We noted a severe restriction of germination in grain harvested from the calcium sulfamate treated plots.

In greenhouse tests we were able to demonstrate that calcium sulfamate is an excellent eradicant of wheat stem rust mycelium present in the host tissues, if it is applied before the rust uredia break through the epidermis. Thus, all rust mycelium developing in a wheat plant during the 9 to 10 day period following infection may be eradicated by a single spraying with calcium sulfamate. However, leaves developing after the plants are treated do not seem to be protected against rust.

## Results of Tests with Systemic Fungicides

Of the materials tested, CMU and acti-dione possibly fall in this class.

CMU appeared to have little or no effect on rust infection or yield. The slight increases in yield of the CMU treated plots over the check (Table 2) are probably chance variations. At the rates used, CMU had no visibly adverse effect on the wheat plants. However, it was noticed that some weeds growing among the treated wheat plants were adversely affected by the CMU applications.

Aqueous solutions containing only 0.125 ug. of acti-dione per millilitre, reduced substantially the germination of urediospores of stem and leaf rusts. As a spray in the greenhouse, it reduced rust infection substantially in seedlings at 10 ug./ml., but was phytotoxic at higher concentrations. In this respect it was inferior to Zineb. In a field plot experiment a single spraying with acti-dione at 10 ug./ml. appeared to reduce rust infection temporarily, but caused damage to the youngest leaves. No increase in yield resulted.

## Summary and Conclusions

There are at least four requisites that a chemical must fulfill before it can be used successfully for rust control.

1. It must be known to control rust satisfactorily either systemically or as a protectant.
2. The cost of the chemical must be low enough to make its application profitable.
3. The supply must be adequate to meet a considerable demand.
4. There must be a practicable means of applying it.

At the present time we do not know of any chemical available that meets all of these requirements.

## SUMMARIZING AND LOOKING AHEAD

W. M. Meyers, Panel leader

Probably the most important conclusion that can be drawn from the panel on wheat rust is the need for having varieties with different sources of resistance instead of depending upon a single source of resistance as has been the case in most of the wheat growing areas in the past and even at the present. This is, of course, not a new viewpoint, but was certainly given considerable emphasis during the discussion. Before it will be possible, however, for the plant breeders to develop varieties carrying different or combinations of different sources of resistance, it will be necessary for us to have very much more information regarding the resistance genes available. Several different varieties are being used extensively in breeding programs as sources of resistance. However, little is known regarding the genetic relationship of these varieties so far as resistance is concerned. For example, it is not known whether the different Kenya selections have the same or different genes for resistance to race 15B. The answer to this question will be available only after further intensive study which should be pushed forward as rapidly as possible.

PANEL: SMUTS AND MINOR DISEASES OF WHEAT
Leader, I. M. Atkins, Texas

## DWARF SMUT IN COLORADO

D. W. Robertson

Dwarf smut occurs in the northwest portion of the State and has been reported in the San Juan Basin in southeastern Colorado. As yet, no reports of the disease have been made on the eastern side of the Continental Divide. Work being conducted involves testing of varieties from various stations showing resistance and the attempt to develop resistant varieties using Wasatch as one parent and Comanche and Cheyenne as the other parents. All seed preparation, inoculation, threshing, and weighing of seed is done in the smut area. No seed, smut spores, or equipment is transported to the eastern part of the State.

The following results are typical of the occurrence of bunt and yields of grain obtained in the test in 1954 which contained 18 varieties:

| Variety | State or C.I. no. | Bunt | Avg. bu. per acre |
|---|---|---|---|
| | | Pct. | |
| Cheyenne | 8885 | 91.0 | 7.7 |
| Wasatch | 12925 | 0.0 | 26.2 |
| Mqo.-Oro x O-T-F | 12723 | 0.2 | 26.5 |
| Do. | NP48500 | 1.0 | 26.8 |
| Do. | Neb. 491160 | 0.0 | 29.6 |
| Turkey x Oro | 12705 | 0.8 | 26.4 |
| Pawnee x C.I. 12250 | 13011 | 3.0 | 29.6 |
| Comanche x C.I. 12250 | 13013 | 0.2 | 21.9 |

It was found that in 1954 a high percentage of the bunt was not of the dwarf bunt type; therefore, prior to planting the 1954-55 test, microscopic examination was made of the heads of bunt used for inoculum to insure presence of the dwarf smut form.

## A REPORT ON MINOR DISEASES OF WHEAT IN TEXAS

I. M. Atkins

Septoria tritici and Septoria nodorum of wheat can be found nearly every season and cause some damage in local areas, but since facilities and personnel are limited no research has been undertaken on these diseases. Powdery mildew, (Erysiphe graminis var. tritici) is of some importance in the more humid areas, but except for records on reaction of strains no research has been conducted.

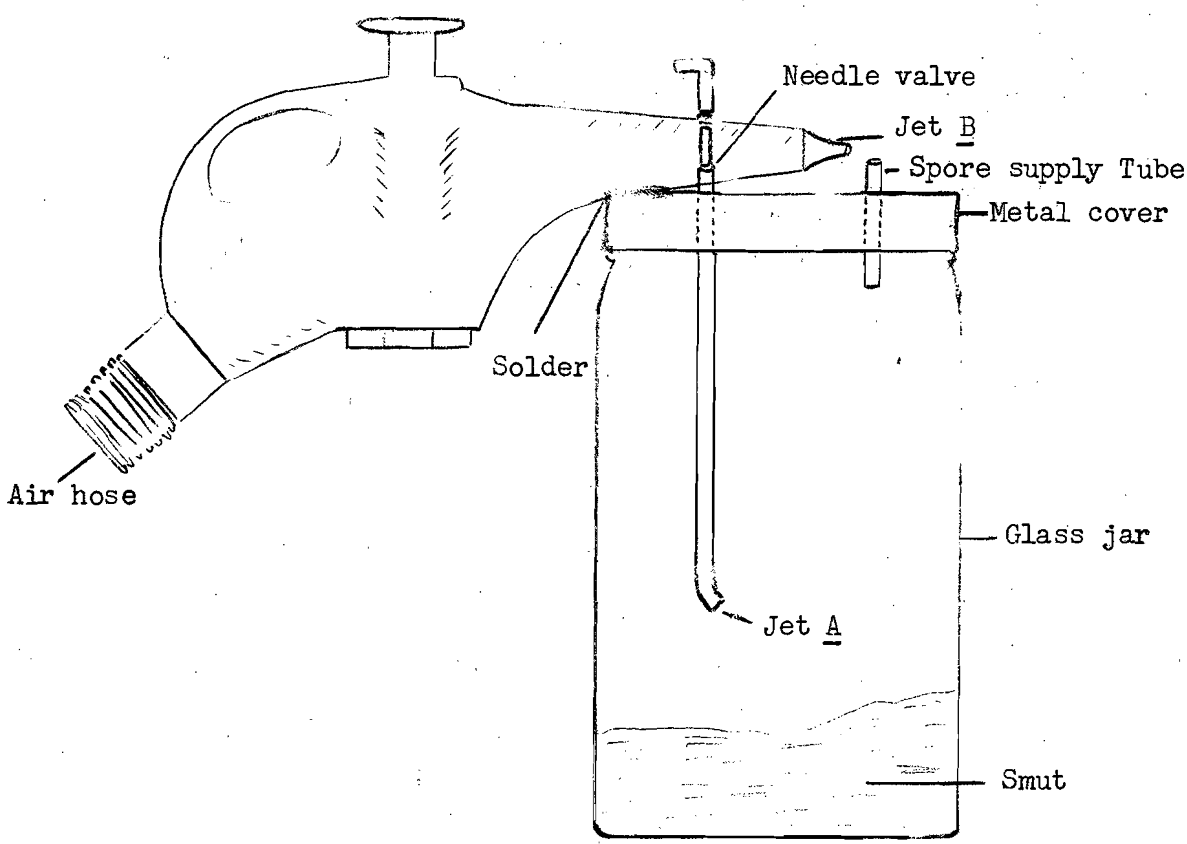
Bunt (Tilletia spp.) causes some damage each season in the drier sections of the State. However, as prevalent species can be easily controlled by seed treatment, no special emphasis is given to research on this problem except as one objective in the breeding program. A number of resistant varieties are available and all new lines considered for distribution are tested regularly. Loose smut (Ustilago tritici) is prevalent and the cause of considerable concern by farmers because of the difficulty of seed treatment. Considerable attention is being given this problem in the breeding program. An experiment is in progress to determine the effectiveness under local conditions of the water soaking method of control which is used on barley in Canada. Tests on the use of live steam as a control measure have been made but have not been effective.

Rather serious losses in a localized area of some 5,000 acres in the Rolling Plains area of Texas have been caused by root and foot rots in combination with white grubs and wireworms. Nematodes also are suspected of being involved in this particular complex. Attempts to conduct research on this problem have been ineffective because of severe drought the past two seasons.

There have been several instances in the State where the crop has behaved abnormally, resulting in moderate to severe local losses in the crop. Mosaic and other virus disorders have been suspected but attempts to explain the situation or to identify it with any insect injury, insect transmission, soil conditions, or disease situation have not been possible to date. In 1953, damage in the central Texas area was often associated with the variety Quanah but in other instances no association with variety was evident. Some of these abnormal conditions have been photographed in color.

APPARATUS FOR INOCULATING WHEAT AND BARLEY WITH LOOSE SMUT
BY AIR BLAST TECHNIQUE

M. B. Moore, Minnesota




DeVilbiss Air Gun, type DGA

<u>Specifications</u>: Jet A is 1/16" inside diameter.
Jet B has been made in two sizes and each has been satisfactory for inoculations at the following air pressures:

Jet 1.6 mm. (.064")
- Wheat - 60 lbs.
- Barley - 60 lbs.

Jet 1.1 mm. (.045")
- Wheat - 80 lbs.
- Barley - 60 lbs.

Spore supply Tube C is 1/8" inside diameter.

<u>Operation</u>: Gun is held about 1" from side of head and "burped" one to three times for each spikelet in wheat or group of three spikelets in barley. When gun is burped, some air passes through needle valve and Jet A to raise cloud of spores which are carried up through Tube C to be picked up by principal blast at Jet B. Heads must be inoculated at mid-anthesis or earlier.

Devised by Moore and Munnecke
University Farm, St. Paul, Minnesota

# WHEAT LOOSE SMUT AND BUNT INVESTIGATIONS IN KANSAS

E. D. Hansing

## Physiologic Races of Loose Smut, Ustilago tritici

Experiments were conducted from 1943 to 1954 to determine the prevalence and distribution of races of loose smut in Kansas. From 14 to 22 differential winter wheat varieties were used during the first 3 years. In 1946, however, a standard set of differential varieties was used as follows: Wabash (C.I. 11384), American Banner (C.I. 6943), Purdue No. 1 (C.I. 11380), Hussar (C.I. 4843), Early Premium (C.I. 11858), Nabob (C.I. 8869), Forward (C.I. 6691), Trumbull (C.I. 5657), Kangip (C.I. 11382), and Leap (C.I. 4823). (Bever, Phytopathology, 1947)

Five collections which were distinct and represented five different races were used to inoculate the differential varieties from 1946 to 1951. Physiologic race 1 was characterized by the susceptibility of Wabash and the resistance of the other varieties. Race 3 was characterized by the susceptible or intermediate reaction of the six varieties, Wabash, American Banner, Purdue No. 1, Hussar, Early Premium, and Nabob, and the resistance of the other four varieties. All of the differential varieties were susceptible or intermediate in susceptibility to race 6. Race 10 was similar to race 1 except that Kangip was intermediate in susceptibility. Race 11 was characterized by the susceptibility of American Banner and Hussar and the resistance of other varieties.

Altogether, 126 field collections of loose smut were identified to a definite race. Eight collections from the varieties Triumph, Tenmarq, Comanche, and Iobred were identified as race 1. Two collections from Early Premium and 3 collections from Vigo were identified as races 3 and 6, respectively. Twelve collections were identified as race 10. Eleven of these came from Tenmarq, Ponca, Westar, Pawnee, Turkey, and Blackhull, while 1 was collected from the soft wheat variety Fulcaster.

Race 11 was identified 101 times and was generally the most prevalent race both by number and by the varieties from which it was collected. It was collected and identified from the 17 hard red winter wheat varieties, Comanche, Wichita, Tenmarq, Turkey, Red Chief, Blue Jacket, Early Blackhull, Blackhull, Kiowa, Stafford, Cheyenne, Chiefkan, Red Jacket, Kanred, Nebred, Pawnee, and Triumph; also from the 5 soft red winter wheat varieties, Clarkan, Kanqueen, Harvest Queen, Moking, and Royal. No infection resulted when the smut collected from Pawnee and Triumph was used to reinoculate these varieties; consequently, it was assumed that they were from mixtures of susceptible varieties in these varieties.

Physiologic races 1, 10, and 11 were generally distributed in Kansas while races 3 and 6 occurred only in eastern Kansas where a small acreage of soft wheat was grown.

Twenty-eight winter wheat varieties which have been grown in Kansas during the last three decades were inoculated individually with each of the 5 races. Pawnee and Kawvale had the highest type of resistance. Ponca, Triumph, and Vigo also had fairly good resistance. All of the other 23 varieties were susceptible having average infections from 48 to 75 percent to at least 1 race.

Kiowa, Cheyenee, Royal, and all of the ten Blackhull varieties were highly resistant to races 1 and 10, susceptible to race 11, and variable in reaction to races 3 and 6. In general, this type of reaction is similar to that of the differential varieties, American Banner and Hussar.

Westar and Quanah were highly resistant to race 11 and intermediate or susceptible to the other races having a reaction similar to Wabash.

Vigo was resistant to races 1, 3, 10, and 11 and intermediate in susceptibility to race 6 or in general had a reaction similar to Forward and Leap.

Wichita, Comanche, Tenmarq, Turkey, Kharkof, Kanred, Nebred, and Iobred were intermediate in reaction or susceptible to all five races.

### Inheritance of Resistance to Loose Smut of Wheat in the Crosses of Kawvale x Clarkan (Cooperative - Elmer Heyne)

$F_1$, $F_2$, and $F_3$ data from reciprocal crosses of Kawvale (resistant) with Clarkan (susceptible) and $F_3$ data from the backcross progeny to each parent were studied for reaction to loose smut race 11. The resistance of Kawvale was dominant and probably due to at least two factors. A major factor gave high resistance, 0 to 10 percent infection, and a minor factor or factors gave moderate resistance, 11 to 45 percent infection. The combination of all factors gave immunity to race 11.

Inoculation of florets at the time of pollination indicated that the resistance to race 11 was controlled by the embryonic genetic constitution of the $F_1$ plant rather than the genetic constitution of the female parent.

No association was found between loose smut reaction and reaction to leaf rust or awn expression.

### Increase of Acreage of Varieties of Wheat Resistant to Loose Smut and Bunt (Cooperative - Plant Breeding)

In 1939 the resistant variety Kawvale was grown on 6 percent of the acreage of wheat in Kansas. In contrast, 15 years later in 1954 Pawnee, Triumph, Ponca, and Kawvale, all with good field resistance to loose smut, were grown on 40 percent of the acreage of wheat.

Even greater progress has been made in the control of bunt by the use of resistant varieties. In 1939 no varieties of wheat grown in Kansas were resistant to bunt. In 1954 Comanche, Kiowa, and Pawnee, all of which had good field resistance to bunt, were grown on 49 percent of the acreage of wheat in the State. Concho, another variety resistant to bunt, was recommended in 1954.

### Breeding Wheat with Resistance to All Races of Bunt, Including Dwarf Bunt (Cooperative - Plant Breeding and Entomology)

In 1940, six compound wheat crosses were made to develop a wheat variety for Kansas that would be resistant, especially to the Oro races of bunt and to dwarf bunt. These types of bunt did not occur in Kansas at that time.

Several selections were obtained which were resistant to races of bunt, including dwarf bunt, which we did not have in the State. These selections also had good resistance to leaf rust, better resistance than Pawnee to hessian fly, yield fairly comparable to Pawnee, and better milling quality than Pawnee. One of these selections from Marquillo-Oro x Oro-Turkey-Florence 47B8 (C.I. 12723) was increased to 15 pounds of seed and, if dwarf bunt makes its appearance in Kansas or portions of adjacent States, it would be satisfactory for further increase and distribution in infested areas. Fortunately, dwarf bunt has not been reported in Kansas up to and including 1954.

Since 1947, crosses have been made with these resistant selections to add shorter and stiffer straw, earlier maturity, and resistance to loose smut.

### Fungicide Seed Treatment of Wheat

Panogen was recommended in Kansas in 1951 after 3 years of extensive testing. It contains a volatile organic mercury in a red liquid carrier in complete solution. It should be applied at the rate of three-fourths of an ounce per bushel of seed. After treating, the seed is not moist or sticky; however, the material adheres rigidly to the seed coat. The liquid may be applied with one of the Panogen treaters or with some other treater which mixes it thoroughly with the seed. Panogen also may be diluted with water and applied equally well with any of the slurry machines. A distinct advantage of Panogen is that there is no poisonous dust in the air during treating and planting operations.

Vancide 51 was recommended in Kansas in 1953 after four years of testing. It contains two metal salts in a water solution and was the first new nonmercurial liquid seed treatment recommended for wheat. The material adheres rigidly to the seed coat and after treating the seed is not moist or sticky. Furthermore, there is no dust in the air during the treating, handling, or planting operations. Distinct advantages of Vancide 51 are no injury to seedlings from overtreating, no irritation to human skin, and a low order of toxicity to warm-blooded animals.

## MINOR WHEAT DISEASES IN OKLAHOMA

H. C. Young, Jr.

### Septoria Leaf Blotch

In an inoculated nursery the reaction to Septoria leaf blotch was determined for a number of hard red winter wheats (see table). Red Chief and Nabob were the most resistant varieties and both are being used as a source of resistance.

## Helminthosporium Root Rot

A nursery was inoculated with Helminthosporium sativum by mixing the inoculum with the seed as it was planted. Records of the amount of root rot, as evidenced by dead plants, were taken at heading time (see table). It may be noted that the varieties ranked almost in the order of their maturity. Since the 1954 season favored the later maturing wheats, it would appear quite likely that soil and weather factors have a pronounced influence on root rot development.

Reaction of Several Hard Red Winter Wheat Varieties to Root Rot Caused by Helminthosporium sativum and to Septoria Leaf Blotch in 1954

| Variety | Root rot rating 1/ | Leaf area destroyed by Septoria 2/ |
|---|---|---|
| | | Pct. |
| Blackhull | - | 41 |
| Cheyenne | 1.0 | 30 |
| Blue Jacket | 1.0 | 34 |
| Tenmarq | 1.5 | 36 |
| Westar | 1.5 | 71 |
| Kiowa | 1.5 | - |
| Hard Federation Hybrid (12515) | 1.5 | - |
| Comanche | 2.0 | 35 |
| Concho | 2.0 | 30 |
| Kanking | 2.0 | - |
| Pawnee | 2.5 | 49 |
| Red Chief | 2.5 | 9 |
| Kharkof | 3.0 | - |
| Ponca | 3.5 | 33 |
| Triumph | 3.5 | 68 |
| Wichita | 4.0 | 59 |
| Nabob | - | 9 |
| Early Blackhull | - | 62 |
| Kawvale | - | 43 |

1/ Rated from 1.0 (practically free of root rot) to 4.0 (severe).
2/ Notes by Robert Renfro.

## WHEAT DISEASE PROBLEMS OF THE PACIFIC NORTHWEST

O. A. Vogel

Wheat production in the Pacific Northwest runs the gamut of a wide variety of disease hazards. Prominent among these are the smuts, the root rots, and the snowmolds. Less prominent are the rusts, powdery mildew, the viruses, and the maladies of undetermined cause. Currently, as in the past, the primary emphasis in research is on the smuts with only sporadic effort being directed toward the root rots and snowmold. Research on other disease problems is almost entirely lacking.

The long-standing emphasis of research on smut is due to the widespread prevalence, the persistent nature, and the obvious economic importance of this disease. Also widespread are the root rots which take a heavy annual toll in yield. This loss is largely obscured by the nature of the disease and is not subject to accurate calculation. Even so, the economic significance of the root rot complex in this region is indisputable. Consequently, there is need for a more concerted effort toward the solution of this problem.

The snowmolds (Typhula and Fusarium), long regarded as confined to local areas of high snowfall throughout the region, are gradually spreading into areas of lesser snow cover. The economic importance of these diseases is generally recognized and there is an increasing awareness of their regional scope. Hence, there is need for a regional program of research leading to more effective measures of control.

The perennial occurrence of such wheat diseases as the rusts and powdery mildew poses a constant threat to wheat production of this region. Stem rust control through barberry eradication is known to be only partially successful. The race problem in stem rust, leaf rust, and stripe rust precludes complete control through resistant varieties. Powdery mildew constitutes a similar problem. Practically nothing is known of the basic nature and potentialities of these diseases in this region. Intensive study of these problems, along with those of undetermined cause, is highly essential to a well balanced and adequate approach to the solution of wheat disease problems in the Pacific Northwest.

The results of a general survey of the research needs, as analyzed by individual states, have been incorporated in a regional research report which is due for publication in the future.

## HARD RED WINTER WHEAT WORK IN PROGRESS AT WISCONSIN*

H. L. Shands

The Wisconsin winter wheat investigations are concentrated on soft quality type, with a limited amount of attention on the hard type. High yields with midseason maturity are sought. Suitable quality, stiff straw, winter hardiness, and resistance to several diseases are needed. Shorter strawed types are being bred by use of $BN^{10}$ as a donor parent. Early selections from the cross $Pawnee^2$ x C.I. 12662 are under test as well as selections from C.I. 12662 x Blackhawk and a similar cross. Sources of resistance to rusts now being used are listed elsewhere.

Sources of Septoria resistance in use are:

| | | |
|---|---|---|
| C.I. 12658 | Ky. 37 | Frondoso x (Trumbull-Hope-Hussar) |
| C.I. 12659 | Ky. 39 | Frondoso x (Trumbull-Hope-Hussar) |
| C.I. 13078 | Cornell 82al-2-4-7 | |
| C.I. 13172 | X287-1 = (Gladden x Kansas 500) x (29408 A1-16-2-4-3 x Kansas 500) | |

Sando selections

Only natural infection has been used so far in learning Septoria reaction. Head, observational, and rod rows are inoculated by the hypodermic needle method of injecting chlamydospores into flowers for learning loose smut reaction. Varietal reaction to powdery mildew is observed under natural infection conditions. Bunt tests are made for most selections in the nursery.

## RECOMMENDATIONS - SMUT AND MINOR DISEASES

I. M. Atkins, Panel Leader

It is recommended that (1) the Uniform Bunt Nurseries be continued and that continuous search and guard be exercised against establishment of new races of bunt, especially low bunt, in the Great Plains; (2) we continue to utilize the best known sources of resistance to bunt and loose smut in our breeding programs; (3) further studies of methods of seed treatment for loose smut control be made, especially with reference to the long-soak water method; (4) studies of the nature of resistance to bunt and loose smut be expanded; (5) additional research work on the complex problem of root and foot rots of wheat be initiated as soon as possible; and (6) further studies of Septoria, mildew, and other minor diseases be made as time and facilities permit.

LUNCHEON TALK, JANUARY 19

# PLANT RESEARCH IN THE U. S. DEPARTMENT OF AGRICULTURE

A. H. Moseman
Director, Crops Research, Agricultural Research Service, U.S.D.A.

The subject assigned to me this noon is "A Review of Plant Research in the U. S. Department of Agriculture." As you know, the Department's total program of research on plants is broad and rather complex. I am sure, however, that most of you are familiar with a large part of our field crops research, because approximately 70 percent of our funds are spent in cooperative work with the State Agricultural Experiment Stations in the regions where the particular problems exist.

I shall not attempt to review all of our plant research activities but would prefer to consider first the status of support for our current wheat production research program; secondly, some of the major problems and objectives in our crop research activities; and finally, some of the new developments that indicate the direction of emphasis in our plant research program.

## Support for Wheat Production Research

The cooperative hard red winter wheat research program is generally recognized among crop scientists as one of our best organized and integrated research activities, with effective State, Federal, and industry cooperation. We have achieved a type of teamwork between the various scientific disciplines and between the participating States that is not surpassed in effectiveness in any other research project with which I am familiar. The program has excellent support from the trade and from organizations of wheat growers. This has been reflected in the financial support for our over-all wheat production research program in recent years. I believe it would be worth while to review some of the tangible evidence of such support.

Federal appropriations for wheat stem rust research were increased by $28,900 in 1952; $20,000 in 1953; $40,000 in 1954; and $40,000 in 1955. Funds for research on mosaic disease were increased by $80,000 in 1952, divided equally between studies on the entomological aspects and those on the disease itself. Since 1947, the support for research on wheat stem sawfly has been increased by $27,500 for the agronomic and breeding problems and by about $53,000 for entomological studies. Funds for smut control research in the Pacific Northwest were increased by $10,000 in 1953; $78,000 in 1954; and $10,000 in 1955. We had an increase for wheat quality research (for the support of our regional quality laboratories) of $50,000 in 1949 and another $50,000 during the current year.

As a result of these increases, and taking into account various program adjustments since 1947, we have had a total increase in our wheat breeding, disease, and quality research program of about $430,000, from $272,000 to $702,000.

The production research program for wheat is one of the best supported crops research projects in the Agricultural Research Service. No other field crop has enjoyed increased support even approaching the 158 percent in added funds that we have had for wheat research.

I have mentioned specifically only Federal fund increases, but we recognize that funds from State sources also have been increased materially for this co-operative work.

This support, both State and Federal, has come about largely through the recognition by growers and industry of the value of research. It reflects their confidence in the job you have been doing and can do in the future. Our task now is to utilize these additional research resources most effectively in helping farmers to meet the current problems concerned with wheat production.

There has been a growing public recognition of the potential benefits from agricultural research in helping farmers solve the many problems inherent in today's complex farming operations. It is not necessary for us as scientists to convince ourselves of the need for and value of research in agriculture. It might be well, however, to consider some of the factors that have been influential in achieving a broader appreciation of agricultural research needs and potentialities.

## Meeting Demands of Increased Population

There has been considerable attention focused on the agricultural demands of our constantly increasing population. Census Bureau projections indicate we will have about 176 million people by 1960 and 200 to 220 million people by 1975. We also can expect to have more individuals in the higher age groups. At present one of every 12 persons in the United States is age 65 or over. By 1980 it could easily be 1 in 9. We have no real fear of starving in this country in the next 25 to 50 years, or beyond, but we are interested in having our people eat as well in the future as they do today. We recongize, too, that millions of people in the United States should improve their diets.

## Reducing Crop Production Hazards

The need for a stronger research program in crop production was brought into focus during the past year by the report on losses in agriculture prepared by a committee of scientists in the Department. This appraisal considers losses from various hazards and is based on average yields, prices, and losses between 1942 and 1951. According to these estimates, annual production losses in farm crops from all causes amount to 8.3 billion dollars. They make up 20 percent or 1/5 of the annual farm production potentials.

Plant diseases reduce the total value of crops affected by 2.8 billion dollars or about 6.9 percent of the total production potential. Diseases are taking annual tolls of more than 700 million dollars and 21 million acres of potential production from the five crops, corn, wheat, oats, barley, and flax. Disease losses in forage crops are particularly serious, running to 50 percent of the annual clover crop and 35 to 40 percent of the alfalfa crop.

The annual loss from insects is estimated at nearly two billion dollars or about 4.7 percent of the potential production. The European cornborer caused an annual loss of more than 80 million dollars during the period 1942 to 1951. This insect took 90 million bushels of the potential production in 1953, more than 125 million dollars worth, and indications across the corn belt are that the cornborer was even worse this past year.

The annual loss to wheat, oats, and barley in the Great Plains from greenbugs was estimated at 25.5 million dollars. Losses during the last few years have been relatively light, primarily because of the effectiveness of new insecticide chemicals.

According to the 1952 insect survey, the wheat stem sawfly took a toll in Montana and North Dakota of 7.9 million bushels of wheat valued at nearly 17 million dollars. This insect was at least as bad in 1953 and 1954.

The third member of the "big 3" in agricultural pests is weeds. Along with hail and mechanical damage, weeds reduced crop value by 2.4 billion dollars or 5.9 percent of the potential production. Weeds not only compete with crops for light and mineral nutrients, they also increase the cost of labor and equipment and impair the quality of farm products.

These tremendous losses that farmers of this country suffer every year from insects, diseases, and weeds are small in comparison with what they would have been if the results of research, new pesticides and improved cultural practices, had not been available for use in combatting them. While we have come a long way in controlling these hazards, we still have far to go. It will take much more effective research, plus the widespread use of new findings on farms, to reduce these losses substantially.

## Cropping Adjustments

Our research programs over the next several years should be geared to assist farmers in making effective crop production adjustments. Although we cannot predict with complete certainty what our cropping patterns will be by 1975, we can expect to have less trouble with surpluses. For most crops the outlook is pretty favorable.

Since future nutritional needs will undoubtedly require more animal products, we can expect substantial increases in the production of feed grains such as barley, oats, and sorghum, of oilseed meals, and of forage crops and pastures in general.

