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# PROCEEDINGS...

## ELEVENTH HARD RED WINTER
## and
## ELEVENTH HARD RED SPRING

## joint wheat workers conference

KANSAS STATE UNIVERSITY
MANHATTAN, KANSAS
FEBRUARY 6-8, 1968

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service
Crops Research Division
and
Agricultural Experiment Stations, Cooperating
in the
Hard Red Winter
and
Hard Red Spring
Wheat Regions

# PROCEEDINGS

# ELEVENTH HARD RED WINTER and ELEVENTH HARD RED SPRING WHEAT WORKERS CONFERENCE

Kansas State University
Manhattan, Kansas
February 6 - 8, 1968

Report not for publication1/

Agronomy Department
Agricultural Experiment Station
Lincoln, Nebraska
June, 1968

1/This is a conference report of the cooperative investigations containing data, the interpretation of which may be modified with additional interpretation. Therefore, publication, display, or distribution of data or any statements herein should not be made without prior written approval of the Crops Research Division, ARS, USDA, and the cooperating agency or agencies concerned.

CR-50-68

# FOREWORD

This was a joint conference of wheat workers in the hard red winter and hard red spring wheat regions. Workers from the Western Region, the Eastern Soft Wheat Region, Canada, Mexico, and Argentina also participated. The conference involved researchers from state and federal agencies and the private sector of the wheat industry.

The conference was jointly sponsored by the Hard Red Winter and the Hard Red Spring Wheat Improvement Committees. Both of these committees, as well as the National Wheat Improvement Committee, met during the conference. Also meeting prior to the conference was the North American Leaf Rust Research Workers Committee.

Abstracts or full texts of most of the presentations are contained herein. No attempt has been made to include the many ideas and comments voiced during the informal floor discussions. Since such informal discussions were encouraged rather than lengthy formal presentations, the material contained in this report does not adequately reflect the full treatment of the conference topics.

Appreciation is expressed to B. C. Curtis, F. H. McNeal, K. A. Lucken and J. W. Schmidt for their leadership in organizing the main conference topics "Barriers to the Improvement of Wheat" and "Hybrid Wheat". A word of thanks is due also to the local arrangements committee at Kansas State University under the chairmanship of E. G. Heyne.

V. A. Johnson and K. L. Lebsock
Regional Wheat Improvement Leaders,
Hard Winter and Hard Spring Wheat
Regions, respectively

ELEVENTH

HARD RED WINTER
and
HARD RED SPRING
JOINT WHEAT WORKERS CONFERENCE

Manhattan, Kansas

February 6 - 8, 1968

Program
Morning, February 6
Williams Auditorium
E. G. Heyne, presiding

Afternoon, February 6
Williams Auditorium
Barriers to the Improvement of Wheat (continued)
F. H. McNeal, Discussion Moderator

Morning, February 7
Little Theater, K-State Union
D. G. Wells, presiding

Hybrid Wheat
K. A. Lucken, Discussion Moderator

Afternoon, February 7
Little Theater, K-State Union
H. C. Young, Jr., presiding

Hybrid Seed Production
J. W. Schmidt, Discussion Moderator



Morning, February 8
Little Theater, K-State Union
Regional Programs
K. L. Lebsock and V. A. Johnson, presiding

# HOW SHOULD BREEDING SYSTEMS BE REVISED TO DEVELOP VARIETIES WITH MAXIMUM GRAIN YIELDS?

Norman E. Borlaug

It is my contention that progress in the development of higher yielding wheat varieties is being slowed primarily by the extreme conservatism of most wheat breeders, coupled with the status quo attitudes of the grain and milling industries.

Most wheat breeders have become slaves to their own narrowly based gene pools. They have, with but few exceptions, shortsightedly organized their programs in such a way that they have given disproportionate emphasis at the expense of yield to the following two aspects of varietal improvement:

1. Improvement in disease and insect resistance.

2. Maintaining status quo (good or acceptable) milling and baking quality, while improvements are being made in disease and insect resistance.

Perhaps somewhere between 70 and 80 percent of the entire wheat breeding effort in the U.S.A. and Canada in the past 30 years has been devoted primarily to developing new varieties with better resistance to diseases (especially to the rusts and smuts) and to insects (Hessian fly and sawfly).

As new races of rust, for example, have appeared rendering a formerly acceptable commercial variety, such as Thatcher, susceptible, new sources of resistance have been found and crossed into it. Subsequently, Thatcher has been used as the recurrent parent in long backcross programs so as to assure that both the phenotype of Thatcher and its milling and baking quality was recovered in the progeny. Unfortunately this ultra conservative system, which is advantageous and almost foolproof from both a plant pathology and cereal chemistry point of view has been disastrous when viewed from the standpoint of improvements in grain yield and agronomic type. As production costs mount and yields remain stagnant the farmer is stuck in a cost-price squeeze.

## Increasing Grain Yield

One of the first lessons which we learn in genetics is that maximum levels of heterosis are obtained when we cross genetically distinct parents. This principle we promptly ignore in our breeding programs in self-pollinated plants. It has been our experience that wheat crosses that give high yielding $F_1$ progeny are also likely to produce high yielding lines in advanced generations that will exceed the grain yield of either parent.

It is our contention that a crossing program designed to increase grain yield in wheat should involve:

1. Crossing of unlike outstanding parental types within the spring wheat groups (that is, between the best commercial variety in one zone of operation and the best varieties from aggressive spring wheat breeding programs in other parts of the world).

2. Crossing unlike outstanding parental types - within the winter wheat group from the world's best winter wheat breeding programs.

3. Crossing outstanding parental spring wheat varieties with outstanding parental winter wheat varieties.

Breeding for the Simultaneous Improvements in Grain Yield, Improved Agronomic Type, Wider Adaptation, Better Disease Resistance and Improved Quality

The Mexican program uses a broad approach in its wheat breeding effort. It prescribes to both making many diverse crosses and growing large $F_2$ and $F_3$ populations of each cross. It contends that progress in breeding lags because of lack of variability in segregating populations. It also contends that too many of the world's wheat breeding programs are currently oversophisticated and that "the worshipping of gadgets and computers" have replaced common sense and a sense of urgency. Living and working with the wheat plants has become outmoded and old-fashioned. Physical work, sweat, sun, dust, and mud are to be avoided and are considered undignified for a scientist. Excuses of high labor costs are too often used as an excuse to justify small poorly oriented breeding programs.

The Mexican program is a proponent of variability and large segregating populations. It advocates the critical choice of environments under which to select segregating populations. It also advocates the use of the proper screening tests for grain yield, (potential), agronomic type, disease resistance and quality in early generations ($F_2$, $F_3$ and $F_4$). When these procedures are followed it contends that it is possible to simultaneously make improvements in grain yield, agronomic type, breadth of adaptation, disease resistance and milling and baking quality.

To obtain and maintain adequate variability in the program it makes and grows more than 1,500 $F_1$ crosses each year (two seasons). These crosses represent combinations between the best Mexican varieties and lines, and the most promising wheats selected from aggressive programs in other parts of the world. The crosses are not made blindly but with considerable knowledge concerning important heritable characters, including quality of each of the parents. Nevertheless, more than half of the new crosses are discarded in the $F_1$ (plant) generation.

All $F_2$ populations that are sown each year, generally from 500 to 750, are grown at two locations in Mexico, as well as at two locations in Argentina, India and Pakistan. A minimum of 2,000 plants is grown in each $F_2$ population at each location, when seed permits.

Every effort is made to continuously modify, reincorporate and increase variability into the breeding program. Frequently double crosses are made between the most outstanding but only remotely related $F_1$ crosses. New crosses are also constantly being made between outstanding $F_3$ and $F_4$ plants from different crosses, and between these outstanding plants and the best advanced lines and commercial varieties. This type of recurrent reselection combined with vigorous recrossing, and employing adequate screening tests in early segregating generations, keeps the Mexican program dynamic and has prevented its stagnation.

The Use of the International Spring Wheat Yield Nursery to Select Parents for Increasing Grain Yield

In recent years it has become increasingly clear that certain spring wheat varieties have outstanding yielding ability under a wide range of climatic, soil, moisture, and disease conditions. (1,2,3,4,5,6,7,8,) The data from the Third Cooperative International Spring Wheat Yield Nursery - which is your data - is summarized in a preliminary manner in the attached tables. From these data it is clear that some varieties such as: 1)Pitic 62, 2)Lerma Rojo 64, 3)Penjamo 62, 4)Nainari 60, 5)Crespo 63, 6)Huelquen, and 7)Triple Dirk, are high yielding at many locations, both when grown on fertilized and non-fertilized soil, and under irrigated and non-irrigated conditions.

Several of the newer high yielding Mexican varieties (Table 1 and Table 2A, B and C), i.e. 8156 (from Penjamo "S" x Gabo 55); INIA 66 and Noroeste (both derived from Sonora 64A x Lerma Rojo 64A); CIANO (from Pitic-Chris x Sonora 64); Tobari 66 (from Sonora 64A x Tezanos Pintos Precoz); and Jaral 66/ from Sonora 64 X (Tezanos Pintos Precoz x Nainari) /, were derived from crosses involving the aforementioned high yielding parents. All of the latter are distinct improvements in industrial quality, disease resistance and agronomic type over the former group.

Some of these varieties, as well as other newer experimental lines, are as good in milling and baking characteristics as the best U.S.A. and Canadian hard red spring wheat varieties. This improvement indicated clearly that simultaneous improvements can be made in yield, adaptation, agronomic type, disease resistance and quality if we organize our programs properly, and implement them vigorously.

I maintain we all remain too conservative in our breeding programs. Our yearly advancements in increasing world grain yields via genetics on a per capita basis, is less than the population growth. We are losing ground! Most of the current increases in grain yield that the U.S. farmer is exploiting - to stay in business and not go bankrupt with the current deflated prices - comes from improvements in cultural practices, i.e. fertilizer, better weed control, and better manipulation of soil moisture - not from higher yielding varieties. When are we going to change this? It appears to me that the time is late!

## Literature Cited


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Preliminary summary table of the Third International Spring Wheat Yield Nursery, 1966-67. Regional mean yield in kilos per hectare and rank.

TABLE 1.--INTERNATIONAL MAIZE AND WHEAT IMPROVEMENT CENTER (CIMMYT)

| Var. No. | Variety or strain | Origin | Over all mean 36 sta. yield | rank | N.America 14 sta. yield | rank | Africa 10 sta. yield | rank | Asia 12 sta. yield | rank |
|---|---|---|---|---|---|---|---|---|---|---|
| 32 | Pitic 62 | Mex. | 3600 | 1 | 3977 | 1 | 3242 | 2 | 3872 | 2 |
| 7 | Lerma Rojo 64A | Mex. | 3532 | 2 | 3657 | 9 | 3138 | 4 | 4126 | 1 |
| 24 | Pjsib x Gb55(red) | Mex. | 3459 | 3 | 3663 | 8 | 3410 | 1 | 3707 | 3 |
| 37 | Inia 66 | Mex. | 3412 | 4 | 3843 | 2 | 3044 | 6 | 3696 | 4 |
| 21 | Penjamo 62 | Mex. | 3323 | 5 | 3721 | 5 | 3188 | 3 | 3541 | 5 |
| 28 | Pjsib x Gb55(w) | Mex. | 3305 | 6 | 3810 | 3 | 2959 | 7 | 3467 | 9 |
| 12 | Nainari 60 | Mex. | 3265 | 7 | 3759 | 4 | 2725 | 16 | 3506 | 7 |
| 1 | Nar sib$^2$ x Pj sib | Chile | 3162 | 8 | 3596 | 13 | 2798 | 11 | 3474 | 8 |
| 49 | Tobari 66 | Mex. | 3116 | 9 | 3704 | 6 | 2770 | 13 | 3177 | 16 |
| 40 | Noroeste 66 | Mex. | 3112 | 10 | 3682 | 7 | 3090 | 5 | 3512 | 6 |
| 36 | Crespo 63 | Col. | 3110 | 11 | 3623 | 10 | 2768 | 14 | 3147 | 20 |
| 2 | Napo 63 | Col. | 3089 | 12 | 3438 | 15 | 2684 | 20 | 3432 | 10 |
| 4 | Huelquen | Chile | 3086 | 13 | 3605 | 11 | 2542 | 30 | 3298 | 13 |
| 19 | Triple Dirk | Aust. | 3066 | 14 | 3161 | 21 | 2812 | 10 | 3160 | 18 |
| 22 | Bajio 66 | Mex. | 3064 | 15 | 3433 | 16 | 2607 | 24 | 3409 | 12 |
| 42 | P162-Chris sibxS64 | Mex. | 3028 | 16 | 3599 | 12 | 2598 | 26 | 3272 | 14 |
| 41 | Roque 66 | Mex. | 3008 | 17 | 3564 | 14 | 2681 | 21 | 3053 | 24 |
| 14 | Sonora 64 | Mex. | 2893 | 18 | 3188 | 19 | 2794 | 12 | 3061 | 23 |
| 23 | C-306 | India | 3871 | 19 | 2927 | 28 | 2607 | 25 | 3418 | 11 |
| 38 | Jaral 66 | Mex. | 2850 | 20 | 3343 | 17 | 2524 | 33 | 2952 | 29 |
| 46 | Nariño 59 | Col. | 2837 | 21 | 2296 | 49 | 2388 | 39 | 3002 | 25 |
| 35 | Tacuari | Arg. | 2833 | 22 | 3108 | 22 | 2458 | 35 | 3132 | 22 |
| 33 | Yaqui 50 | Mex. | 2819 | 23 | 2900 | 29 | 2584 | 27 | 3239 | 15 |
| 25 | NP 881 | India | 2805 | 24 | 3243 | 18 | 2552 | 29 | 2907 | 35 |
| 29 | Pakistan 5725 | Pak. | 2769 | 25 | 2748 | 41 | 2927 | 9 | 3139 | 21 |
| 15 | C-271 | Pak. | 2762 | 26 | 2873 | 30 | 2701 | 18 | 3168 | 17 |
| 18 | Carazinho | Brazil | 2745 | 27 | 2809 | 35 | 2425 | 37 | 3160 | 19 |
| 9 | Giza 150 | Egypt | 2735 | 28 | 3046 | 25 | 2702 | 17 | 2765 | 40 |
| 45 | Centrifen | Chile | 2729 | 29 | 3044 | 26 | 2650 | 22 | 2868 | 39 |
| 6 | Mendos | Aust. | 2726 | 30 | 2762 | 40 | 2936 | 8 | 2869 | 38 |
| 30 | Tiba 63 | Col. | 2724 | 31 | 2975 | 27 | 2573 | 28 | 2952 | 30 |
| 27 | Bonza 63 | Col. | 2716 | 32 | 3106 | 23 | 2437 | 36 | 2818 | 42 |
| 26 | Giza 144 | Egypt | 2704 | 33 | 3172 | 20 | 2526 | 32 | 2631 | 44 |
| 13 | Bonza 55 | Col. | 2691 | 34 | 3072 | 24 | 2230 | 43 | 2922 | 33 |
| 10 | NP 832 | India | 2690 | 35 | 2849 | 32 | 2647 | 23 | 2998 | 26 |
| 5 | NP 824 | India | 2674 | 36 | 2866 | 31 | 2528 | 31 | 2993 | 27 |
| 43 | Gaboto | Arg. | 2662 | 37 | 2834 | 33 | 2407 | 38 | 2966 | 28 |
| 34 | Gabo | Aust. | 2627 | 38 | 2815 | 34 | 2748 | 15 | 2647 | 43 |
| 17 | Crim | U.S.A. | 2589 | 39 | 2795 | 38 | 2326 | 40 | 2893 | 37 |
| 39 | NP 880 | India | 2588 | 40 | 2738 | 42 | 2694 | 19 | 2761 | 41 |
| 3 | C-273 | Pak. | 2568 | 41 | 2807 | 36 | 2288 | 42 | 2905 | 36 |
| 20 | C-591 | India | 2559 | 42 | 2796 | 37 | 2212 | 44 | 2924 | 32 |
| 44 | Klein PetisoxRaf. | Arg. | 2549 | 43 | 2655 | 43 | 2291 | 41 | 2922 | 34 |
| 16 | C-518 | India | 2519 | 44 | 2526 | 47 | 2469 | 34 | 2927 | 31 |
| 11 | Chris | U.S.A. | 2445 | 45 | 2790 | 39 | 2117 | 45 | 2561 | 45 |
| 48 | ElGaucho | Arg. | 2264 | 46 | 2633 | 45 | 1706 | 46 | 2515 | 46 |
| 8 | Justin | U.S.A. | 2024 | 47 | 2563 | 46 | 1513 | 48 | 2153 | 47 |
| 31 | Selkirk | Canada | 2009 | 48 | 2637 | 44 | 1627 | 47 | 1919 | 48 |
| 47 | Thatcher | U.S.A. | 1664 | 49 | 2335 | 49 | 919 | 49 | 1699 | 49 |
| | Station mean yield | | 2824 | | 3124 | | 2564 | | 3054 | |