Wheat is now one of our most critical surplus crops, and it promises to remain a surplus problem in the immediate years ahead. One major contributing factor is the constant threat of several diseases that can strike the different wheat growing areas and reduce or literally wipe out the crop. As long as our wheat growers must use varieties that are not able to withstand potential disease epidemics, they will always tend to overplant. Durum wheat growers lost 65 percent of their crop to race 15B of stem rust in 1953 and about 75 percent in 1954. Race 15B also accounted for most of the 25 percent loss in bread wheats last year. We must remove such disease hazards if we are ever going to be able to set an acreage pattern that will gear our planting more specifically to our needs.

A second problem that requires additional attention is the limited alternatives farmers have for use of land taken out of wheat. In the Pacific Northwest, winter wheat is one of the most efficient crops to grow to utilize the moisture available. In the High Plains, crop alternatives are also limited, although sorghum can be substituted for wheat. It may be possible, too, with some additional research to develop winter barley varieties that will approach wheat as an efficient winter crop in this area. If we are to expect farmers to adjust their crop production to fit new demands, we must supply them with the background information to do this profitably. Also the best opportunity for farmers to increase their incomes appears to lie in reducing costs. This means cutting losses from diseases, weeds, and insects. It means cutting the man hours of labor required to produce an acre yield. It means selecting alternative crops that fit in well with other farm operations. These farming aids must be provided largely through publicly supported research.

I believe the best expression of the need for public-supported research in agriculture was the statement a rice grower made at a research advisory committee meeting I attended last month. He said, "No farmer can expect to live long enough to learn how best to farm his land from his own experience."

## Significant Program Adjustments

I should like to review, in the time remaining this noon, some of the crop research activities that have been strengthened or that we contemplate emphasizing in our future programs. These examples have been selected primarily because I believe they suggest the approach that will be taken in solving many of our crop improvement and production problems.

## Increased Use of Foreign Germ Plasm

We are giving more attention to the utilization of germ plasm material from foreign sources. At the present time we have 15,000 accession numbers in our World Collection of wheat, 5,200 in oats, 6,500 in barley, and 2,500 in rice.

We have conducted rather continuous foreign explorations for new strains of cereals and other field crops. For example, from 1936 through 1939 we had a plant explorer in Asia searching the Himalaya and Hindu-Kush Mountains for cereals that might be better suited for growing under cold-temperature conditions. In 1954 about 1,000 new small grain cereals were introducted, including more than 250 wheats and barleys from Afghanistan, Turkey, and Iran. An additional 300 wheats came in from Argentina, Brazil, Peru, and Egypt as a result of testing programs for disease resistance. About 150 wheats were also received from Yugoslavia for screening.

Just this month a collection of several thousand wheats arrived from Afghanistan. This latest collection represents most all the strains of wheat in that country, whether growing wild or as a cultivated crop. They were presented to our explorer in Afghanistan by a collector who had gathered them from all over the country for exhibition at a fair.

You notice that we keep going back to Afghanistan and other countries of the Near East. This, of course, is because the Near East is the home of the small grain cereals. There will be found the greatest variation and the greatest possibility of finding the genes we need for improving our commercial cereal crops.

Some of the recent foreign introductions are already showing up in our breeding programs. The Norin 10 wheat, which Dr. S. C. Salmon brought back from Japan in 1946, has been used by Dr. O. A. Vogel and others in the Pacific Northwest to produce some extremely promising hybrid combinations. Wheats from Kenya with stem rust resistance and from Canada and Palestine with sawfly resistance, oats from Argentina and Uruguay with crown rust resistance, and barley from Yugoslavia with rust resistance are all being used by plant breeders in various parts of the country.

## Foreign Testing for Plant Diseases

In addition to introducing foreign germ plasm, we are conducting tests in many foreign countries to study the importance of forms of diseases not yet found in the United States but which may be introduced in the future. Scientists at 31 different locations throughout the world are furnishing us with information on the response of wheats to many races and biotypes of stem rust and other diseases. This international cooperative testing program has been extended to other cereals, including barley, oats, and rice.

We have demonstrated the value of the foreign studies of crop diseases with other important crops. In 1947 members of our staff went to Brazil and other South American countries to study Tristeza disease of citrus, which was causing tremendous losses in those foreign areas. Then, about 3 years ago, Tristeza was found in Florida and more recently in Texas citrus-growing areas. The information obtained in South America regarding symptoms of the disease, its manner of spread, and the vectors responsible for spread, not only helped us to identify Tristeza in Florida and Texas, it has also been extremely helpful in our research on the disease.

Similarly, one of our plant pathologists went to Europe in 1951 to study the virus yellows disease of sugar beets, which was reducing the crop by 20 to 50 percent in certain European fields. These studies enabled our scientists to identify this disease in certain sugar beet-producing sections of this country. Although domestic losses have not been as great as those in Europe, we know the potential danger and have already increased our research effort to minimize this hazard.

I believe the important thing is that we have succeeded in establishing contacts with foreign scientists and in developing a pattern of cooperation that will be useful and simple to follow with other crops that warrant similar attention.

## Growth Chambers and Winter Generations

In recent years we have given added attention to procedures that will reduce the time required to isolate the desired combination of characters in plants following hybridization. Plant scientists in the United States and Canada have utilized special growth chambers in which light and temperature can be carefully controlled to speed up plant growth and fruiting. These facilities have made it possible to obtain 5 or possibly 6 generations of spring wheat, barley, or oats in a single year.

For some of our crops, arrangements have been made to grow segregating generations or seed increase plantings in the Southern States. Our Southwestern Irrigation Experiment Station at Brawley, California, has been utilized effectively in speeding up the spring wheat and small grain breeding projects. Our cotton breeders have arranged for a winter station at Iguala, Mexico, and we are growing winter crops of tobacco at Cocoa, Florida. These facilities serve cooperating State research workers, as well as our Federal staff.

It is still necessary to conduct field tests in the local production areas to evaluate agronomic characters, varietal adaptation, and quality, but it should be possible through these procedures to reduce the time required for development of new varieties from ten to possibly five or six years.

## Fundamental Studies for Plant Disease Control

The recent increased financial support for research on cereals has made it possible to give much-needed attention to fundamental studies on the diseases of these crops. We have added staff to evaluate more adequately the race picture in the wheat rusts. This year we are employing a physiologist to be located at the Minnesota Station to explore further the chemical control of rust. These studies will concentrate on learning how the chemicals are abosrbed, how they are retained by the plant, what they do to the plant structure, and the mechanism by which they exercise control of the rust.

The fundamental studies on wheat smuts were strengthened a year ago when additional staff members were placed with Dr. C. S. Holton, in cooperation with the Washington Agricultural Experiment Station at Pullman. The further increased support this year has made it possible to employ a biochemist at Corvallis, Oregon, to study the nature of smut resistance in wheat.

About a year ago, Dr. Agnes Moorhead was employed at Lincoln, Nebraska, to take the leadership in serological research on the false stripe virus disease of barley, as well as studies on wheat streak mosaic, soil-borne mosaic, and bromegrass mosaic virus diseases.

Another potentially fruitful field that we are exploring is the use of antibiotics for the control of bacterial and virus diseases. Streptomycin, terramycin, and certain other materials have been found effective in controlling halo blight of beans, bacterial spot in tomato plant beds, bacterial spot of pepper, blackleg and soft-rot decay of potatoes, pear blight, fire blight of apples, and several other bacterial diseases of crops. Although we know that antibiotic materials are absorbed and move through the plants, we still lack a real understanding of how these materials produce the results observed. Until we have this understanding, we will not be able to take full advantage of the potential benefits antibiotics offer. We are concerned particularly with the possibility of antibiotics or chemicals for the control of virus diseases, which are especially devastating and costly in the tree fruits where growers must remove infected trees and frequently replant entire orchards. Our crops research program was strengthened this year with an added appropriation of $50,000 specifically to pursue the use of antibiotics in control of plant diseases.

We have observed some interesting results recently on the influence of various organic materials on soil-borne pathogens. Dr. W. B. Moore of our staff conducted some tests in Florida last year to determine the effect of various organic materials in soils infected with rhizoctonia root rot. When snap beans were grown in pots to which 5 percent by weight of dry sugarcane bagasse was added there was practically no root rot. In contrast, in the controls the disease was as high as 67 percent. Dry residues of ramie and millet were also fairly effective. Addition of green material to the soil had little or no effect. In field trials, a delay in planting beans after turning under organic matter resulted in much less rhizoctonia and similar disease loss than when the beans were planted immediately after the residue was plowed under. These results are only preliminary, but they provide encouragement for further studies of significance to crops such as wheat and small grains that suffer loss from root rot.

## Insect Control Research

There has been a tremendous increase in the use of insecticide chemicals as a result of the many new compounds that have come on the market since World War II. This has focused attention on the possible health hazard from insecticide residues on food or feed crops. We feel that the present procedures for evaluating such chemicals and registering them for use provide reasonably adequate protection. In order to develop more specific background information on the pesticide residue problem, our program was strengthened this year to provide additional staff members at the laboratory at Vincennes, Indiana; Moorestown, New Jersey; and Yakima, Washington. A new laboratory is being established at Tifton, Georgia, in cooperation with the State Experiment Station to give special attention to pesticide residues on cereal and forage crop plants. Attention will be given to effects of chemical residue on flavor and quality and to improvement of techniques for analyzing for residues.

Another line of research that is receiving added attention is the use of systemic insecticides for control of certain types of insects on cereals, cotton, and other crops. Some materials have been found to be effective as systemics for the control of aphids in tree fruits, for control of thrips, aphids, and fleahoppers in cotton, and for the control of mites and greenbugs on wheat and small grains. Demeton, when used with a methocel sticker as a seed treatment for oats, wheat, and barley, has given excellent control of greenbugs up to 43 days after seeding. These results are all preliminary, but the approach is important. If we can develop specific controls for some of these destructive insects without injuring beneficial insects, we will have made a real advance in the protection of insect predators that provide natural controls and of insects essential for pollination of some crop plants.

Our research on insects attacking the wheat crop was modified this fall through the transfer of headquarters for some of our key personnel. Dr. R. G. Dahms was transferred to Beltsville, Maryland, to serve as Assistant Head of the Cereal and Forage Insects Section. Mr. C. F. Henderson was moved from Garden City, Kansas, to Stillwater, Oklahoma, to assume the responsibilities for small grain insect research formerly handled by Dr. Dahms. Studies on the brown wheat mite were transferred from Garden City to Logan, Utah, primarily to permit observations under conditions where mite infestations have been more consistent and heavier in recent years. Mr. F. V. Lieberman will be in charge of the work in Utah. We feel that additional information must be developed on the significance of the damage by the mite and the effectiveness of various control measures if we are to develop efficient and economical controls that can be recommended to growers. Another recent personnel shift was the transfer of Mr. H. W. Somsen to Manhattan to replace R. V. Connin on the wheat insect program.

## Nematology Investigations

Another field of work that has been strengthened this past year is our research on nematodes. There is a growing recognition of damage caused by nematodes to many crops. The research program on these pests has been extremely limited until recently. It was strengthened substantially by additional State funds in California a year ago and increased Federal funds during this current year.

The added Federal support has enabled us to establish trained nematologists at certain key points to assist in the identification of nematode species and in the development of experiments to produce effective controls. One such headquarters is at Auburn, Alabama, where we expect to concentrate on nematodes attacking cotton, peanuts, and other crops in that Southeastern area. A second headquarters has been established at Baton Rouge, Louisiana, where attention will be given to nematodes attacking sugarcane, rice, cotton, and other crops. A third location is being developed at Madison, Wisconsin, to give attention to the potato rot nematode and other nematodes affecting crops in the North Central States. We also have increased our staff working on sugar beet and citrus nematodes.

One significant finding that has resulted from this expanded program is the identification of a species of nematode in Texas rice-growing areas that had not previously been isolated in this country. This species has been destructive in Indonesia and other Far Eastern countries. The laboratory at Baton Rouge, cooperating with the staff at the Beaumont, Texas, Rice Station, found the new species. We feel that this added service will be extremely valuable in pointing up the nature of the nematode problems, so that we can proceed more intelligently with research to develop specific controls for these destructive pests.

## Other Problems That Need Attention

I have reviewed or summarized a number of the activities that we are strengthening as a result of recent adjustments in program or additional financial support. I should like now to consider a few areas of crops research that should receive more specific attention in the future.

## Oat Breeding and Disease

We are still suffering tremendous losses from diseases to the oat crop, which ranks third in farm value among our cereals. Losses from rusts in 1953 and 1954 averaged about 95 million dollars in Iowa, Minnesota, and Wisconsin. The damage in 1953 from stem rust was the worst for a quarter-century and that from crown rust for a decade. New rust races, including race 7A of stem rust and race 263 of crown rust, were identified from Canadian collections in 1953. The new race of crown rust has not yet been isolated in the United States, but it is a serious potential threat because most of our commercially grown new varieties and selections are highly susceptible to this race.

Losses in 1945 from Helminthosporium were 100 million dollars; in 1949 from red leaf, 50 million dollars; and in 1951 from Septoria, 25 million. These losses, which could be reduced through development of resistant varieties, provide ample justification for a stronger research program in oat improvement.

### Forage Improvement, Including Weed and Brush Control

Because of increased emphasis on the use of forage crops on acreage taken out of wheat and other grains, and the need for increasing the efficiency of our levestock production, a much more adequate research program on forage improvement is essential. Disease losses in hay and pasture are estimated at more than a billion dollars annually. Unfortunately, these losses are not readily recognized by farmers, because yield measurements are not as easily made on these crops as they are on harvested crops. Bacterial wilt of alfalfa has been controlled by resistant varieties, but losses from black stem, leaf spot, and anthracnose are still extremely severe. Leaf and stem diseases and root and crown rots cause an annual loss in red clover of more than 300 million dollars. Birdsfoot trefoil is a leading pasture legume in the humid area, but it is difficult to establish and is so susceptible to rhizoctonia that established stands are destroyed before reaching maximum production. The use of Ladino clover has dropped significantly in recent years because of disease and a lack of persistence under grazing. Similar problems exist with regard to most of our grasses. Less than a dozen of the 75 or more important forage grasses have been improved by breeding for higher yield and quality.

We build up our supplies of forage germ plasm. In recent years we have conducted special exploration for grasses and legumes in India, Pakistan, and Afghanistan. We also have about 2,500 items from domestic explorations in Nebraska, Kansas, Texas, and New Mexico, largely native grasses and legumes collected under severe drought conditions in recent years.

The lack of adequate attention to forage crop improvement is indicated by the relative appropriations for our Federal research programs. We have available only $71,000 for our research on all clovers, about $70,000 for improvement research on Lespedeza, lupines, and other miscellaneous legumes, and about $157,000 for our research on all species of grasses. On the other hand, our present support for research on wheat production is over $700,000. When we consider the importance of forage crops in our farm economy and the complexity of the problems in establishing and maintaining productive pastures and range areas, we can appreciate the inadequacy of the present research program.

### Research on Grain Sorghums

More attention should be given to the development of hybrid grain sorghum adapted for growing in the hard winter wheat area. One of our major crop adjustment problems will be in the High Plains region and in other areas where substitute crops should be developed to replace wheat acreage. The potential benefit of commercial hybrids in grain sorghum, with yield increases up to 50 percent, has not been realized because of our limited research program on this crop. Our present Federal appropriation is less than $52,000. We could well afford to devote more support and attention to a crop that has such great potentials in providing economical feed supplies as well as providing relief in our wheat surplus problem.

## Crop-Climate Relations

One of the weakest points in our entire program of grain production research is in crop physiology. Certain of the States have some work going on, but physiological studies specifically related to grain crops are decidedly limited. Basic research is far from adequate, for example, on such important factors as winter-killing, drought, injury from high temperatures and late spring frosts, or the relationships between temperature, moisture, humidity, and sunlight and the development of disease and insect pests.

There is great need for additional research to guide adjustment in our crop production practices, or crop improvement through breeding, to minimize the effects of extremes in temperatures, rainfall, and other unfavorable environmental conditions. In order to develop crop plants that can tolerate unfavorable conditions, the various climatic factors should be studied separately and in various combinations. This could best be done in plant growth chambers in which environmental conditions could be carefully controlled.

Let's consider winter hardiness in wheat as an example. We have known for a long time that varieties differ in their ability to withstand cold weather. Eighteen years ago I was helping Dr. K. S. Quisenberry and his associates move the flats of different winter wheats and winter barleys through the freezing chambers at the Nebraska Station. How much progress have we made in understanding the basis for cold-hardiness in crop plants since that time? We still must depend too much upon the trial-and-error process of freezing chambers to eliminate tender plants that may or may not have been preconditioned properly for a differential test.

We need more background information on the physiological make-up or combinations of chemicals in plants that give them ability to stand extreme cold. With such knowledge of resistance, not only to low temperatures but also to heat and drought, we could undoubtedly develop more efficient and effective techniques for selecting varieties better adapted to various wheat-growing areas.

The progress the last ten years in developing an understanding of plant-growth-regulating chemicals, through the use of radioisotopes and other techniques, lends encouragement to greater knowledge of plant physiological processes. The complex hazards of weather provide a challenging target for crop physiologists and plant breeders. We should give such research the support it deserves in comparison with other fruitful areas of plant science.

I have mentioned only a few of the areas of research in which we are weak and some of the approaches we are taking in our research efforts to solve some of the most pressing problems, primarily in grain production. The problems in other crops and in other farming enterprises are just as pressing.

The task before us is enormous but increasing numbers of agricultural leaders are recognizing that support for agricultural research should be brought more in line with the magnitude of the problems. Our research is benefitted by this progressive support of farmers, industry, and consumers. By working together, we can most effectively meet our responsibilities.

WEDNESDAY AFTERNOON, JANUARY 19

H. Knutson, Chairman

## RECENT STUDIES IN RESISTANCE OF WHEAT TO GREENBUGS IN OKLAHOMA, TEXAS, AND KANSAS

Oklahoma - R. G. Dahms

Work has been under way since 1947 at Stillwater, Oklahoma, on the development of greenbug resistant small grains. This has been a cooperative project between the Entomology Research Branch and Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture, and the Entomology and Agronomy Departments, Oklahoma Agricultural Experiment Station.

Since it is necessary to maintain a heavy insect population in any insect resistance study, considerable time has been spent in developing techniques. The first resistance tests were made by caging greenbugs on plants growing in 6-inch flower pots. Each pot contained one plant of eight different varieties (seven test varieties and one check). In these tests preference was determined by counting the number of greenbugs on each plant, and tolerance was measured by the number of days the plants lived after being infested. This method gave a satisfactory measurement of resistance but was too slow for gross screening of varieties.

The method now being used is to plant ten varieties in rows (nine test varieties and a check) in 15 x 20 x 2-3/4-inch greenhouse flats. The plants are infested with greenbugs two weeks after seeding, and the number of days each plant lives after infestation is used as a tolerance measurement.

Varieties that showed some resistance under greenhouse conditions were seeded in nursery plots in the field and exposed to heavy greenbug infestations. If heavy natural infestations were not present, infestations were obtained manually by liberating greenbugs reared in the greenhouse on the growing plants.

In these studies, approximately 50 barley varieties have been found that are highly resistant to greenbugs. Slight differences in greenbug resistance in oat varieties have been noted but no variety has been found highly resistant.

Varieties of 14 wheat species have been tested for greenbug resistance. None has shown a high degree of tolerance, but greenbugs showed less preference for all of them than for the Pawnee check. The durums as a group were more tolerant than any of the other wheat species. None of the agrotricums (wheat x grass) tested were highly resistant.

Only one wheat variety has been found that exhibits a high degree of tolerance to the greenbug. This variety was discovered as a mixture in a durum, Dickinson 485, C.I. 3703. The resistant selection is not a typical durum, but more nearly resembles a common spring wheat. However, cytological examination indicates that it is a 14-chromosome wheat. In the greenhouse flat tests under heavy greenbug infestations, this selection lived approximately three times as long as Pawnee. The Dickinson resistant selection also was very resistant under field conditions.

Texas - H. L. Chada

All of the greenbug resistance studies at the Denton, Texas, Station have been conducted in a controlled environment insectary. It is insulated, air-conditioned by refrigeration in summer, heated in winter, and a year-round temperature of about 70° F. is maintained. The relative humidity remains rather constant at around 50 percent. Sixteen hours of artificial light is supplied by fluorescent fixtures just above the plants. In this insectary, all variables, except the plants themselves, are practically eliminated. The original testing procedure employed was the "pot method" developed by Dr. R. G. Dahms. The "flat method" is now being used for making a gross separation of resistant and susceptible varieties.

Two hundred Oriental wheat varieties, mostly Chinese, were tested for resistance, using the "pot method". Pawnee, a wheat susceptible to greenbugs, was used as a check. Most of the varieties were as susceptible as or more susceptible than Pawnee. Twelve showed more resistance than the check. Several of these have been used in crosses by Dr. D. E. Weibel. One hundred and fifteen other wheats obtained from Dr. I. M. Atkins' stock (mostly Chinese) were also tested. They were all as susceptible to greenbug attack as Pawnee.

Out of 103 oat varieties tested for resistance, only Andrew, C.I. 4170, showed more resistance than the check, Cammelia, which is fairly susceptible. Since little is known about the greenbug resistance in oats, the World Oat Collection of 4,998 varieties has been obtained from Beltsville and it will be screened for resistance.

Fifty-five selections of 1952 barley involving several crosses were available for testing at the Denton Station. None showed as much resistance as Omugi. Most of them showed as much susceptibility as Wintex.

The resistance ratings of 855 $F_3$ barley head selections involving 3 crosses made at the Denton Station were obtained. From 110 selections of the Texan x Omugi cross, 13.6 percent showed more resistance than Omugi. Of the 631 selections of the Cordova x Omugi cross, 24.2 percent showed more resistance than Omugi. Of the 114 selections of the Texan x Ludwig cross, 14.9 percent showed more resistance than Omugi. The resistant selections have been planted in pots in the greenhouse, and seed of them will later be planted in the field. They will be subjected to further testing for resistance at a later date.

Kansas - R. H. Painter

Differences in susceptibility of wheat varieties have been known since the observations of Atkins and Dahms in the 1942 outbreak. But differences found have not been large enough for ease of handling in crosses.

The first real break in greenbug resistance studies on wheat came with the discovery by Dr. R. G. Dahms of a selection from Dickinson, C.I. 3707, with high tolerance to greenbugs.

Plants of this selection show little loss of chlorophyll after greenbug feeding, less stunting, and much less evidence of red spotting. Plants of Dickinson, C.I. 3707, can be overwhelmed by numbers of greenbugs. Also, there is a lower fecundity of female feeding on this variety. Resistance of this variety has been confirmed at Manhattan both in the laboratory and in the field. Crosses have been made with Kansas wheats. The $F_1$ appears intermediate in reaction to greenbugs.

Using Dickinson as a resistant check and Pawnee as a susceptible standard, 1,118 varieties, mostly foreign plant introductions, have been rated in flat tests. Those giving the better rankings and those that appeared mixed for reaction are being retested.

Results of First Set of Greenhouse Tests on Tolerance to Greenbugs of Part of the World Wheat Collection

| | Number of rows of | | | |
|---|---|---|---|---|
| Rank | Dickinson, C.I. 3707 | Pawnee | Test varieties* | Characteristics of rank |
| 1 | 6 | 0 | 0 | Aphids present, no discoloration |
| 2 | 24 | 0 | 3 | Slight discoloration, but no stunting |
| 3 | 16 | 4 | 48 | Some discoloration and/or stunting |
| 4 | 3 | 35 | 425 | Considerable discoloration and/or stunting |
| 5 | 0 | 20 | 642 | One or more plants dead, rest badly injured |
| Totals | 49 | 59 | 1,118 | |
| Average rank | 2.33 | 4.27 | 4.53 | |

* One row per variety. Those varieties ranking 2, 3, and part of those ranking 4 are being retested.

# BIOLOGY, CONTROL, AND COMPARISON OF MITES OTHER THAN ACERIA TULIPAE ATTACKING WHEAT

C. F. Henderson, Oklahoma

The three most important mites attacking small grains in the hard red winter wheat area are the brown wheat mite, Petrobia latens (Müller); the winter grain mite, Penthaleus major (Duges); and the so-called white grain mite, Oligonychus pratensis (Banks).

## Brown Wheat Mite

When first hatched, the brown wheat mite is bright red in color and has six legs. The adult is brownish-purple and has eight legs. This mite is extremely small, and may be overlooked by anyone not actually searching for it in the foliage of the plants or on the ground. The brown wheat mite does most of its feeding in the afternoon, with maximum populations occurring on the foliage about two hours before sunset. Few mites are found on the plants after dark when temperatures begin to drop. Mites are ordinarily present in the field from September or October until some time in June.

The brown wheat mite lays two types of eggs. The winter egg is red, globular in shape, and has a fine hair or bristle at the apex. The summer egg is bell-shaped and covered with a white waxy coating. These eggs are deposited on discolored basal leaves of the plant and under clods and debris on the soil surface. Occasionally they are deposited at greater depths, in cracks extending into the ground.

The summer eggs are deposited in April or May, and carry the species from one wheat crop to the next. Hatching of the eggs requires contact with free moisture, and possibly a weathering period which breaks down the waxy coating and permits moisture to penetrate. When rains occur in the fall, about the time that the wheat starts to germinate, in September or October, the eggs begin to hatch. Population counts made in several fields of continuous and fallow-land wheat south of Garden City, Kansas, from October 1952 to May 1953, showed larger numbers of mites in continuous than in fallow-land wheat. Almost no mites were present in the fallow-land fields from October to February, inclusive. Populations began to increase in these fields during March. In April there were about one-third as many mites in the fallow-land as in the continuous fields. At this time of year, however, mite populations begin to decline, and soon reach low levels. In May, mites were more abundant in the fallow-land fields than in the continuous, but by this time few mites could be found in any of the fields. This difference in populations between continuous and fallow-land fields suggests the possibility of crop rotations as a means of controlling the mite.

Observations indicate that there are at least three possible methods for fallow-land fields to become infested: (1) the carrying over of summer eggs to the second year; (2) mite movement on the ground; and (3) mite movement in the air.

Heavy infestations of the mite, and in some cases severe damage, have been reported during the past few years from the south-central portion of the Great Plains area, including southwestern Kansas, southeastern Colorado, and the Oklahoma and Texas Panhandles. Also, reports of severe injury have been received during several years from locations in the Western Plateau area, particularly southeastern and northwestern Utah and southeastern Idaho. In all cases, however, drought was a contributing factor.

In 1952 and 1953, a large number of acaricidal tests were conducted to determine the most effective chemical control measures against the brown wheat mite. Applications were made as emulsion sprays with ground equipment. Effective initial control, as determined from counts made 6 days after treatment, was obtained with parathion at 1/4 and 1/2 pound per acre, Metacide at 1/4 pound, and demeton at 1/4 pound, all of which are phosphorous compounds. The sulfur compounds, as well as many of the organic phosphates, were ineffective against this mite. Counts made 18 days after treatment indicated that parathion at 1/2 pound per acre was the only effective treatment among those applied. Several commonly used chlorinated hydrocarbon insecticides not having any known acaricidal value such as aldrin, chlordane, toxaphene, and DDT were also tested with negative results.

Two large-scale airplane tests were conducted against the mite. A spray of parathion at 1/2 pound in 2 gallons of diesel oil per acre was the best treatment in both tests, and parathion at 1/2 pound in 1 gallon of diesel oil the second best. The poorest results were with 1/4 pound of parathion in 2 gallons of diesel oil and 1/2 pound in 2 gallons of water as an emulsion. Unfortunately, even the best treatment did not always achieve satisfactory results when applied commercially. Also, two or more applications might be required to reduce populations to non-economic levels, because of the hatching of eggs not affected by the spray.

To determine the effect of the mite on yield of wheat, populations were kept at low levels in both continuous and fallow-land wheat fields by 1 to 3 applications of parathion made from February to May 1953. In the first test 2 applications were made to 11 continuous wheat fields and populations were maintained at a level 90 percent below those in the checks. In 6 fallow-land fields, 2 to 3 applications reduced populations 91 percent and 1 application in 6 fallow-land fields reduced populations 96 percent. At harvest time, yield records were taken in these same treated and check fields. With a 4.8 bushel yield in the 11 continuous fields, there was a non-significant difference of 10 percent in yield favoring the treated plots. With an average of 7.8 bushels per acre, 6 treated fallow-land fields had a non-significant increase of 36 percent. In the 6 other fallow-land fields, with an 11.3 bushel average, there was a significant difference of 25 percent in favor of the treatment.

## Winter Grain Mite

The winter grain mite has caused considerable damage to small grains in north-central and central Texas during the past few years. Farmers and county agents have observed this injury for years, but attributed it to freezing weather. One county agent reported having seen it as early as 1919.

The adult mite is much larger than the brown wheat mite, being about 1 mm. in length. It is dark brown to black in color, often with a greenish or purplish tinge. The mouthparts and legs are reddish orange. The genital opening is ventral, which separates it from other genera of the family (Eupodidae).

There are two generations of the winter grain mite in Texas. The first develops from the aestivating summer eggs. The second generation develops from eggs deposited by the first generation adults, and these in turn lay the summer or aestivating eggs. Mites are present in the field approximately from November 1 to April 15. The female deposits kidney-shaped eggs which are plump and reddish-brown when first laid. Within a few days the eggs become wrinkled and are straw colored. These eggs are deposited on the sheath leaves and stems of food plants and on the soil near the base of the plants. They may be deposited singly, but are usually found in large numbers close together. The eggs hatch into tiny reddish-brown, six-legged larvae. These develop into eight-legged nymphs and later adults.