TABLE 1. (continued)

| Var. No. | Variety or strain | Origin | Over all mean 36 sta. yield | rank | Mexico irrig.*3 sta. yield | rank | U.S.A. irrig. 2 sta. yield | rank | N. America irrig. 5 sta. yield | rank |
|---|---|---|---|---|---|---|---|---|---|---|
| 32 | Pitic 62 | Mex. | 3600 | 1 | 3166 | 18 | 6271 | 1 | 4408 | 6 |
| 7 | Lerma Rojo 64A | Mex. | 3532 | 2 | 3342 | 13 | 5239 | 10 | 4101 | 14 |
| 24 | Pjsib x Gb55(red) | Mex. | 3459 | 3 | 3200 | 16 | 5556 | 6 | 4142 | 13 |
| 37 | Inia 66 | Mex. | 3412 | 4 | 4278 | 2 | 4637 | 30 | 4522 | 3 |
| 21 | Penjamo 62 | Mex. | 3323 | 5 | 3974 | 4 | 5635 | 4 | 4638 | 1 |
| 28 | Pjsib x Gb55(w) | Mex. | 3305 | 6 | 3418 | 12 | 6014 | 2 | 4456 | 4 |
| 12 | Nainari 60 | Mex. | 3265 | 7 | 3318 | 14 | 5472 | 8 | 4180 | 11 |
| 1 | Nar sib$^2$ x Pj sib | Chile | 3162 | 8 | 4051 | 3 | 4994 | 17 | 4428 | 5 |
| 49 | Tobari 66 | Mex. | 3116 | 9 | 3819 | 5 | 5233 | 11 | 4385 | 7 |
| 40 | Noroeste 66 | Mex. | 3112 | 10 | 3788 | 6 | 5054 | 14 | 4295 | 8 |
| 36 | Crespo 63 | Col. | 3110 | 11 | 3448 | 11 | 4763 | 24 | 3974 | 15 |
| 2 | Napo 63 | Col. | 3089 | 12 | 3760 | 8 | 5030 | 15 | 4232 | 10 |
| 4 | Huelquen | Chile | 3086 | 13 | 2785 | 26 | 5605 | 5 | 3911 | 17 |
| 19 | Triple Dirk | Aust. | 3066 | 14 | 2040 | 41 | 4899 | 20 | 3184 | 38 |
| 22 | Bajio 66 | Mex. | 3064 | 15 | 3774 | 7 | 4962 | 19 | 4249 | 9 |
| 42 | P162-Chris sibxS64 | Mex. | 3028 | 16 | 4318 | 1 | 5026 | 16 | 4601 | 2 |
| 41 | Roque 66 | Mex. | 3008 | 17 | 3674 | 9 | 4885 | 21 | 4158 | 12 |
| 14 | Sonora 64 | Mex. | 2893 | 18 | 3203 | 15 | 4625 | 31 | 3772 | 19 |
| 23 | C-306 | India | 2871 | 19 | 2505 | 29 | 4877 | 22 | 3454 | 29 |
| 38 | Jaral 66 | Mex. | 2850 | 20 | 3470 | 10 | 4622 | 32 | 3931 | 16 |
| 46 | Nariño 59 | Col. | 2837 | 21 | 3122 | 20 | 4462 | 37 | 3658 | 20 |
| 35 | Tacuari | Arg. | 2833 | 22 | 2251 | 36 | 5158 | 13 | 3414 | 31 |
| 33 | Yaqui 50 | Mex. | 2819 | 23 | 2249 | 37 | 4641 | 38 | 3206 | 36 |
| 25 | NP 881 | India | 2805 | 24 | 3039 | 22 | 4976 | 18 | 3813 | 18 |
| 29 | Pakistan 5725 | Pak. | 2769 | 25 | 3052 | 21 | 4042 | 48 | 3448 | 30 |
| 15 | C-271 | Pak | 2762 | 26 | 3116 | 17 | 4361 | 39 | 3614 | 21 |
| 18 | Carazinho | Brazil | 2745 | 27 | 1955 | 46 | 4540 | 34 | 2869 | 45 |
| 9 | Giza 150 | Egypt | 2735 | 28 | 2315 | 33 | 5199 | 12 | 3468 | 28 |
| 45 | Centrifen | Chile | 2729 | 29 | 3122 | 19 | 4111 | 46 | 3517 | 23 |
| 6 | Mendos | Aust. | 2726 | 30 | 2377 | 31 | 4199 | 44 | 3104 | 41 |
| 30 | Tiba 63 | Col. | 2724 | 31 | 2878 | 24 | 4461 | 38 | 3511 | 25 |
| 27 | Bonza 63 | Col. | 2716 | 32 | 2698 | 27 | 4638 | 29 | 3474 | 26 |
| 26 | Giza 144 | Egypt | 2704 | 33 | 2029 | 42 | 5739 | 3 | 3513 | 24 |
| 13 | Bonza 55 | Col. | 2691 | 34 | 2455 | 38 | 4803 | 23 | 3394 | 32 |
| 10 | NP 832 | India | 2690 | 35 | 2279 | 39 | 5475 | 7 | 3558 | 22 |
| 5 | NP 824 | India | 2674 | 36 | 2255 | 35 | 5364 | 9 | 3499 | 27 |
| 43 | Gaboto | Arg. | 2662 | 37 | 2074 | 40 | 4670 | 27 | 3112 | 40 |
| 34 | Gabo | Aust. | 2627 | 38 | 2207 | 38 | 4522 | 35 | 3133 | 39 |
| 17 | Crim | U.S.A. | 2589 | 39 | 2187 | 39 | 4682 | 26 | 3185 | 37 |
| 39 | NP 880 | India | 2588 | 40 | 2920 | 23 | 4049 | 47 | 3371 | 34 |
| 3 | C-273 | Pak. | 2568 | 41 | 2852 | 25 | 4185 | 45 | 3385 | 33 |
| 20 | C-591 | India | 2559 | 42 | 2512 | 28 | 4549 | 33 | 3327 | 35 |
| 44 | Klein PetisoxRaf. | Arg. | 2549 | 43 | 2009 | 43 | 4311 | 41 | 2930 | 44 |
| 16 | C-518 | India | 2519 | 44 | 2402 | 30 | 3468 | 50 | 3028 | 42 |
| 11 | Chris | U.S.A. | 2445 | 45 | 2001 | 44 | 4484 | 36 | 2995 | 43 |
| 48 | El Gaucho | Arg. | 2264 | 46 | 1878 | 45 | 4339 | 40 | 2862 | 46 |
| 8 | Justin | U.S.A. | 2024 | 47 | 1718 | 47 | 4018 | 49 | 2638 | 48 |
| 31 | Selkirk | Canada | 2009 | 48 | 1706 | 48 | 4250 | 43 | 2721 | 47 |
| 47 | Thatcher | U.S.A. | 1664 | 49 | 922 | 50 | 4295 | 42 | 2271 | 49 |
| | Station mean yield | | 2824 | | 2814 | | 4804 | | 3613 | |

*Included Toluca summer station through error (seriously damaged by flooding).

TABLE 1. (continued)

| Var. No. | Variety or strain | Origin | Over all mean 36 sta. yield | rank | U.S.A. rainfed 5sta. yield | rank | Canada rainfed 4sta. yield | rank | N. America rainfed9sta. yield | rank |
|---|---|---|---|---|---|---|---|---|---|---|
| 32 | Pitic 62 | Mex. | 3600 | 1 | 3361 | 1 | 3778 | 1 | 3546 | 1 |
| 7 | Lerma Rojo 64A | Mex. | 3532 | 2 | 3233 | 5 | 3187 | 7 | 3212 | 5 |
| 24 | Pjsib x Gb 55(red) | Mex. | 3459 | 3 | 3185 | 6 | 3181 | 8 | 3183 | 6 |
| 37 | Inia 66 | Mex. | 3412 | 4 | 3177 | 7 | 3145 | 9 | 3163 | 7 |
| 21 | Penjamo 62 | Mex. | 3323 | 5 | 2562 | 25 | 3108 | 10 | 2804 | 15 |
| 28 | Pjsib x Gb 55(w) | Mex. | 3305 | 6 | 3116 | 8 | 3222 | 4 | 3163 | 8 |
| 12 | Nainari 60 | Mex. | 3265 | 7 | 3306 | 3 | 3376 | 3 | 3337 | 2 |
| 1 | Nar sib$^2$xPj sib | Chile | 3162 | 8 | 2687 | 18 | 2857 | 22 | 2763 | 17 |
| 49 | Tobari 66 | Mex. | 3116 | 9 | 2973 | 12 | 3083 | 12 | 3022 | 11 |
| 40 | Noroeste 66 | Mex. | 3112 | 10 | 3008 | 10 | 3190 | 6 | 3089 | 10 |
| 36 | Crespo 63 | Col. | 3110 | 11 | 3321 | 2 | 3207 | 5 | 3271 | 4 |
| 2 | Napo 63 | Col. | 3089 | 12 | 2690 | 17 | 2817 | 25 | 2746 | 21 |
| 4 | Huelquen | Chile | 3086 | 13 | 3055 | 9 | 3604 | 2 | 3299 | 3 |
| 19 | Triple Dirk | Aust. | 3066 | 14 | 3249 | 4 | 2996 | 15 | 3137 | 9 |
| 22 | Bajio 66 | Mex. | 3064 | 15 | 2262 | 39 | 3060 | 13 | 2617 | 25 |
| 42 | P162-Chris sibxS64 | Mex. | 3028 | 16 | 2432 | 33 | 2802 | 26 | 2596 | 27 |
| 41 | Roque 66 | Mex. | 3008 | 17 | 2867 | 13 | 3099 | 11 | 2970 | 12 |
| 14 | Sonora 64 | Mex. | 2893 | 18 | 2473 | 32 | 2766 | 27 | 2603 | 26 |
| 23 | C-306 | India | 2871 | 19 | 2279 | 37 | 2522 | 38 | 2400 | 39 |
| 38 | Jaral 66 | Mex. | 2850 | 20 | 2613 | 22 | 2931 | 17 | 2754 | 18 |
| 46 | Narino 59 | Col. | 2837 | 21 | 3007 | 11 | 2823 | 24 | 2933 | 13 |
| 35 | Tacuari | Arg. | 2833 | 22 | 2727 | 16 | 2894 | 19 | 2801 | 16 |
| 33 | Yaqui 50 | Mex. | 2819 | 23 | 2568 | 23 | 2633 | 31 | 2594 | 28 |
| 25 | NP 881 | India | 2805 | 24 | 2562 | 26 | 2937 | 16 | 2673 | 23 |
| 29 | Pakistan 5725 | Pak. | 2769 | 25 | 2040 | 45 | 2056 | 49 | 2047 | 47 |
| 15 | C-271 | Pak. | 2762 | 26 | 2003 | 46 | 2290 | 43 | 2131 | 46 |
| 18 | Carazinho | Brazil | 2745 | 27 | 2501 | 31 | 3056 | 14 | 2748 | 20 |
| 9 | Giza 150 | Egypt | 2735 | 28 | 2622 | 20 | 2627 | 32 | 2624 | 24 |
| 45 | Centrifen | Chile | 2729 | 29 | 2798 | 14 | 2284 | 44 | 2570 | 30 |
| 6 | Mendos | Aust. | 2726 | 30 | 2242 | 40 | 2643 | 30 | 2420 | 36 |
| 30 | Tiba 63 | Col. | 2724 | 31 | 2364 | 34 | 2531 | 37 | 2438 | 35 |
| 27 | Bonza 63 | Col. | 2716 | 32 | 2620 | 21 | 2887 | 19 | 2738 | 22 |
| 26 | Giza 144 | Egypt | 2704 | 33 | 2792 | 15 | 2880 | 21 | 2831 | 14 |
| 13 | Bonza 55 | Col. | 2691 | 34 | 2662 | 19 | 2862 | 22 | 2750 | 19 |
| 10 | NP 832 | India | 2690 | 35 | 1794 | 49 | 2570 | 34 | 2139 | 45 |
| 5 | NP 824 | India | 2674 | 36 | 1890 | 48 | 2663 | 29 | 2233 | 44 |
| 43 | Gaboto | Arg. | 2662 | 37 | 2568 | 24 | 2541 | 36 | 2556 | 31 |
| 34 | Gabo | Aust. | 2627 | 38 | 2173 | 42 | 2899 | 18 | 2496 | 33 |
| 17 | Crim | U.S.A. | 2589 | 39 | 2279 | 38 | 2560 | 35 | 2404 | 37 |
| 39 | NP 880 | India | 2588 | 40 | 2071 | 44 | 2148 | 48 | 2105 | 48 |
| 3 | C-273 | Pak. | 2568 | 41 | 2233 | 41 | 2223 | 46 | 2229 | 43 |
| 20 | C-591 | India | 2559 | 42 | 2165 | 43 | 2388 | 42 | 2264 | 42 |
| 44 | Klein PetisoxRaf. | Arg. | 2549 | 43 | 2305 | 36 | 2474 | 40 | 2380 | 41 |
| 16 | C-518 | India | 2519 | 44 | 1899 | 47 | 2181 | 47 | 2024 | 49 |
| 11 | Chris | U.S.A. | 2445 | 45 | 2514 | 29 | 2673 | 28 | 2585 | 29 |
| 48 | ElGaucho | Arg. | 2264 | 46 | 2503 | 30 | 2278 | 45 | 2403 | 38 |
| 8 | Justin | U.S.A. | 2024 | 47 | 2530 | 28 | 2434 | 41 | 2487 | 34 |
| 31 | Selkirk | Canada | 2009 | 48 | 2536 | 27 | 2573 | 33 | 2553 | 32 |
| 47 | Thatcher | U.S.A. | 1664 | 49 | 2306 | 35 | 2514 | 39 | 2398 | 40 |
| | Station mean yield | | 2824 | | 2594 | | 2785 | | 2678 | |