During the heat of the day, if the soil is moist and there is plenty of foliage, the winter grain mite may be found on the moist soil in the shade. If the soil is dry and there is little foliage, the mites dig into the ground for 4 or 5 inches until moisture is reached. During the night they feed on the foliage and in a heavily infested field the foliage will be covered with feeding mites until sunrise, when they again descend to the ground.

Heavily infested fields have a grayish or silvery appearance and do not first turn yellow as with brown wheat mite injury. When large numbers of mites feed on a plant, the tips of the leaves turn brown and die and when the feeding continues the plant is often killed. There are two types of injury, foliage reduction throughout the winter and reduction in yield of grain. Where winter grazing is practiced, the reduction in forage probably is of the greater importance as farmers rely on small grains for fall and winter pasture.

Cropping practices have a marked effect on the occurrence of damage caused by this mite. It was found that (1) fields planted to small grains continuously for three years had heavy mite populations and severe injury, (2) fields planted to small grains for two years had light populations and spotted damage, and (3) fields not planted to small grains the previous year had no injury and mites were absent or very scarce. Thus, eliminating continuous cropping practices would greatly reduce mite infestations and injury.

Chemical control tests were conducted against the winter grain mite. In one typical test most of the materials gave almost perfect control and some when applied at dosages as low as 1/8 pound per acre. The phosphorous and sulfur compounds tested were very effective in controlling this mite. One application of parathion or TEPP at 1/4 pound per acre is sufficient to give seasonal control. This is the easiest to control of all small grain mites studied thus far.

### Other Small Grain Mites

Another grain mite, Oligonychus pratensis, was reported to be the most serious pest to small grains at Clovis, New Mexico, in 1952-53. This mite is much smaller than either the brown wheat mite or the winter grain mite and, being light in color, is very inconspicuous. In the fall this mite is located in small colonies on the leaves of the wheat plants. When the plants begin to tiller in the winter, the mites move to the crowns of the plants near the soil surface. In May the mites leave the bases of the plants and move to the upper leaves and heads.

In contrast to the other two mites, Oligonychus pratensis causes much webbing. Some heavily infested plants are killed by a combination of mite feeding and lack of soil moisture.

Parathion and demeton gave the best control against Oligonychus. However, this mite appears more difficult to kill than the brown wheat mite or the winter grain mite.

## PANEL: VIRUSES AFFECTING WHEAT; VECTORS, RESISTANCE AND CONTROL
Leader, J. W. Schmidt, Nebraska

## WHEAT STREAK MOSAIC VIRUS IN KANSAS

W. H. Sill

### Survey Method for Predicting Epiphytotics

A survey method is now available which, if used properly, can predict spring epiphytotics in winter wheat. In brief, random samples of planted wheat are collected during the fall and winter in the areas to be surveyed. These are marked as to location, taken to a warm greenhouse, and allowed to grow. As symptoms appear on diseased plants the positive sample locations are marked on a map along with the percent of diseased plants in each sample. The location and approximate severity of any impending epiphytotic is shown by the number of positive samples from any area and the percent of diseased plants. With this system, it has been possible to predict the wheat streak mosaic outbreaks in Kansas with reasonable accuracy for years. The technique works because it is necessary in winter wheat for infection to occur in early fall while the plants are young. Winter wheat plants infected in the spring are not damaged much by the disease.

## Does Mosaic Wheat Make Good Bread?

This question was asked so many times that controlled experiments now in their third year were initiated in cooperation with Mr. K. F. Finney (USDA) working in the Milling Department at Kansas State College. As a preliminary statement we can definitely say that neither major virus disease of wheat causes a deterioration in the milling quality.

## Wheat Streak Mosaic - Host Range

Based upon a thorough screening of many families of both monocotyledonous and dicotyledonous plants and many varieties of major crop plants, there is reasonable assurance that this virus is confined to a relatively narrow host range among the grasses. Among the crop plants tested only wheat and a few millets have been susceptible enough to be damaged severely by the disease. Oats, rye, barley, and some corn varieties, although systemically infected by the disease, are not hurt appreciably. Sorghum, sugar cane, smooth brome, and many other grasses have been immune.

## Strain Studies and Electron Microscopy

This work is being conducted and is in the second year, but any report now would be premature. However, hundreds of wheat streak mosaic virus collections indicate that the intermediate types are more common in the field than the mild or severe symptom types.

## Other Viruses

Two other small grain viruses are becoming of economic significance in Kansas. These are barley stripe mosaic (false stripe) and the oats blue dwarf-red leaf complex or disease. Both were widespread in the 1954 crop in the State. The first was collected in five random barley samples from southeastern counties during the winter of 1953-54. All diagnostic tests described by McKinney were utilized and each sample proved to be this virus. About 30 percent of approximately 1,000 seeds collected from diseased plants have carried the disease. A preliminary study of seedling symptom development has been made and a system of seed certification based upon seedling symptoms would appear to be possible if needed. The second disease has been seen in abundance in eastern Kansas and some yield reduction has been apparent but no research has been conducted. However, both of these diseases are difficult to identify by symptoms alone. Many essentially symptomless plants may be infected sufficiently to reduce yield. The losses may well be far more than have been suspected. Such losses probably have been blamed heretofore upon other supposed causes.

# WHEAT CURL MITE, ACERIA TULIPAE (K), IN RELATION TO WHEAT AND WHEAT MOSAIC

R. H. Painter, Kansas

The seasonal history of this mite has been followed in the field and in experimental plantings near Manhattan. Mr. William Gibson has been responsible for many of the observations given here. As the plant matures, beginning with the early seedling stage, the adult mites migrate toward the younger leaves. After flowering, the mites and eggs have been found behind the glumes and on the green kernel. Earlier, they are commonly found between the ligule and the leaf blade.

As a means of passing the summer, volunteer wheat appears to be the most important breeding host supplemented sometimes by western wheat grass. Eriophyid mites, probably mostly Aceria have been collected in the field on the following weed grasses found in and around wheat stubble fields: green bristlegrass, barnyardgrass, common switchgrass, stinkgrass, Canada wildrye, smooth brome, and switchgrass. Most of these plants are probably only subsistence hosts. The mite has also been found on two occasions in the curl of sorghum seedlings alongside of wheat fields. Mites are more abundant on the weed grasses just after harvest. Later the numbers dropped off, reaching a low point in August and building up again afterward.

## Surveys for Eriophyid Mites on Wheat

The first survey was conducted in December 1953 on wheat brought in by Dr. Sill and Dr. Fellows in connection with their mosaic survey. Among 94 counties from which wheat was sampled, in 83 at least one pot from one field was infested by mites. A second survey was carried out by the group working on wheat mosaic during late September and early October 1954. This survey was made mostly on volunteer wheat. Mites were found in about 1/3 of the 253 fields entered. Wheat infested with mites was found in 43 among the 62 counties surveyed. In each field entered, up to as many as 10 leaves per field were examined for the presence or absence of mites. The following conclusions can be drawn from these surveys:

(1) Mites were frequently more abundant in areas where plants showed mosaic symptoms. This probably reflects a longer period of multiplication in these areas.
(2) Mites may survive and thrive on wheat in the field in the absence of mosaic.
(3) An August and early September mite survey based on the examination of volunteer might make possible the forecast of areas where mosaic is likely to occur and where special effort should be made to eliminate volunteer.

## Migration of Mites from Host to Host

It appears fairly well established that most of the movements of this mite are by air currents. Dr. Stuart Pady found mites on the slides which he used for a study of rust spore collections about harvest time. These slides were exposed on top of the chemistry building at least 1-1/2 miles from the nearest wheat field. The mites were identified by Dr. H. H. Keifer as Aceria tulipae (K).

It can be shown that as the wheat plant dries out or is placed under adverse conditions the mites tend to swarm in large numbers at the tips of the leaves. Here they may be picked up more readily by the wind. This habit may be of importance in the spread of mites, especially in more arid regions.

Phoresy or "hitchhiking" may be another and perhaps less important method of spreading. Mites have been seen to climb up on aphids, leaf hoppers, and other insects. These insects have then been seen to take wing. Experiments have been set up to determine whether mites are carried from plant to plant in this way. Among eight such experiments conducted with various insects, three experiments (all involved greenbugs) have been successful.

A series of dates of planting have been made in an attempt to follow what happens to this mite in the field. Three dates of planting plots were set out near Manhattan. Plot A, planted July 27 to October 15 at two weekly intervals, was infested at one end on September 1 with viruliferous mites. Plot B, planted on the same dates, was infested with non-viruliferous mites on September 2. These two plots were at the Soil Conservation Nursery and were irrigated when necessary. Plot C was planted at the Agronomy Farm at two weekly intervals beginning August 10 to October 15. Ever since originally seeded, plants from each plot were examined each week for the presence, number, and stage of mites to be found. Among many other observations the following results can be recounted:

(1) The mites appeared promptly in the plots on September 9 on A and B and by September 1 on Plot C.
(2) The mite spread slowly to other later plantings. On December 15, the first mites were found on the October 1 planting.
(3) The presence of mites appeared to be less variable than the actual numbers present on the individual leaves.
(4) On December 15 after exposure to about 12° F., eggs, live nymphs, and adults were still present and exposed on the upper leaves.
(5) Adults continually move toward the central leaf of each tiller where they usually may be found if present. They leave behind eggs and nymphs on older leaves.
(6) The "artificial volunteer" now under study has had fewer mites than actual volunteer in nearby fields that came up at about the same time. The reason for this is not clear.

In all of these studies one is impressed with the fact that mites can be found even though the amount of leaf area which can be examined microscopically is infinitely small compared to the leaf area exposed in wheat fields.

## Chemical Control of the Mite and Possible Limitation of the Spreading of Mosaic

Since presumably one bite by one mite is sufficient to transmit mosaic, control of mosaic by chemical control of the mite would generally not be considered promising. The study of such a control was undertaken because of its possible use under special circumstances and because it may be possible to limit the spread of mosaic within fields through control of the mite. There are two possibilities: (1) through the use of sprays and (2) through seed treatment with systemic miticides. These studies were conducted by Mr. E. J. Kantack at Manhattan and Mr. T. Harvey at Hays under the general direction of Dr. H. Knutson.

### Spraying Tests

More than 40 different chemicals were given a preliminary test in the greenhouse. The more promising ones were taken to the field and tested last spring or are in the process of being tested this fall. Seven different tests were conducted or are in the process of being conducted on wheat under a wide variety of conditions and last spring also on western wheat grass. Some of the tests involved infestations of another Eriophyid mite, *Vasates mckinziei*. Under some conditions little control was effected by any of the materials used. Under some conditions Endrin at 1/2 pound per acre and 2 or 3 others appeared to give the best results. This conclusion is necessarily tentative.

### Seed Treatment or Treatment at Seeding Time

Various materials like Systox which may be picked up by the plant and thus protect it from the mite were placed on the seeds or put with the seeds at planting time. In the greenhouse some of these materials showed promise. Plantings were, therefore, made this fall to test the length of time mites could be kept off the plants and the efficacy of such treatment in limiting the spread of mosaic. The border rows around these tests were heavily infested with viruliferous mites. These plots, as well as the spray test plots, will be examined for the presence of mosaic in the spring.

## FACTORS RELATED TO THE WHEAT STREAK MOSAIC PROBLEM IN ALBERTA AND ITS CONTROL

J. T. Slykhuis
Lethbridge, Alberta

*Aceria tulipae* K., an efficient vector of wheat streak mosaic virus, also carries an additional substance which causes severe chlorosis, necrosis, and stunting of wheat. This substance appears to be a virus which is not manually transmittable. In nature it occurs in association with wheat streak mosaic and contributes to the yellowing and to the crop damage usually attributed entirely to the manually transmittable streak mosaic virus. The mites alone cause a longitudinal rolling of wheat leaves, but no pronounced chlorosis unless they are very numerous.

*Aceria tulipae* transmitted the wheat streak mosaic virus to the species of wild and cultivated grasses that were infected by artificial sap inoculation. The mites could be reared on barley, rye, some millets, and several wild grasses, but wheat was the most susceptible host tested. Only those grasses that were susceptible to both the mites and streak mosaic virus harbored the disease complex so that wheat sown in association with them became infected with streak mosaic. Although mites classified as *A. tulipae* were found in nature on *Hordeum jubatum* L., *Agropyron smithii* Rydb., and *Elymus canadensis* L., attempts to rear mites from these grasses on wheat failed. Attempts to rear *A. tulipae* from wheat on these grasses also failed. At present there are no perennial hosts known to be carriers of both the wheat streak mosaic virus and *A. tulipae* under natural conditions in Alberta. Winter Wheat is the only host that harbors the virus and the mite through the winter. The importance of winter wheat as an overwintering host in Alberta is emphasized by the limitation of the known range of wheat streak mosaic to the areas where winter wheat is grown.

In Alberta the perpetuation of wheat streak mosaic is predominantly associated with a continuous cycle of immature wheat. Winter wheat harbors the disease through the winter. Spring wheat can acquire the disease from winter wheat. Occasionally some spring wheat crops are very late maturing. Winter wheat may be planted in an adjacent field before the spring wheat is mature, and consequently acquires a severe dose of the disease from the spring wheat. Sometimes infected volunteer wheat on summerfallow land is not eliminated soon enough before winter wheat is sown in the same field. Immature wheat plants provide an excellent breeding ground for the vector as well as the virus, and they pass the disease along to the new crop.

Mite infestations and hence the danger of streak mosaic infection can be eliminated by destroying infected hosts, mainly immature wheat, by cultivation. The mites perish when the host plants become thoroughly desiccated or partially decomposed, hence the rate of destruction is influenced by temperature and soil moisture. A delayed seeding date may help avoid some of the sources of the disease. But even when there is a continuous source of infection the damage resulting from the disease is much greater in winter wheat sown in August and early September than in that sown later. The control measures recommended in Alberta therefore include eliminating the sources of the disease and seeding at the dates already recommended by the agronomists on the basis of long-term experiments.

Information on wheat streak mosaic and its control is eagerly sought by farmers in Alberta, especially those who have suffered severe crop loss. There is optimistic evidence that the recommendations are not only being heeded, but are proving effective.

## STUDIES OF ACERIA TULIPAE IN KANSAS

R. V. Connin

### Abundance and Distribution as Related to Spread of Wheat Streak Mosaic

Field observations on Aceria tulipae (K.), vector of wheat streak mosaic, were made in Kansas in 1953-54. These observations were carried on as part of a study of the ecology of the mite and its relation to the spread of wheat streak mosaic.

In the spring of 1953 the mite was found abundantly on fall seeded wheat in a six county area in north central Kansas. This area also contained most of the mosaic found in the 1953 crop. During the summer months of 1953 two large areas of volunteer were found which contained numerous mites and diseased plants. These areas were located in north central and central Kansas. When the fall seeded wheat emerged in the fall of 1953, mites were found in the same general areas in which they had been found on volunteer during the summer. These areas were also the most severely diseased areas in the 1954 crop.

The mite was also found on western wheatgrass, Agropyron smithii Rydb. throughout the year in both 1953 and 1954, but apparently mites from this grass had little to do with infesting the seeded wheat.

In 1954 observations on the role of volunteer wheat on the populations of the mite and spread of the disease were continued during the summer months. Both volunteer wheat and eriophyid mites were rather scarce during the summer, but a few small scattered areas were kept under observation. Data from these observations cannot be summarized until observations on the fall seeded wheat are completed.

The data obtained to date suggest that the volunteer wheat, which appears early enough, provides the best and probably the major oversummering host for the mite.

### Host Range

During the winter of 1953-54, studies were carried on in the greenhouses at Manhattan, Kansas, on the host plants of A. tulipae. Plants studies included 24 species of wild grasses, 27 varieties of wheat, 6 varieties of barley, 16 varieties of oats, 12 sorghum varieties, 10 corn varieties, and 5 varieties of sudan grass.

The mite was able to reproduce on all of the wheat, barley, corn, sorghum, and sudan varieties and on 12 of the wild grasses. The degree to which the populations increased varied considerably with the wheat and barley varieties appearing to be favored hosts.

Wheat streak mosaic was transmitted by the mite from wheat to all of the wheat and barley and to a number of the oats and wild grasses.

## WHEAT MOSAIC IN OKLAHOMA

D. F. Wadsworth and H. C. Young, Jr.
Presented by D. F. Wadsworth

### Soil-borne Mosaic

This disease first appeared in north central Oklahoma in 1952. Since that time the known area has increased until, in 1954, some 20,000 acres were found to be affected. A test nursery was established in a diseased field in the fall of 1952. Disease incidence and yields have been taken for two seasons (Table 1) and indicate that only three of the commonly grown hard red winter wheats are resistant. These are Concho, Comanche, and Westar. Concho has been the top yielder in this nursery for both years.

Yellow Streak Mosaic

Several hundred varieties and strains of wheat have been tested for resistance to yellow streak mosaic both in the greenhouse and in a field observation nursery and all have been susceptible. A yield nursery has been grown and inoculated for two years. In this nursery some degree of tolerance has been found in the variety Concho (Table 2). In 1954 when the inoculation was rather severe, the yield of this variety was cut almost 50 percent, yet it outyielded the second ranked variety by almost double.

In 1954 a test was made of the effect of different dates of inoculation on yield. The variety Concho was used. Early fall inoculations proved to be the most severe (Table 3). When two inoculations were made in the same plot, the yield was depressed slightly more. Single inoculations in early spring had little effect on the yield. If control of the mite vector by chemical means is effected, studies of this nature will be of value in determining the critical periods for insect control.

Table 1. The yield of several hard red winter wheat varieties in a soil-borne mosaic nursery at Tonkawa, Oklahoma

| Variety | 1953 yield1/ | 1954 Yield | 1954 Infection | Two-year avg. yield |
|---|---|---|---|---|
| | | | Pct. | |
| Concho | 38.2 | 36.4 | 2 | 37.3 |
| Westar | 36.8 | 33.3 | 5 | 35.1 |
| Comanche | 36.3 | 32.9 | 4 | 34.6 |
| Pawnee | 35.0 | 28.3 | 49 | 31.7 |
| Wichita | 37.0 | 23.8 | 50 | 30.4 |
| Triumph | 35.1 | 24.7 | 71 | 29.9 |
| Cheyenne | 34.8 | 24.7 | 63 | 29.8 |
| Red Chief | 34.7 | 23.9 | 48 | 29.3 |
| Blue Jacket | 30.5 | 27.5 | 48 | 29.0 |
| Tenmarq | 31.3 | 26.1 | 83 | 28.7 |
| Kiowa | 33.4 | 23.5 | 53 | 28.5 |
| Ponca | 34.5 | 22.3 | 61 | 28.4 |
| Kanking | - | 30.5 | 50 | - |
| Harvest Queen (Susceptible) | 28.5 | 16.9 | 74 | 22.7 |
| Harvest Queen (Resistant) | 31.2 | 26.4 | 6 | 28.8 |
| Red Winter Spelt | 28.6 | 6.6 | 99 | 17.6 |

1/ Disease symptoms scarcely visible even in very susceptible varieties.

Table 2. The yield of several hard red winter wheat varieties inoculated with yellow streak mosaic

| Variety | 1953 yield1/ | 1954 yield2/ | Two-year avg. yield |
|---|---|---|---|
| Concho | 39.1 | 16.1 | 24.0 |
| Triumph | 30.1 | 8.9 | 19.5 |
| Pawnee | 29.4 | 5.1 | 17.3 |
| Westar | 25.8 | 8.1 | 17.0 |
| Wichita | 26.0 | 7.6 | 16.8 |
| Comanche | 22.3 | 5.2 | 13.8 |
| Ponca | 19.8 | 6.2 | 13.0 |
| Hard Federation Hybrid (12515) | - | 9.6 | - |

1/ Inoculated in February 1953.
2/ Inoculated in November 1953.

Table 3. The yield of Concho inoculated with yellow streak mosaic at various dates

| Date of inoculation | Yield in bushels |
|---|---|
| November 1953 | 18.8 |
| November 1953 and December 1953 | 15.6 |
| November 1953 and February 1954 | 15.4 |
| December 1953 and February 1954 | 18.8 |
| February 1954 | 33.9 |
| Check (no inoculation) | 35.9 |

## RESISTANCE OF WHEAT VARIETIES AND CROSSES TO THE YELLOW STREAK AND SOIL-BORNE MOSAICS

H. Fellows, Kansas

### Yellow Streak Mosaic

Varieties vary from year to year and between regions the same in their reaction to yellow streak mosaic virus. This makes several years' testing necessary before drawing conclusions as to resistance of any variety. Up to the present time many foreign plant introductions, domestic varieties, agrotricums, and new crosses have been tested by artificial inoculation in field plots. Many of these have been discarded as highly susceptible. A comparatively few have shown enough promise for further tests.

Some domestic varieties have been subjected to yield tests. These show that there is a distinct difference in susceptibility of varieties to this disease. However, none of our best domestic varieties is resistant enough to be recommended to growers on this basis alone. The best are among the Blackhull derivatives. It is believed that a continuation of testing combined with a breeding program will result finally in the discovery of a variety or varieties sufficiently resistant and agronomically acceptable.

### Soil-borne Mosaic

Five plots were grown in naturally infected soil at widely separated points in eastern Kansas. The year was favorable for soil-borne mosaic so consistent readings were possible. There were 89 standard varieties, crosses, and selections tested. The results showed that Comanche, Westar, Concho, and Royal have high resistance. Eleven of the crosses involved also did very well. Certain individual plant selections were also superior. It appears at this time that the losses from soil-borne mosaic can be greatly reduced by the use of resistant varieties.

## RESISTANCE OF SMALL GRAINS AND AGROPYRON-WHEAT HYBRIDS TO ERIOPHYID MITES

R. V. Connin

Studies were made with 21 agropyron-wheat hybrids received from Kansas workers and 14 received from Canadian sources. The first studies were made to compare mite transmission of wheat streak mosaic with manual inoculation of the disease. However, rather striking differences were noted in the survival rate of *Aceria tulipae* on these various crosses and a resistance project was begun.

High temperatures in the greenhouse caused the resistance studies to be discontinued until this fall and only the 35 agrotricums noted above have been tested. Six of these crosses on which the mite populations decreased or did not build up are: TA-30, Kharkof x *A. elongatum*; TA-34, Vernal x *A. intermedium* (amphiploid); TA-36, *T. turgidum* x *A. intermedium* (amphiploid); TA-40, Kharkof x *A. intermedium* (amphiploid); Ks. 52-6408, Sando hybrid, (wheat-rye x *A. elongatum* x Cheyenne); and Ks. 52-6605, Sando hybrid, (wheat x *A. elongatum* x Pawnee).

The 27 commercial wheat varieties discussed in the host range studies also have been investigated for resistance. However, all of these varieties were extremely susceptible to infestation by *A. tulipae*.

RECOMMENDATIONS OF THE PANEL ON VIRUSES AND THEIR VECTORS

Virus diseases have become increasingly important hazards in the hard red winter wheat region. Although research has helped to accumulate considerable information relative to the general epidemiology of these diseases, their effective control is dependent on continued research. Accordingly, we are recommending to the Hard Red Winter Wheat Conference that personnel participating in these research projects:

1. Study details of the interrelationships of viruses, hosts, and vectors.
2. Further studies on the control of viruses and their vectors.
   a. Cultural
   b. Chemical
   c. Biological
   d. Host resistance
3. Continue and enlarge upon the studies of those cereal virus diseases not receiving major attention at the present time.
4. Initiate additional basic research on viruses and vectors, e.g., taxonomy of vectors, methodology.
5. Consider the establishment of a regional varietal testing program to be administered by the regional coordinator.

| | |
|---|---|
| W. B. Allington | W. H. Sill, Jr. |
| R. V. Connin | J. T. Slykhuis |
| H. Fellows | R. Staples |
| R. H. Painter | D. F. Wadsworth |
| J. W. Schmidt | |

DINNER TALK, JANUARY 19

# A HALF CENTURY OF WHEAT IMPROVEMENT

S. C. Salmon
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Whenever I think of wheat improvement in the United States I am reminded of Sir William Crookes who, as president of the British Association for the Advancement of Science in 1898, created a sensation in the United States and startled his own countrymen by warning them of the "deadly peril of not having enough to eat because wheat production could not keep pace with the increase in population." "It is almost certain" he said, "that within a generation the ...United States... will be driven to import and like ourselves will scramble for a lions share of the wheat crop of the world." He went on to say that "the details of the catastrophe no one can predict but the general direction is obvious enough." Crookes you will note was deadly serious as well he might be. Furthermore, he was not an alarmist and he was in a position to command all pertinent facts bearing on the situation. Yet he was completely wrong as you, of course, know. How wrong he was is shown by the fact that our average production of wheat during the past 15 years is almost precisely double the 596,000,000 bushel average for the five years ending in 1898, and we have been compelled to call on the Government to restrict acreage in order to prevent further additions to a burdensome surplus.

There is just one reason why Crookes' prediction did not come true; namely, the enormous improvement of the past half century due to agricultural research. You may remember that the Hatch Act, establishing the State Agricultural Experiment Stations, had been passed only 11 years before. Both the State stations and the research bureaus of the U. S. Department of Agriculture were just getting well under way. Some research had been conducted but it had had little effect on agricultural production. Mendel's laws were still unknown to the world. We were attempting to improve wheat and other cereals by continuously selecting the plumpest and heaviest kernels from the largest heads of the best plants. We knew practically nothing about the control of insects, diseases, and weed pests. The fact that rust is caused by a fungus and not by a mysterious disorder of the cell sap had been known only about 30 years.

Kansas and Nebraska farmers were still debating the merits of Turkey wheat as compared with spring wheat and soft red winter. North and South Dakota and Minnesota were growing Fife and Bluestem. Montana was not then considered in the wheat-growing area. Spring wheat only was being grown in the Inland Empire of the Pacific Northwest.

I do not wish, nor do I consider it necessary, to tire you with the details of the truly remarkable advances that have been made since these early years. Most of you are familiar with the introduction and subsequent wide distribution of the famous Marquis variety of spring wheat, soon replaced in part by Ceres, both by Thatcher, and Thatcher in turn by a host of stem rust-resistant varieties including Rival, Pilot, Cadet, Renown, Regent, Rushmore, Mida, and Lee, with Selkirk on the way. You know of the development of the durum wheat industry, entirely a product of 20th century research. You are, of course, familiar with the almost complete replacement in recent years of Turkey by medium-early and early-maturing varieties such as Pawnee, Comanche, Wichita, Westar, and Ponca and of the almost complete disappearance of the varieties grown in the Eastern States previous to 1900. Most of you are aware of the outstanding achievements in the Pacific Northwest including first the production of the famous Washington hybrids in which was combined the tall but stiff straw of the Australian spring varieties with the winter hardiness of the winter varieties; the breeding of bunt-resistant varieties when bunt became a major problem; and finally the breeding of the short-strawed, winter-hardy, bunt-resistant varieties now generally grown. No doubt you have been disturbed, as I am sure all of us have been, by the setback, a temporary one I believe, in the control of stem rust because of the recent appearance of race 15B and a similar setback in the development of satisfactory bunt-resistant varieties for the Pacific Northwest. These situations are disturbing to be sure, but, even so, I believe it is fair to say that our position is far superior to what it was 50 years or even 30 or 20 years ago. For one thing, we know in each case why we have failed. We have a much better appreciation of the size of the job and the numerous complexities that are involved. And I, for one, feel confident that we have the material and the know-how to correct each situation. For this reason it seems reasonable to regard both as nothing more than a temporary lull in our forward march.

You also know of the equally important advances in cultural practices, including the extensive use of fallow in the Great Plains, improvements in methods of handling fallow, the proof of the value of early plowing for winter wheat, the phenomenal increase of mechanization in wheat production, and the great reduction in labor required to grow wheat; all due in large part to research of various kinds during the past 50 years.

Last year I attempted to determine just what new varieties produced during the past 50 years mean to the American farmer. I am sure you will realize there is no really accurate way of getting at this and that any figures must be regarded only as an estimate and probably a rather rough one. I approached the problem by comparing yields and quality of old and new varieties grown together in experimental trials and then making certain downward adjustments for the well known fact that yields in experimental fields are often higher than in farmers' fields. I came up with an estimated increase of around 235,000,000 bushels per year. By this, I mean that if farmers today had to depend on varieties grown 50 years ago and other conditions were the same, the total production for the United States would be some 235,000,000 bushels less than what it is.

Actually this is probably an ultra-conservative estimate since it assumes conditions including disease, insect, and weed pests comparable to those during these past years. There seems to be no reasonable doubt, however, that without research, losses from these pests would have been far greater. In fact, it is almost certain that without research, some areas like the eastern Dakotas and Minnesota and the Palouse area of the Pacific Northwest would not now be growing wheat because of the great losses from stem rust and bunt, respectively, that almost certainly would have occurred. Also some of the new areas that have been brought into production would not have been broken from the sod.

In any event, the estimated gain in production due to varieties adds up to about two-fifths of the increase in production since 1898. No one has attempted an estimate of the gains in production due to the some 15,000,000 acres of fallow we now have in the Great Plains and didn't have in 1898, of the effects of better management of fallow, of early plowing and more timely seeding, and of other improved cultural practices, nor of the amount added to production because of the additional acreage which presumably would still be in sod if there had been no research. It seems not unreasonable that the gains due to these improvements could easily equal the other three-fifths of the 600,000,000 bushel increase. Hence, it is probably no exaggeration to say that without research Crookes' prediction would have been substantially realized.

One other achievement which seems to me especially important which, however, is not limited to wheat, is the confidence which the public has in your work. Forty or 50 years ago a stranger in a farming community was likely to be accorded more recognition and respect if he represented a business rather than an agricultural college or an experiment station. Part of this, no doubt, was due to the ultra-conservatism and prejudice of farmers, but not all of it. It was partly due to the fact that recommendations from experiment stations sometimes were not technically sound or they were not practical. Such recommendations, it is ture, were few and far between but it takes only a few to destroy confidence. How different it is today. Farmers are now breathing down your necks for seed of the newest variety or for the latest bits of information. Let us keep it that way, if we can, and I believe we can. It must be realized, however, as I believe is generally the case, that one of our most difficult jobs is to judge when we have sufficient technical information to justify recommendations, and to interpret experimental data in terms of farm practice. It is much to the credit of this and similar groups that so few mistakes have been made.

I would like to consider briefly some of the reasons for so much progress during the past 50 years. One undoubtedly is improved techniques and methods. For example, one of my first experiences with wheat breeding was to operate a centgener machine. This, some of you will remember, was a machine designed to space-plant 10 rows of 10 plants each of wheat or other small grain, in order (1) to facilitate the continuous selection of the best heads from the best plants and (2) to measure the yielding capacity of the progeny of the selected plants. It was invented and first used by Willet M. Hays of the Minnesota Station in the early 1890's, but was quite generally adopted and used by experiment stations engaged in small grain breeding.

I cannot remember precisely the capacity of a centgener machine but it couldn't have been more than 200 to 300 centgeners per day and was probably less. Neither is there available any information regarding the accuracy of the yield tests. Since single centgeners of each selection only were planted and since plots were extremely small, the precision must have been of a very low order. Professor Alvin Kezer of the Colorado Station in a paper published in 1906 has given us a hint as to their capacity since he estimated that with certain improvements he had made, it was then possible for a six-man crew to plant

275 centgeners per day as compared with 80 per day before the improvements were made. But taking either figure, what a contrast as compared with the 100 rod rows or the 150 head rows per hour per man often attained by modern plant breeding crews. It may surprise you as it did me to learn that centgener machines and continuous selection were still used at some stations as late as 1915, or some 15 years after Johannsen disproved the theory of continuous selection. This suggests that experimenters as well as farmers are sometimes ultra-conservative and sometimes adhere too strictly to conventional thinking.

Another outstanding achievement was the substitution of artificial for natural epidemics in breeding for resistance to disease and insect pests, first used by Bolley of the North Dakota Station for flax wilt in the early days of the present century. It is no longer necessary to wait for a natural epidemic to determine resistance to most of our important disease and insect pests. This means that susceptible selections can be discarded in early generations instead of later and in many cases after expensive yield and quality tests have been conducted. Certainly much of our success in breeding varieties resistant to rust, bunt, and hessian fly is due to these methods. The same philosophy is involved in breeding for resistance to weather hazards as, for example, by exposure to artificially produced cold, heat, and drought, and by permitting border rows to stand after harvest in order to determine susceptibility to shattering and lodging. For assistance in developing these methods and in other ways also, we owe much to the plant pathologists and the entomologists. Plant physiologists also have helped but their contribution has been less because there is little they have been able to do without special facilities which they have not been able to get. We also are greatly indebted to cereal chemists for the development of suitable techniques for testing for quality and for a much better understanding of the conditions that determine quality.

There has been very material improvements in field plot techniques in addition to the substitution of rod rows for centgeners as mentioned above. The first field experiments at Rothamsted, for example, consisted of a single half-acre plot of each treatment. Interestingly enough, early field experiments at the Kansas Station consisted of small (about one-fiftieth acre) plots replicated five times. This practice was begun in the early 1890's, continued for a number of years, and then abandoned. At some other stations, including the Illinois Station, early experiments were duplicated. When I first had a part in conducting field experiments in about 1907, the generally accepted practice was to use single tenth-acre plots for each treatment. In about 1914 or 1915 multiple small plots were almost completely substituted for the single large plot system in variety tests. This was partly or perhaps entirely due to the influence of two papers, one by Wood and Stratton in 1910 and the other by Mercer and Hall in 1911. The significant features of these papers in this connection were their emphasis on plot replication as a means of reducing error and on the use of statistical methods for measuring the reduction in error. We, therefore, should credit the statistician with some assistance. Also, we should not forget the important contributions by Kiesselbach of the Nebraska Station regarding plot competition and border effects.

Another series or groups of achievements of the greatest importance are those that have provided a better understanding of the wheat plant, of the factors affecting wheat production, and of those relating to the breeding of new varieties. Wheat breeders today would, I believe, throw up their hands in frustration without the knowledge we now have regarding physiologic races and their build-up and spread. We no longer believe in continuous selection, not so much because it failed as because of our better understanding of genetic principles. We understand variety adaptation much better than we did 50 years ago, partly as a result of research and partly from general farm experience. It did not require any research to prove that winter wheat seldom can be grown successfully in North Dakota nor spring wheat in Kansas. Research would have helped, however, because without a doubt it would have provided the same information in much less time and at much less expense. In central Kansas, for example, spring wheat was grown for at least 10 years and soft winter wheat for 25 or 30 years after the introduction of Turkey wheat. This illustrates a fact, the importance of which is not always realized, that without research we usually do learn but we learn the hard way. We must, on the other hand, credit research with most of the information we now have regarding the relation between earliness and yield in the southern Great Plains and the inverse relation between earliness and winter hardiness; also, the integration of these various relations with variety adaptation. We have acquired some scattered but valuable bits of information of the relation between susceptibility to high temperatures and variety adaptation as exemplified by Hope hybrids in the Southern Plains, including especially the variety Quanah in Texas. The effect on quality of high temperature during the fruiting period is another important addition to our knowledge and understanding.

Altogether, it has been a great half century, without doubt the most interesting and exciting of any during the long history of the human race, and I am glad to have had a small part in the progress that has been made. I'm inclined to think that the best thing I have done is to keep out of the way and not interfere with those who really wanted to do something. But I suspect you gentlemen are far more interested in the half century ahead.

I see no reason to believe that the achievements of the next half century will not be even greater than for the one just behind us. Any one of you, I am sure, can visualize a larger number of substantial and almost certainly attainable achievements than anyone a half century ago, then anticipated. It may be accepted as an established fact that scientific achievements tend to increase in a geometrical rather than an arithmetical progression. This is true because each succeeding generation builds on what has gone before. As has been said numerous times but is worth repeating, we see farther today because we stand on the shoulders of our predecessors.

I can without difficulty think of numerous problems crying for solution. From the immediately practical point of view, there is the important and difficult continuing problem of pest control. Both dollar-wise and percentage-wise, I doubt if the losses are materially less today than they were 50 years ago. Control of one pest has usually been offset by an increase in others or by others taking their place; for example, such as race 15B of stem rust, wheat stem sawfly, mosaic diseases, dwarf bunt, and flag smut. We have no more than scratched the surface in the control of lodging, losses from winterkilling, drought, late spring freezes, and what have you. Here again, advances in some areas have been offset by retrogression in others. There is, so far as I know, no reason why we should not have varieties of wheat as hardy as winter rye and early varieties as winter-hardy as Turkey or Yogo. Some people probably will tell you these things cannot be done just as we were told 40 years ago that successful crosses between durum and common wheat were impossible. This may be true, but the chances are good that some day someone who has not heard about the insuperable difficulties will make the attempt and will succeed.

Another important problem is quality. So far, we have been satisfied if new varieties were equal to the old in quality. You could add greatly to your prestige among grain dealers, millers, and bakers and also help the hard winter growers by producing varieties of as good quality as the best of the spring wheats. Before long we are going to think of varieties of even better quality than anything we now have.

I can think of no single achievement that would please more winter wheat growers than new superior varieties that do not easily lodge. I realize that much progress in this direction has been made, but I believe that more is possible.

We need all kinds of information that will give us a better understanding of the nutrition of the wheat plant, the inheritance of valuable characteristics especially in wheat relatives, the chemical, physical, or physiological basis for resistance to diseases, insects, winterkilling, drought, and high temperatures. Any or all of these things are, I believe, possible achievements within the next 50 years.

I suspect, however, that agricultural investigators of the next half century are going to be confronted with many new problems; some like those of the past and others quite different that will require some critical and original thinking.

One problem right on the doorstep is how much time or what proportion of your time should be devoted to so-called basic or fundamental research. We have always had this problem, although seldom stated just that way. Right now it is a popular subject, everybody talks about it and everybody is for it. I doubt if anyone who has seriously thought about research problems is not in favor of more research of this kind. But some people seem to believe, erroneously I think, that agricultural investigators deal only with applied research which is somehow different from or even not compatable with basic research. One inference that I especially disagree with is to the effect that agricultural investigators are really not capable of research of a basic caliber. Some influential people would set up a distinct and separate organization to allocate funds for basic research.

To me basic research is nothing more than trying to determine why, rather than merely how, and more often than not grows out of and is in reality a part of our overall research program. This, in fact, is the way most of our present understanding has been obtained. For example, our current knowledge of physiologic races of disease organisms, the remarkable recent development of fungicides, insecticides, and herbicides, much of our knowledge of plant and animal genetics, and most of our knowledge of plant and animal nutrition are contributions of agricultural research. One of the most important biological discoveries of all times, the role of insects in transmission of disease, was made by Theobald Smith in an attempt to find a method for controlling cattle tick fever. So it seems to me altogether probable that in the future also our most important basic research will be related closely to, grow out of, and be an integral part of our research designed primarily to solve practical problems.

You will certainly have with you the problem (as old as civilization) of putting first things first. By this, I mean choosing not merely those problems that most adversely affect the farmer but more especially those from which the greatest return from each research dollar can be expected. The choice involves judgment as to what problems are most important and judgment also as to whether with the facilities at ones command a solution reasonably can be expected. Decisions of this kind are among the most important and difficult ones we are called upon to face. In this connection, I often wonder how much progress the Greeks at the height of their scientific achievement would have made in investigating the reason for the beneficial effect of legumes on the yield of the following crop. This effect was well known early in the history of agriculture but the reason escaped discovery until less than 100 years ago. The answer, I think, is obvious if you remember that nitrogen was not discovered until 1772 and the role of bacteria was scarcely suspected until after 1850.

I do not mean to discourage an attack on difficult problems nor to infer that the solution of present-day problems will be as long delayed as was this one. I do suggest that problems that seem impossible of solution today may appear perfectly feasible tomorrow because of new developments. Hence we need to be continually alert to any new developments. Or it may be possible to separate a problem into smaller segments, the solution of which may lead to a better understanding of the larger problem. This is precisely what many of you are doing. Thus cytological and genetic studies of wheat-rye crosses and of wheat-agropyron crosses may eventually lead the way to more winter-hardy wheats. Attempts to understand drought and drought resistance have mostly met with defeat. Here again you are studying heat resistance which, under some conditions, is closely related to drought and which is more easily studied than is drought itself.

I wonder also whether we may not occasionally overlook relatively simple and easily solved problems the solution of which would contribute far more than we realize. One specific problem I have in mind is our need for more information regarding the principles that govern variety adaptation, some phases of which will be discussed during this conference. I have been impressed with the fact that few of the station reports that come to us provide anything like adequate information as to why certain varieties or groups of varieties perform better than others. They give detailed information on relative yields but often make no attempt to explain why. This is easy to understand but I am not so sure it can always be so easily justified. For when we know nothing more about a variety than the fact that it has given relatively high yields at particular stations for a brief period of years we really know very little about it. If, on the other hand, we know that it matured too early or too late, was severely winterkilled at certain stations in certain years, severely injured by late spring frost in some areas, or that it was attacked by rust, mosaic, hessian fly, or injured by hail or other very unusual conditions at other stations, we then begin to have a sound basis for evaluating it. I realize that we do have much information of this kind and I am merely raising the question as to whether we are doing the best that can be done.

Right now I would like to know why Concho has such a remarkable yield record for the past few years. Is it especially resistant to heat or drought, does it mature at a particularly favorable date, or is it perhaps due to its recently discovered resistance to mosaics which may have been present though undetected in the experimental trials in which it has been grown. I would like to know why certain derivatives of Fronteira and Frondosa have such phenomenal yield records for several years and for a considerable number of stations in the southeastern United States. They are resistant to rust but this almost certainly is not the only reason. Dr. Da Silva in Brazil has recently pointed out that Fronteira gives very satisfactory yields in certain areas where others almost completely fail because of iron and aluminum toxicity associated with an acid condition of the soil. He has also pointed out that the adaptation of certain Brazilian grasses to the Southeastern States suggests the possibility of soil conditions there similar to those in Brazil. These suggestions regarding both Concho and Fronteira are frankly speculative, but whatever the facts I believe you will agree that more complete information regarding the reasons for their performance would aid materially in evaluating them, in predicting where and under what conditions they may be expected to be satisfactory and possibly point the way to greater achievement in the future.

You are going to be concerned I believe and properly so with methods of research including further improvements in techniques such as efficient measures of drought resistance which we do not have, more effective and less expensive methods of determining winter hardiness, and more effective methods for eliminating poor quality lines and perhaps low-yielding lines earlier in the breeding program. I am thinking also of the over-all methods or the philosophy of research. We have, for example, the case method, the empirical method, the statistical method, the deductive method, and the inductive or so-called scientific method. We use these methods, some of them more or less intuitively and without, it seems to me, any real understanding of the advantages, disadvantages, and limitations of each. There is not time to discuss them even if I had the answers, which I do not. I shall take the time to state that we could use them more effectively if we had a better understanding of them and also suggest that there should be somewhere in these United States some person or persons or even a Department in a University or College whose function it is to make an objective study of these various methods as applied to agricultural research.

There are many other achievements of the last half century and problems of the next that might profitably be discussed and much more might be said about those that have been considered, too many, of course, to be examined at this time. So, in closing, may I express the hope that I have provided a sound basis for an abundant optimism for the years ahead, tempered with enough caution so you will not be discouraged by an occasional frustration and, above all, will not be complacent even though achievements of the past may seem to justify it.

THURSDAY MORNING, JANUARY 20

B. S. Miller, Chairman

## MICRO TESTS AND THEIR USE IN DETERMINING MILLING AND BAKING BEHAVIOR

M. D. Shogren, Kansas

Micro baking equipment for routine use was designed and constructed. The equipment included dough mixer, oven, fermentation cabinet, sheeting rolls, molder, bread pans, and loaf volume meter. Farinograph curves were obtained using 10 grams of flour.

Using the micro baking equipment, a micro baking method was developed to aid the plant breeder. Doughs weighing approximately 13 grams were mixed, fermented, and baked in comparing the micro method to the standard A.A.C.C. method. Correlations were obtained ranging from $r = 0.749$ to $0.948$ with different groups of samples.

This technique along with a micro milling technique and the usual chemical analyses were applied to wheat samples from Texas, Oklahoma, Kansas, and Nebraska.

## COMPARISON OF FIELD PERFORMANCE AND QUALITY CHARACTERISTICS OF TWO PAIRS OF ISOGENIC LINES OF WINTER WHEAT

### Field Performance

I. M. Atkins, Texas

Pairs of isogenic lines were developed for this study by the method suggested by Atkins and Mangelsdorf. One pair differed with respect to the presence or absence of awns and the other pair differed in seed color, one member of the pair having white kernels, the other red kernels.

The awned and awnless pair, C.I. 13002 (awned) and C.I. 13003 (awnless) from the cross Kanred x Clarkan was grown in the U.S.D.A. Uniform Yield Nursery of hard red winter wheat. Results were obtained from 13 stations in 1953 and 12 stations in 1954. Data recorded were yield of grain, test weight per bushel, date of first head, date full ripe, plant height, and limited observations on leaf and stem rust. Averages and number of observations for each character were as follows:

| Item | 1953 | | | 1954 | | |
|---|---|---|---|---|---|---|
| | Number observa-tions | C.I. 13002 (awned) | C.I. 13003 (awnless) | Number observa-tions | C.I. 13002 (awned) | C.I. 13003 (awnless) |
| Yield of grain, bushel | 13 | 21.5 | 19.7 | 12 | 28.1 | 26.2 |
| Test weight, pound | 12 | 55.8 | 54.8 | 12 | 54.9 | 53.5 |
| Date headed | 11 | 5-25 | 5-25 | 11 | 5-18 | 5-19 |
| Date ripe | 8 | 6-22 | 6-22 | 9 | 6-17 | 6-17 |
| Plant height | 12 | 30.8 | 31.7 | - | - | - |
| Stem rust, percent | 4 | 34.3 | 31.7 | 5 | 41.6 | 38.6 |
| Leaf rust, percent | 1 | 70.0 | 70.0 | 5 | 32.8 | 35.8 |

It is interesting to note that in only 4 instances out of 25 tests in the 2 seasons did the awnless member outyield the awned member of the pair. Two of these instances were with irrigated tests and 2 were where the crop was grown under favorable conditions in the more humid areas. The differences in test weight are even more striking for in only 1 instance out of 24 tests did the awnless member give a higher test weight than the awned member. Differences in other characteristics are probably non-significant.

Previous to these tests in the regional nursery, ten pairs of awned and awnless isogenic lines were compared at Denton, Texas, in four seasons during the period 1947-52. Results of these tests have been prepared for publication and will appear soon. Briefly, the results obtained at Denton were as follows:

| Item | Average of ten awned lines | Average of ten awnless lines |
|---|---|---|
| Yield of grain, bushel | 26.0 | 24.9 |
| Weight per 1,000 kernels, grams | 30.8 | 28.7 |
| Stand, culms per 16 square foot | 558 | 571 |
| Number kernels per head | 18.6 | 18.8 |

In this test, which was grown in a 10 x 10 Latin square, all awned lines yielded significantly higher than awnless lines and the weight of 1,000 kernels was significantly higher in all instances. Differences in other characters were non-significant.

Red and white seeded isogenic lines from a cross of Sinvalocho x Wichita were sown in replicated yield tests at four locations in Texas in 1953 and 1954. Results are reported in the table:

| | Number observations | 201-46-33-1 (red seeded) | 201-46-33-2 (white seeded) |
|---|---|---|---|
| Yield of grain, bushel | 8 | 23.8 | 25.2 |
| Test weight, pound | 7 | 60.9 | 60.9 |
| Plant height, inch | 6 | 28.7 | 28.2 |
| Date first head | 7 | 4-25 | 4-26 |
| Date full ripe | 5 | 6-4 | 6-4 |

Variability was rather high in these tests and differences between the lines for all characters was non-significant. The quality characteristics of the white seeded line as compared to that of the red seeded member of the pair was of major interest and were studied by Mr. K. F. Finney of the Hard Winter Wheat Quality Laboratory at Manhattan, Kansas.

## Quality Characteristics

K. F. Finney, Kansas

Milling and baking properties were determined for two isogenic lines of Kanred x Clarkan, C.I. 13002 (awned) and C.I. 13003 (awnless), grown at several locations in 1953, and for two isogenic lines of Sinvalocho x Wichita, 201-46-33-1 (red seed coat) and 201-46-33-2 (white seed coat), grown at several locations in Texas in 1953 and 1954.

Although climatological factors impaired mixing requirements, crumb grains, and loaf volumes, a comparison of the data for the red versus white samples within each station quite clearly indicates that they are identical, for all practical purposes, in milling and baking properties. Similar comparisons indicate that the awned and awnless samples also are identical, for all practical purposes.

## $F_2$ PROGENY TEST FOR EARLY QUALITY EVALUATION

E. G. Heyne and K. F. Finney, Kansas

Micro-quality tests have been described for measuring many of the separate chemical and physical properties of hard wheat flour, but the macro-methods have been superior for evaluating varieties for quality. A modification of the plant breeding procedure in Kansas, called the $F_2$ progeny test, makes it possible to use macro-methods fairly early in the breeding program.

The plants are space-planted in the second generation of a new cross and harvested individually. In the third generation an increase of each $F_2$ plant is obtained; and without making selections, sufficient seed is produced in the $F_4$ generation to provide grain for milling and baking tests which can be repeated if desired in the $F_5$ generation. The selection of increased $F_2$ bulks for quality and agronomic characters can be made simultaneously during the early generations of a cross. Plant selections are made in the $F_5$ or $F_6$ generation of the bulk $F_2$ progenies that have superior physical, baking, and agronomic characters. Thereafter, pure lines are produced for further study.

The value of this $F_2$ progeny test can be illustrated with the crosses Chiefkan, a poor quality wheat, with Tenmarq, Comanche, and Cheyenne which are good quality wheats. $F_2$ bulk progeny tested in $F_5$ and $F_6$ varied from poor to good in quality. Pure line selections from the poor quality $F_2$ families gave only poor quality loaves of bread. Selections from the mediocre quality $F_2$ increases gave pure lines that varied from poor to good in baking potentialities; whereas all pure line selections from the good quality $F_2$ families had good baking properties. The correlations of loaf volumes of the $F_5$ and $F_6$ bulked $F_2$ progeny versus the loaf volumes of the pure line selections ($F_8$) originally made from the $F_5$ bulked progeny were highly significant for three crosses. Correlation coefficients of 0.88, 0.84, and 0.97 were obtained for the $F_5$ bulks versus the $F_8$ pure line selections; whereas values of 0.68, 0.81, and 0.84 were obtained for $F_6$ bulks versus the $F_8$ pure lines. All selections from the poor bulks also had relatively poor physical dough properties. The physical dough properties of the selections from the good $F_2$ bulks, in contrast, were approximately equal to the good parent.

This modification of the line or pedigree method of breeding provides a procedure whereby the macro-baking and other macro-testing procedures can be utilized for determining the quality characteristics of new hard wheat varieties during the early segregating generations when it is advisable to make selections for quality.

This procedure also works effectively on other characters such as test weight, straw strength, shattering, adaptation, and maturity.

## THE VALUE OF LARGE-SCALE MILLING AND BAKING QUALITY STUDIES IN THE VARIETY DEVELOPMENT PROGRAM

J. A. Johnson, Kansas

Knowledge concerning the specific milling characteristics of wheat and baking quality of the flour must be evaluated in relation to how it will be used and who will use it. Baking quality must be defined in terms of oxidation, fermentation and absorption requirements, mixing time, and other physical dough properties. Experimental milling and baking tests as a part of the Hard Red Winter Wheat Development Program, are important in quality evaluation in both government and commercial laboratories. Tests can start early in the development of a new wheat variety by use of micro-tests. Later, large-scale milling and baking tests can be employed to test the new wheat variety on a comparative commercial basis and such tests afford an opportunity to study the milling and baking characteristics. The responsibility of judging the milling characteristics can be shared by a number of expert commercial millers.

In the large-scale baking tests, bread is produced under conditions that the flour will be subjected to eventually. If a flour gives any baking trouble, it is known before the wheat variety is released. Collaborator tests are designed to evaluate the baking characteristics and determine the importance and desirability of those characteristics from the commercial processor's point of view. Thus, the responsibility of judging is again shared. The samples used in the collaborative tests are coded so the varieties being tested are not known. Collaborators testing these samples in numerous baking methods agree very well on the evaluation of the baking quality characteristics.

Large-scale milling and baking tests of hard red winter wheat have been conducted for the past six years through a cooperative effort of industry and government agencies. Varieties in question are grown at several locations; samples can be milled separately to study the effect of environment or can be blended to reduce cost and labor and eliminate disturbing environmental influences. Extensive tests of representative samples should be performed two to three years before decision is finally made and the wheat released.

## WHEAT PRICE STRUCTURE IN RELATION TO GEOGRAPHICAL AREAS

J. H. McCoy, Kansas

Wheat price differentials between and within the various wheat-producing regions of the United States are not new phenomena. In addition to class price differentials, there has always been variation in price within a given class of wheat. Since inauguration of the federal grade standards, price differences have been assignable to characteristics which comprised the grain standards, e.g. test weight, damaged kernels, etc. Presumably, these characteristics are indicative of quality. In addition to grade factors, other characteristics such as moisture content and protein content have long been recognized as price determining factors and on occasion substantial price differentials are applied. From a marketing standpoint such characteristics as these differentiate one lot of wheat from another. In their major end uses these lots of wheat are not perfect substitutes. They are to a degree different commodities and, hence, command different prices. In some respects these characteristics also are associated with particular geographical areas and have given rise to geographical price differences within a region producing a given class of wheat.

Another wheat price differential has attracted a major share of attention in Kansas especially in recent years. It is a recognition that significant differences exist in wheat even within a given class, grade, and protein content. Reasons for differences in gluten quality apparently are not well established in all respects although it has been well established that (1) wheat variety, (2) certain climatic conditions, and (3) soil factors may influence protein characteristics. To the extent that variety is a factor, the predominance of varieties of undesirable gluten quality in certain geographical areas has tended to give rise to area price differentials. There are so many other price influencing factors that it has been difficult to isolate the effect of variety. The support program has tended to overshadow market prices. No differentiation is made in loan rates for variation in protein quality. When the support rate is above market price, such differentials tend to disappear.

During the 1950-51 crop year, we carried out a study which gave an approximation of gluten quality price differentials. Climatic conditions were not an important factor that year and in the area covered soil was not considered to be a major factor. Gluten variation was attributed primarily to varietal characteristics. Our data showed that early in the 1950-51 season, No. 1 hard wheat of 14 percent protein from northwestern Kansas was quoted about $.05 per bushel over wheat of the same grade and protein content from the Meade County area of southwestern Kansas. According to variety surveys, this southwestern area has had a predominant acreage of varieties classified as relatively undesirable in gluten quality. The reverse situation has characterized the northwestern area. This differential narrowed as the season progressed until it practically disappeared by February. I was told by mill buyers and grain merchandizers at that time that mills, anxious to get a supply of the more desirable type of high protein wheat, bid the price up early in the season. After sufficient quantities had been acquired for the season, the price differential disappeared.

A comparison also was made on 12 percent protein wheat. During that season, low protein wheat from the southwestern Kansas area sold fully as high if not slightly higher than wheat of similar protein content from northwestern Kansas. It will be recalled that a strong export demand existed that year, stimulated by the Korean conflict. There was evidence that we were exporting low protein wheat. Wheat moving into export from southern portions of Kansas has a freight advantage over wheat from the northwestern area. This may account for the apparent tendency of price to be slightly higher in the southwestern area.

These data point up two important things: (1) area price differential for wheat of a given protein level may change during the season, and (2) at any given time area price differentials may vary for different protein levels.

In 1951-52 our data showed no consistent area price differentials. Perhaps the abnormally wet season in 1951 was a factor in this situation.

We did not carry out studies on 1952-53 or 1953-54 crops. The situation during those years, however, appears to be fairly obvious. Hot winds and low humidity during the ripening stage apparently damaged the gluten quality of a major proportion of Kansas wheat. The area price differential which drew major attention during this period was not within Kansas but between Kansas and southwestern Nebraska. Virtually all Kansas hard winter wheat was of subnormal quality from the standpoint of gluten strength.

During the current season (1954-55) we have another study under way. For the first time, we find that several terminal grain firms are making specific bids to particular localities. These firms have kindly furnished us with copies of their bids which make it relatively easy to determine area price differentials. The geographical coverage extends into southern Nebraska and northeastern Colorado so we can make interstate as well as intrastate comparisons.

This analysis is being made on No. 1 hard winter wheat of 12 percent protein basis Kansas City. During the crop year to date the greatest price differences occurred in late September. At that time prices in southwestern Nebraska were $.31 per bushel over prices in southwestern Kansas. Prices in the Bird City, St. Francis area of northwestern Kansas, were about $.20 over southwestern Kansas. This is wheat of identical grade and protein content. Presumably the differences in prices were due to variations in gluten quality.

Price differences over the area on July 7, August 4, and December 8, respectively, were determined. A small island of premium wheat was found to exist in the central part of the hard winter wheat area of Kansas, in the vicinity of Ness and Rush Counties. On July 7 wheat from this area commanded $.04 per bushel more than wheat from the surrounding area. On December 8 the difference was $.07. It currently is $.08. Throughout most of the season to date wheat from the northern tier of counties in northwestern Kansas has been quite consistently about $.12 to $.14 per bushel over southern Kansas. An exception was early August when the difference was about $.05.

During most of the season prices in the second tier of counties from the north in northwestern Kansas have been substantially below prices only for a few miles to the north, i.e. the northern tier of counties. Prices in Nebraska (in the Imperial and Elsie areas) have been in the neighborhood of $.12 a bushel over the best prices in Kansas.

In my estimation the importance of these price differentials lies, not in merely pointing them out on maps and charts, but in pointing out implications to our production, marketing, and pricing systems. Prices in a competitive economy are the reflection of market forces. As such, they perform two major functions; namely, to allocate productive resources in the sense that they direct production of things people want as expressed by prices they pay, and to distribute income in the sense that what people pay is income to the person who sells.

The market mechanism is designed to allow the interplay of forces of supply and demand. In the market place, people who have freedom of action and money express their preferences in dollars and cents. Notwithstanding the imperfections of prices, the general consensus is that they do a reasonably good job of indicating consumer preferences.

We need a great deal more research on the efficiency of our price and market systems and we are working on it. There is plenty of evidence, however, that farmers have responded to price changes where feasible alternatives were available. For example, there is direct relationship between hog production and hog prices. This is directly related to my topic. It points to the implications of geographical and local wheat price differentials.