TABLE 2-A Preliminary report of the Third International Spring Wheat Yield Nursery 1966-67. Locations and mean yield in kilos per hectare. International Maize and Wheat Improvement Center (CIMMYT).

| Var. No. | Variety or strain | ECUADOR | MEXICO (rainfed) | | MEXICO (irrig.) | U. S. A. (irrig.) | | U. S. A. (rainfed) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sta. Catalina | San Martin | CIAB | CIANO | Logan, Utah | Aberdeen, Idaho | St. Paul Minn. | Grand Forks Minn. | Casselton, N.D. | Palmer, Alaska | Davis Calif. |
| 1 | Nar sib²x Pj sib | 4011 | 2844 | 4955 | 4355 | 4266 | 5721 | 2107 | 2361 | 2385 | 2240 | 4344 |
| 2 | Napo 63 | 5794 | 2811 | 4300 | 3988 | 4647 | 5412 | 2320 | 2284 | 2787 | 2209 | 3849 |
| 3 | C-273 | 3437 | 1811 | 4133 | 2611 | 4034 | 4336 | 1513 | 1587 | 1905 | 1881 | 4281 |
| 4 | Huelquen | 4066 | 2322 | 3977 | 2055 | 5033 | 6176 | 2422 | 2397 | 4170 | 1957 | 4330 |
| 5 | NP 824 | 4905 | 1011 | 3444 | 2311 | 4860 | 5869 | 1038 | 935 | 1007 | 1978 | 4491 |
| 6 | Mendos | 728 | 1644 | 2722 | 2766 | 4574 | 3815 | 1418 | 1906 | 2385 | 1882 | 3617 |
| 7 | Lerma Rojo 64A | 1351 | 2095 | 3266 | 4666 | 4869 | 5610 | 2390 | 3004 | 4173 | 1920 | 4677 |
| 8 | Justin | 3973 | 1533 | 2255 | 1367 | 3649 | 4386 | 1933 | 2394 | 2961 | 1928 | 3336 |
| 9 | Giza 150 | 833 | 1722 | 3222 | 2000 | 5246 | 5152 | 1743 | 1840 | 2553 | 2106 | 4869 |
| 10 | NI 832 | 5411 | 1261 | 3511 | 2066 | 5164 | 5786 | 776 | 798 | 1103 | 2150 | 4143 |
| 11 | Chris | 1752 | 1894 | 2444 | 1617 | 3993 | 4975 | 1981 | 2633 | 2925 | 1470 | 3560 |
| 12 | Nainari 60 | 2289 | 2155 | 3811 | 3988 | 5377 | 5567 | 3086 | 3128 | 3510 | 2077 | 4731 |
| 13 | Bonza 55 | 3899 | 1483 | 3877 | 2004 | 4188 | 5418 | 1721 | 2582 | 2718 | 1908 | 4379 |
| 14 | Sonora 64 | 327 | 1455 | 3322 | 4833 | 4679 | 4570 | 2019 | 2273 | 2405 | 1554 | 4112 |
| 15 | C-271 | 4553 | 761 | 5044 | 3544 | 4620 | 4103 | 916 | 1378 | 1453 | 1539 | 4727 |
| 16 | C-518 | 3850 | 483 | 3933 | 2789 | 3340 | 4596 | 945 | 1102 | 1577 | 1852 | 4018 |
| 17 | Crim | 130 | 1694 | 2689 | 2178 | 3962 | 5402 | 2284 | 2614 | 2955 | 1886 | 4292 |
| 18 | Carazinho | 839 | 855 | 2378 | 2033 | 4238 | 4842 | 2266 | 1935 | 3194 | 1520 | 3591 |
| 19 | Triple Dirk | 450 | 1322 | 1744 | 3055 | 4847 | 4950 | 2073 | 2927 | 4197 | 2303 | 4647 |
| 20 | C-591 | 3294 | 305 | 4177 | 3055 | 4307 | 4790 | 1252 | 1704 | 2050 | 1820 | 4001 |
| 21 | Penjamo 62 | 1654 | 3655 | 3789 | 4477 | 5400 | 5870 | 2426 | 2828 | 2958 | 1203 | 3395 |
| 22 | Bajio 66 | 1617 | 2078 | 4200 | 5044 | 4284 | 5639 | 2483 | 2019 | 2572 | 1445 | 2793 |
| 23 | C-306 | 3671 | 983 | 3200 | 3333 | 5037 | 4716 | 1404 | 1773 | 1848 | 1947 | 4425 |
| 24 | Pj sib x Gb55(r) | 660 | 1878 | 3555 | 4166 | 5073 | 6038 | 2327 | 2897 | 3632 | 2018 | 5052 |
| 25 | NP 881 | 2943 | 2261 | 3900 | 2955 | 4651 | 5300 | 2530 | 2859 | 2934 | 1529 | |
| 26 | Giza 144 | 1425 | 1433 | 2944 | 1711 | 5618 | 5861 | 2017 | 1979 | 2940 | 2535 | 4491 |
| 27 | Bonza 63 | 4677 | 2239 | 3822 | 2033 | 4134 | 5142 | 1734 | 2030 | 3194 | 2821 | 3319 |
| 28 | Pj sib x Gb55(w) | 944 | 2478 | 3977 | 3800 | 5409 | 6618 | 2134 | 2515 | 3279 | 2146 | 5506 |
| 29 | Pakistan 5725 | 3319 | 500 | 4900 | 3755 | 4456 | 3628 | 1121 | 938 | 1766 | 2203 | 4170 |
| 30 | Tiba 63 | 4745 | 2933 | 3400 | 2300 | 4297 | 4625 | 606 | 2491 | 2933 | 1882 | 3907 |

(Continued - )

(Continued from page 15)

TABLE 2-A

| Var. No. | Variety or strain | ECUADOR Sta. Catalina | MEXICO (rainfed) San Martin | MEXICO (rainfed) CIAB | MEXICO (irrig.) CIANO | U. S. A. (irrig.) Logan, Utah | U. S. A. (irrig.) Aberdeen, Idaho | U. S. A. (rainfed) St. Paul Minn. | U. S. A. (rainfed) Grand Forks Minn. | U. S. A. (rainfed) Casselton, N.D. | U. S. A. (rainfed) Palmer, Alaska | U. S. A. (rainfed) Davis Calif. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | Selkirk | 3233 | 1528 | 2789 | 800 | 3975 | 4514 | 2052 | 2564 | 2782 | 2067 | 3217 |
| 32 | Pitic 62 | 4950 | 1755 | 3711 | 4033 | 6272 | 6269 | 2926 | 3407 | 3949 | 1908 | 4615 |
| 33 | Yaqui 50 | 2468 | 225 | 4022 | 2500 | 4524 | 4758 | 2184 | 2050 | 2833 | 2170 | 3577 |
| 34 | Gabo | 586 | 1122 | 2544 | 2955 | 4892 | 4151 | 1411 | 1803 | 1108 | 2150 | 4393 |
| 35 | Tacuari | 3992 | 320 | 4311 | 2122 | 4438 | 5877 | 2367 | 2461 | 3329 | 1868 | 3609 |
| 36 | Crespo 63 | 4960 | 2844 | 4877 | 2622 | 4937 | 4588 | 2763 | 2963 | 3717 | 2419 | 4744 |
| 37 | Inia 66 | 2061 | 2736 | 5244 | 5355 | 4370 | 4904 | 3016 | 2496 | 3485 | 2010 | 4878 |
| 38 | Jaral 66 | 3184 | 2345 | 4033 | 4033 | 4033 | 4837 | 3016 | 2478 | 3050 | 1324 | 3199 |
| 39 | NP 880 | 3042 | 2272 | 3677 | 2811 | 3902 | 4195 | 1795 | 2064 | 2223 | 800 | 3475 |
| 40 | Noroeste 66 | 1320 | 2622 | 4488 | 4255 | 4574 | 5535 | 3260 | 2552 | 3350 | 1743 | 4134 |
| 41 | Roque 66 | 2567 | 1678 | 5488 | 3855 | 4638 | 5132 | 2749 | 2494 | 3450 | 1764 | 3876 |
| 42 | PI162-Chris sib x S64 | 2153 | 3455 | 5155 | 4344 | 4547 | 5505 | 2715 | 2711 | 2560 | 1093 | 3083 |
| 43 | Gaboto | 2801 | 922 | 3011 | 2289 | 3922 | 2017 | 2751 | 2751 | 3006 | 1668 | 3395 |
| 44 | Klein PetisoxRaf. | 1339 | 1672 | 2344 | 2011 | 4099 | 4523 | 2005 | 2298 | 2491 | 1229 | 3502 |
| 45 | Centrifen | 3807 | 2033 | 4233 | 3099 | 3765 | 4457 | 2751 | 2835 | 2320 | 2311 | 3773 |
| 46 | Narino 59 | 5059 | 3355 | 3222 | 2789 | 3600 | 5324 | 3274 | 2723 | 3016 | 2200 | 3822 |
| 47 | Thatcher | 845 | 1289 | 1211 | 267 | 3786 | 4803 | 1662 | 2416 | 2112 | 2598 | 2740 |
| 48 | El Gaucho | 1543 | 678 | 3322 | 1633 | 3888 | 4790 | 2440 | 2502 | 2748 | 1517 | 3310 |
| 49 | Tobari 66 | 4128 | 2403 | 5588 | 3466 | 4670 | 5796 | 2770 | 2416 | 3623 | 2014 | 4041 |
| 50 | Klein Rendidor* | 2147 | 106 | 2022 | 867 | 4828 | 4596 | -- | 1702 | 3003 | -- | 3377 |
| | Station mean yield | 2755 | 1745 | 3646 | 2939 | 4526 | 5098 | 2085 | 2278 | 2748 | 1893 | 3953 |

* local varieties have been substituted.

(Continued)

(continued from page 16) TABLE 2-A

| Var. No. | Variety or strain | ECUADOR (Sta. Catalina) | MEXICO (rainfed) San Martin | MEXICO (rainfed) CIAB | MEXICO (irrig.) CIANO | U. S. A. (irrig.) Logan, Utah | U. S. A. (irrig.) Aberdeen, Idaho | U. S. A. (rainfed) St. Paul Minn. | U. S. A. (rainfed) Grand Forks Minn. | U. S. A. (rainfed) Casselton, N.D. | U. S. A. (rainfed) Palmer, Alaska | U. S. A. (rainfed) Davis, Calif. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Latitude | | 00°22' | 19°N | 20°N | 27°N | 41°45 | 45°56N | 45°N | 45°N | 47°N | 61°N | 38°N |
| Altitude | | 3058 M | 2675 M | 1765 M | 40M | 1350M | 1320M | 294M | 294M | 276M | 60M | 16M |
| Irrig. or rainfed | | rain | rain | irrig. | irrig. | irrig. | irrig. | rain | rain | rain | rain | rain |
| Fertilizer applied | | NPK | NP | NP | NP | N | N | 0 | NPK | 0 | NPK | 0 |
| Date seeded | | Mar. 6 | June9 | | Dec. 5 | May7 | Apr. 4 | May5 | Apr. 25 | May16 | May12 | Jan. 28 |
| Lodging | | + | + | ++ | ++ | | t | 0 | + | + | - | + |
| Diseases stem rust | | + | ++ | + | - | - | + | + | ++ | ++ | - | - |
| leaf rust | | + | + | t | ++ | - | - | + | + | ++ | - | - |
| stripe rust | | ++ | ++ | + | - | - | + | - | - | - | - | - |
| Other diseases | | sept. | - | - | - | mildw. | - | - | - | shatter | - | - |
| Other factors | | | - | insects | - | crusting | - | - | gophers | dry&cold | - | weather |
| Area harvested | | 2.70m² | 3m² | 1.5m² | 3m² | 1.49m² | 3.4m² | 1.49m² | 2.97m² | 3.2m² | 2.45m² | 2.97m² |
| Conversion factor | | 1.234 | 1.111 | 2.222 | I.111 | 2.269 | 0.961 | 2.269 | 1.133 | 1.025 | 1.389 | 1.133 |

TABLE 2B--Preliminary Report of the Third International Spring Wheat Yield Nursery 1966-67. Locations yield in kilos per hectare.

INTERNATIONAL MAIZE AND WHEAT IMPROVEMENT CENTER (CIMMYT)

| Var. No. | Variety or strain | CANADA Sas-katoon | Regina | Winni-peg | S. AFRICA Mac-donald Col. | Ste-llen-bosch | Rus-ten-burg | Rivier-son-derend |
|---|---|---|---|---|---|---|---|---|
| 1 | Nar sib$^2$xPj sib | 3009 | 1483 | 3705 | 3232 | 1645 | 4684 | 2446 |
| 2 | Napo 63 | 2940 | 1263 | 3950 | 3115 | 1307 | 3374 | 2360 |
| 3 | C-273 | 2550 | 1183 | 2417 | 2740 | 662 | 4621 | 980 |
| 4 | Huelquen | 3921 | 1750 | 4078 | 3347 | 1785 | 4912 | 2216 |
| 5 | NP 824 | 2839 | 1461 | 2511 | 3841 | 802 | 4382 | 1600 |
| 6 | Mendos | 2712 | 1458 | 3078 | 3325 | 1127 | 4374 | 2406 |
| 7 | Lerma Rojo 64A | 3285 | 1626 | 4578 | 3258 | 2002 | 5503 | 2511 |
| 8 | Justin | 2173 | 1367 | 2830 | 3365 | 1447 | 2889 | 2246 |
| 9 | Giza 150 | 2599 | 1576 | 3388 | 3946 | 677 | 4805 | 2623 |
| 10 | NP 832 | 2520 | 1425 | 2450 | 3901 | 697 | 4287 | 1761 |
| 11 | Chris | 2986 | 1550 | 3520 | 2637 | 1520 | 3383 | 2360 |
| 12 | Nainari 60 | 3582 | 1482 | 4525 | 3916 | 1138 | 4837 | 2944 |
| 13 | Bonza 55 | 2930 | 1573 | 3727 | 3216 | 1474 | 3799 | 2204 |
| 14 | Sonora 64 | 2658 | 1204 | 3813 | 3387 | 1562 | 6004 | 1490 |
| 15 | C-271 | 2494 | 1341 | 2091 | 3242 | 291 | 4556 | 1375 |
| 16 | C-518 | 2476 | 1541 | 2137 | 2569 | 289 | 4838 | 702 |
| 17 | Crim | 2580 | 1612 | 3430 | 2620 | 2150 | 4147 | 2726 |
| 18 | Carazinho | 3617 | 1445 | 3761 | 3401 | 888 | 3892 | 3513 |
| 19 | Triple Dirk | 2835 | 1594 | 3833 | 3720 | 1606 | 4245 | 3882 |
| 20 | C-591 | 2503 | 1353 | 2456 | 3240 | 604 | 4454 | 947 |
| 21 | Penjamo 62 | 2948 | 1840 | 4364 | 3278 | 1419 | 5314 | 2733 |
| 22 | Bajio 66 | 2948 | 1344 | 4283 | 3663 | 1487 | 5672 | 1868 |
| 23 | C-306 | 2418 | 1368 | 2811 | 3609 | 665 | 4343 | 493 |
| 24 | Pj sibxGb55(red) | 3229 | 1665 | 4150 | 3680 | 1187 | 5105 | 3047 |
| 25 | NP 881 | 2823 | 1544 | 3915 | 3466 | 1302 | 4327 | 1982 |
| 26 | Giza 144 | 2385 | 1480 | 3479 | 4174 | 737 | 4112 | 1548 |
| 27 | Bonza 63 | 2621 | 1793 | 3738 | 3395 | 850 | 4004 | 2118 |
| 28 | Pj sibxGb55(w) | 2730 | 1905 | 4320 | 3831 | 1342 | 4950 | 3204 |
| 29 | Pakistan 5725 | 2908 | 1523 | 2088 | 1706 | 578 | 5479 | 403 |
| 30 | Tiba 63 | 1970 | 1268 | 3069 | 3815 | 1745 | 4625 | 1669 |
| 31 | Selkirk | 2494 | 1293 | 3536 | 2968 | 1405 | 3331 | 1997 |
| 32 | Pitic 62 | 3951 | 1821 | 5060 | 4280 | 1771 | 5281 | 3232 |
| 33 | Yaqui 50 | 2612 | 1152 | 3765 | 3002 | 1563 | 4683 | 2018 |
| 34 | Gabo | 3115 | 1594 | 2910 | 3976 | 799 | 5266 | 2169 |
| 35 | Tacuari | 2748 | 1527 | 3457 | 3843 | 2184 | 4028 | 3349 |
| 36 | Crespo 63 | 2955 | 1749 | 4232 | 3893 | 1832 | 4218 | 2871 |
| 37 | Inia 66 | 3205 | 1613 | 4657 | 3103 | 1786 | 5557 | 3968 |
| 38 | Jaral 66 | 2616 | 1217 | 4089 | 3801 | 1424 | 4730 | 1964 |
| 39 | NP 80 | 1758 | 632 | 2956 | 3244 | 1668 | 4241 | 2034 |
| 40 | Noroeste 66 | 2964 | 1337 | 4902 | 3555 | 1987 | 5027 | 2523 |
| 41 | Roque66 | 3091 | 1720 | 4228 | 3355 | 1575 | 5175 | 1498 |
| 42 | Pi62 Chris sibxS64 | 2683 | 1098 | 3763 | 3662 | 1805 | 4964 | 2543 |
| 43 | Gaboto | 2451 | 1264 | 3199 | 3252 | 760 | 3806 | 3042 |
| 44 | Klein Petiso x Raf. | 2159 | 1258 | 3908 | 2571 | 1104 | 4324 | 2694 |
| 45 | Centrifen | 2133 | 1079 | 3446 | 2478 | 970 | 4596 | 3122 |

(Continued)

TABLE 2-B (continued)

| Var. No. | Variety or strain | CANADA Saskatoon | CANADA Regina | CANADA Winnipeg | Macdonald Col. | S. AFRICA Stellenbosch | S. AFRICA Rustenburg | S. AFRICA Riviersonderend |
|---|---|---|---|---|---|---|---|---|
| 46 | Narino 59 | 2371 | 1633 | 3267 | 4020 | 1664 | 3995 | 1989 |
| 47 | Thatcher | 2641 | 1331 | 3135 | 2948 | 1348 | 1936 | 3212 |
| 48 | El Gaucho | 2630 | 1014 | 2346 | 3123 | 619 | 2841 | 2075 |
| 49 | Tobari 66 | 2528 | 1731 | 4595 | 3476 | 1772 | 4852 | 2364 |
| 50 | Klein Rendidor | 2503 | 964 | 3450 | -- | 222 | 3601 | 2676 |
| | Average | 2782.32 | 1441 | 3548 | 3371 | 1265 | 4488 | 2256 |
| | Latitude | 52°N | 50°N | 50°N | 45°N | 33°56'S | 25°S | 34°S |
| | Altitude | 509M | 565M | 225M | 28M | 90M | 1230M | 150M |
| | Irrig. or rainfed | rain | rain | rain | rain | irrig. | irrig. | rain |
| | Fertilizer applied | 0 | NP | N+P | NPK | N+P | N | N |
| | Date seeded | 5/17 | 5/24 | 5/19 | 5/5 | 12/29 | 6/2 | 5/11 |
| | Lodging | t | + | + | + | 0 | ++ | - |
| | Disease: stem rust | - | - | late | - | +++ | + | - |
| | leaf rust | - | - | late | - | + | - | - |
| | stripe rust | - | - | 0 | - | 0 | - | - |
| | Other disease | saw-fly | - | - | pow. mild. | - | - | septor. |
| | Other problems | v.dry | drouth | - | - | - | aphid | - |
| | Area harvested | $1.86m^2$ | $2.98m^2$ | $1.51m^2$ | $1.70m^2$ | $3m^2$ | $3m^2$ | $3m^2$ |
| | Conversion factor | 1.814 | 1.111 | 2.203 | 1.984 | 1.111 | 1.111 | 1.111 |

Table 2-B

| Var. No. | Variety or Strain | MOROCCO Rabat | LYBIA Sidi Mesri | EGYPT Sakha | SUDAN Ed Damer | SUDAN Kashmel Girba A | SUDAN Kashmel Girba B | EGYPT Giza |
|---|---|---|---|---|---|---|---|---|
| 1 | Nar sib$^2$xPj sib | 2478 | 4895 | 1577 | 1722 | 589 | 304 | 6483 |
| 2 | Napo 63 | 1711 | 4184 | 1577 | 2150 | 750 | 259 | 5788 |
| 3 | C-273 | 2422 | 3636 | 1755 | 1128 | 868 | 522 | 4661 |
| 4 | Huelquen | 2877 | 3251 | 2178 | 1728 | 609 | 597 | 4511 |
| 5 | NP 824 | 2088 | 3621 | 2261 | 1755 | 720 | 650 | 5677 |
| 6 | Mendos | 3477 | 4206 | 2533 | 2261 | 1085 | 743 | 5338 |
| 7 | Lerma Rojo 64A | 2700 | 3703 | 3233 | 2083 | 1118 | 693 | 6694 |
| 8 | Justin | 1244 | 2177 | 1378 | 2122 | 87 | 28 | 1450 |
| 9 | Giza 150 | 2466 | 3362 | 1550 | 1527 | 1313 | 753 | 5922 |
| 10 | NP832 | 2411 | 4606 | 2589 | 1688 | 892 | 582 | 5005 |
| 11 | Chris | 2000 | 2916 | 2005 | 1150 | 711 | 431 | 4088 |
| 12 | Nainari 60 | 1989 | 3962 | 2244 | 1672 | 960 | 628 | 5288 |
| 13 | Bonza 55 | 2366 | 4176 | 1565 | 1467 | 763 | 383 | 3344 |
| 14 | Sonora 64 | 2222 | 4058 | 1472 | 1794 | 655 | 292 | 7155 |
| 15 | C-271 | 2422 | 5287 | 2583 | 1389 | 682 | 855 | 5164 |
| 16 | C-518 | 1539 | 4554 | 1883 | 1255 | 1071 | 803 | 5577 |
| 17 | Crim | 3172 | 4184 | 1894 | 383 | 310 | 210 | 3905 |
| 18 | Carazinho | 1911 | 3606 | 2111 | 711 | 749 | 473 | 4861 |
| 19 | Triple Dirk | 3622 | 4443 | 1928 | 767 | 1140 | 565 | 4788 |
| 20 | C-591 | 1222 | 4176 | 1855 | 1339 | 1168 | 805 | 3955 |

(Continued)