When wheat from the various areas is sold at different prices on the terminal market, we assume that differences exist in the wheat and that for some reason buyers have a greater preference for the higher priced wheat. This does not ignore the fact that available quantities may also be a price factor. It follows that the reflection of consumer preferences through the pricing mechanism back through marketing channels to the producer would tend to induce him to produce that wheat which has the greatest preference. The price differentials presented were for a relatively recent period. We do not have specific data on the situation in earlier years, although there is substantial evidence that such differences are of a fairly long standing. Why do not producers in the low price areas respond by producing enough of the more desirable types of wheat to equalize prices? The answer to that has many ramifications. However, I have a great deal of respect for the judgment of farmers and there probably are some good reasons why they haven't responded.

During some of this time the price support program has tended to obscure these differences. At other times, strong export demand has provided an outlet for the less desirable wheat, although there is serious doubt about the long run merit of that action. With a decline in market importance of these factors it is to be expected that price differentials will be more pronounced.

As mentioned earlier, some of the factors which affect gluten quality are beyond the control of producers. Weather is one example. Perhaps soil is another. Possibly varieties can be developed or practices devised which will alleviate the effects of weather. Until that time, however, it appears that producers can do little about it.

Another deterrent is the difficulty involved in comparing prices. Farmers usually know what surrounding shipping points are paying in comparison to their home town, but at much greater distances they have little for concrete comparison. And it must be remembered that factors other than gluten quality affect local prices.

Perhaps the greatest obstacle to farmers' response is the failure of local markets to reflect price differences to individual farmers. The price differentials shown earlier were area price differences. Buyers ordinarily classify areas on the basis of predominance of type of wheat shipped out. In an area shipping predominantly weak gluten wheat, there may be some farmers producing the more desirable type. At the local market they all get the same price. In this situation something other than price determines the type of wheat produced, e.g. yield. Of course, this is true even where price differentials are in evidence. Price differences must be great enough to offset yield differences. Income, which involves both price and yield, is the more important consideration.

There are several practical reasons why local operators do not price individual lots of wheat on the protein factor. In the first place, there is no satisfactory test by which either protein content or gluten quality can be readily determined at the local elevator. To the extent that variety is a factor, this obstacle could be at least partially overcome by a knowledge of identification from kernel characteristics. But, under certain circumstances this becomes quite technical. Even if a satisfactory test were available, separate binning and shipping would present difficulties in some cases.

A good friend of mine asked this question: "What is going to happen to these price differentials when you persuade all the farmers to grow the so-called desirable wheat?" We've been working on the problem for a long time and apparently it is a long way from being solved. I believe I detect a movement among members of the trade and farmers that may lead to improvement in the quality of Kansas wheat. As I talk with grain men now they tell me of practices which five or six years ago were classed as impossible. My colleagues in the Extension Service tell me that current price differentials are attracting more than usual attention among farmers.

PANEL: WHEAT STORAGE
Leader, M. Milner, Kansas
Participants, D. A. Wilbur, Kansas State College; L. S. Cuendet, University of Minnesota; and M. Milner, Kansas State College, who also acted as moderator.

The speakers indicated briefly their research identification with the biological and biochemical aspects of grain storage. Professor Wilbur listed two major areas of interest in his field as (1) the conditions on the farm which affect the development of populations of grain infesting insects and (2) the application of protectants in wheat to prevent insect damage during the period of farm storage.

Dr. Cuendet summarized research on stored grain problems being conducted at the University of Minnesota under the following headings: (1) Influence of oxygen and carbon dioxide concentration on the growth of fungi in stored grain; (2) The effect of preliminary wetting and fungal growth followed by drying on the subsequent storage behavior and rate of deterioration of grain; (3) The isolation and identification of toxic materials secreted by molds harmful to seed viability; (4) Use of vital stains to follow the loss of viability of the grain in storage; and (5) Utility of anaerobic storage and its influence on the microfloral population.

Dr. Milner listed work in the Department of Flour and Feed Milling Industries, Kansas State College, including (1) experiments on the use of preservatives to inhibit spoilage in storage, (2) the significance of the browning reaction in the production of sick wheat, and (3) the development of techniques for the detection and elimination of hidden insect infestation in grain in order to raise the sanitary status of wheat.

Questions raised during the ensuing discussion included the utility of chemical preservatives for damp stored grain; the relative importance of field infestation as a source of stored grain infestation by insects; the nature of the fungi responsible for accelerated respiration; heating and deterioration of stored wheat; and the relationship between chemical and biological agencies involved in the sick wheat problem.

The panel members agreed that research in the following areas should receive major attention:

1. Location and characterization of zones of winter survival of grain infesting insects on the farm.
2. Intensified development of new insecticides and protectants.
3. The relationship of metabolism of fungi and their end products to chemical deterioration, loss in viability, and change in chemical and physical properties of stored grain.
4. Clarification of the relationship between mold activity and the browning reaction in the embryo of sick wheat.

5. The nature, properties, and mode of action of the material secreted by storage fungi which is toxic to seed viability.
6. Determination of the effect of the sick wheat condition on the technological (milling and baking) properties of wheat.
7. Development of sensitive means to detect evidence of fungal and browning deterioration in wheat.
8. Development of tests to determine the relative susceptibility of grains to germ deterioration, as well as means to detect incipient stages of this condition.
9. Utility of storage under anaerobic conditions and the use of ionizing radiations to preserve grain in storage.
10. Intensified study and development of rapid means to determine hidden infestation in wheat and insect fragments in cereal products.

## THURSDAY AFTERNOON, JANUARY 20

J. R. Quinby, Chairman

PANEL: HARDINESS OF WHEAT TO COLD, HEAT, AND DROUGHT
Leader, S. C. Salmon, U.S.D.A.

## UNIFORM WINTER HARDINESS NURSERIES

L. P. Reitz

Data have been accumulated for 31 years from the Uniform Winterhardiness tests grown in the central and northern portions of the United States and in southern Canada. Thirty-three stations participated by growing a nursery 5 or more years during this period. Among the stations reporting differential killing in 75 percent or more of the years were Ames, Iowa; Archer, Wyoming; Waseca and St. Paul, Minnesota; Ashland, Wisconsin; Brookings and Redfield, South Dakota; Langdon, North Dakota; Morden, Manitoba; and Indian Head, Saskatchewan. Fifteen stations got killing in fewer than 65 percent of the years and four other stations got varietal responses of a sort not typical of the Plains area.

The Supplementary Winterhardiness Nursery was grown at six stations from 1938 to 1953. During this period the following sequence of years occurred with differential killing (X), all surviving (S), or all completely killed (O):

| | |
|---|---|
| Colby, Kansas | SOOXSSSSSSSS |
| Akron, Colorado | XSOXSXXSXSSSSOSS |
| Alliance, Nebraska | XSOXXXXSXXXSXXXX |
| Brookings, South Dakota | XXXOXOXXSXOXOOXS |
| St. Paul, Minnesota | XXSXXOXXXXOXXSXS |
| Dickinson, North Dakota | (Since 1950) OOOX |
| Moccasin, Montana | XXXXXOXSSXXXXXXS |

Three stations per year, on the average, have gotten differential killing, and no year has passed without at least one station providing some useful data. Differentiation among the entries depends upon the local conditions prevailing at the site of the planting and upon the level of hardiness represented by the selections being tested. For example, selections with an average hardiness level suitable for north central Texas might be differentiated in a planting where Minnesota selections would all survive.

Tests of this sort are useful and have been maintained at the insistence of breeders in the region, mainly, it is feared, because no better method for testing winter hardiness was available. More ciritical and efficient evaluation procedures would do much to increase the effectiveness of our breeding work.

Relative Frequency of Some Hazards Affecting Varietal Performance in the Uniform Yield Nursery, 1932-1952

| Station and years of records | | Total number of years with: | | | | | |
|---|---|---|---|---|---|---|---|
| | | Drought | Winterkill | Hail | Lodging | Shattering | Spring freeze |
| Denton | 21 | 4 | 3 | 0 | 4 | 1 | 2 |
| Chillicothe | 13 | 5 | 0 | 0 | 3 | 1 | 0 |
| Bushland | 15 | 10 | 3 | 1 | 0 | 0 | 1 |
| Stillwater | 15 | 6 | 1 | 0 | 3 | 0 | 0 |
| Woodward | 18 | 13 | 0 | 0 | 5 | 4 | 1 |
| Manhattan | 21 | 5 | 0 | 2 | 15 | 1 | 2 |
| Hays | 20 | 10 | 2 | 0 | 5 | 2 | 3 |
| Akron | 19 | 14 | 4 | 1 | 2 | 1 | 1 |
| Fort Collins | 20 | 2 | 1 | 1 | 14 | 0 | 2 |
| Hesperus | 6 | 1 | 0 | 1 | 3 | 0 | 2 |
| Ames | 12 | 0 | 8 | 0 | 4 | 0 | 0 |
| Lincoln | 21 | 8 | 9 | 0 | 10 | 1 | 2 |
| North Platte | 18 | 10 | 7 | 1 | 4 | 1 | 1 |
| Alliance | 20 | 8 | 13 | 2 | 2 | 0 | 0 |

# WINTER WHEAT AND RESISTANCE TO CLIMATIC FACTORS IN SOUTH DAKOTA

V. A. Dirks

Winter hardiness is the greatest problem in winter wheat production in South Dakota. The northern limit of winter wheat culture cuts through the State, and the area favoring this crop has been considered very restricted.

Winter wheat acreage, however, has quadrupled in South Dakota in 30 years, rising from 90,000 harvested acres in the 1926-30 period to 400,000 acres in the 1951-54 period. Winter wheat now comprises 1/6 of the State wheat acreage and produces 1/5 of the State wheat crop. The yield advantage of winter over spring wheat in South Dakota counties varies from 50 percent in western counties to 10 percent in central counties at the fringe of the winter wheat area.

The increased acreage can hardly be attributed to hardier varieties. In 1926-30 the grower used Minturki and Turkey 144. Today the varieties are Nebred (40 to 50 percent), Minter (20 percent), and southern types (30 to 40 percent) notably Wichita, Pawnee, Blue Jacket, and others. The average hardiness of the crop has, if anything, decreased.

Probably the outstanding gains have been in the field of management and farm practices. The following appear to be especially significant: (1) Widespread use of fallow, made possible by strip farming, subsurface tillage, and other methods reducing wind erosion; (2) Adoption of soil and moisture conservation practices; (3) Use of fertilizer and good rotation practices; and (4) Specialized farm machinery such as deep furrow and press drills and subsurface tillage devices. These advances in management appear to have been a major factor in the increased success of winter wheat culture in South Dakota.

Further extension of the winter share of South Dakota's wheat acreage appears to depend on (1) further improvement and wider adoption of present management practices and (2) breeding of varieties with a little more hardiness than that of Minter or Nebred, and a maturity level of Nebred or earlier.

Consequently, winter wheat breeding at the South Dakota Station is concerned almost entirely with increasing the winter hardiness of the crop. Results indicate that the gains possible by changing from spring to winter habit in wheat far exceed gains possible by breeding for disease resistance in present varieties of spring wheat.

The grower at present considers winter wheat as the first attempt at utilizing a given crop year. Should his crop fail or kill out, he may plant spring wheat, oats, corn, sorghum as millet, depending on his moisture situation. This procedure suggests that a revaluation of our concept of risk may be in order. The grower is presently investing $5 per acre on the possibility of his winter wheat making a stand in spring. If his crop survives, he expects to gain an average of $10 to $12 per acre over spring wheat sown on the same land.

## EARLY MATURITY AND WINTER HARDINESS

V. A. Johnson, Nebraska

Winter wheat varieties that have a high degree of winter hardiness are characteristically late maturing. Conversely, varieties that mature early are generally lacking in winter hardiness. Exceptions to this apparent relationship do exist, however.

C.I. 12711, a Nebraska selection from a cross of Turkey x Cheyenne, is an excellent example. It is comparable to Pawnee in maturity and approximately five days earlier than Nebred and Kharkof under eastern Nebraska conditions. The record of C.I. 12711 in the Uniform Winterhardiness Nursery during the last five years indicates that it is fully as winter-hardy as Nebred and Kharkof.

Comparative spring survival of four winter wheat varieties in the Uniform Winterhardiness Nursery is given in the table which follows:

| Location | Years | Spring survival | | | |
|---|---|---|---|---|---|
| | | C.I. 12711 | Nebred | Kharkof | Minter |
| Laramie, Wyoming | 4 | 78.3 | 84.5 | 80.0 | 75.3 |
| St. Paul, Minnesota | 3 | 38.0 | 25.3 | 21.0 | 54.3 |
| Waseca, Minnesota | 5 | 63.8 | 52.6 | 58.6 | 63.2 |
| Brookings, South Dakota | 3 | 51.3 | 67.7 | 66.3 | 83.3 |
| Dickinson, North Dakota | 2 | 8.5 | 2.5 | 7.0 | 7.3 |
| Lethbridge, Alberta | 3 | 60.0 | 61.3 | 67.3 | 76.0 |
| Alliance, Nebraska | 3 | 82.0 | 85.3 | 76.7 | 88.7 |
| Average - 23 Station years | | 58.4 | 57.6 | 57.4 | 66.9 |

## RESEARCH IN WINTER HARDINESS AT LETHBRIDGE, ALBERTA

J. E. Andrews, Cereal Breeding Laboratory

Winter hardiness is one of the most important desirable characters for winter wheat varieties for western Canada. Selection for this character is given major consideration in the breeding program. However, in the last four years, conditions favorable to selection for this character have not existed. This emphasizes the need for rigid laboratory tests for at least some of the factors contributing to winterkilling. The development of such tests will probably be difficult unless much more fundamental information on winterkilling and winter hardiness is obtained.

Considerable variation in spring survival due to differential packing of tractor whell marks has been observed at Lethbridge. Information on causes and effects of this variation will be published shortly.

Difficulties in obtaining adequate fall stands due to dry soil have been experienced. These have been overcome by using a deep furrow type of power seeder. It moves the dry surface soil aside and allows seeding in the moist soil below without covering too deeply.

The following investigations related to winter hardiness are in progress at Lethbridge:

1. Investigations to determine the effect of various environmental factors, particularly light and temperature, on the hardening process.

2. Investigations of temperatures to which winter wheat is exposed in Alberta and of temperatures associated with winterkilling in the field. This is being carried out by means of continuously recording thermocouples placed at specific locations above and below the soil surface in winter wheat plots.

3. Investigations of the biochemical changes which accompany hardening.

(The above three are under the supervision of Dr. D. W. A. Roberts, Plant Physiologist.)

4. Artificial freezing tests for cold resistance. A simple test which would allow the testing of a very large number of lines is desirable in a breeding program. One such test under investigation at present involves testing in the sprouted seed stage. Various combinations of freezing temperatures and duration of freezing are being investigated. Although investigations have not been completed, the following appears promising. Seeds were allowed to germinate for 16 hours at room temperature, then placed in a 0° C. cold room for six weeks, and frozen for 16 hours at -15° C. Average survival was closely related to field survival but variation between replicates was very high.

## THE WINTER HARDINESS SITUATION IN THE PACIFIC NORTHWEST

D. W. George, Oregon

In undertaking these studies, it has been necessary to decide which members of the complex that may cause loss of stand during the winter months will be considered as true tests of winter hardiness. It is obvious that much of the stand loss during cold weather cannot properly be charged to lack of cold tolerance. Some of the different conditions which may kill or weaken wheat plants during the course of the winter are: (1) Extreme cold which may catch the plants prior to hardening, while hardened, or after a certain amount of dehardening has occurred; (2) Heaving, a result of recurrent or prolonged freezing of a wet soil resulting in root injury; (3) Failure to obtain a stand. (Deep planted seedlings apparently lack the necessary vigor to emerge from a cold, crusted soil); (4) Disease injury (Snow mold is widely recognized in areas where snow cover persists. That other soil-borne organisms may weaken the plants at times appears likely. In some freezing tests the variety Rio has suffered mortality that does not appear to result from cold injury.); and (5) Other conditions or combinations such as recurrent freezes, no single one of which is severe enough to cause winterkill.

We in the Pacific Northwest are worried. Probably none of our improved varieties has had a high order of winter hardiness. Rio, a selection from Turkey, is probably the best from that standpoint. Of the club wheats, Hymar was probably the most hardy of a rather mediocre lot.

Spring wheats have been and still are very important in the Pacific Northwest and, inevitably, spring varieties with their lack of hardiness have entered into many crosses in the breeding program. Meanwhile, few winters are severe enough to eliminate nonhardy lines. We may have reached a point where one killing winter would destroy a great deal of public confidence in our new varieties and in the breeding program which produced them. We know that Elmar and Brevor lack the hardiness of Hymar that may have been hardy enough for our conditions.

The cereal program at the Pendleton Station has been concerned with winter hardiness since the Station was established in 1932 and several publications have resulted. Winterkill, when present in the nursery, was noted and described in the annual reports.

However, in checking over the annual reports covering 25 years' data, the disturbing factor noted was the recurrent comment that "this was an unusual season." Apparently cold is one of the "unusual" conditions, for winterkill is reported in only four of the years. During that time a great many lines were being tested at the Station, but obviously no good measure of their relative hardiness could be had.

An important phase of the expanded wheat research program in the Pacific Northwest is the projected program for winter hardiness studies. When I arrived at Pendleton, conventional cold chambers had already been constructed and used in a preliminary way; just enough to demonstrate the shortcomings of the equipment. Now we are well on the way toward getting improved equipment installed. So far, we have run no tests.

Our job at Pendleton is threefold: (1) To develop a technique by which we can recognize winter-hardy segregates as they appear in the breeding program; (2) To conduct fundamental studies of winter hardiness; and (3) To test varieties and selections to determine their relative hardiness and potential value to the breeding program.

## WINTER HARDINESS STUDIES IN KANSAS

A. W. Pauli

Plants of hard red winter wheat growing in the field have been observed to die after suffering only moderate apparent injury from low winter temperatures. In artificial freezing experiments some tillers survived, while others on the same plant died. Examination of these plants showed that a portion or all of the crown tissue had been killed. The death and deterioration of the crown tissue appeared to prevent the translocation of water and nutrients from the roots to the tops. This would seem to account for the death of a wheat plant in which the top and roots had received only limited freezing injury.

One of the primary problems in studies on winter hardiness has been the lack of a reliable test. In this connection, studies are under way on chemical combinations associated with hardiness at different stages of growth and development, and the degree of resistance to plasmolysis.

Seeds which have just germinated have been artificially frozen in an attempt to minimize the several variable conditions associated with the normal artificial freezing technique. Results have been variable.

Limited cold hardiness studies of several Agrotricums have indicated that few possess a degree of cold hardiness significantly higher than many wheat varieties now in commercial production. Data thus far indicate that some of these Agrotricums probably attain more hardiness to low temperatures if planted from one to two weeks earlier than the recommended date of planting for wheat. Others seem to follow wheat very closely in this respect.

## DIFFERENTIAL VARIETAL RESPONSES OF WINTER WHEAT GERMINATION AND EARLY GROWTH TO CONTROLLED LIMITED MOISTURE CONDITIONS

R. P. Pfeifer, L. M. Powell, and R. Helmerick, Wyoming
Presented by R. P. Pfeifer

In 1953 varieties of winter wheat were observed in field trials at 3 locations to differ in their ability to germinate and grow under limited moisture conditions. Tests were conducted using osmotic solutions of mannitol to determine the differential, varietal responses of germination, and early growth. Seeds were also grown in soil which was reduced to 7 and 11 atmospheres tension by means of pressure membrane apparatus.

In all trials seed of the variety Yogo significantly produced a greater percentage of germination with higher growth ratings than did the variety Cheyenne. Seed grown at 2 locations was tested. In these experiments there were no significant differences observed that were caused by the environmental effect of producing the seed at different locations. Thus, the responses to the conditions of controlled limited moisture were considered to be inherent to the varieties studied.

More recent studies to determine the variation between individual plant selections in the variety Cheyenne are in progress. So far, extreme variation occurs in about 1.5 percent of the population studied. The minimum accumulative growth is 22 millimeters and the maximum accumulative growth is 299 millimeters of epicotyl growth for a 9-day test period in solutions of 7 and 11 osmotic pressures. The least significant difference required between these rates of growth at the 1 percent level is 88.8 millimeters.

## RESPONSE OF CERTAIN WINTER WHEAT VARIETIES TO HEAT CHAMBER CONDITIONS

G. O. Throneberry, Kansas

| Variety | Percent mortality | |
|---|---|---|
| | Plants 1/ | Tillers 2/ |
| Kiowa | 13.3 | 29.6 |
| Kanking | 13.4 | 32.4 |
| Ponca | 15.4 | 32.6 |
| Concho | 18.0 | 31.8 |
| Pawnee | 21.0 | 39.6 |
| Wichita | 21.0 | 44.4 |
| Apache | 21.4 | 37.3 |
| Comanche | 23.6 | 40.2 |
| Triumph | 27.2 | 47.6 |
| Sioux | 28.9 | 47.4 |
| Yogo | 33.4 | 51.0 |
| | L.S.D. = 7.6 | L.S.D. = 8.8 |

Heat chamber temperature = 126° F.

1/ Mean of 27 replicates of 3 pots each.
2/ Mean of 25 replicates of 3 pots each.

## WINTER WHEAT PERFORMANCE UNDER DROUGHT CONDITIONS

R. W. Livers, New Mexico

The Plains Substation near Clovis, New Mexico, has now conducted wheat yield trials for five years. In each of these years the winter wheat production for the State has been consistently around 20 percent of the 1931-1950 average, due primarily to extended drought conditions. Yield trials of ten winter wheat varieties for five years show yearly means ranging from 1.5 to 4.0 bushels per acre. Variety means ranged from 3.7 bushels per acre for Cheyenne down to 2.1 for Comanche. Varietal differences were highly significant. The recommended varieties Cheyenne, Westar, and Apache were significantly better than Tenmarq, Pawnee, Turkey, Triumph, and Comanche. Year x variety interaction was significant. However, varietal variance was significantly greater than year x variety variance, indicating consistency of some varieties for the period.

Such demonstrations of varietal differences under extremely droughty conditions offer the only assurance we have that new varieties can be developed which will be better adapted to the dry high plains area than those now in use. Breeding, selection, and strain testing under the local climatic conditions is the approach being used in New Mexico. Several techniques of plant screening under controlled or partially controlled conditions seem worthy of further investigation and may prove to be of assistance in selecting for specific plant characteristics when the characteristics can be shown to be useful in a semiarid environment.

NOTE: For recommendations of the panel on wheat hardiness, see Resolutions Committee Report, page 144.

PANEL: FERTILIZERS FOR WHEAT IN THE GREAT PLAINS
Leader, H. F. Murphy, Oklahoma

Dr. Murphy introduced the discussion topic by pointing out the fact that harvesting of grain and subsequently selling it on the market is in effect selling fertilizer or elements of fertilizer off the land at a calculable rate. He further commented that the return of these elements to the soil in the form of fertilizers is most important and if we fail to do so we may run out of nutrients in the soil in the not-too-distant future. Percentage-wise young plants are high in the elements of growth in proportion to the same elements in the soil. Fundamental work done in England and elsewhere has indicated that nitrogenous fertilizer applications after the wheat is in head do not affect yield but may affect protein content of the grain.

Wheat fertilizer in Kansas was discussed by F. W. Smith. He listed the objectives of fertilizer research initiated in 1946 as follows: (1) to determine the effect of fertilizer elements on wheat production, (2) to investigate the amount of fertilizer, particularly nitrogen, needed, (3) to study the effect of nitorgen applied at different dates, and (4) to study the effect of fertilizer on wheat quality as measured by protein and test weight.

Results of this work in Kansas have indicated that approximately 50 pounds of nitrogen, together with potash and phosphorus, may increase the yield of wheat as much as 50 percent. Recent work is aimed at determining where soil deficiencies exist and to what extent they exist. Further efforts will be aimed at using the plant as an indicator of the deficiency rather than the soil itself.

# EXPERIMENTAL WORK WITH FERTILIZERS FOR WINTER WHEAT IN NEBRASKA

R. A. Olson

A comprehensive program of fertilizer testing with winter wheat has been under way in Nebraska since 1948. This has involved approximately 30 complete factorial replicated experiments each year with N, P, and K on major soils throughout the State, as well as a few more detailed experiments on two of the outlying experiment stations.

A wide range of soil conditions is represented in the wheat producing acreage of Nebraska, from the Chestnut soil group in the West through the Chernozem group, several intermixed azonal and intrazonal groups, and the Prairie soils of the East. Textural range is from loamy sand to silty clay, pH from about 5.5 to 8.5, organic matter content from a trace to 5 percent, soluble phosphorus (Bray No. 1) from a trace to 50+ ppm. Additionally, ranges in mean annual rainfall of from 16 to 34 inches and of mean annual temperature from 45 to 53° F. exist. These variations give rise to the especial need for the Experiment Station Outstate Testing project which permits fertilizer testing over the entire State.

Major objectives of the Nebraska Outstate Testing fertility program with wheat to date have been:

(1) Evaluation of fertility status of soils, by region and by soil series;
(2) Determination of efficient time, rate, and method of fertilizer application by regions and specific soil series;
(3) Study of effectiveness of different carriers of the fertilizer nutrients;
(4) Evaluation of fertilizer influence on wheat quality; and
(5) Calibration of laboratory soil testing procedures to needs of wheat for fertilizer supplements.

Experiments for comparing different methods of tillage and residue management for wheat, with fertilizer interactions, have been under way at the North Platte and Alliance Stations since 1950 and 1949, respectively. A new experiment was initiated at North Platte in 1954 for measuring the response of wheat to N fertilizer as influenced by soil moisture supply at planting (adjusted by supplemental irrigation preplanting), and one at Alliance for determining the response of wheat to fertilizer under optimum conditions of irrigation.

Results to date indicate very widespread need for supplemental N in the continuously cropped eastern two-thirds of the State, lesser need being apparent in the dry farming western third where summer fallowing is extensively practiced. Phosphorus is generally deficient for wheat in the eastern third of the State and on soils which are sandy, calcareous, or severely eroded elsewhere in the State. There has been little evidence of K response anyplace in the State to date.

Forty pounds of N per acre has proved near optimum for average soils in most sections of the State, although 80 pounds may be needed on strongly eroded uplands. Twenty pounds $P_2O_5$ (available) per acre has proved adequate on P deficient soils, when applied with the seed at planting, 50 pounds or more being required for comparable response with broadcasting before or after drilling. Fall and spring applications of N fertilizer have given comparable results in terms of yield alone, winter treatment usually proving inferior.

Ammonium nitrate, urea, and anhydrous ammonia have proved about equivalent, ammonium sulfate being of equal value in most cases but occasionally much less effective when broadcast in the spring, and calcium cyanamid least efficient. Superphosphate, ammonium phosphate, and nitric phosphate (TVA) of high water solubility have proved superior for wheat under all soil conditions, metaphosphate comparable on acid but much less effective on calcareous soils, Rhenanian process and low water solubility nitric phosphates intermediate in value for most soils, and fused and rock phosphates of little value at practical rates of application.

Test weight of wheat has been adversely affected by N fertilizer alone and benefitted by P fertilizer, in the latter case more than enough to counteract the reducing action of N in the subhumid section of the State but not so in the semiarid portion. Phosphorus fertilizer has caused a slight depression in protein content, but N has markedly increased protein in all sections in most years. The latter might well become a factor of major concern for western Nebraska (average increase, + 1.5 percent protein from 40 pounds N per acre) where the strong gluten wheats produced bring substantial premiums on the market if of high protein content.

Studies involving radioisotope tracer work and P yield response data have established the Bray and Kurtz No. 1 laboratory P testing method valid for the gamut of Nebraska soil conditions. With the calibration ranges established, the method has been more than 90 percent effective in predicting wheat yield response to phosphate in field experiments during the past three years. In the case of nitrogen soil testing, a nitrification rate measurement has correlated well with yield response data ($r = -.864^{**}$) with continuously cropped soils. Organic matter percentage values have not shown significant relationship to yield response.

No distinct differences in mean response to tillage and residue management methods have been apparent to date at the outlying experiment stations, with or without fertilizers. It should be pointed out that drought or hail has limited yields in most years since this work was initiated.

One year's results at North Platte indicate promising possibilities for predicting N fertilizer response of wheat in the dry regions on the basis of moisture stored in the soil at planting.

We anticipate continuing investigations in the directions briefly outlined above. There will likely be an expansion of activity in the direction of further authenticating soil tests and adapting them to the routine requirements of an operational soil testing laboratory. Some expansion in fertility work with wheat under irrigation is likely.

# SUMMARY OF FERTILIZER RESEARCH ON WHEAT IN TEXAS

K. B. Porter

Fertilizer tests on winter wheat in Texas have been conducted in recent years. Results indicate that economical use of fertilizers on dryland wheat is probably limited to North Central and South Texas.

Tests during the period of 1949-52 in North Central Texas, conducted by the Denton Station on Houston soils, show that economical increases in yield can be obtained by spring applications of 30 pounds of nitrogen. No consistent affect on the yield was found from phosphorus or potassium applied in a band with the seed. Plots receiving 30 pounds of nitrogen yielded 24.0 bushels compared to 14.3 bushels per acre for the check plots. Tests conducted during the 1952-53 season, however, indicated the most economical fertilizer treatment to be 60 pounds of $P_2O_5$ banded with the seed and 30 pounds of nitrogen per acre applied as a top dress in the spring.

Tests at the Chillicothe Station during recent years have indicated little response to nitrogen or phosphorus even though soil tests indicate a deficiency of phosphorus.

The Temple Station has been able to increase the winter survival of small grain by the use of phosphorus banded with the seed.

Tests conducted in the Panhandle of Texas indicate responses of dryland wheat to fertilizer, primarily nitrogen, to be slight and too small to be of economic value. The greatest response to nitrogen under dryland conditions has been on the lighter soils, but even on these soils moisture is the limiting factor most years.

Irrigated wheat in the Panhandle has responded to spring applications of nitrogen with increases in yield of economic value. The magnitude of the increases in yield resulting from spring applications of nitrogen have varied with the irrigation and cropping practices followed. The greatest response in tests conducted in 1954 was on irrigated wheat following grain sorghum. In this case, 33 pounds of nitrogen from anhydrous ammonia nearly doubled the yield of grain. Higher rates, up to 90 pounds of N per acre, failed to give a greater increase in yield.

Although soil tests indicate a deficiency of phosphorus, little response to phosphorus has been obtained in the few and inadequate tests conducted in the Panhandle. In a factorial type fertilizer test conducted on the Amarillo Station to determine what influences the fertility level might have on shattering of wheat phosphorus banded beneath the seed stepped up the heading date from 4 to 5 days. Yields were not obtained in tests.

Nitrogen fertilizers in tests conducted in the Panhandle of Texas in 1954 tended to increase the protein content of the grain; however, rates of nitrogen giving the most economical increases in yield increased the protein content of the grain very little.

More adequate tests are needed to determine fertilizer needs and practices as related to moisture levels maintained on irrigated wheat, to rate of planting, to cropping practices, and to other factors.

## FERTILITY WORK ON WINTER WHEAT IN SOUTH DAKOTA

V. A. Dirks

### Effect of Fertility Level on Winter Survival and Yield of Winter Wheat and Rye

Minter winter wheat and Pierre rye are being tested for response to six fertility treatments, each with six replications, at Redfield, South Dakota.

| | |
|---|---|
| 0- 0-0 | |
| 40- 0-0 | Wheat with and without straw cover |
| 80- 0-0 | |
| 0-40-0 | |
| 0-80-0 | Rye without cover |
| 80-80-0 | |

Seedings are on irrigable land, cropped in 1954. Irrigation is available to remove the effect of low or variable soil moisture on fall growth and potential survival. Half the winter wheat plots received a straw cover to insure survival; the remainder are not covered. Fertilizer was placed in the row alongside the seed.

Survival notes will be taken in spring. Fall growth was excellent and some differential growth in favor of high nitrogen levels was observed. The covered plots should survive and provide estimates of fertility response on yield; the bare plots should furnish information on fertility as affecting both survival and yield. The Redfield Station may be considered North of the present winter wheat area in the State. This work was begun in September 1954, L. O. Fine and V. A. Dirks cooperating.

### Rotation and Fertility Experiments on Winter Wheat

Studies are in progress at the Range Field Station, Cottonwood, South Dakota, on rotations, tillage methods, and soil fertility amendments as affecting winter wheat stands and yields.

Cooperative experiments on farms in the winter wheat area (Bennett. Tripp, Lyman, Haakon, and Lawrence Counties) are also being conducted. This work has been carried for several years now; the results so far indicate a good response from nitrogen except on summer fallow. Moisture in fall is essential to getting a fertility response. This work has been conducted by B. L. Brage of the Agronomy Department, South Dakota Agricultural Experiment Station. The effect of fertility practices on grain quality have also been considered.

Future plans call for a continuation of the present work in the southwestern part of the State. The Redfield work may be modified to take advantage of information that may come from the present study.

# WHEAT FERTILITY IN WESTERN OKLAHOMA

H. V. Eck

## Present Research

Wheat fertilizer research has been conducted in western Oklahoma during the last four years as a major part of the soil management program for that area. Experiments currently are under way at 19 locations, 12 of which have uniform tests in which nitrogen and phosphorus alone and in combination are studied. Ammonium nitrate and anhydrous ammonia nitrogen are being compared at three locations in an experiment which consists of four rates of application (0-20-40 and 80 lbs./A) and two dates of application (fall and spring) of the two materials. Rate and date of application of anhydrous ammonia are being studied at two locations. Rates of application are 20-40-80 and 160 pounds of nitrogen per acre and the dates are plowdown; fall; spring; one-half plowdown, one-half fall; one-half plowdown, one-half spring; and one-half fall, one-half spring. Rates of nitrogen application under two methods of tillage, plow and stubble-mulch, and the effect of seven fertilizer treatments on five wheat varieties are under study at separate locations. One purpose of this experiment is to find whether or not there is any variety-fertilizer interaction involved.

## Results

The three seasons of experience and experimental results furnish information for the following conclusions:

1. The use of phosphorus fertilizer is profitable in most areas of western Oklahoma. It will not give yield response at all locations every year, but it more than pays for itself over a period of years in yield and, in addition, it promotes rapid initial growth, rooting, and tillering, and it hastens maturity. As a result of its initial effects, the phosphorus fertilized wheat furnishes more wheat pasture and it goes into the winter with healthier, deeper rooted plants than the unfertilized wheat.

2. Yield response from nitrogen fertilizer is more dependent on climatic conditions than that from phosphorus fertilizer. In the three years, nitrogen response was profitable over most of the western area one year, unprofitable over most of the area one year, and profitable in the west central area, but not further west the third year. Along with its effect on yield, nitrogen fertilizer gives increased fall growth on the sandier soils and those very low in available nitrogen; promotes tillering, especially in the spring; gives longer straw; increases the protein content of the grain; and delays maturity.

3. Spring applied nitrogen gives slightly higher yields than fall applied nitrogen.

4. Anyhdrous ammonia and ammonium nitrate nitrogen are about equal in their effect on wheat plants.

5. Grain protein increases with increasing rates of nitrogen application.

## Future Plans

Plans for the future call for a continuance of the type of research now under way, a study of the effects of residual nitrogen and phosphorus on the ensuing wheat crop, and a study of cropping systems in which wheat will be the main cash crop.

## RECOMMENDATIONS OF THE PANEL ON WHEAT FERTILIZERS

H. F. Murphy, Panel Leader

More research is needed on the nutrition of the winter wheat plant as a basis for the practical application of fertilizers on the soils of the Great Plains for wheat production. Both yield and quality are concerned.

It is recognized that in the Great Plains area, fertility is being sold with little addition being made. Such a practice eventually requires the use of fertilizers as well as better soil management.

It is highly important that research in the region on the use of fertilizers and other soil management practices be given increased support in the several States.

DINNER TALK, JANUARY 20

# MEETING THE NEEDS OF OUR OVERSEAS' CUSTOMERS

E. J. Bell
Director, Grain and Feed Division
Foreign Agricultural Service, U.S.D.A.

Producers of hard red winter wheat, along with other wheat growers, are faced with many perplexing problems. The principal problem at the moment is how to find markets for the wheat they raise. Improving the quality of the product is the most important thing which can be done to help growers expand their outlets. So, I come to you with a conviction that the work you are doing is of utmost significance, not only to wheat farmers, but to all others whose livelihood depends upon the prosperity of this important agricultural region.

During the past several years there has been much discussion of our wheat marketing problem and how the wheat growers can best serve the needs of their customers at home and abroad. I know that all of you are acutely aware of the need for more accurate information about the qualities of wheat than can best be used by millers and bakers and the need for developing varieties that possess the desired characteristics.

Tonight I should like to review with you some of the developments in the export field which have direct and vital significance in the program you men have developed for the States in the hard red winter wheat area.

It is unnecessary for me to point out to this audience that the United States is geared to the production of more wheat than we use in this country and that substantial quantities of our product must be sold abroad. We usually have a substantial supply of hard red winter wheat which finds its way into the markets of the world, so you are dealing with a class of wheat that is a very important part of the U.S. export trade. It is also well known that other countries, especially those in Western Europe, have increased their local production of wheat so they do not need to import as much as they did immediately after World War II. With three big crops in Canada in 1951, 1952, and 1953 and with the return of Argentina as a major grain exporter, competition has become exceedingly keen.

As we shift from a buyers' market to a sellers' market, more attention is focused upon wheat quality. With buyers in a position to pick and choose, we hear more complaints about the quality of our product than we did a few years ago when importers were glad to get almost any kind of wheat. We in the Foreign Agricultural Service have felt that such complaints needed to be scrutinized. We do not want to accept, at their face value, statements made by import buyers in the course of trading negotiations. On the other hand, we need to know in technical terms which of the complaints are justified and why. We also need to know the specific qualities of wheat best suited to the requirements of millers and bakers overseas.

In order to get more specific scientific information about the quality of our wheat in comparison with the wheat from other countries, our organization has obtained the services of Dr. J. A. Shellenberger of Kansas State College, a distinguished member of your group. Dr. Shellenberger is now spending two months in Europe as a Consultant to the Foreign Agricultural Service. He is accompanied by Mr. Dale Vining of our Grain Division who will assist in collecting representative samples of wheat as it is received from different parts of the world. These samples will be carefully analyzed in laboratories of the U. S. Department of Agriculture. Tests will be made on grading factors, milling and baking properties, mixing time and other characteristics of the dough, and any other tests in common use among cereal chemists to determine the suitability of wheat for different purposes. While in Europe, Dr. Shellenberger will visit European laboratories and study the testing methods used by millers, bakers, and cereal chemists. From this study, we hope to accomplish two results. Dr. Shellenberger will bring back valuable guides to plant breeders which will be helpful in developing varieties for the export market. We also hope that he can give our customers overseas some practical suggestions on how they can best use the wheat we are now selling to them.

Without attempting in any way to anticipate the results of Dr. Shellenberger's project, I think you may be interested in some of our preliminary observations. During the past year, representatives of the Foreign Agricultural Service have been in every part of the world where United States' wheat is sold. First, there were the Agricultural Trade Missions sent out last spring at the request of President Eisenhower. These missions were made up of businessmen and farmers from all parts of the United States with experience in producing and marketing different agricultural products. Then I had a chance to make a short trip to England, Germany, Belgium, and France in June when I had some preliminary discussions on the subject of wheat quality with millers, importers, and research agencies. Last fall Earl Corey, formerly in the grain business in Kansas City, spent three months in Europe studying markets there in some detail. Art Cummings, another grain marketing specialist, spent two months in Latin America and West Africa and Earl Pollock made two trips to the Far East. In every case, these men came back convinced that we need to improve the quality of the wheat we send abroad if we are going to hold our markets.

When I went to Europe last June, I took occasion to talk with government officials, importers, processors, and research workers about this subject. I didn't have time to go into it as thoroughly as the problem justifies, but I did get some rather interesting reactions. I wanted to know just what there is about our wheat that appears to be different from the wheat they received from us 5, 15, or 25 years ago.

There has been quite a lot of discussion about the Federal grades, but our Federal grain standards have not been changed materially for many years. The amount of foreign material, damaged kernels, wheat of other classes, and test weight requirements are the same now as they were before the war. When I got right down to cases, I found that quality factors are very important and certainly there is a need for a review of our Federal grading system to see whether it really does meet the needs of the wheat marketing conditions of 1955. Much more could and should be said at this point about U. S. grading and marketing practices, but I believe you are interested in phases of the problem which more directly apply to your wheat improvement program.

One important topic of the conversations in which I engaged last June in Europe had to do with the variability in the baking qualities of different cargoes of the hard red winter wheat. As you all know, the wheat of Europe is predominately soft red winter with low protein content and weak gluten quality. When flour from this wheat is used in the homes or in small neighborhood bakeries, an excellent quality of bread can be baked, even though the strength of the flour leaves much to be desired. With the development of large commercial bakeries, flour with stronger gluten is required to blend with local wheat in order to make a satisfactory product.

The experience in Europe in recent years is comparable to what we went through in the United States a number of years ago. With the expansion of wheat growing into the High Plains, the United States began to produce Turkey Red in the winter wheat area and Marquis in the spring wheat area. Both of these varieties had excellent quality for blending with softer wheats in meeting the requirements of the commercial bakery. U. S. millers have long paid premiums for high protein hard wheat because we have seldom produced more than enough of this kind of wheat to supply our domestic requirements.

During the dry years of the 30's the hard red winter wheat which found its way into export channels probably had a higher protein content than the hard red winter wheat which we have exported in recent years. Because of climatic conditions, wheat exported from the United States during recent years has not been as high in protein content as it was before the war, and there have been wide differences in the baking qualities of different shipments, all grading No. 2 hard winter.

I also found folks in Europe talking about factors which seem much more important to them than the quantity of protein as shown by the Kehldah test. In Europe, attention is directed toward the strength of the gluten as shown by other tests. These tests include wet gluten determination, use of the Chopin extensometer, Brabender extensograph, and other devices to test the strength, elasticity and other qualities of the dough. I saw enough in a few short weeks of discussions with European chemists and processors to lead me to believe that we need to take a very careful look at the quality of the gluten and other indications of baking quality in the varieties of hard red winter wheat that are now being grown in the United States.

Now, I didn't get into this thing in sufficient detail to warrant any conclusions, but I did see and hear enough to lead me to think that this is something which requires very careful scientific investigation and analysis. I certainly would not want to go off half-cocked in any general statements about the quality of the wheat now being grown, because it is entirely possible that a careful analysis of some of the newer varieties will show how these varieties can be used to better advantage by overseas millers and bakers. On the other hand, I have seen enough to convince me that we cannot look upon the export market as a dumping ground for inferior wheat. Varieties that are unsatisfactory for the miller and baker in the United States are also unsatisfactory to the miller and baker abroad, and the kind of wheat and flour that our millers and bakers use is the kind that millers and bakers in other countries also desire.

European millers sometimes speak of the wheat in their grist as "local" wheat, "blending" wheat, and "filler" wheat. The local wheat, as I mentioned before, is usually soft red winter. The blending wheat most desired is hard red wheat, high in protein content, from semiarid regions. They often get cargoes of No. 2 hard winter that have excellent blending properties. Then, there is the filler wheat, making up to 1/3 of the grist that is anything they can get cheap. I regret to report that many cargoes of No. 2 hard winter have come in this category. I presume these are shipments originating in the more humid parts of this region where protein content is usually low. It is possible some of the less desirable shipments have been from localities growing varieties with poor baking qualities. In any event, one of the big complaints we have heard about hard red winter wheat moving abroad has been its variability.

So I bring you a number of questions: What can be done to insure more uniformity in the baking quality of hard red winter wheat? What can be done to standardize shipments abroad so the overseas buyer can be sure of the blending properties of the wheat he buys? What can be done to help our customers overseas make the best use of what we have to sell? Our ability to obtain, with your help, the answer to these questions, may have an important bearing on the future prosperity of this great wheat producing region.

## THE RELATION OF ENDOSPERM STRUCTURE TO THE MILLING AND BAKING PROPERTIES OF WHEAT

R. M. Sandstedt, Nebraska
(Presented as a motion film and talk the evening of January 20)

The milling properties of wheats and the injury to the starch during milling are primarily dependent on the hardiness of the endosperm during the milling process. In the hard wheats the hardiness can be quite largely controlled by proper conditioning prior to milling.

Motion pictures taken through the microscope, showing the breakdown of endosperm particles when subjected to a shearing pressure, indicate how the breakdown of hard wheats differs from the breakdown of soft wheats and how these differences account for the great differences in the physical properties of the flours. It is shown that softening the endosperm by high tempering allows the same type of disintegration as is obtained from the soft wheats; consequently, such flours made from hard wheats have the physical characteristics of soft wheat flours.

Starch granules are easily damaged by pressure such as that applied by grinding procedures. The damage is particularly notable during dry milling and accordingly is of great importance to the wheat milling industry and is of primary concern to the baker.

A normal starch granule when placed in cold water swells to only a very limited extent (perhaps 30 to 40 percent); on the other hand, in hot water the granule swells tremendously, taking up 10 or more times its own weight of water (this is gelatinization). However, if a granule is crushed or otherwise physically injured it swells in cold water just as the normal granule does in hot water. The damage to a granule does not necessarily extend to all parts of the granule; it may be a very limited damage, a mere bruise at one point. The swelling in water takes place only in the injured portion. The rapid swelling of injured granules may be shown by taking high-speed motion pictures (64 pictures per second) through the microscope as the granules are flooded with water.

A normal starch granule is resistant to action of the digestive enzymes. Gelatinized granules have lost this resistance, correspondingly injured granules or injured portions of granules also have lost their resistance.

The swelling and digestion of injured granules may be shown by taking motion pictures of starch flooded with an enzyme solution, the first rapid swelling is recorded at 64 frames per second and the more slow subsequent digestion by lapsed-time techniqeus varying from 2 frames per second to 1 frame in 3 seconds. These pictures show why starch acts as it does, how milling damage affects the water absorption and handling properties of doughs, and the effects of enzyme action on the properties of doughs.

FRIDAY MORNING, JANUARY 21

D. W. Robertson, Chairman

## WHAT 22 YEARS OF DATA SHOW ABOUT EARLINESS AND YIELD

L. P. Reitz

The Uniform Yield Nursery contained 150 different selections and varieties of wheat during the period 1932 to 1953. About 30 were grown each year at 10 to 16 stations. This was a diverse group with respect to earliness and represented a range from a few days later than Kharkof to as much as 3 weeks earlier. A simple tabulation was made of all yields at all stations as a departure from Kharkof by 1-day maturity classes. All years were combined and the data were put in graphic form for each station.

A summary of the yields by 1-day maturity classes for all varieties grown in the Uniform Yield Nursery is given in the following table:

| Station and number years record | | The two highest-yielding maturity classes (days earlier than Kharkof) | | Average bushels increase in grain yield per day of earliness* |
|---|---|---|---|---|
| | | Highest class | Second high | |
| Denton | 18 | 13 | 8 | 0.7 |
| Chillicothe | 15 | 17 | 9 | 0.1 |
| Bushland | 15 | 0 | 2 | -0.1 |
| Stillwater | 20 | 16 | 15 | 0.5 |
| Cherokee | 7 | 10 | 8 | 0.2 |
| Woodward | 22 | 14 | 9 | 0.6 |
| Manhattan | 22 | 13 | 14 | 0.9 |
| Hays | 19 | 10 | 9 | 0.6 |
| Colby | 4 | 9 | 8 | 0.6 |
| Akron | 17 | 9 | 11 | 0.5 |
| Fort Collins | 19 | 13 | 8 | 0.1 |
| Hesperus | 13 | 0 | -2 | -0.8 |
| Ames | 11 | 9 | 4 | 0 |
| Lincoln | 22 | 5 | 7 | 1.0 |
| North Platte | 16 | 6 | 9 | 1.0 |
| Alliance | 15 | 8 | - | 0.6 |

* From Kharkof maturity class to the midpoint between the two highest-yielding classes.

Most stations showed an ascending yield curve for varieties increasingly earlier than Kharkof to a definite point or plateau after which additional earliness resulted in declining yields. No particular trend was apparent at Bushland, Ames, or Fort Collins. A reversal in general trend was noted for Hesperus.

From these studies an optimum plateau of maturity is indicated for most of the stations. Extensive adaptation tests on selections outside this range cannot be justified unless the selections embody characteristics that enable them to surmount the limiting effects of extreme lateness or extreme earliness.

## ARE WE MAKING SUFFICIENT USE OF THE BACKCROSS METHOD?

C. A. Suneson

For this discussion, I am assuming that backcrossing is one of the established methods of plant breeding, and that there is sufficient published information (both domestic and foreign) to supply technical and practical guidance to any plant breeders who might want to use the method. It is also assumed that you know that our group of breeders in California, while collectively making wide use of backcross technics, are also variously using all the other breeding methods. In my own case, I have 16 bulk populations of barley which probably would excite some of you. Only as wheat breeders have we been exclusive backcrossers, and that for 20 years.

In the execution of any breeding program, but particularly in one where methods are still formative, the setting, the problems, the supporting technical information, the interpretations and the objectives compose a total program complex which greatly influence the success of the breeding method. Perhaps the Latin American title of Engineer-Agronomist gives the best job description. In the perspective of its use in California, backcross breeding is more than a method for character transfer. It is a program for crop improvement in which backcrossing is a core element, but with a form and finish created by the engineer-agronomist. The Rockefellow program in Mexico is a backcross breeding program, yet it differs markedly from ours. Thus, I am suggesting that in serving this "combination salad" from California, there may be an opportunity to find some useful ideas regardless of your "tastes" or selective ideas.

For background, the California environment is important. Only Texas is larger than California. Wheat is grown below sea level and to elevations above 5,500, on dry land at precipitation levels as low as six inches, and under a variety of irrigation systems. We grow white and red wheats, both winter and spring. Our share of the total national production is less than 1.5 percent. For 25 years only two professional workers in the California experiment station have been predominantly engaged in breeding and genetic studies with barley, wheat, and oats, and there are no other workers in the State completely specialized on cereal crop production problems.

### What Has Been Done in Wheat Improvement

Administrators often measure success in terms of production, sales, and operating costs. Since 1928, wheat breeders in California have concentrated on improving 11 varieties of wheat. A total of 18 backcross improvements of these varieties have been released. In this, Dean Briggs had the dominant role in producing 14, so any subsequent use of the words <u>we</u> or <u>our</u> is intended to reflect <u>his</u> long-time leadership.

Since 1937 the 11 varieties under our programs have increased slightly and now occupy 95 percent of our acreage. Of this, more than 3/4 is now sown to backcross improved stocks. The 6 varieties given the most breeding attention occupy 1/3 more acres than in 1937. This shows that successive improvements are being absorbed. Other varieties, including new introductions from other States or countries, now occupy only half as many acres as in 1937 and less than 5 percent of our total.

Costs can only be generalized, but the total outlay for the breeding and genetics programs variously contributing to the release of the 18 improved wheat varieties and the publication of more than twice that number of technical papers was about $275,000. Included are salaries, operating expense and equipment, and administrative costs for State and Federal wheat improvement activities within California for the 31-year period 1922-1952. For this investment in research and breeding there is <u>much</u> evidence of accomplishment.

One such measure is reflected by specific objectives realized. As a result of improved seed treatment, bunt could be collected from only 5 to 10 percent of California's fields during the thirties. Breeding subsequently brought the problem under near complete control. About one smutty field per year is now brought to our attention by marketing or extension agencies. As would be expected, nearly all such smut is <u>not</u> race T-1 to which our improved varieties are all resistant.

Our stem rust history prior to 1940 was about the same as for the entire northern Great Plains. Our race picture is simpler since only races 11, 17, and 56 have been collected. We don't have barberry, but we do have year-around persistence of the red spore stage. For the years 1940-1950 a predominant "2-type resistance" was sufficient to provide near-complete protection. Such resistance now permits considerable rusting, and we assume there have been one or more mutations. Three varieties are already further improved to completely protect from this new biotype of rust, and another variety is ready for release. Three gene systems are variously involved. Rust has been under practical control for 15 years.

In the Montezuma Hills where annual plant infestations by hessian fly from 1922-1944 ranged from 50 to 100 percent, the release of Big Club 43 has brought this problem under near complete control. A small residue of susceptible variety acreage has not produced a breakdown in resistance. Big Club 43 has remained protective for 10 years.

### Important Factors in the Execution of the Program

Following a major reorganization of our Agronomy Department in 1928, in which Dr. Briggs shifted from Plant Pathologist with U. S. D. A. to Cereal Breeder for the California Station, there has been continuous and unqualified support for Briggs' program.

The Genetics Division at Berkeley and more particularly Dr. Clausen was the silent partner in evaluating and advancing the technical phases of the program.

The attainment of leadership in studies on the inheritance of bunt resistance was a primary goal. In this there was distinctive emphasis on both gene and race identification and on a simple classification of infection differences.

Genetic studies from which reserve genes can be stock piled, and ultimate cumulative consolidation of such genes into a single variety have become basic in our operations. In the latter there is a difference in procedure from that being contemplated in the Mexican program.

The initial backcross breeding sought mass use of resistance by transferring Martin bunt resistance into all the principal varieties. This was achieved between 1937 and 1942 with 11 releases.

There was far more testing before release of our backcross improved varieties than is generally realized. It is true that conventional yield and quality tests were minimized. There was greater interest in determining whether genetic theory on recombination had been met, and if there were disruptive associations. For testing, cumulative experience with a single donor parent in several backcrossing programs has advantages. It is one reason for our interest in naming both gene and donor variety in genetic designations, and using relatively few donor parents in our programs.

The security, time, and economy values which accrue from multiple line backcrossing and a final mixing of many lines is one of the strongest links in our method. It also adds flexibility for the future. We think Americans have been oversold on pure lines.

Weak resistance was initially acceptable because it was better than no resistance, and was easy to transfer. Later we accumulated genes to improve both the level of resistance and race coverage. Levels of resistance generally considered inadequate under epidemic test conditions have proven quite effective when widely used.

In choosing to improve 11 varieties, there was no initial emphasis on "suitability". It was on action. We are now further improving only 6 varieties of wheat. Their suitability for improvement is increasing.

The California Crop Improvement Association was specifically organized during the thirties to provide (1) a facility for identification of otherwise indistinguishable seed stocks, and (2) to better distribute and supply improved wheat seed. Without this, our improved varieties would have been quickly lost. With it (and as a by-product of backcrossing) we now have an enormous seed certification program with other crops.

Teaching and extension facilities have participated in furthering the total program. I have mentioned that an occasional smutty field is encountered. Most of our growers know that any of our 11 varieties of wheat with a number attached to the name is resistant to only about half of the races of smut in America. They also know that quarantines and sanitation are important for protecting this resistance. When a local smut problem is noted, we recommend disposal of the entire crop for feed or milling, cleaning of contaminated machinery, and purchase of certified seed (disease free). We believe that resistance to a seed-borne disease can have an enduring effectiveness if Foundation and certified seed stocks are kept clean, and are continuously available. Since special hazard areas naturally benefit most from improved releases, growers there are most prone to use improved varieties. By limiting rust spore production in such areas, there is a lessened hazard, even with non-improved varieties, elsewhere in the State.

## Significance

For the California Experiment Station, no one work with plants is more widely known or favorably regarded by the agricultural segment of the population than the backcross program for wheat improvement.

Under other conditions California's total program might need modification, but perhaps not as much as has been arbitrarily assumed.

## Restatements Pertinent to Backcrossing

We use the backcross method more than any other breeding method because:

(1) We cannot place great faith in the projectability of short term yield or quality tests.
(2) We do not want to gamble against extremely high recombination odds.
(3) Successive variety releases do not require significant changes in production, marketing, or industrial use practices.
(4) Our costs are low, and the time requirement for producing an improved variety is short.
(5) Our results are reproducible.
(6) We and our associates have more time for research on fundamentals since neither we nor our supporting science laboratories are committed to variously evaluate and finally reject thousands of "unknowns". In our program, testing and rejection are minimized.
(7) From the technical assay of early generations it is possible to schedule and publicize releases long in advance. This helps our public to believe in our prowess.
(8) The method is very flexible, and gains can be accumulated.
(9) Positive measures of progress and of character differences can be obtained and demonstrated from paired tests of near-isogenic lines. We are greatly interested in this "tool".
(10) Cohesive linkages can be more easily detected and dealt with. They may be either useful associations or breeding barriers.
(11) Breeding programs to service very diverse areas can be concentrated at one site.
(12) Distinctive engineer-agronomist research and planning disciplines arise from the near-isogenic nature of our material. In 1953 we lined up 17 plots for photo interpretation studies of rust infection. There were six isogenic groups (varieties) and five different genetic resistance groups included. It was "unique resource material".

Briggs and Allard reported 15 distinct backcross improvement programs with Baart wheat at our station. Of these, eight have been completed and up to six character changes consolidated into a single stock. In so consolidating characters, or in changing such things as height, maturity, awn type, and seed color of this wheat, new problems and uncertainties arise, even for an experienced backcrosser. This continuous challenge I like.

To me, backcross breeding can be likened to a motor vehicle, more versatile than most, with several speeds for going both forward and back, and with many special check indicators for gauging present and future potential for "going places". It is economical and easy to operate. The more you drive it the more you learn about it. Try it, and you might buy it. Gadgets or accessories can be added as needed or desired.

# EFFECT OF ENVIRONMENT AND GENETIC FACTORS ON CHARACTERS IN HARD RED WINTER WHEAT

D. E. Weibel, Texas

The effectiveness of selection for quantitative characters is dependent upon the heritable variability present in segregating populations. The importance of variation is universally understood by crop breeders, but the degree of heritability of different characters, the rate of improvement that can be expected from selection, and the relative usefulness of various associations among plant and seed characters are not as well established.

Methods of analysis commonly applied to studies of qualitative characters are not applicable for evaluating the inheritance of quantitative characters. Special mathematical techniques adapted to aid in interpreting continuous rather than particulate data have been developed and have received wide usage in recent years. Generally these methods are designed to evaluate the relative effects of heredity and environment on the expression of plant characters and to establish relationships among characters that might aid the plant breeder in selecting.

The purpose of this study was to evaluate segregating populations of five hard red winter wheat crosses for six plant and seed characters. Data were recorded from spaced-plants of the parents, and of the $F_1$ and $F_2$ generations grown in 1951-52 in a randomized complete block design at Manhattan, Kansas. $F_3$ lines were grown in a 10 x 10 triple lattice design during the 1952-53 season along with entries of the parents, and of the $F_1$ and $F_2$ generations and backcrosses to both parents. All data were analyzed on an individual plant basis.