TABLE 2-B (Continued)

| Var. No. | Variety or strain | MOROCCO Rabat | LYBIA Sidi Mesri | EGYPT Sakha | SUDAN Ed Damer | SUDAN Kashmel A | SUDAN Girba B | EGYPT Giza |
|---|---|---|---|---|---|---|---|---|
| 21 | Penjamo 62 | 2511 | 4606 | 2594 | 1833 | 1057 | 700 | 7243 |
| 22 | Bajio 66 | 1955 | 4332 | 806 | 1678 | 604 | 249 | 7432 |
| 23 | C-306 | 2778 | 4591 | 2355 | 1561 | 1575 | 948 | 4816 |
| 24 | Pj sib x Gb55(red) | 4022 | 4969 | 2305 | 1222 | 1090 | 557 | 8377 |
| 25 | NP 881 | 2578 | 4776 | 2239 | 1183 | 414 | 563 | 4905 |
| 26 | Giza 144 | 2900 | 3740 | 2028 | 1217 | 1172 | 789 | 5233 |
| 27 | Bonza 63 | 2433 | 5021 | 1839 | 1128 | 750 | 392 | 4249 |
| 28 | Pj sib x Gb55(w) | 3600 | 3628 | 2650 | 1267 | 1269 | 513 | 5549 |
| 29 | Pakistan 5725 | 1722 | 5295 | 2049 | 1827 | 1378 | 609 | 7583 |
| 30 | Tiba 63 | 1989 | 4310 | 2239 | 1839 | 993 | 483 | 5011 |
| 31 | Selkirk | 2389 | 2947 | 1305 | 211 | 183 | -- | 2283 |
| 32 | Pitic 62 | 2689 | 5650 | 3283 | 1728 | 858 | 307 | 6149 |
| 33 | Yaqui 50 | 2500 | 4028 | 2922 | 1111 | 985 | 406 | 4600 |
| 34 | Gabo | 2911 | 4710 | 2055 | 2005 | 1080 | 603 | 3933 |
| 35 | Tacuari | 2466 | 3288 | 2122 | 1255 | 821 | 524 | 4272 |
| 36 | Crespo 63 | 3177 | 4339 | 2533 | 1633 | 1076 | 637 | 4427 |
| 37 | Inia 66 | 2555 | 4147 | 2055 | 1894 | 688 | 407 | 6122 |
| 38 | Jaral 66 | 2255 | 4147 | 1228 | 1355 | 422 | 144 | 6472 |
| 39 | NP 880 | 2855 | 4517 | 2716 | 1350 | 1235 | 629 | 4666 |
| 40 | Noroeste 66 | 2311 | 4295 | 3622 | 1805 | 1345 | 287 | 6600 |
| 41 | Roque 66 | 2166 | 4539 | 1172 | 1483 | 434 | 268 | 7394 |
| 42 | Pi62 Chris sibxS64 | 2889 | 4139 | 850 | 367 | 739 | 238 | 6655 |
| 43 | Gaboto | 2433 | 3192 | 2072 | 1900 | 702 | 482 | 4033 |
| 44 | Klein Petiso x Raf. | 2011 | 2503 | 2038 | 1472 | 851 | 157 | 4566 |
| 45 | Centrifen | 1655 | 3991 | 2783 | 1400 | 336 | 80 | 5888 |
| 46 | Narino 59 | 2466 | 4413 | 2472 | 1100 | 957 | 358 | 3744 |
| 47 | Thatcher | 1489 | 903 | 861 | 67 | 62 | 0 | 644 |
| 48 | El Gaucho | 1878 | 3391 | 1883 | 105 | 145 | 98 | 2939 |
| 49 | Tobari 66 | 2722 | 3880 | 2072 | 1833 | 951 | 342 | 5916 |
| 50 | Klein Rendidor | 2278 | 2607 | 2387 | 1189 | 0 | -- | 5594 |
| | Average | 2419 | 3998 | 2074 | 1382 | 808 | 447 | 5139 |
| | Latitude | 34°N | 32°N | 31°N | 17°35'N | 15°N | 15°N | 31°N |
| | Altitude | 25M | 25M | 21M | 353M | 440M | 440M | 21M |
| | Irrig. or rainfed | rain | irrig. | irrig. | irrig. | irrig. | irrig. | irrig. |
| | Fertilizer applied | NPK | NP | N+P | N | NP | 0 | N+P |
| | Date seeded | 11/28 | 11/10 | 11/20 | 12/6 | 12/1 | 12/9 | 11/30 |
| | Lodging | + | + | + | - | - | - | ++ |
| | Disease: stem rust | - | + | 0 | - | - | - | + |
| | leaf rust | - | ++ | ++ | - | - | - | + |
| | stripe rust | - | + | - | - | - | - | - |
| | Other disease | - | mild. | - | - | - | - | - |
| | Other problems | - | shat. | birds | weeds | sown out | seas. | |
| | Area harvested | 3m² | 2.25m² | 3m² | 3m² | 3m² | 3m² | 3m² |
| | Conversion factor | 1.111 | 1.481 | 1.111 | 1.111 | 1.111 | 1.111 | 1.111 |

TABLE 2-C--Preliminary Yield Information from the Third International Spring Wheat Yield Nursery for 1966-67. International Maize and Wheat Improvement Center (CIMMYT)

| | | TURKEY | | CYPRUS | LEBANON | | JORDAN | ISRAEL |
|---|---|---|---|---|---|---|---|---|
| Var. No. | Variety or strain | Adapazari | Eskisehir | Syngrassi | Beirut | Tel Amara | Deir Alla | Beit Dagam |
| 1 | Nar sib$^2$xPj sib | 3777 | 2222 | 3677 | 2947 | 3694 | 265 | 6119 |
| 2 | Napo 63 | 3455 | 2189 | 3177 | 3137 | 3736 | 478 | 5999 |
| 3 | C-273 | 2644 | 1311 | 2311 | 2004 | 2494 | 1922 | 5483 |
| 4 | Huelquen | 2755 | 2178 | 3277 | 2226 | 2566 | 1122 | 6733 |
| 5 | NP 824 | 2600 | 1567 | 2877 | 2229 | 2916 | 2022 | 4672 |
| 6 | Mendos | 3011 | 1244 | 2666 | 2226 | 2628 | 1789 | 3940 |
| 7 | Lerma Rojo 64A | 5032 | 2478 | 3266 | 3524 | 3694 | 1567 | 8129 |
| 8 | Justin | 2933 | 1822 | 1953 | 4092 | 2022 | 1500 | 1293 |
| 9 | Giza 150 | 2477 | 1011 | 1878 | 2492 | 2683 | 1211 | 4593 |
| 10 | NP 832 | 2300 | 1488 | 3000 | 2349 | 3116 | 2355 | 4246 |
| 11 | Chris | 2522 | 1199 | 1922 | 2162 | 2019 | 1822 | 4593 |
| 12 | Nainari 60 | 3444 | 1822 | 3333 | 2571 | 3283 | 2555 | 5253 |
| 13 | Bonza 55 | 2311 | 2133 | 3060 | 2509 | 2422 | 1733 | 4895 |
| 14 | Sonora 64 | 3678 | 1589 | 2178 | 2592 | 2911 | 311 | 5253 |
| 15 | C-271 | 3355 | 1261 | 2855 | 2317 | 3411 | 2155 | 5888 |
| 16 | C-518 | 2778 | 1372 | 2200 | 2692 | 2683 | 1711 | 4796 |
| 17 | Crim | 2478 | 1955 | 2433 | 3029 | 2678 | 1800 | 4316 |
| 18 | Carazinho | 3988 | 1811 | 2989 | 2304 | 3244 | 2289 | 5476 |
| 19 | Triple Dirk | 3744 | 1378 | 3211 | 2859 | 3494 | 2255 | 5446 |
| 20 | C-591 | 2733 | 1550 | 2311 | 1721 | 2872 | 1844 | 4846 |
| 21 | Penjamo 62 | 2777 | 1278 | 3411 | 2634 | 3010 | 1144 | 6829 |
| 22 | Bajio 66 | 2711 | 1661 | 3033 | 2626 | 3844 | 522 | 6917 |
| 23 | C-306 | 2977 | 2100 | 2444 | 3199 | 3355 | 1778 | 4768 |
| 24 | Pj sibxGb55(red) | 3633 | 1966 | 3666 | 3542 | 1900 | 1478 | 6486 |
| 25 | NP 881 | 2400 | 1766 | 2899 | 2437 | 2400 | 1611 | 5139 |
| 26 | Giza 144 | 2044 | 1150 | 2444 | 2426 | 1955 | 1778 | 3417 |
| 27 | Bonza 63 | 2966 | 2289 | 2811 | 2925 | 2400 | 867 | 3103 |
| 28 | Pj sibxGb55(w) | 2977 | 2166 | 3021 | 2751 | 2466 | 733 | 5844 |
| 29 | Pakistan 5725 | 2489 | 1467 | 1322 | 2717 | 3516 | 1111 | 5356 |
| 30 | Tiba 63 | 2744 | 1989 | 2478 | 2617 | 3450 | 478 | 4383 |
| 31 | Selkirk | 2022 | 1244 | 1367 | 2159 | 1928 | 744 | 2413 |
| 32 | Pitic 62 | 3988 | 2778 | 4021 | 3175 | 3616 | 2055 | 2923 |
| 33 | Yaqui 50 | 3566 | 2144 | 2787 | 3262 | 3422 | 1111 | 5369 |
| 34 | Gabo | 1678 | 867 | 1667 | 3204 | 2150 | 1900 | 2820 |
| 35 | Tacuari | 3477 | 2166 | 2766 | 2429 | 2083 | 2711 | 5989 |
| 36 | Crespo 63 | 2977 | 2011 | 3189 | 2729 | 2883 | 1322 | 2760 |
| 37 | Inia 66 | 2822 | 2389 | 3222 | 2507 | 3733 | 700 | 7409 |
| 38 | Jaral 66 | 2055 | 1617 | 2300 | 2776 | 2883 | 211 | 6209 |
| 39 | NP 880 | 2722 | 1355 | 2710 | 1279 | 3305 | 1911 | 5509 |
| 40 | Noroeste 66 | 4244 | 2266 | 2721 | 2842 | 3433 | 489 | 7486 |
| 41 | Roque 66 | 2611 | 1989 | 2622 | 2609 | 2366 | 233 | 6179 |
| 42 | P162-Ch.sibxS64 | 3444 | 2044 | 3011 | 2417 | 3100 | 389 | 6816 |
| 43 | Gaboto | 2899 | 1789 | 2700 | 2681 | 2389 | 2355 | 5329 |
| 44 | Klein Pet. x Raf. | 3044 | 1605 | 2944 | 2018 | 2916 | 778 | 5423 |
| 45 | Centrifen | 2055 | 1789 | 2687 | 2576 | 2694 | 1067 | 6333 |

(Continued)

TABLE 2-C (continued)

| Var. No. | Variety or strain | TURKEY Ada-pazari | TURKEY Eskise-hir | CYPRUS Syn-grassi | LEBANON Beirut | LEBANON Tel Amara | JORDAN Deir Alla | ISRAEL Beit Dagam |
|---|---|---|---|---|---|---|---|---|
| 46 | Narino 59 | 3633 | 2122 | 2678 | 2242 | 2439 | 489 | 5103 |
| 47 | Thatcher | 2089 | 1239 | 1244 | 2371 | 1816 | 444 | 1906 |
| 48 | El Gaucho | 2089 | 1978 | 2187 | 2212 | 1989 | 1744 | 4720 |
| 49 | Tobari 66 | 2700 | 1650 | 2578 | 2801 | 2794 | 1389 | 7079 |
| 50 | Klein Rendidor | 2266 | 2200 | 2366 | 2801 | 3122 | 611 | 5353 |
| | Station mean yield | 2942 | 1775 | 2677 | 2619 | 2838 | 1318* | 5203 |
| | Latitude | 40°N | 36°45 | N35°6' | N33°50 | N33°N | 32°12' | N 32°N |
| | Altitude | 33M | 789M | 50M | 995M | 950M | -70M | 28M |
| | Irrig. or rainfed | rain | rain | rain | rain | rain | irrig. | rain |
| | Fertilizer applied | NPK | P | N+P | NP | NPK | 0 | NP |
| | Date seeded | 12/25 | 3/23 | | 11/8 | 12/12 | 11/23 | 12/3 |
| | Lodging | t | + | t | | t | + | + |
| | Diseases: stem rust | t | t | - | | ++ | + | - |
| | leaf rust | ++ | + | + | | ++ | ++ | ++ |
| | Stripe rust | + | ++ | - | | ++ | + | + |
| | Other disease | - | - | mild. | - | - | - | - |
| | Other problems | - | shat. | weeds | - | - | birds | - |
| | Area harvested | $3m^2$ | $3m^2$ | $3m^2$ | $2m^2$ | $3m^2$ | $3m^2$ | $3m^2$ |
| | Conversion factor | 1.111 | 1.111 | 1.111 | 1.666 | 1.111 | 1.111 | 1.111 |

* Data not used because of severe bird damage.

TABLE 2-C

| Var. No. | Variety or strain | IRAN Gorgan | IRAN Ahwaz | SAUDI ARABIA Dirab | IRAQ Baghdad | PAKISTAN Lyallpur | INDIA Pusa Biheer |
|---|---|---|---|---|---|---|---|
| 1 | Nar $sib^2xPj$ sib | 2622 | 4788 | 1189 | 3738 | 5136 | 1778 |
| 2 | Napo 63 | 3422 | 4922 | 836 | 3665 | 4753 | 1889 |
| 3 | C-273 | 3533 | 4255 | 2284 | 3142 | 3676 | 1722 |
| 4 | Huelquen | 3277 | 5922 | 1315 | 3017 | 3263 | 2444 |
| 5 | NP 824 | 2966 | 5288 | 1868 | 3427 | 3683 | 1833 |
| 6 | Mendos | 2678 | 4722 | 1119 | 3862 | 2662 | 2666 |
| 7 | Lerma Rojo 64A | 3444 | 6011 | 1223 | 4405 | 5026 | 3277 |
| 8 | Justin | 2433 | 3266 | 954 | 2581 | -- | 333 |
| 9 | Giza 150 | 2744 | 5488 | 1261 | 3625 | 2486 | 2444 |
| 10 | NP 832 | 2966 | 5332 | 1591 | 3692 | 3680 | 2222 |
| 11 | Chris | 2933 | 3844 | 1237 | 2781 | 3021 | 2499 |
| 12 | Nainari 60 | 3233 | 6011 | 1617 | 3661 | 4564 | 3277 |
| 13 | Bonza 55 | 3066 | 4255 | 1780 | 4018 | 2675 | 1944 |
| 14 | Sonora 64 | 2889 | 5033 | 713 | 3315 | 4913 | 1667 |
| 15 | C-271 | 2855 | 5011 | 1462 | 4413 | 3638 | 1555 |
| 16 | C-518 | 3033 | 5388 | 2139 | 3130 | 2964 | 1944 |
| 17 | Crim | 2911 | 4666 | 1480 | 4026 | 2406 | 2333 |
| 18 | Carazinho | 3119 | 4788 | 1420 | 2621 | 2711 | 2444 |
| 19 | Triple Dirk | 3255 | 4788 | 1578 | 4026 | 3523 | 3555 |
| 20 | C-591 | 3333 | 4822 | 1773 | 3625 | 3553 | 1944 |

(Continued)

TABLE 2-C (Continued)

| Var. No. | Variety or strain | IRAN Gorgan | IRAN Ahwaz | SAUDI ARABIA Dirab | IRAQ Baghdad | PAKISTAN Lyallpur | INDIA Pusa Biheer |
|---|---|---|---|---|---|---|---|
| 21 | Penjamo 62 | 3044 | 5422 | 688 | 4825 | 4074 | 3499 |
| 22 | Bajio 66 | 2289 | 5077 | 1102 | 5159 | 4267 | 2222 |
| 23 | C-306 | 3929 | 5577 | 2298 | 4403 | 3573 | 2389 |
| 24 | Pj sibxGb55(red) | 4133 | 5388 | 1232 | 5142 | 4504 | 2889 |
| 25 | NP 881 | 3344 | 4844 | 1042 | 3352 | 2927 | 2333 |
| 26 | Giza 144 | 2633 | 5222 | 1659 | 3121 | 2668 | 2833 |
| 27 | Bonza 63 | 2855 | 4344 | 1229 | 2774 | 2730 | 2389 |
| 28 | Pj sib xGb55(w) | 3777 | 5377 | 2302 | 4278 | 4645 | 2000 |
| 29 | Pakistan 5725 | 3044 | 5544 | 1325 | 4254 | 4581 | 2050 |
| 30 | Tiba 63 | 2929 | 4122 | 1079 | 3857 | 4217 | 1555 |
| 31 | Selkirk | 2066 | 3066 | 857 | 3156 | -- | 833 |
| 32 | Pitic 62 | 4177 | 5977 | 1839 | 4127 | 3507 | 3333 |
| 33 | Yaqui 50 | 2822 | 4688 | 1082 | 4112 | 3387 | 2222 |
| 34 | Gabo | 2433 | 4911 | 1581 | 3825 | 3517 | 3110 |
| 35 | Tacuari | 2789 | 4766 | 1607 | 3975 | 2762 | 2778 |
| 36 | Crespo 63 | 3189 | 5166 | 2316 | 4140 | 3679 | 2722 |
| 37 | Inia 66 | 3900 | 4788 | 766 | 3558 | 5593 | 3666 |
| 38 | Jaral 66 | 2722 | 4133 | 797 | 3917 | 4236 | 1778 |
| 39 | NP 880 | 2578 | 3833 | 1405 | 3440 | 2770 | 2222 |
| 40 | Noroeste 66 | 3811 | 4311 | 1055 | 2909 | 4394 | 2666 |
| 41 | Roque 66 | 2966 | 4655 | 1240 | 3319 | 3745 | 2333 |
| 42 | P162-Ch.sibxS64 | 2833 | 4544 | 984 | 3599 | 4530 | 1944 |
| 43 | Gaboto | 2622 | 4644 | 1628 | 3953 | 2625 | 2333 |
| 44 | Klein Pet. x Raf. | 3266 | 3633 | 1443 | 3017 | 3428 | 2333 |
| 45 | Centrifen | 2522 | 3477 | 1324 | 2529 | 3585 | 2111 |
| 46 | Narino 59 | 3166 | 4311 | 1270 | 3546 | 3298 | 2222 |
| 47 | Thatcher | 2589 | 2511 | 560 | 2195 | -- | 167 |
| 48 | El Gaucho | 2499 | 3611 | 1350 | 3315 | 2346 | 1889 |
| 49 | Tobari 66 | 3077 | 5411 | 1619 | 2664 | 3413 | 2333 |
| 50 | Klein Rendidor | 3155 | 4755 | 1271 | -- | 4848 | 2666 |
| | Station mean yield | 3037 | 4734 | 1376 | 3658 | 3685 | 2272 |
| | Latitude | 36°51'N | 31°20'N | 24°N | 33°N | 31°3'N | 25°59'N |
| | Altitude | 50M | 20M | 570M | | 213M | 165M |
| | Irrig. or rainfed | irrig. | rain | irrig. | irrig. | irrig. | irrig. |
| | Fertilizer applied | 0 | 0 | N | 0 | N+P | NPK |
| | Date seeded | 12/24 | | 11/28 | 12/5 | 11/16 | 12/18 |
| | Lodging | - | t | + | t | + | 0 |
| | Diseases: stem rust | - | | - | - | + | - |
| | leaf rust | - | + | - | - | + | + |
| | stripe rust | ++ | + | - | - | + | - |
| | Other disease | - | - | - | - | - | - |
| | Other problems | v.dry | cold | frost | - | - | birds |
| | Area harvested | $3m^2$ | $3m^2$ | $3m^2$ | $3.6m^2$ | $3m^2$ | $3m^2$ |
| | Conversion Factor | 1.111 | 1.111 | 1.111 | .926 | 1.0 | 1.111 |

# USING MALE-STERILITY TO AID IN LOCATING SOURCES OF HIGH YIELD GENES

(Abstract)

R. W. Livers

Techniques to aid in discovering parental wheat stocks which can contribute genes for increasing yields would be useful in any program of breeding improved varieties or hybrids. Performance of potential parent varieties themselves has been the best guide in choosing which parents to use. Now that male-sterile and fertility-restoring varieties are becoming available, we can begin to consider additional information from field performance of $F_1$ hybrids as a guide in evaluation of parental stocks. Furthermore, this gives us a means of detecting good yield potential in varieties which themselves are not adapted in an area. For example, Tascosa is not hardy enough to give good yields in central Kansas. However, data from $F_1$ hybrids suggests that Tascosa is a promising donor of yield genes in crosses with adapted Kansas varieties.

We have now the opportunity to grow $F_1$'s between adapted and non-adapted wheats in the field. Crosses can be made in the greenhouse by pollinating adapted male-steriles with selected exotic strains. Growing $F_1$'s in the field might reveal some $F_1$'s of exceptional vigor, but these $F_1$'s would usually be male-sterile or nearly so.

We can carry this idea one step farther. Suppose we cross a group of exotics on Bison male sterile in the greenhouse in sufficient quantity to grow $F_1$ plots in the field. Inter-plant these $F_1$ field plots (in an isolated area) with a fertility-restoring pollinator such as Cheyenne restorer. Assuming the $F_1$'s to be sterile the seed production from them after pollination by Cheyenne restorer would form the basis for a yield trial. On trial would be a series of 3-way crosses: (exotics x Bison) x Cheyenne. Genetically these would be 50% Cheyenne, 25% Bison and 25% exotic. A three-way cross with high performance would suggest that the particular exotic involved is contributing something useful to yield. We would be seeing the effects of different exotic donors in a uniform genetic background, the 75% contribution of adapted varieties.

# BREEDING FOR YIELD IN WHEAT

D. R. Knott

In Canada we seem to have a particularly difficult time combining high yield with high milling and baking quality. Both are complex in inheritance and are difficult to measure until fairly advanced generations when material is reasonably homozygous although early generation testing shows some promise. Under normal breeding procedures, by the time testing is started the number of lines has been reduced to the point where the chance that one will be both high yielding and high quality is relatively low. To get around this we are trying a system as follows:

1. Make a cross in the greenhouse in the fall.

2. Grow the $F_1$ plants in the greenhouse in the spring.

3. Grow the $F_2$ population in the field during the summer and select for the more heritable characteristics such as height, maturity, plant type and disease resistance.

4. Take one or more seeds from each $F_2$ plant and plant very thickly in the greenhouse in the fall (the number of seeds taken from one plant depends on the population desired.)

5. Repeat the process by taking one seed from each $F_3$ plant and plant in the greenhouse in the spring.

6. Grow $F_5$ rows in the field. If desired frequent checks can be planted and yield measured. An initial protein analysis can be done on the seed.

7. A preliminary yield test is then run on a fair number of $F_6$ lines the following year.

The material will not always be completely uniform but further purification can be done on the promising lines.

Much of the difficulty in breeding for yield could be overcome if we could develop an accurate method for measuring the yield potential of early generation material, particularly $F_2$ plants. Some years ago we tested the effectiveness of visual selection in $F_2$ plants spaced a foot apart each way. Yields were tested in the $F_3$ and the regression of $F_3$ plot yields on $F_2$ plant yields calculated. "Good" $F_2$ plants did give higher yielding $F_3$'s than "poor" $F_2$ plants did, but the $F_3$ ranges were not greatly different. The regression values varied considerably but were mostly positive. For several crosses the $F_3$ plot yields increased about 1 gm. (on a mean of about 250 gms.) - not a very useful amount.

Recent tests with various foreign varieties on the Canadian prairies have indicated that considerably higher yields are possible. Whether high quality wheats with the same high yield potential can be produced is an open question at the moment.

# IS LACK OF EQUIPMENT A PROBLEM IN WHEAT IMPROVEMENT?

(Abstract)

J. A. Wilson

Probably most breeders working with wheat observe some weaknesses in their procedures that could be corrected or alleviated provided the "proper equipment" were available. The deficiencies may be in the slowness of hand operations or inefficiencies in the equipment being used. Equipment utilized in a temporary manner sometimes becomes a permanent feature of a procedure. Recurrent improvement of technic through adapting improved equipment should be the philosophy of progressive wheat breeding programs. No one should feel that they have the ultimate in equipment, but rather seek the best available with an open-mind towards change.

Early generation improvement methods should yield useful information even though simplicity and speed are emphasized; yet, in later generations methodology must give more emphasis to accuracy. Generally, it is difficult to obtain both, and a compromise is inevitable.

The need for acquiring equipment must be determined by "cost-effectiveness-analyses". A new piece of equipment may do the same job more efficiently than 20 men or an out-of-date implement, and thereby, be economically justifiable. If the new equipment is only slightly better, it should be analyzed as to the number of years of savings required to pay back the extra or original investment. If its "pay-out" time is 10 years or more, it may be a poor investment, especially of the expected life of the equipment is not long.

Recognizing the possibilities for improvement of equipment in a procedure is the big step in making advancement in technic. The more obvious simple needs have already been recognized and dealt with, but the more complex problems have been overlooked or ignored.

With the advent of hybrid wheat breeding, bagging equipment and procedures are required. Many procedures have been tried, but no superior bagging method has been evolved for management of a large field crossing program.

Small samples used in early generation quality analyses require cleaning. The large numbers associated with this type of program requires efficient cleaning equipment that is not now available. Also, seeding procedures are made more efficient by thorough cleaning of seed before planting.

Processing of head and plant selections through threshing to packeting is largely done by hand methods. Automatic equipment that thresh, treat and packet small head samples could be of great help in the breeding effort. New machinery must be developed to achieve this objective.

Seeding rate for nursery yield plots is largely determined by weight or weight based on seed number. Seeding on the basis of seed number would be more accurate, but some sort of seed counter which operates faster than the conventional types should be developed in order to count out all the seed required for each nursery plot in the yield trial.

Nursery seeders that space-plant could be valuable in breeding programs geared to plant selection or mass selection in bulk populations. Some progress has been made with field-size planting equipment, but effort should be made in developing a practical nursery seeder.

Promising self-cleaning combines for both field and nursery plots are now available from Austria (PAM 150) and West Germany (Hege Plot Combine). However, a smaller size is still needed for combining single rows from among discard rows.

An "Equipment Newsletter" published every 3rd year as a supplement to The Wheat Newsletter could be useful as a source of compiled information on new wheat breeding innovations.

# IS LACK OF EQUIPMENT A PROBLEM IN WHEAT IMPROVEMENT?

(Abstract)

Charles Hayward

Nurseries of commercial programs are becoming quite large and in most areas reliable labor is difficult to obtain. Of necessity, much of the plant breeder's time is devoted to routine tasks when it could more profitably be utilized in research areas and/or in handling more material.

Improved versions of present plot and laboratory equipment plus new more efficient types of equipment are needed.

The wheat breeder has a distinct need for quality equipment and tests which will allow him to evaluate materials at an early generation on small amounts of seed. This equipment and tests must give reliable and repeatable results which will be accepted by other plant breeders, cereal chemists, millers and bakers.

# USE OF EQUIPMENT TO EXPAND WHEAT BREEDING PROGRAM

Walter L. Nelson

The wheat breeding program at Washington State University is dependent upon our ability to handle large populations from many crosses of diverse genetic backgrounds. To get maximum exposure to disease and climatic hazards, one or more plantings of early generation lines are seeded at as many as eight locations. Each nursery site includes about 700 of these lines planted in duplicate, and in addition one or more plantings of late generation materials for yield data under that specific disease and climatic environment. Each of these locations involves 1 to 4 acres of land, and thousands of individual plots varying in size from one row 8' long to 4-row plots up to 40 ft. long. Seeding conditions vary from ideal to extreme, often requiring deep seeding to a depth of six to eight inches. Distance to sites varies from 50 to 250 miles with some sites requiring as many as four trips to include date of seeding trials. These sites are in addition to our ten regular locations for regional and state yield nurseries, the large populations of breeding material at Pullman and Lind, and the special nurseries for the extension service.

The key to this program is two special planters, three specially equipped trucks, and cultivating and spraying equipment adapted to plot work. One eight-row planter was built and developed by Dr. O. A. Vogel. Using the same planter head, another 4-row deep furrow planter with adjustable row width was built at the Dry Land Research Unit. Each 4-row head of these planters has the capacity to seed 1000 to 3000 rows per hour depending upon row length. Each plot can be a separate row or any combination of rows. Seed is put up and stored in plastic boxes ready for planting whenever seeding conditions are favorable for study of the particular disease or environmental response, and can be planted by either planter. At two locations in 1967, two plantings were made with each planter.

Weed control is accomplished with a special 8-row roto tiller cultivator for the 8-row plantings and also with small roto-spade type garden tractors for grassy weeds. Spray application of Bromoxinil during the fall and early spring has been very effective for broad leaf weeds, especially those hard to kill with 2,4-D. These applications are put on by small sprayers designed for fast and efficient plot application.

The mechanization of harvest has not been adequately solved. The Dry Land Research Unit has used a plot combine for ten years. It has been satisfactory for the harvest of 4-row yield plots, but is limited to about 300 plots per day. Dr. O. A. Vogel is working on a harvester that should add materially to the efficiency of plot harvest.