The quantitative nature of the characters under study was apparent and verifiable from the smooth frequency distributions. A comparison of $F_1$ means with mid-parental values indicated dominance or partial dominance of earliness, tallness, many heads, high yield, high kernel weight, and high bushel weight for all crosses. Heterosis was evident in 43 percent of the $F_1$ comparisons, 25 percent of the $F_2$ comparisons, and 23 percent of the $F_3$ comparisons for all characters in all crosses. It was most evident for grain yield and least evident for bushel weight.

Estimates of heritability were calculated (1) by the relative variance of $F_2$ method, (2) by a comparison of $F_2$ and reciprocal backcross variances, (3) by regression of $F_3$ progeny means on $F_2$ plant values, and (4) by the components of variance of the $F_3$ analysis of variance. In general the last method gave the highest estimates while the regression of $F_3$ progeny means on $F_2$ plant values gave the lowest estimates. The average of 25 estimates of heritability for each character over all crosses provided the following values: date first bloom, 36.0 percent; plant height, 50.2 percent; kernel weight, 45.2 percent; and bushel weight, 49.5 percent. It was concluded that individual plant selection in $F_2$ for these characters should be effective and satisfactory for practical breeding purposes although it might not be equally effective for all crosses. Heritability values obtained for number of heads and grain yield were only 1.3 and 7.7 percent, respectively. For these characters it was concluded that individual plant selection in $F_2$ would not be effective and, therefore, that the rate of improvement could not be expected to exceed that from random selections.

Phenotypic, environmental, and genotypic correlation coefficients among characters were calculated (1) from $P_1$, $P_2$, $F_1$, and $F_2$ data by covariance analyses and

(2) from $F_2$ and $F_3$ data by regression analyses. The phenotypic correlations obtained in $F_2$ and $F_3$ generations showed that early blooming was correlated with short plants in some crosses and with tall plants in other crosses. Early blooming was correlated with many heads, high grain yeild, high kernel weight, and high bushel weight. It appeared that the selection of early maturing $F_2$ plants would be effective in obtaining plants with high kernel weight and high bushel weight, but that only a random sample would be obtained for number of heads and grain yield in view of the low heritability of these characters.

Tall plants were strongly correlated with many heads and high grain yield, but due to the low heritability of the latter characters it appeared that short, high yielding selections could be obtained. Tall plants were highly correlated with high kernel weight and high bushel weight in certain crosses indicating that difficulty might be expected in the selection of short, high kernel weight and high bushel weight plants.

The highest correlations obtained were between number of heads and grain yield, but since both characters exhibited very low heritability values the association probably is of limited value as an aid to selection in the $F_2$ generation. Similarly, associations of number of heads with kernel weight and with bushel weight were not considered to be of practical importance.

High grain yield was correlated with high kernel weight and high bushel weight, but due to the low heritability of grain yield it was suggested that selection for kernel weight or bushel weight be practiced in $F_2$ with testing for yield to follow in later generations. The data showed that kernel weight and bushel weight were very strongly correlated, and thus selection for high kernel weight in $F_2$ should also be effective in obtaining plants with high bushel weight.

Environmental correlations involving number of heads or grain yield generally were larger, while genetic correlations were smaller than phenotypic correlations. The expression of these characters was greatly influenced by environmental factors and heritable variation was low. The remaining characters had higher heritabilities and generally the environmental correlations were smaller while genetic correlations were larger than phenotypic correlations.

# THE BIOCHEMICAL FACTORS INVOLVED IN THE RESISTANCE OF THE WHEAT PLANT TO ATTACK BY THE HESSIAN FLY

F. Y. Refai, E. T. Jones and B. Miller
(Presented by F. Y. Refai)

For many years cooperative research by entomologists and plant breeders has been fruitful in developing wheat varieties resistant to the hessian fly. Notable achievements are Pawnee and Ponca wheats.

The factors which determine resistance or susceptibility of the wheat plant to hessian fly infestation have been of interest to many investigators. Some workers believe that physical structure of the wheat stem is the major factor which determines resistance or susceptibility. Others have suggested biological explanations. The present work has dealt with the biochemical aspects of resistance as related to both the wheat plant and to the fly itself. Some of the results were negative while others suggest biochemical explanation for resistance of the plants and damage to infested plants.

Although there was a significant difference among the respiration activity values for different varieties of wheat, these values were not correlated with the degree of hessian fly resistance. The hydrogenion concentration of the cell sap also did not show any difference among different varieties, and there was no evidence that the infested wheat had a virus infection.

Promising results obtained can be divided into two categories:

1. Physical structure of the wheat plant. A positive correlation was found between the degree of resistance and the resistance of the stem to shear. Also, a positive correlation existed between the degree of resistance and the percentage of hemicellulose present in the stem. The ash, protein and crude fiber content of the wheat stems were not correlated with resistance.

2. Biological activities within the plant itself. Chromatographic analyses showed that the amount of free sugars (sucrose, glucose, and fructose) increased markedly in hessian fly infested plants. It also was found that the larva secrete a substance into the plant, which blocks the activity of the plant phosphorylase. This enzyme is responsible for building higher carbohydrates from sugars produced by photosynthesis.

Both audio and visual proof have been obtained which show that the hessian fly larva obtains its food from the plant through a vacuum sucking action.

# EFFECTS OF SEMI-DWARF GROWTH HABIT ON YIELD AND PROTEIN CONTENT OF WINTER WHEAT

O. A. Vogel, Washington

The relation of plant height to yield and quality of winter wheat was discussed in a much different light at Pullman last summer than it was 20 years ago. In 1934 the winter wheat nursery was so badly lodged and tangled that the harvesting operation was essentially one of peeling off each consecutive row of the 700-odd plots by starting in one corner and ending in the opposite one. Those of us who had developed sore backs and short tempers harvesting the mess of tall and medium tall wheats certainly were heartened by the report from the late Dr. B. B. Bayles that a new short strawed club wheat named Alicel, which was released by the Oregon Station in eastern Oregon in 1932, was promising to outperform the taller soft wheats in eastern Oregon as impressively as it had been outperforming the hard red bread wheats at the dry land station at Moro, Oregon. This variety, selected in 1924 at the Moro Station, had shown such wide adaptability in Oregon that Dr. Bayles predicted it would outperform the commercial wheats in eastern and central Washington.

The late Dr. E. F. Gaines, however, showed considerable skepticism because the highest yield records at Pullman were among the moderately tall selections and varieties. Lending support to his skepticism was the generally unsatisfactory productivity at maturity of the semi-dwarf selections which appeared to be very attractive at the heading stage of growth. He suggested that the short and very short selections did not have sufficient leaf surface manufacturing area, and/or did not have sufficiently extensive root systems to make maximum use of the high productive capabilities of the soil and climatic factors of eastern Washington. Needless to state there was considerable pro and con philosophizing by the various participants regarding the most efficient and/or practical plant heights for the various major winter wheat producing areas of the Pacific Northwest. There was general agreement, however, that the major breeding activities with winter wheat at Pullman and Pendleton should be toward the production of short strawed varieties which were resistant to lodging and bunt. The most practical yield levels hereafter would be taken care of by economic factors.

In subsequent years the prediction of Dr. Bayles was more than fulfilled. The new short strawed white club winter wheat hybrids not only outyielded the taller varieties in the soft wheat areas of Oregon, Washington and Northern Idaho, but had replaced much of the hard red winter wheat in Oregon. Their rapid movement into the hard red winter wheat areas of Washington is now the subject of considerable concern among millers and grain dealers.

Actually his predictions would have been fulfilled much sooner had it not been for the fact that some of the best yielding short strawed hybrids could not be released earlier because they were insufficiently resistant to bunt and/or were of poor milling quality. As a result of a succession of new high yielding short strawed winter wheat hybrids being turned down for release we now have at Pullman a Western Wheat Quality Laboratory and a Bunt Research Laboratory.

In 1948 Dr. S. C. Salmon sent a collection of short and very short strawed Japanese wheats to Pullman for observation. One of these, Norin 10, became the first extremely short stiff strawed variety which appeared to have a satisfactory head and kernel type. Since this variety was shorter than the short varieties by approximately as much as the short varieties were shorter than the tall ones, it was dubbed a semi-dwarf variety. In 1950 a smaller number of semi-dwarf $F_2$ segregates from a cross of Norin 10 x Brevor appeared to be unusually productive. Several of the selections in $F_3$ were sufficiently attractive to be placed in preliminary yield trials for 1952. Three of the lines therein, Selections 1, 4 and 10, were advanced to the 1953 varietal trials. Their performances compared with commercial varieties, especially under conditions favoring rank vegetative growth, were surprisingly attractive. However, enthusiasm for the future of semi-dwarf wheats was dampened when it was discovered that these selections were highly male-sterile, and that the high yields were partly due to the out-crossing resulting from the pollen shed by adjacent common wheats.

A subsequent intensive search for normal pollinating lines resulted in the discovery of a small number of reselections which appeared to be much more in their flowering habits. Two of these, Selections 14 and 17, in their first and very limited yield trials in 1953, appeared to perform at least as attractively as the original Selections 1, 4 and 10. Needless to state most of the available seed stocks were used for planting comparative adaptation nurseries for study in 1954. One of these adaptation studies, entitled "The comparative performance of semi-dwarf and commercial varieties in early fall seedlings", was conducted by a graduate student. His data are now in the process of being analyzed.

A second study was begun in conjuction with the regular station winter wheat varietal trials at Pullman, Pomeroy and Walla Walla. Data on comparative plant and grain characters of eight of the typically distinct commercial varieties and hybrid selections are given in Table 1. Each of the eight varieties is more or less representative of a distinct performance characteristic which either is or may become important to the tri-state area of the Pacific Northwest.

Rio is the most widely recommended hard red or Turkey type in Oregon and Washington. Its performance is very similar to that of Kharkof, the latter a commonly used check variety for bread wheats. Hymar is the last of the tall club varieties to become commercially important in the three states. Elmar, a short soft white club variety, is the most widely grown single variety in the Pacific Northwest, representing roughly one-half of the total winter wheat production. Brevor is classed as a very short variety and is the leading soft white common winter wheat in Washington and Northern Idaho. Uma represents a medium tall variety with a characteristic slow spring recovery and a relatively low tillering habit, a characteristic usually resulting in an unusually low ratio of straw to grain for its height. 27-15 x Rex-Rio -41 is a new short strawed hard white bread type with an outstanding performance record in both the soft and hard wheat areas of the Pacific Northwest. It is being considered for release as a new type in Oregon and Washington. Selection 17 of Norin 10 x Brevor is a high yielding semi-dwarf line which happens to be

TABLE 1. Summary of comparative data on plant and grain characters of typically distinct commercial varieties and hybrid selections of winter wheat grown at Pullman, Pomeroy and Walla Walla, Washington in 1954.

| Variety | C.I. No. | Type | Plant Height Inches | No. Heads 16 sq. ft. | Sheaf Weight Tons/A. | Straw Weight Tons/A. | Grain Yield Bu./A. | Protein % 14% Moist. | Protein Yield Lbs./A. | Straw to Grain Ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| Rio* | 10061 | Red | 49 | 794 | 5.9 | 4.2 | 52.4 | 9.24 | 291 | 2.7 |
| Hymar** | 11605 | Club | 49 | 531 | 5.9 | 4.4 | 51.4 | 8.63 | 266 | 2.9 |
| Elmar** | 12392 | Club | 41 | 472 | 5.5 | 3.7 | 61.0 | 7.81 | 286 | 2.0 |
| Brevor** | 12385 | White | 39 | 649 | 6.4 | 4.5 | 63.4 | 7.36 | 280 | 2.4 |
| Uma** | 12247 | White | 45 | 516 | 5.8 | 3.7 | 69.0 | 8.19 | 338 | 1.8 |
| 27-15 x Rex-Rio -41* | 12696 | White | 40 | 611 | 6.0 | 3.9 | 69.6 | 7.76 | 324 | 1.9 |
| Norin 10 x Brevor -17 | 13254 | Red | 29 | 617 | 5.7 | 3.5 | 73.0 | 7.38 | 323 | 1.6 |
| Norin 10 x Brevor -14 | 13253 | Red | 25 | 617 | 5.3 | 3.2 | 68.3 | 7.27 | 297 | 1.6 |

* Use for bread

** Use for pastry

slightly taller than Norin 10. Selection 14 of Norin 10 x Brevor represents a high yielding line with significantly shorter straw than Norin 10. These semi-dwarfs appear to be representative of only two of the many apparently fixable height levels which range all the way from shorter than Selection 14 to taller than Brevor.

The above data represent averages taken from 4 nurseries at the three locations. The conditions of growth in all four nurseries were favorable for good yields of grain with relatively low protein. There was no unusually heavy straw production nor yield-reducing lodging in any of the nurseries. Therefore, the comparative varietal performances can be considered as representative of somewhat intermediate growing conditions in Washington. In other words, under conditions very favorable for rank vegetative growth, the semi-dwarfs would be expected to be outstandingly superior in performance, with the reverse expected for the very dry or droughty conditions.

Although the shortest variety is one-half as tall as the tallest one, there is relatively little difference in sheaf weight between them. There is no apparent correlation between plant height and sheaf weight among the remaining varieties. This lack of correlation is not attributed to differences in stand density, the latter expressed as the number of heads per 16 feet of row.

The apparently low correlation between plant height and straw weight is not unexpected because the lightest portion of the culm is the intermode, and the differences due to shorter internodes is off-set in some cases by differences in stand density and/or diameter of culm.

It is notewrothy that the last four varieties, which range in height from 25 to 45 inches, exceeded the highest yielding commercial variety in yield of both grain and protein and in efficiency of production, the latter shown by the low ratios of straw to grain. From these data, as well as from observations elsewhere, it can be concluded that there is no evidence that the present levels of semi-dwarf growth habit are detrimental to yield of grain. Furthermore, since the protein contents of the two semi-dwarfs are not out of line with those of other high yielding soft textured wheats, there appears to be no detrimental effect of the present levels of semi-dwarf growth habit on protein content.

At present we are primarily interested in the most practical breeding objectives, and in research projects designed to aid in realizing these objectives. I shall conclude by pointing to some future investigations that appear to be worthwhile.

1. Although I am inclined to favor the semi-dwarf heights falling within the range of Selections 14 and 17, the most efficient and practical plant heights for the various major wheat producing areas are not known. Projects designed to shed light on this subject should prove to be very worthwhile.

2. Some of our irrigation farmers are already talking about growing high protein wheat under irrigation. They contend that if they do not have to be concerned with lodging, they can manage their fertility and

water practices so as to produce so-called 100-bushel yields of high protein bread wheat. These thoughts began as a result of some good natured ribbing. They cease to be funny any more. I for one, think that such wheats can be realized. I'll go one step further by predicting that in the forseeable future the 100-bushel yields from present short strawed varieties, which now gain headlines in the local papers, will give way to yields from semi-dwarf varieties of between 125 and 150 bushels. However, before above-100-bushel yields become a common occurrence on irrigated land, it will be necessary to do a much better job of controlling cercosporella foot rot, mildew, and other yield reducing diseases, than is done at present. Investigations should be undertaken to determine the most practical sources of resistance, as well as the most practical direct chemical control of these diseases.

3. The original purpose of breeding for semi-dwarf winter wheats was to produce varieties better adapted to early fall seedings for erosion control. The grain from wheat grown under such conditions naturally is expected to be low in protein. Since conditions are not always favorable for seeding early, would it be possible to breed semi-dwarfs which, in late seedings, produce moderately high protein in either or both the low and intermediate rainfall areas? These possibilities certainly should be investigated. Furthermore, by making good use of the late spring recovery and the low rate of tillering growth habits, characteristic of the variety Uma, it might be possible to partially off-set the usual reduction of protein which accompanies the high yields in early seedings. Certainly time is ripe for launching upon some interaction studies which include plant type, growth habit, plant height, date and rate of seeding, fertility levels and management, and protein content.

Now that I already am out on a limb I shall also predict that, among other notable accomplishments, we may soon have a semi-dwarf wheat that will produce high yields of at least moderately high protein on some of the highly fertile dry farmed fields in the now low protein areas of eastern Washington.

# INTERNATIONAL GENETICS RESEARCH

E. G. Heyne, Kansas

At the American Society of Agronomy meetings at St. Paul last fall several people interested in wheat discussed three questions, namely; nomenclature and symbolization of genes in wheat, a wheat monograph, and a wheat newsletter. The first two problems have an international basis and the other is primarily of local interest.

The next International Genetics Congress will be held in Canada in 1958. However, at the meetings in Europe in 1953 a resolution was made that a genetic symposium would be held in Japan in 1956 pertaining to certain phases in the field of genetics partially to compensate the Japanese who had wished to have the Congress in 1958. A subject of interest to this group at the symposium in Japan in 1956 is the discussion to be held on nomenclature and symbolization of genes in wheat.

The committee of the American Society of Agronomy that worked on wheat nomenclature was abandoned in 1952 and the ball was literally caught by the Japanese and they have been carrying it since. However, a cytogenetic committee is active in Canada and this group thoroughly discussed the rules for nomenclature and symbolization of genes with Dr. Matsumura last March at Edmonton. Previously, the Canadian workers, Dr. Kihara, and Dr. E. R. Sears discussed the problem in Saskatoon in February 1953.

The Canadian workers deemed it essential that they have a representative at this symposium in 1956. In so far as Canada and the United States are world leaders in wheat production and probably in wheat genetics and cytogenetic research, I believe both countries should be represented. A resolution will be presented later to this conference concerning this question.

One of the recommendations of the American Society of Agronomy committee on wheat nomenclature in 1952 was that something should be done concerning a monograph on wheat. This too had not received active attention, in so far as I could find out, during the last two years. Dr. B. C. Jenkins and myself discussed this question with Dr. A. G. Norman, chairman of the American Society of Agronomy monograph committee. His committee was cognizant of the recommendation of the American Society of Agronomy wheat nomenclature committee but stated that the initiative for the publication of a wheat monograph should come from the wheat people. In other words, we failed to follow up the recommendation vigorously enough. Therefore, a questionnaire was sent out to many of you concerning the preparation of a wheat monograph. Replies to date overwhelmingly suggest we wait until the English version of the Japanese book on wheat is available for study before a decision of a wheat monograph be undertaken by North American workers. All replies will be forwarded to the monograph committee to help them in deciding what should be done.

I am in favor of working very closely with the Canadians on these two problems and believe we can make a unified report on the nomenclature question at the Symposium in 1956 and also a united contribution on a wheat monograph. At the St. Paul meetings there was an expression by some of the Canadians that they wished to retain their identity in international wheat work with which I am in full agreement. This, I am sure, will not interfere in any way with our close cooperation.

The National Oat Newsletter has been enjoyed and also of value to the oat workers in the United States. I understand the Canadians also find their Cereal News of considerable interest. Therefore, we at Kansas State College, have offered to organize a wheat newsletter for the United States workers. The plan is to prepare an informal type of newsletter similar to that prepared for oats. A number of us miss the Cereal Office reports discontinued some years ago. This type of newsletter for both wheat and oats, although only on an annual basis, will be welcome I am sure. The replies I have received to date on this have been enthusiastic, but not in the direction I had wished. Everybody wants to receive such a report but the contributions have been slim. Such a newsletter is made up of your contributions so your participation is what it takes to get one on its way.

## ROUND-TABLE DISCUSSION: UNIFORM EXPERIMENTS IN THE HARD RED WINTER REGION

Friday Noon, January 21

Dr. L. P. Reitz led the discussion of the current regional testing program. He indicated that there are now eight different types of uniform nurseries and that cooperator interest in the nurseries has been high. He asked for suggested changes in the nurseries, particularly regarding check varieties.

Discussion of Uniform Yield Nursery and Uniform Plot Series:

Dr. Reitz stated that the varieties Kharkof, Blackhull, and Early Blackhull have been used as checks in the Uniform Yield Nursery since 1932. The Uniform Yield Nursery has been used for regional testing in the six central and southern states. It is entirely a nursery-type test. He added that several cooperators have replaced the large drilled plots of the Uniform Plot Series with nursery plantings. Except where very good equipment has been used for these plantings, the results have not been entirely satisfactory. In the Uniform Plot Series, Kharkof, Tenmarq, and Early Blackhull have been the uniform check varieties in the southern district, and Kharkof, Tenmarq, and Pawnee in the central district.

E. G. Heyne: Kharkof is it as far as a check is concerned. I favor using only one check.

A. M. Schlehuber: I do not favor the continued testing of Tenmarq and would, also, second E. G. Heyne's suggestion.

I. M. Atkins: Regarding the Uniform Yield Nursery checks, I favor using all three varieties. In the Plot Series, we perhaps need to reduce the number of checks. We do need an early variety for long-time comparisons. In our state setup, we are using these same three varieties. This is very useful for comparison with what we had 30 years ago.

R. Livers: I think that having only one check is unsatisfactory because of the variableness of one variety. A mean of three checks is more usable for gauging new varieties.

E. G. Heyne: I am interested now in beating Concho, not Kharkof. I cannot see that I am learning anything by comparisons with Early Blackhull. If such a study (against these checks) is wanted, we would set up a long-time experiment with sufficient varieties. In the present setup, we have too many changes anyway. Let's keep the checks at a minimum.

A. M. Schlehuber: I would agree with E. G. Heyne that three varieties are not enough for statistical analysis; therefore, hold checks down to a minimum.

I. M. Atkins: Kharkof and Tenmarq or Turkey are so much alike that I would not object to dropping one of these, but we need an early one. In Texas, Kharkof does so poorly that we get little value from it.

T. E. Haus: We maintain at Akron all of the old varieties as check; for example, Wichita for earliness, Minturki for winterhardiness, etc. I would like to ask who the checks are for?

L. P. Reitz: For you and others in the region.

R. Livers: I like to think of the regional series as a type of experiment which none of us are able to run at our stations.

Harry Young: It seems to me that it boils down to whether you want long-time evaluations or just evaluations of new varieties. These checks are variable for different regions.

R. E. Atkins: I can see no point in carrying the field plot series. For our use we need only a few checks.

I. M. Atkins: In our case, spring freezes have knocked out perhaps one variety (e.g. Wichita). Without an early check, we would have no way of evaluating this.

A. M. Schlehuber: I would agree.

L. P. Reitz: Would not Tenmarq fill the bill?

A. M. Schlehuber: No, we have maintained Comanche for similar reasons.

L. P. Reitz: We have needed a region-wide study, and have now had this for 25 years. How much longer should we continue? It seems that the consensus of opinion is that we should reduce the late or mid-late checks by one.

R. E. Atkins: What do the "quality" people want?

L. P. Reitz: Two or three varieties of known behavior but with different quality. This brings up the problem of Red Chief, a variety desired as a check by the quality people.

I. M. Atkins: If we drop Early Blackhull, we will not have that quality check.

A. E. Lowe: Tenmarq has outlived its usefulness as a variety and a check. I would suggest that it be replaced.

L. P. Reitz: How many would seriously oppose dropping Tenmarq as a check variety from the Uniform Plot Series? (no answers). If we drop Tenmarq, would it be satisfactory to leave the Plot Series with Kharkof and Early Blackhull as checks in the Southern District and Kharkof and Pawnee in the Central? (Everybody expressed satisfaction with this arrangement as stated).

Uniform Yield Nursery

L. P. Reitz: The Uniform Yield Nursery is now being planted at 17 stations in the six states of the southern and central districts. At present five varieties are being included as checks. These are Kharkof, Blackhull, Early Blackhull, Comanche, and Pawnee. This nursery has also been grown in Illinois for soil mosaic reaction.

I. M. Atkins: I would suggest that we leave Kharkof, Blackhull, and Early Blackhull in.

H. Young: Could not Comanche replace Blackhull?

L. P. Reitz: We would lose data for the 5-year period when Comanche was not in the test.

W. M. Ross: We would like to see the checks replaced with current varieties.

A. M. Schlehuber: Quality is also a consideration here.

I. M. Atkins: I believe there is a value in a long-time check program. If you change checks periodically, you have no continuity.

A. M. Schlehuber: I move that we continue the three varieties (Kharkof, Blackhull, and Early Blackhull) as permanent checks and that the others be considered as interim checks.

R. E. Atkins: Second.

Motion carried on voice vote.

T. E. Haus: I would like to see an increase in the number of entries. However, I would not like to see as rapid a turnover as there is in the spring wheat nursery, but more than we now have.

L. P. Reitz: The policy has been to keep a variety at least two years. If you eliminate it after one year, you are really dropping it without having seen the data. Therefore, if it is in once, then it is tested two years--this has been our past policy. Entry changes have been from 2 to 8 per year, usually about four or five.

I. M. Atkins: Is anybody interested in the awned-awnless study? I am sorry that we did not specify that the isogenic lines were to be grown side by side in a replication. If there is no interest in them, we will drop them at the end of this year (from the Uniform Yield Nursery).

L. P. Reitz: We accept that kind of material only as a check of a scientific principle, and would not accept these if it means the exclusion of promising varietal material. I would not like to see the nursery become the other entirely.

Supplementary Winterhardiness Nursery
(6 stations in northern states)

L. P. Reitz: We have had an offer from the Canadian group for extending this nursery into Canada. I would like to sound out R. E. Atkins at Ames and the Minnesota people about nurseries in Iowa and at Waseca, Minnesota.

D. E. Weibel: How much seed would then be required?

L. P. Reitz: 150 grams.

R. E. Atkins: What is in this nursery?

L. P. Reitz: The Uniform Yield Nursery entries and additional entries from the southern and central areas.

R. E. Atkins: We would be interested in growing it.

I. M. Atkins: Is there any material in these that has outstanding stem rust resistance?

L. P. Reitz: Not yet, but there will be next year.

I. M. Atkins: We could grow a short row of each entry at College Station for determination of stem rust and mildew reaction.

L. P. Reitz: There is always the problem of having sufficient seed. Perhaps we could discontinue some stations.

C. O. Johnston: We could switch some stations; drop those that haven't been giving differential killing and pick up new stations.

V. A. Johnson: Next to Akron, what station has given the least information?

L. P. Reitz: Dickinson. Seeding and stand difficulties should be investigated there.

R. E. Atkins: How is this nursery planted?

L. P. Reitz: In 8-foot rows as a duplicated series.

D. E. Weibel: Could we hold the station number the same but change locations?

L. P. Reitz: Yes, or we might seed more thinly.

Uniform Winterhardiness Nursery

L. P. Reitz: This nursery usually contains about 25 entries and is primarily a nursery for the northern district. We have accepted very few entries from the southern district.

(There was no further discussion of this nursery.)

Uniform Smut Nursery

L. P. Reitz: This nursery has about 50 entries, planted in duplicate plots, and inoculated with local collections of bunt.

H. C. Young: Do you maintain checks here too?

L. P. Reitz: Kharkof, Red Chief, Cheyenne, Wasatch, Minturki, Oro, Hussar, Relief, and Ridit.

E. D. Hansing: It would be well to maintain the present checks.

L. P. Reitz: Without Relief we might not have picked up one recent change in races as we did.

H. C. Young: We would like to see Comanche in.

L. P. Reitz: Could we substitute Comanche for Oro?

C. O. Johnston: Comanche carries the Oro resistance. I believe we could substitute.

L. P. Reitz: Consensus is that Comanche be substituted for Oro.

E. D. Hansing: In Kansas we have watched the weather very carefully and have had good luck, but it is a good policy to plant on two dates.

L. P. Reitz: Consensus seems to be that we plant at two dates.

Approved by Conference.

L. P. Reitz: What about the policy of sending out smut-free seed and having it smutted by the cooperator? We have done this in the past with Kansas and Montana.

C. O. Johnston: We should be on the lookout for new collections.

E. D. Hansing: I would favor sending smut-free seed to all places. It is easy to smut the seed. Care needs to be taken to prevent new races from being spread out through the region.

C. O. Johnston: Fort Collins, Denton, and Stillwater plantings are the only ones now being smutted.

<u>All cooperators agreed to smut their own seed hereafter.</u>

T. E. Haus: What is the procedure of collecting for possible new races?

L. P. Reitz: We have sent out tester varieties when new races were suspected.

Collections from the variety were then sent to Dr. Holton for identification.

C. O. Johnston: I would like to point out that at the last conference we decided to send new varieties to Dr. Holton for a dwarf bunt test. Three states have participated.

D. E. Weibel: What are the sources of resistance to dwarf bunt?

C. O. Johnston: Selections from C. I. 12250 crossed with Pawnee, Comanche, and Nebred are very good. Also Oro-Turkey-Florence x Marquillo-Oro (C.I. 12723) and Wasatch.

Uniform Rust Nursery

L. P. Reitz: This is a national rust nursery for the purpose of studying the naturally occurring rust and testing new varieties and selections of wheat. There has been a lot of uncertainty about who nominates varieties and who does what in this nursery. It is now handled by the coordinators for the regions with the help of key men in the regions. Mr. C. O. Johnston is a key man to assist the coordinator on this for the Hard Red Winter Wheat region. W. Q. Loegering coordinates it at the National level.

C. O. Johnston: There has been some misunderstanding in this region. I would like to have men of the region send in a few of the very best selections.