Through the use of highly mobile special equipment at Washington State University, we have been able to screen very large populations of breeding materials under natural disease and environmental conditions in the field. At the present time a uniform set of entries was planted at locations permitting screening under natural infections of snow mold (Typhula and Fusarium), Urocystis flag smut, Cerosporella root rot, Fusarium root rot, and Cephalosporium blight disease. Next year one or more plantings will be made in Ophiobolus infected soils. Close cooperation with the plant pathologists is maintained for obtaining desirable new breeding materials, evaluations of segregating generations, and to increase, improve or develop disease epidemics.

One of the most rewarding benefits from this program is the discovery of new sources of resistance and or new levels of tolerance to some diseases from crosses made for other purposes. To mention some, our flag smut nursery revealed high resistance to Wanser, much better than either parent. Some of the new short strawed varieties show good levels of tolerance to root rot, when both parents were highly susceptible. The variety McCall was released after tests in snow mold nurseries indicated better tolerance than an equally high yeilding sister selection Wanser. This is the bonus we get from exposing the uniform sets of populations to many different disease and climatic conditions.

The success of the wheat breeding program at Washington State University is the result of close cooperation among State and Federal personnel in Agronomy, Plant Pathology and in the Wheat Quality Laboratory. Equally important is the support of the wheat industry of the state which has financed much of the cost of the new equipment and puts about $100,000 into the wheat research program each year.

# VACUUM OPERATED SPACE SEEDER

N. D. Williams

A multi-row, vacuum operated seeder suitable for seeding wheat kernels individually has been constructed. Four seeder units were mounted on the lift system of a small 4-wheel tractor. The vacuum operated seed selectors are similar to a prototype developed by I. C. Sweetman in New Zealand.

The seed selector reel consists of a 2-inch diameter steel shaft with eight holes drilled radially to accomadate Luer-loc hypodermic needle adaptors. Hypodermic needles of a suitable guage were shortened to about 1/4-inch so that the distance from the tip of the needle to the shaft is a standard length. The selector reel shaft was drilled axially to accommodate a brass vacuum head of 1 1/2-inch diameter. The vacuum head was drilled axially for vacuum and pressure connections to a groove around the circumference of the vacuum head. The groove was blocked on each side of the pressure connection. The selector reel revolves around the stationary vacuum head. A kernel becomes attached to each needle by vacuum as it revolves through a seed hopper. Each kernel is ejected from the needle into a seed tube as the needle passes over the pressurized section of the vacuum-pressure groove.

The seed selector mechanism was mounted on a flexible-type corn planter unit available commercially. The seed selector is driven from a combination press, drive, and guage wheel. Seed spacing can be regulated and varied in a wide range by varying the sprocket combinations of the drive system.

A rotary type vacuum pump driven from the fan shaft of the tractor is used to supply vacuum. Exhaust from the vacuum pump supplies positive pressure for ejecting kernels from the needles and for cleaning the needles.

The precision of plant spacing obtained with the seeder is not perfect, and occasional doubles and misses occur. Precision of spacing is affected by the amount of vacuum, guage of needle, cleanliness of seed, and position of the seed hopper. With clean seed and proper adjustment, the precision of plant spacing is adequate for most purposes.

# IS BREEDING FOR MILLING AND BAKING QUALITY AN IMPEDIMENT TO IMPROVEMENTS IN OTHER AREAS?

E. G. Heyne

We can say that nearly all characteristics of a plant species being used for economic use are or have barriers in relation to other characters in the improvement of the species by breeding. In fact that is the task at hand for the plant breeder to overcome and should be viewed as a challenge. We cannot consider any one character without consideration of other characters.

In plant breeding programs we are not interested in the status quo even though we use procedures that do not effectively allow us to transgress from the present model of the species under cultivation in a local area. A minimum objective can be stated as: The new cultivar should be equal or nearly so in all important characteristics to the one it is to replace and exceed the old cultivar in one or more important characteristics.

As we need to consider the whole species there is bound to be some interference of one character with another. For example, to be of practical value, a cultivar bred for high yield must also have a stiff or strong stalk. Some compensation for both characters may be necessary if the total objective is to be reached, and it rarely is the first time so another attempt will need to be made. Thus breeding becomes a step-wise manner of achieving the goal.

Wheat is used primarily for food and has many qualities for this purpose; it stores easily and for long periods, it can be used in a number of different ways and is a relatively nutritious plant food with above average protein content in relation to other cereal foods.

Quality, in its broad sense, should have the number one priority for the breeding objectives of wheat for the Great Plains. With proper equipment and large enough populations breeding for high quality does not offer any more impediments to wheat breeding objectives than other characters in relation to its importance.

A safeguard to breeding any species is to insist on an integrated program where all the characteristics are carefully evaluated in relation to the whole. We should avoid one-level, one-idea approaches to wheat breeding. The idea of impediments can be mind-made stumbling-blocks and I believe that with proper genetic engineering we can develop a better wheat plant in relation to all important factors of the species.

# BARRIERS TO THE IMPROVEMENT OF WHEAT

L. D. Sibbitt

Is breeding for milling and baking quality a barrier to wheat improvement? Possibly yes -- to a degree. However, as we understand, there is no shortage of wheat in the world, but there is a shortage of quality wheat. At the recent C.Q.C. Wheat Quality Conference, held in Minneapolis, Dr. Gilles presented a paper entitled "Wheat Quality -- A Vital Factor in Marketing Upper Midwest Bread Wheat and Durum". Most of the text is relevant to this question. But, of course, time does not permit another presentation of this timely article, however, I would like to quote a few pertinent sentences taken from it which are as follows:

"The traditional markets for hard red spring wheat and durum produced in the Upper Great Plains region of the United States have been the domestic markets of the United states", and "Inasmuch as per capita consumption of wheat in the U.S. has remained relatively constant for a number of years, the potential to sell increasing quantities of wheat lies primarily in the export markets." "In most of the countries of Western Europe, the vitreous, high protein common wheats and durum wheat have acceptable quality for pasta products cannot be produced." "Because the consumers in the Common Market countries prefer pasta products made from semolina, it would seem very realistic that a substantial market for durum wheats will exist in Western Europe". "The importance of spring wheat quality in the export markets appears very significant, particularly when one considers current market trends in Europe where increased local production is a rising deterrent to U.S. exports. One observes that during the current marketing year, exports of hard red winter wheat are down about 50%. In the same period, however, the exports of hard red spring in the European markets have increased by about 35,000 tons over the previous year. It is the feeling of many that this is due primarily to the fact that the quality of the hard red spring wheat currently being delivered to the European markets has desirable quality characteristics". "Throughout the world, wheats produced in the Upper Great Plains region of North America are prized for the quality and quantity of their proteins". "In my opinion, one of the quickest ways for the Upper Great Plains region to lose its wheat market will be to lose sight of the need for quality".

Needless to say that all of us in the Department of Cereal Chemistry and Technology at NDSU concur with these statements.

Other Barriers

Lack of exchange of material and information on the part of plant breeders with each other and with the cereal technologists.

a. Potential new HRS wheat varieties from other states which have shown promise from a quality standpoint in preliminary tests should be in N. D. station Field Plots for at least two years (ND produces over 50% of the U.S. spring wheat crop).

b. Proper quality conclusions cannot be formulated on the basis of one year's test.

c. A situation might arise if a neighboring state were to release a variety and we (in the area where it would be grown to the greatest extent) would not have sufficient information to either recommend or reject it.

d. The Uniform Regional Nurseries are very desirable plots. But they are still Nurseries. We would like to see plots where we could get about 5 lbs. of wheat for milling, baking, physical dough and biochemical tests.

Lack of Personnel and lack of Equipment.

a. These two usually go hand in hand - both are necessary for an expanded research program.

b. New modern equipment.

c. Updating old equipment.

d. Newer processing techniques in quality evaluation.

e. Need for trained people knowledgeable in Cereal Chemistry and Technology (more jobs than trained people at present time).

Lack of a good single determination for quality.

a. Studies should be made to see if such a test can be devised.

b. All laboratory tests will tell something about quality but none so far will give an adequate and reliable measure of overall quality.

c. Possibly examine these tests:
   1. Flour Disk Reflectance as a measure of Breadmaking Quality (R. M. Johnson)
   2. Pelshinke Test (modification to suit HRS wheats)

Early generation testing on a "go" or "no go" basis.

a. Might be tied in with preceding item.

b. Existing procedures might be used.

c. Recognition of the fact that to be effective, quality control decisions must be firm. (Get rid of the dogs)

Use of Fertilizer and Irrigation Plots

a. Can we reduce the number of years of testing - if, during one year, we tested under fertilizer conditions or irrigation conditions or a combination of both.

# WHEAT QUALITY CONSIDERATIONS IN BREEDING PROGRAMS AND THE USE OF EARLY GENERATION SCREENING TESTS TO IMPROVE PROGRAM EFFICIENCY

Evangelina Villegas, Norman E. Borlaug and Charles F. Krull

It is our contention that breeding for good milling and baking quality need not necessarily impede progress in the development of higher yeilding varieties.

It has already been pointed out that in the Mexican program concurrent improvements are being made in developing higher yielding, broadly adapted varieties with improved agronomic type, improved disease resistance and improved milling and baking quality. Never-the-less, in the vast majority of the wheat breeding programs in the Americas such concurrent improvement is not being accomplished. Improvements in grain yields have lagged. The result has been that the wheat breeder too often unjustly blames the cereal chemist for setting quality standards he cannot attain while simultaneously increasing grain yields and improving other important characteristics. Too often breeders have resorted to the use of long backcross programs, to avoid problems with quality, but by so doing they have simultaneously greatly reduced the possibility of increasing grain yield.

Although we feel that the breeders are in part justified in their criticism of the inflexibility in grain quality standards, as explained in the following paragraphs, we nevertheless feel that many of the quality problems encountered by wheat breeders can be circumvented if an adequate series of early generation screening tests for quality are employed.

Before going into an explanation of some of the screening tests for quality that have been used successfully in the Mexican program, we wish to call attention to some of the overall considerations that influence wheat grain quality and wheat's present and possible future position in competition with other cereal grains in both the domestic and the international markets.

Certain factors affecting grain quality have been at work in the past which have provided a definite advantage quality-wise and market-wise to wheats from certain regions and countries. We feel that this "status quo advantage" is about to be broken because of breakthroughs in genetic improvement. If the heretofore "privileged regions" (quality-wise), such as the Northern Spring Wheat Regions of the U.S.A. and Canada, remain complacent, they will lose their unique market advantage.

Viewing the cereal grain markets broadly, everyone working in wheat research, wheat production, wheat utilization and wheat handling and industrialization, should be increasingly concerned about wheat's position in the future. Increasing competition from other cereal grains in international markets is almost certainly forthcoming.

The discovery of the Opaque 2 gene which greatly improves the nutritional value of corn, poses one threat and challenge. What are we doing about improving the nutritional value of wheat through genetic manipulation? Very little is being done up to the present time. Is the effort adequate?

Recent research breakthroughs such as the development of high yielding, broadly adapted semi-dwarf rice varieties IR 8, (bred by the International Rice Research Institute) will also bring wheat under greater competition in the grain markets of the world. What are we doing about this? Unless we increase yields and maintain, or better yet improve wheat quality, wheat will price itself out of its fair share of the expanding world grain markets within the next two decades.

What are we as wheat scientists going to do about these challenges in the next two decades?

Competition between Different Wheat Classes in Domestic and International Markets, and between Wheat and Other Cereals

The hard red spring wheat regions of the U.S.A. and Canada have traditionally occupied a favored position in the domestic and international wheat markets of the world. Their favored position has been attained because of:

1. The outstandingly good protein quality of the principal commercial varieties

The varieties Red Fife, Marquis, Thatcher and their derivatives were bred and selected for their excellent milling and baking quality. The unusual combination of strong well-balanced (extensible) gluten strength has been their outstanding feature. This genetic superiority has been maintained for the past forty years by effective breeding programs.

2. High Grain Protein Levels

This important advantage is the result of the interaction of climate and soil conditions under which the Northern Hard Red Spring Wheat Market class has been grown. Scientists up to the present have contributed nothing to this advantage. In the future, however, the high protein advantage of northern spring wheats will come under increasing pressure and competition both in domestic and international markets as the result of increased grain protein content in wheats from other regions and other exporting countries.

In recent years it has been shown that the Frondoza or Atlas 66 high protein gene can increase grain protein content by 2 percent. This action is independent of grain yield. The incorporation of this gene into high yielding Hard Red Winter Wheat varieties will make this winter wheat region more competitive with wheats produced in the hard spring wheat region.

Aggressive agronomic research in the winter wheat region, which is currently largely lacking, designed to determine the best timing, rates, kinds and methods of nitrogenous fertilizer application will probably contribute to further increasing grain protein content in the foreseeable future. Progress through this approach will further erode the grain protein content advantage of the hard red spring wheat class.

The protein quality (especially strength) advantages of spring wheats over winters will shrink in the future, as breeding programs in the hard red winter wheat region increase their effort to correct protein quality defects. This effort is already underway in a number of breeding programs, both hybrid and conventional. The gluten strength of Mexican spring wheat varieties Jaral 66, Tobari 66, INIA 66, CIANO 67, and an especially promising line from the cross II22429, (Tezanos Pintos Precoz-Sonora 64A) (Lerma Rojo 64A x Tezanos Pintos Precoz-Andes dwarf) are already being incorporated into hard winter wheats in a number of different U.S. breeding programs.

Eventually the genes controlling high levels of grain protein and better protein baking quality (strength) will both be incorporated into high yielding hard winter wheat varieties. When such varieties are grown under proper fertilization they will be fully competitive market wise-with the hard red spring wheats.

We have reasons to believe that improvements in gluten (protein) strength will be forthcoming soon in French winter wheats. Similar improvements, through breeding, are under way to improve the protein quality of eastern European and Russian winter wheats.