H. C. Young: Do we get a lot of information from all of the differentials and checks?

C. O. Johnston: Perhaps we do not need all the checks but some are necessary for studies on the rust itself.

H. C. Young: I would like to see these reduced and have more entries.

C. O. Johnston: Should we contact the other regions about this?

H. C. Young: Yes.

I. M. Atkins: It is actually just a small nursery with very little work. We could have many more entries.

H. C. Young: We don't get any information from Democrat and Mediterranean which rust every year.

L. P. Reitz: The original purpose for having the differentials in was to pick up new races and attempt to do some field identification.

E. G. Heyne: I look at this as plant breeding work from a service standpoint and don't see the value of all of these checks and differentials. If you want an experiment for this, set it up with that in mind and for that purpose.

L. P. Reitz: I would like to remind you that once you nominate an entry, you must maintain the seed supply and submit seed each year. We also would welcome suggestions in regard to the International Rust Nursery. There are still other nurseries that could be discussed, and we will hear about a possible mosaic nursery at the program this afternoon.

FRIDAY AFTERNOON, JANUARY 21

R. P. Pfeifer, Chairman

Panel: BREEDING PROGRESS IN INTERSPECIFIC CROSSES TO OBTAIN WINTER-HARDINESS, SOLID STEM AND OTHER DESIRED CHARACTERS IN WINTER WHEAT

Leader: A. M. Schlehuber, Oklahoma

Dr. Schlehuber introduced the panel topic by reviewing briefly some of the historical background of interspecific and intergeneric crosses. Among other things, he mentioned the visit to Russia of the late Dr. Gaines who brought back to the United States information concerning the use of yarovization and the successful crosses between common wheat and the Agropyron grasses. Dr. Schlehuber further commented on the reported success of the production of intergeneric hybrids and perennial wheat types in Russia and posed the following series of questions:

Why has the use of Agropyron in crosses with wheat and intergeneric crosses in general in this country not been more successful?

Has it been because there are too many genes involved or is it possible that the resistance genes of Agropyron when placed in a common wheat genetic background are not effective?

Do we have any assurance that the genes being sought in wide crosses will hold up any longer than the genes already present in the common wheats?

Is it feasible to transfer a small chromosome segment for resistance in the common wheats?

Has the work done thus far been a large enough sample of trails to determine whether the transfer of resistance genes in these wide crosses can be effectively accomplished?

## PROGRESS IN BREEDING FOR LEAF RUST RESISTANCE, QUALITY, YIELD, AND TEST WEIGHT WITH AGROPYRON-WHEAT HYBRIDS IN OKLAHOMA

A. M. Schlehuber

Of the numerous Agrotricums now available at the Oklahoma Agricultural Experiment Station, the ones listed in Tables 1 - 3 are in the most advanced stages. Their seedling reaction to 16 leaf rust races is shown in Table 1. The reaction of all lines is either R (resistant) or R+(0;=zero fleck, highly resistant) to all 16 races. The wide base for resistance in these lines is of particular interest. C.I. 13020 appears to have the best type of resistance with the least amount of leaf necrosis.

Preliminary quality data indicate high protein content, fair to questionable to unsatisfactory flour yield and texture of kernel (too soft), and from good to fair to poor to very poor evaluations of dough mixing properties. An attempt is being made to correct these deficiencies by crossing some of the better lines with "strong" flour wheats such as Comanche, Ponca, and the very strong wheat C.I. 12406 (Marquillo-Oro X Oro-Tenmarq).

Yield and test weight comparisons indicate that C.I. 13020 is approximately equal to Ponca and Pawnee in yield and test weight. C.I. 13014, a 44-chromosome line, is the poorest agronomic type. leaf rust resistant types with the "strong" quality parents. Inasmuch as it is not known how many successive backcrossings are necessary in order to obtain the desired level of quality, selection without further backcrossing will be practiced within a portion of each backcrossed generation. Knowledge of the relative quality increments per backcrossing generation would be valuable information.

Table 1 — Seedling reaction of Agropyron-Wheat hybrids and Westar to individual leaf rust races*.

| | | | Variety or Hybrid | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | T.A.-el. Parent | Triticum-Agropyron elongatum X Pawnee (Stillwater Sel. No.) | | | | | |
| Leaf Rust Race | Westar | Stw. 493959 C.I. 12720) | 524447 | 524448 (C.I. 13014) | 524450 | 524455 | 524464 | 524467 (C.I. 13020) |
| 1 | — | — | 0;R+ | 1,R | 0;R+ | 0;R+ | 0;R+ | 0;R+ |
| 5 | 0;-1+,R | 1-2,R | 0;R+ | R, Seg. | 0;-1,R | 0;R+ | 0;R+ | 0;R+ |
| 9 | 0;-1,R+ | 0;-1,R+ | 0;R+ | 1-2,R | 0;-1-,R+ | 0;R+ | 0;R+ | 0;-1=,R+ |
| 11 | — | — | 0;R+ | R | 0;R+ | 0;R+ | 0;-1,R+ | 0;-1+,R |
| 15 | 0;-2,R | 0;R+ | 0;R+ | 0;-2,R | 0;-1+,R | 0;R+ | 0;R+ Seg. | 0;-1=,R+ |
| 21 | 0;-2+R | 0;-1,R+ | 0;-1+,R | 0;-2,R, Seg. | 0;-1+,R | 0;R+ | 0;-1,R+ | 0;-1=,R+ |
| 28 | — | — | 0;R+ | 0-1,R | 0;-1,R | 0;R+ | 0;R+ | 0;R+ |
| 32 | 0;-1,R+ | — | 0;R+ | 0;-2,R | 0;-2+,R | 0;-1,R+ | 0;-2+,R | 0;-1=,R+ |
| 35 | — | — | 0;R+ | R | 0;-1,R | 0;R+ | 0;R+ | 0;R+ |
| 58 | 4,VS | 0;-1,R+ | 0;R+ | 0;-2,R | 0;-2,R | 0;-1,R+ | 0;-1+,R | 0;-1=,R+ |
| 77 | — | — | 0;R+ | 0-1,R | 0;-1=,R+ | 0;R+ | 0;-1=,R+ | 0;R+ |
| 105 | 0;-2+,R | 0;R+ | 0;R+ | 0;-2,R | 0;-1,R+ | 0;R+ | 0;-1,R+ | 0;-1=,R+ |
| 105A | 4,VS | — | 0;R+ | 0;-2,R | 0;-1,R+ | 0;-1,R+ | 0;R+ | 0;-1=,R+ |
| 105B | 4,VS | — | 0;R+ | 0;-1+,R | 0;-1,R+ | 0;R+ | 0;R+ | 0;R+ |
| 122 | — | — | 0;R+ | 1,R | 0-1,R | 0;-1=,R+ | 0;-1=,R+ | 0;R+ |
| 126 | 0;-1,R+ | 0;R+ | 0;R+ | 0;-1+,R | 0;-2,R | 0;-1,R+ | 0;R+ | 0;-1=,R+ |

* A summary of reactions determined by H. C. Young, Jr., Okla. Agr. Exp. Sta. and C. O. Johnston, Cereal Crops Section, K.S.C., Manhattan, Kansas.

# AGROTRICUM HYBRIDIZATION

J. W. Schmidt, Nebraska

Two decades of research with Agrotricum (Agropyron x Triticum) hybrids have not effected the successful transfer of desirable Agropyron characteristics to a "wheat" having at the same time a chromosome complement cytologically indistinguishable from common wheat. Progress toward that goal has been understandably slow because of the tremendous difficulties involved. Inadequate chromosome homology has, largely, negated genetic crossing-over possibilities. The most promising wheat-like lines now available with chromosome complements approaching those of common wheat have been arrived at through the natural mechanisms that have produced chromosome substitution series. None of these are entirely satisfactory to the wheat breeder for effective use in his wheat breeding programs since cytological instability attends most of them.

The following ideas have been gleaned from work with this material. 1. The resistance to various diseases demonstrated by the hybrids is genetically controlled. 2. A monogenic dominant type of an inheritance is almost a prerequisite for the successful transfer of a given characteristic. 3. Stability of disease reaction and morphological characteristics do not assure accompanying meiotic stability. 4. Various degrees of deleteriousness are associated with most of the desirable characteristics, so that the chromatin material transferred will need to be minute.

On the positive side it can be reported that despite the relatively few crosses that have been studied, resistance to many wheat diseases such as the rusts, smuts, and viruses has been reportedly obtained in the hybrids. As an example of their value, in tests at Kansas State College nearly 60 percent of the lines were resistant to stem rust race 15B even though this race had not been a selection factor.

The hybrids have been disappointing from the standpoint of vigor, yield, and winterhardiness. Since these attributes are probably polygenically controlled, it is not surprising that this should be so. According to Kansas State College data, mean winter survival of 533 segregates in 1948 was only 69 percent as compared to 96 percent for three wheat checks.

The progress in Agrotricum breeding has been slow but sufficiently promising to justify continued research. X-radiation may have to be utilized in order to "cut down" the size of the various interchanges carrying the desired characteristics so that the deleterious effects accompanying them may be eliminated.

# AGROTRICUM BREEDING IN KANSAS

E. G. Heyne

Many Agrotricum selections have been made and studied in Kansas. None of the original crosses, however, were made at the Kansas Station. Stem rust, leaf rust, bunt and mosaic resistant materials have been selected from the introduced material during the years 1939-1951. Crosses back to wheat of the most promising Agrotricums have been disappointing. Wheats with 42 (plus or minus) chromosomes have been obtained but not the high type of resistance to diseases. The original material in 1954 field and 1954-55 greenhouse tests still indicate high resistance to rust so our next procedure will be to recross these Agrotricums to wheat again and follow the disease resistance and not try to recover a 42 chromosome wheat immediately.

# BREEDING PROGRESS IN INTERSPECIFIC CROSSES TO OBTAIN SOLID STEM AND SAWFLY RESISTANCE IN WHEAT

Ruby I. Larson
Science Service Laboratory,
Lethbridge, Alberta

(Presented by J. E. Andrews)

Little work is being done on interspecific crosses to obtain solid stem and resistance to the wheat stem sawfly, Cephus cinctus Nort., in common wheat in the Wheat Cytogenetics project at Lethbridge. None is being done with winter wheat. Two subprojects that may be reported are (1) an attempt to transfer the type of solid stem and sawfly resistance characteristic of the durum wheat, Golden Ball, to the already solid-stemmed, sawfly-resistant variety of common wheat, Rescue, and (2) an attempt to transfer genes for solid stem from the grass Aegilops sharonensis to common wheat. M. D. MacDonald, now on educational leave at the University of Minnesota, is in charge of the latter work.

The results of eight years' study of the transfer of solid stem of the type found in the durum wheat, Golden Ball, to Rescue have shown that the D genome sets the pith pattern to a considerable degree. Chromosome XVI in particular suppresses solid stem in the top internode just below the head. On the other hand, pith distribution in the lowest internodes seems to be dependent on genes in the A and B genomes, as some hexaploid segregates were found having a tendency to become hollow in the lowest internodes as Golden Ball does under conditions unfavorable to pith production. As selection for more solid stem and less solid stem in $F_6$, following continuous previous selection, resulted in $F_7$ lines with different quantities and distribution of pith, it is reasonable to assume that Rescue and Golden Ball differ from one another at several loci in the A and B genomes for genes affecting solid stem. Two years' data on sawfly resistance have shown that lines with very stable pith in the bottom internodes were most resistant to sawfly whereas those that tended to become hollow in the lower internodes were least resistant. Solid stem in the top internode seemed less important. No line more resistant to sawfly than Rescue has been found, but tests are to be continued.

M. D. MacDonald has produced a 56-chromosome amphiploid of the common wheat variety Red Bobs and Aegilops sharonensis. It appears to be immune to races of powdery mildew, Erysiphe graminis, present in the greenhouses at Lethbridge. The extra genome added some pith to the hollow-stemmed Red Bobs. An attempt is being made to produce 22-chromosome alien addition lines as well as alien chromosome substitution lines in order to study the effect of each of the seven Aegilops sharonensis chromosomes on Red Bobs.

# INTERGENERIC CROSSES INVOLVING *TRITICUM*

E. R. Sears

There are many relatives of wheat with characteristics such as disease resistance which would be of value if transferred to common wheat. Against effecting a transfer by ordinary means, however, several restrictions exist:

1. The desired characteristic must be relatively simply inherited, preferably being due to a single gene, and should be epistatic when added to wheat.

2. The species carrying the gene concerned must form a fertile hybrid with wheat.

3. The chromosome carrying the gene must be able to pair with one or more wheat chromosomes.

Methods have recently been developed for circumventing restrictions 2 and 3. These methods may be illustrated by an account of the transfer of leaf-rust resistance to wheat from *Aegilops umbellulata*.

Attempts to cross *Ae. umbellulata* (n = 7) with common wheat have been unsuccessful. The amphiploid *Triticum dicoccoides* x *Ae. umbellulata*, however, was readily crossed with the variety Chinese Spring. Pairing in the hybrid was predominantly 14 pairs (A and B genomes from both *T. aestivum* and *T. dicoccoides*) plus 14 univalents (D genome from *T. aestivum* and U genome from *Ae. umbellulata*). The absence of pairing between the D and U genomes indicated that transfer of the resistance through crossing-over would probably not be possible. Two backcrosses to Chinese, with selection of resistant plants, yielded a resistant plant with a single *umbellulata* chromosome. However, this plant and particularly the 22-pair offspring obtained from it were low in vigor and fertility.

Plants carrying a single added *umbellulata* chromosome were then x-rayed prior to meiosis, and the subsequently produced pollen was used on normal, untreated plants. From the 6137 seeds obtained, 6091 offspring resulted, and 132 of these were resistant. Of the resistant plants, 50 had a translocation involving the *umbellulata* chromosome. Three of these translocations are believed to consist of the intercalation of a small segment of the *umbellulata* chromosome into a wheat chromosome. Most, or possibly all, of the deleterious effects of the foreign chromosome are absent.

The method used in the transfer of *umbellulata* resistance takes advantage of the fact that the chromosome as a whole has strongly deleterious effects on pollen performance as well as on plant vigor and fertility. Pollen carrying the unchanged *umbellulata* chromosome meets with strong adverse selection, while pollen in which the desired chromosome segment has been transferred to a wheat chromosome (and the rest of the *umbellulata* chromosome lost) competes successfully with normal pollen.

Using this induced-translocation technique, transfers will be attempted of leaf- and stem-rust resistance from rye. Wheat-rye amphiploids are already available which are highly resistant to these diseases. Through crossing and backcrossing these amphiploids to wheat, it is hoped to obtain resistant lines with a single added rye chromosome, which can then be used in the x-ray induced transfers.

It is believed that the following activities are desirable for efficient and thorough exploitation of the relatives of wheat:

1. Cytotaxonomic research, particularly in the genus Agropyron, to establish which species are closely enough related to wheat to justify attempts at gene transfers. Genome relationships, where unknown, should be determined.

2. Collection of as many varieties as possible of species closely related to wheat.

3. Thorough canvassing of this material for characters worth transferring to wheat.

4. Transfer of desirable genes through simple crossing and backcrossing, where this method is feasible.

5. Production of amphiploids where necessary for restoring fertility or for improving crossability.

6. Production of alien addition lines and radiation induction of transfers within these lines.

## CYTOGENETIC RESEARCH WITH WINTER WHEAT

John Unrau
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University of Alberta

There are two main objectives in our breeding program with winter wheats: (a) Improvement of winter hardiness and (b) Development of winter wheat with spring wheat qualities.

In the second phase of our program, we mare making a substitution of Thatcher Chromosome IX by Chromosome IX of Kharkof MC22. It is assumed that this substitution line will have winter habit of growth, and may actually have fair winter hardiness. In any case, the line will differ from Thatcher only with respect to one substituted chromosome and should have good quality.

Another phase involves a cytogenetic analysis of winter mutants obtainted in the variety Thatcher after treatment with 2,4-D. There are various types of mutants all involving the characters awning, growth habit and speltoidy in different combinations. It is hoped that it will be possible to determine the genetic changes that have given rise to these mutations.

# GENES FOR RESISTANCE TO STEM RUST AND LEAF RUST FROM AEGILOPS SPELTOIDES

By. E. S. McFadden

A project to transfer stem rust and leaf rust resistance from *Aegilops speltoides* to commercially acceptable hexaploid wheats has been under way for several years. An allohexaploid of *T. dicoccoides* x *Ae. speltoides* was first produced by Sears through colchicine treatment of the $F_1$ hybrids. These allohexaploids were then crossed to the Austin variety and, since the $F_1$ hybrids were self sterile, they were back-crossed to Austin to induce seed setting. In the $F_3$ generation of the backcross, several free-threshing segregates were found which were completely free from both rusts while the Austin parent grown under the same conditions was highly susceptible to leaf rust and developed considerable stem rust localized on the sheaths in the vicinity of the nodes. These resistant segregates were all very similar, and all of them carried certain undesirable characters of *Ae. speltoides* including small pointed seeds, slender stems, ciliated glumes and a type of brittleness of the rachis in which the fracture occurs above the point of attachment of the spikelets. Some of the segregates also showed evidence of some sterility. Seed of the resistant segregates was bulked and grown the following year to allow for further segregation.

Numerous rust-free segregates were selected the following year from the plants grown from the bulked seed of the resistant segregates of the $F_3$ generation of the backcross. All of these re-selections carried the undesirable characters of *Ae. speltoides*, but some improvement in fertility was apparent. Cytological studies of some of the true-breeding re-selections revealed the presence of at least three types - one type with the normal hexaploid number of 42 chromosomes, one with 42 chromosomes and two chromosome fragments and another with 44 chromosomes. Since all of these types produce highly fertile $F_1$ hybrids with *T. vulgare*, it is assumed that they carry close to the full complement of the D set of chromosomes. It is assumed that in the 42 chromosome types either one full chromosome from *Ae. speltoides* has been substituted for one of the normal chromosomes or a fragment of a chromosome from *Ae. speltoides* has become incorporated into one of the normal D-set chromosomes. In the type carrying the extra chromosomes, it is assumed that the extra chromosomes are derived from *Ae. speltoides*. In the type carrying the chromosome fragments, it is assumed that only the fragments are derived from *Ae. speltoides*. It is apparent that the above described re-selections carry the free-threshing, or little k, gene of *T. vulgare* since their hybrids with *T. spelta* produce numerous typical *vulgare* segregates.

The factors for resistance to stem rust and leaf rust do not appear to be closely linked, and the one giving resistance to leaf rust has not been observed to be linked with any characters of *Ae. speltoides*. This leads to speculation that the factor for resistance to leaf rust could possibly be derived from the *T. dicoccoides* parent.

The "speltoides gene", or "speltoides complex", appears to give fairly high field resistance to all races and combinations of races of stem rust that have so far appeared in southern Texas. However, there appears to be a tendency for the resistance to be less effective under high temperatures. Early maturing strains that mature ahead of high temperatures are usually completely rust free at maturity, while late maturing strains that come to maturity while temperatures are high often develop small, distinctly isolated pustules with some sporulation just before maturity of the plants.

In further attempts to separate the speltoides "gene" for resistance to stem rust from the complex of other speltoides characters, crosses and backcrosses have been made to numerous vulgare varieties. Selections from the $F_2$ and $F_3$ generations of these crosses are now growing in the field, but the results are unknown at this time - except that some of them are showing marked resistance to leaf rust. If this second attempt to eliminate the undesirable characters of *Aegilops speltoides* is again unsuccessful, we probably will resort to irradiation of the material.

We have learned recently that the entire "speltoides complex" combines readily with the spelt gene, or big K complex, so as to produce good hulled types suitable for forage and feed grain purposes. Since hulled types of wheat have several advantages over hull-less types for feed purposes in southern Texas, the "speltoides gene", or "complex", may find its most important use in the breeding of hulled feed wheats.

# PROGRESS AND PLANS FOR WHEAT MONOSOMIC RESEARCH AT MINNESOTA

C. R. Burnham and E. Turcotte

(Presented by W. M. Myers)

Several years ago the monosomic crosses of Chinese x Frontana were tested against race 56. The normal $F_2$ and the $F_3$ lines indicated two dominant, duplicate factors for resistance to this race carried by Frontana. One of these was located on Chromosome VI. The other factor has not been located, although all the chromosomes have been tested. $F_3$ lines segregating 3:1 were used to establish stocks homozygous for a single one of these factors. These were intercrossed and $F_2$s produced to distinguish the two kinds of stocks supposedly present. Tests were run last spring with the race of 56 then in use by the Department of Plant Pathology. As a check, $F_2$ material from the original cross was included. Only one factor appeared to be segregating in the $F_2$ of Chinese x Frontana. This fall, the selected homozygous resistant lines and other $F_3$'s originally segregating 3:1 were tested against five different isolates of race 56 of widely different origin. There is no indication that any of these is giving reaction similar to those that might be expected by an isolate similar to the one used several years ago.

The conclusion reached is that for foundation work on the genetics of rust reaction it is absolutely essential that the races and isolates used be preserved so that the same one can be used again in later work. Careful genetic control (pure-lines) of the rust, their maintenance for many years, and the isolation of wheat stocks with known and tested genotypes for rust reaction from each study must be carried out. Stocks of wheat with single factors for rust reaction will be of great value. It is to be hoped that similar genetic stocks of the organism will be produced.

A number of other sources of rust resistance are being crossed with the monosomics to locate the factors for resistance. The cross with normal Chinese is made at the same time to produce $F_2$ and $F_3$ to have an adequate study of the mode of inheritance. Preliminary tests indicate that chromosome 21 of the II-44-22 selection carries a factor for resistance (Kenya source) to race 15B of stem rust.

A monosomic analysis of the leaf rust resistance of Lee has been completed by Dr. A. G. Plessers.

A student (Mr. MacDonald) is working on wheat x rye crosses, using the more winter hardy selections of rye and winter wheat.

The need for more good qualitative characters and then locating them goes without saying. A dominant non-waxy is being tested.

Dr. Snyder is devoting full time to wheat cytogenetics, employing primarily the nullisomic-monosomic method. He is making up substitution races from several varieties in the Chinese and Thatcher backgrounds.

Dr. Hsu is studying crosses of T. orientale with Chinese monosomics. The collection of Triticum orientale that he is using is very highly resistant to rust. $F_1$ plants of crosses with all Chinese monosomics except 2 were dwarfs. In the two cases of $F_1$s that grew normally and flowered, meiotic studies reveal about 14 bivalents and 13 univalents.

## SUMMARY AND FUTURE NEEDS

### Panel on Breeding Progress in Interspecific Crosses to Obtain Winterhardiness, Solid Stem, and Other Desired Characters in Winter Wheat

W. M. Myers, Minnesota

It would appear that we are on the verge of entering a new era of greatly increased work in the field of wheat cytogenetics from which we can expect to obtain many important contributions of eventual value to the wheat breeding program. I believe we are now about to enter this era for two reasons.

First, increased appropriations for wheat breeding research made available in the past two or three years will tend, in the near future, to lessen the pressure on the research personnel for development of new varieties to meet current emergencies and will permit them, therefore, to divert more time to basic research problems leading to a firmer foundation for work in the future.

The second reason is that we now have accumulated much of the necessary basic information on which this greatly expanded program can be built. We know that species of at least three other genera can be crossed successfully with the various species of Triticum. Furthermore, we know a considerable amount regarding the homologies of the chromosomes from these related genera with those from the important Triticum species. Finally, we have the pioneering work of Dr. Sears in developing the monosomic-nullisomic technique whereby we can, so to speak, take the individual chromosomes out of a variety and insert them unchanged into different or common genetic backgrounds. The potentialities of studies of this kind are illustrated by the work of Sears and some of the work reported at this conference by Dr. Unrau. The gene complex carried by each of the 21 chromosomes of a particular variety can be evaluated in a common genetic background as can also the genetic makeup of the same chromosome from various varieties. Using this same technique, gene dosage and interaction effects can be evaluated with considerable precision. Work along this line will yield information that will be invaluable to the plant breeder. Such work is in progress in several locations in the United States and Canada. It should be pushed forward as vigorously as resources will permit.

Considerable discussion has been had at this conference regarding the potentialities and problems involved in transfer of genes from related species or related genera to durum or bread wheat. The desirability of transferring genes for resistance to important diseases, winterhardiness, and other important characteristics is obvious. That such gene transfers can be made when the desired genes are carried in homologous or partly homologous chromosomes in the related species is well known from the work that has been done, particularly in transferring stem and leaf rust resistance from the emmer group to the vulgare wheats. That such genes can also be transferred by alien substitution has been shown by the work reported by Sears at this conference in transferring leaf rust resistance from Aegilops umbellulata to common wheat. Several questions in this connection have been raised.

One of these is whether the resistance genes transferred from a related species can be expected to stand up better against the changes in pathogenicity of the rust organism than those from wheat. There seems to be no positive answer to this question but probably no reason to expect that they will stand up better. On the other hand, the transfer of such genes is important because of the desirability of having multiple sources of resistance to the organism.

Another question is whether these genes will have the same effect when transferred to wheat. It would seem that there might potentially be loss of resistance, partial or complete, due either to a definite inhibiting factor in the common wheat parent or due to what might be spoken of as an unfavorable genetic climate for the introduced genes. There is some evidence that a gene or genes in the D-genome has a dampening effect on rust resistance genes in the A- or B-genome. It would seem possible to obtain positive evidence, by means of monosomic analysis, regarding whether a specific inhibiting effect of one or a few vulgare wheat genes is involved. If there is such an inhibiting effect, there would seem to be the possibility of eliminating the inhibiting gene by irradiation. This is as yet a largely unexplored field but, with the tools available to the cytogeneticist, the factors involved in expression of the alien gene in the new background can be evaluated.

Another question in regard to this general problem is that of whether desirable genes can be introduced from the related species without introducing also too many undesirable genes. The work of Sears in transferring the resistance from Aegilops umbellulata to common wheat would suggest that relatively small segments of the alien chromosome can have substantial deleterious effects. On the other hand, his results indicate also that by use of irradiation it should be possible to insert the desired alien gene in the normal chromosome complement without carrying along too many undesirable genes. This general field of transfer of genes from related species seems to hold enormous potentialities for improvement of bread and durum wheats. It is a field that has been neglected too long and is one to which we should give increasing attention in the future.

There was considerable discussion on winterhardiness at this conference and the suggestion has been made that winterhardiness should be transferred from Agropyron or from rye to wheat. Although it would seem theoretically possible to transfer genes for winterhardiness from these related genera, we must bear in mind that such interspecific and intergeneric transfers have been particularly successful with those genes that can be readily identified, such, for example, as genes for rust resistance. It would seem necessary, therefore, before winterhardiness could be transferred successfully, to develop an accurate test for winterhardiness that could be applied to the small populations that necessarily must be involved in attempts at intergeneric and interspecific gene transfers. In thinking in terms of transfer of genes from related species and genera to durum or bread wheat, another factor seems to deserve some serious consideration. So far, in our wheat breeding program, we have tried desperately to recover the specific qualities of the wheat with which we happen to be working, for example, macaroni making or bread making quality. It would seem that we should maintain a flexible viewpoint both in plant breeding and in cereal technology. There is a possibility that totally new types of wheat useful for food products not now known could be developed from this process of gene transfer. This is suggested by McFadden's report of the possibility of breeding a hulled seed wheat.

## RESOLUTIONS COMMITTEE REPORT

Resolved, that the Hard Red Winter Wheat Conference express its appreciation to the President and staff of Kansas State College for providing the excellent facilities and accommodations for the meetings.

Further, the Hard Red Winter Wheat Conference wishes to express its appreciation to H. H. Laude for his efforts throughout his entire term of office toward all phases of winter wheat improvement.

It is recommended that a committee should be appointed by the head of the Cereal Crops Section of the U. S. D. A., subject to the approval of the chairmen of the wheat improvement committees of the different regions, to work with the Canadian Committee on nomenclature of wheat and preservation of genetic stocks.

Resolved also that the Hard Red Winter Wheat Conference recommend to the U. S. Department of Agriculture that they appoint two delegates, one from the Cereal Section and one state delegate, to represent the Hard Red Winter Wheat group at the International Genetics Symposium to be held in Japan in 1956 (on the committee on wheat nomenclature).

Be it further resolved that such delegates be instructed by the wheat geneticists and breeders so that the delegates may carry out the majority opinion of the group. Further be it resolved that the U. S. Government contribute toward the delegates' expenses.

Few hazards cause such serious and widespread losses to winter wheat growers as do winterkilling, drought, and related weather conditions. On a long-time basis nearly a million acres of winter wheat or about 14 percent of the total seeded acreage in the United States are not harvested, largely because of these factors and in addition yields per acre are often seriously reduced. These hazards have been the subject of considerable study and some progress in controlling or reducing losses has been made. It is clear, however, that progress will be decidedly limited until there is a better understanding of the physiological or biochemical basis of winterhardiness and drought resistance such as can be expected only from basic or fundamental research carried out by competent personnel under controlled conditions in laboratories and greenhouses and correlated or coordinated with field studies.

This conference therefore recommends the establishment at the earliest possible date of a central laboratory for fundamental research relating to weather hazards and the employment of the necessary personnel to carry out such studies in accord with the recommendations of the Hard Red Winter Wheat Improvement Committee as revised in their Report No. 2, June 1954.

David W. Robertson, Chairman

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| Tunali, Mustafa | Kansas State College | Manhattan, Kansas |
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| Vaughn, John R. | University of Wyoming | Laramie, Wyoming |
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