Another change that will be forthcoming to further complicate the export position of Canadian and U.S. Hard Red Spring Wheats relates to the development of high yielding semi-dwarf hard white spring wheat varieties. No such variety exists at present.

Hard white wheats with strong gluten are preferred by all wheat consuming countries from Morocco to India. They are especially desirable for use in Chapattis in the Middle East countries. Currently the development of semi-dwarf, hard white varieties is well advanced in the Mexican, Indian and Pakistan breeding programs.

All of the forementioned predicted changes from breeding and agronomic research efforts already underway in the U.S.A. and in other countries will indirectly exert pressure on the current economic advantages of hard red spring wheats in the world markets. This is no time for the hard red spring wheat programs of the U.S.A. and Canada to be satisfied with "status quo quality and grain yield".

## The Use of Early Generation Screening Tests for Wheat Quality in Breeding Programs

Screening tests are simple tests that can be made rapidly and in large numbers on the small grain samples from individual plants to eliminate undesirable and worthless materials from a breeding program. They are not tests which are to be used for choosing the line that is to be multiplied as a new commercial variety.

The final choice of a superior line which is to be released as a new commercial variety must always be made by a series of well controlled milling and baking performance tests. In such performance tests the promising new advanced lines are carefully compared to the best commercial varieties to determine their suitability for specific consumer product (i.e. pan type bread, pastries, crackers, etc.)

The purpose and proper application of these two very different types of tests in breeding programs is frequently confused by both cereal chemists and plant breeders.

Breeding programs which restrict quality testing to the milling and baking performance tests, however, greatly reduce their efficiency, since such tests cannot generally be made before the $F_5$ and $F_6$ endosperm generation. This means that many inferior, worthless lines are carried forward in the program for a minimum of two years. This is a waste of time, energy and money.

Five years ago, after two years of exploratory evaluation, a series of early generation screening tests for quality was adapted for use in the Mexican program. These tests combined with the standard milling and baking tests in the advanced generations have been highly effective in improving the quality of the new wheats currently emerging from the Mexican program. The newer varieties INIA 66, Tobari 66, CIANO 67, Azteca 67 and Bajio 67 and many other even more promising lines in final stages of evaluation, are products of these methods.

The quality tests currently being used by the Mexican program differ primarily from those in use by other programs in North America in the way the plant materials are handled in the early segregating generations.

The preliminary screening tests for quality, are conducted on grain from individual plants in the $F_3$ and $F_4$ endosperm generations. Secondary screening tests are added in the $F_5$ endosperm generation. The secondary screening tests complemented by standard milling and baking tests are used on $F_6$ and succeeding generations.

The type of test that can be used in preliminary screening is governed by the size of the grain sample and the number of individual plants that can be analyzed in the two to three week period between the harvest of the winter generation and replanting of the summer nursery. All preliminary screening tests must be conducted on an individual plant basis. Under our conditions each plant produces from 5 to 20 grams of seed. Three grams of sample are currently used in the preliminary screening tests. The remainder is used for replanting. From 5,000 to 7,000 individual plants are evaluated at each of two locations in each generation. Approximately 300 plants are evaluated each day. Generally 65 to 75 percent of the individual plants that are analyzed are discarded.

In the secondary screening tests between 300 to 500 of the most promising lines are evaluated each generation. Approximately 30 samples can be analyzed each day. Three hundred grams of sample are needed for these series of tests.

Only those samples showing good promise in the secondary screening tests and in the final milling and baking performance tests are indicated in Table #1.

The Implementation of Quality Tests in the Mexican Breeding Program

Quality evaluations are not only used on lines under development in the breeding program but also for classifying the quality characteristics of each potential parent. This is used as a guide in planning the new crosses that are to be made each season.

In early segregating generations of crosses - the $F_3$ and $F_4$ endosperm generation - the preliminary screening tests are used exclusively. In these tests major emphasis is given to grain classification tests and to Pelshenke values (Table #1). The grain tests eliminate all lines that have poor kernel characteristics, which are likely to result in low grain test weight, high flour ash and low flour yield. The grain tests evaluate samples for grain size, plumpness, texture, vitriousness and color.

The Pelshenke test is used in the preliminary screening tests as a crude measure of gluten strength. It will separate weak wheats from strong wheats. It will not distinguish however, the strong "bucky" types from the well balanced strong types.

Mexico generally grows soft wheats, hard wheats and durum wheats in adjacent fields. There is no regional or geographic separation of wheat production by market classes. It is therefore absolutely necessary to use the preliminary tests - both grain and Pelshenke tests to identify the different market classes. The plants (lines) under study as potential soft wheat varieties must have large soft textured kernels and weak elastic gluten characterized by low Pelshenke values (i.e. 30 to 45 minutes like Lerma Rojo 64). The plants that are saved for the potential development of hard wheat varieties must by contrast have high Pelshenke values (120 to 180 minutes like Sonora 64 or INIA 66) plump, hard textured and medium sized kernels that are readily distinguishable from the soft wheats.

Distinguishable kernel types associated with corresponding gluten types are absolutely necessary to avoid mixing between soft and hard wheats in marketing.

Occasionally in outstanding crosses, involving a soft and a hard wheat parent plants in the $F_3$ endosperm generation with intermediate Pelshenke values (i.e. 70 to 100 minutes) are kept. Such plants are generally heterozygous for both grain type and gluten type. They will segregate in the next generation into both soft and hard wheat types.

The secondary screening test which is considered by us to be of a greatest value for identifying outstandingly promising soft and hard wheats is the Alveogram test. The Alveogram "W value" is a general measure of gluten strength. Wheats with W values above 400 are considered strong wheats, whereas wheats with less than 250 are considered soft wheats.

**Table #1. Quality Tests Employed and Properties Studied by Mexican Wheat Program in Different Endosperm Generations**

| | Preliminary Screening Tests | | Secondary Screening Tests 1/ | | Performance Milling & Baking Tests | |
|---|---|---|---|---|---|---|
| | $F_3$ | $F_4$ | $F_5$ | $F_6$ | $F_6$ | $F_7$ |
| **A Grain Properties:** | | | | | | |
| 1. Plumpness | X | X | X | X | | |
| 2. Size | X | X | X | X | | |
| 3. Texture | X | X | X | X | | |
| 4. Color | X | X | X | X | | - |
| 5. Vitreousness | X | X | X | X | | - |
| 6. Test Weight | - | - | X | X | X | X |
| 7. Protein | | | X | X | X | X |
| **B Chemical and Physical Properties** | | | | | | |
| 1. Pelshenke (wheat meal fermentation) test | X | X | | X | X | X |
| 2. Flour protein | | | X | X | X | X |
| 3. Alveogram Tests | | | | | | - |
| a) W value | | | X | X | X | X |
| b) P/G value | | | X | X | X | X |
| 4. Mixogram | | | X | X | X | X |
| 5. Sedimentation | | | X | X | X | X |
| **C Milling & Baking Performance Test** | | | | | | |
| 1. Milling Properties | | | | | X | X |
| 2. Water Absorption | - | - | - | - | X | X |
| 3. Baking Test | | | | | X | X |

1/ Tests performed whenever line is first cut in bulk; in most cases this is in the $F_6$ endosperm generation. However, in outstanding lines, after best plants have been selected individually, row is cut in $F_4$ endosperm generation.

The Alveogram "P/G value" is the ratio between measured dough tenacity (P) and extensibility (G). The P/G and W values can be used as a guide to selecting wheats with well balanced gluten strength and extensibility in both soft and hard wheats. Wheats either soft or hard - which possess good balance will have P/G values approximating 1/100 of the W value. Wheats with P/G values higher than 1/100 are "bucky".

The P/G and W Alveogram values, supplemented by mixogram scores and sedimentation values determine which lines are worthy of evaluation in the standard milling and baking performance tests.

The correlations between various tests - both preliminary and secondary screening tests and milling and baking quality tests - together with the multiple regression of loaf volume (with bromate) on 4 independent variables for a group of 25 wheats varying from weak to strong gluten are shown in Table #2.

The data show that the Pelshenke value, which is the measure of gluten strength used in the preliminary screening test, is highly correlated with the Alveograms "W value", which is the principal secondary screening test used for judging gluten quality. It is also highly associated with mixing time, sedimentation, mixogram and protein. The Alveogram W value is in turn highly correlated with loaf volume (non-bromated). The correlation (relationship)between Pelshenke value and loaf volume as used in the Mexican program is therefore an indirect one via the Alveogram W value.

It is evident from the data in Table #2 that the sedimentation value is both directly and highly correlated with loaf volume. Therefore it could also be used successfully as a preliminary screening test. We, however, prefer to use the Pelshenke test as the preliminary screening test since it both lends itself better to small grain samples and permits the analysis of from 3 to 4 times more samples that can be evaluated in a given period of time with the sedimentation test.

The multiple regression involving loaf volume with bromate and the four independent variables indicated in Table #2 accounts for 78.1% of the variability for loaf volume. That is by combining only alveograph (both P/G and W) with mixogram and water absorption, we can predict loaf volume on the basis of the preliminary tests.

After five years of employing the aforementioned preliminary and secondary screening tests for quality we are convinced that these tests greatly increase the efficiency of our breeding program. They alone are not used for selecting the lines that will be released as commercial varieties. Standard milling and baking tests are used to make this final choice.

In the light of these data and results why are preliminary and secondary screening tests not employed by most plant breeders and cereal chemists?

Table 2.--Correlations between various tests for milling and baking quality and the multiple regression of loaf volume with bromate on 4 independent variables for a group of 25 wheats varying from weak to strong gluten.

Multiple regression
Dependent variable=
Loaf volume with $BrO_3^-$
$R^2$ = .781
Constant term=-158.131
4 "independent" variables
(not signficant)

| | Correlations (r); d. f. = 23 | | | | | | | | | Multiple regression | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Loaf vol. with $Br\ O_3^-$ | Loaf vol. no $Br\ O_3^-$ | $H_2O$ absorption | Mixing time | Pelshenke | Sedimentation | Mixogram | W, micro | P/G, micro | Partial regression coef. (b) | "t" d.f.=n-k-1=20 |
| Protein, Udy | .20 | .31 | -.22 | .27 | .40 | .26 | .21 | .24 | -.19 | -56.6592 | -6.010** |
| P/G, micro | -.52** | .05 | .35 | .43* | .29 | .45* | .63** | .59** | | 1.0622 | 6.110** |
| W, micro | .16 | .60** | .22 | .69** | .59** | .84** | .68** | | | -23.6822 | -8.930** |
| Mixogram | .33 | .29 | .19 | .82** | .64** | .71** | | | | | (not significant) |
| Sedimentation | .18 | .57** | .31 | .75** | .56** | | | | | | (not significant) |
| Pelshenke | .02 | .27 | .15 | .66** | | | | | | 15 | (not significant) |
| Mixing time | -.14 | .33 | .00 | | | | | | | 15.6639 | 2.834* |
| $H_2O$ absorption | .12 | .03 | | | | | | | | | (not significant) |
| Loaf volume, no $BrO_3$ | .31 | | | | | | | | | | |

* = Significant at the 5% level
** = Significant at the 1% level

## DOES THE LACK OF KNOWLEDGE OF GENOTYPE-ENVIRONMENTAL RELATIONSHIP HINDER WHEAT IMPROVEMENT?

(Abstract)

K. B. Porter

This is a simple question with a complex answer. We might answer it with a simple yes or no, but the answer lies in just what do we know about genotype-environment relationships? I suspect we know more about genotype than we know about environment and more about each as separate identities than their relationship. Our failure to adequately define and our inability to place precise limits on environments adds to the complexity. We all are concerned with environments within an environment. Dryland and irrigation production in a single area represent two distinct environments within an environment while we all are familar with year to year environmental variation at a given location. Not only are we unable to predict our local environment more than a short span of days in the future, we can't be too sure of changes in the Earth's climate. Just recently meterologists reported that, since 1950, the average temperature of the earth has declined to the cold level of 1900 and forecast shorter summers because of air-pollution. On the other hand, weather control research may eventually permit us "to do something about the weather". Environments are not constant. Temperatures, humidity, light intensity, wind, rainfall, length of growing season and other climatic factors are variable, uncontrollable and not precisely predictable. However, soil type, soil fertility and with irrigation even soil moisture to a degree are stable, controllable, and predictable. Rate, date and plant spacing, and other cultural practices which could be included as integral parts of environment, may alter genotypic responses.

What kind of a wheat plant do we want? Isn't it one or many genotypes, sufficiently flexible to make a maximum response to favorable uncontrollable components of environment, insensitive to unfavorable components but with sufficient genotypic or phenotypic specialization to make maximum response to controlled high level production factors? Can we breed wheats with both general and specific adaptation? Pawnee, Scout, and spring wheats from Mexico suggest we can, within limits, do this. But must we rely on the empirical evaluation of genotypes over a wide range of environments or do we have enough knowledge to use more sophisticated methods? If so I should be able to answer such questions as:

1. Can we develop winter wheats for August seeding and grazing and maintain the grain potential of genotypes specifically adapted to October seeding and grain production?

2. Can we develop winter wheats sufficiently hardy for the extreme winters that have a maximum potential in years when survival is of no concern?

3. Can we select for resistance under heavy rust infection and maintain yield potential in the absence of rust or do we fail to see the wheats because of all the rust spores?

4. What is the relationship between photo-period insensitivity, growth habit, winter hardiness and temperature response?

There are a lot of questions we could ask ourselves!

Vavilov described the potential of the wheat plant quite well. First he said, "Although wheat in general appears to be a plant with varieties which are comparatively specialized, nevertheless, in many ecological types there is observed a high degree of ecological plasticity", and secondly, "For the final improvement of wheat great and decisive significance rests in the planned use of the world diversity of wheat".

To state the question somewhat differently, "Does the lack of knowledge of genotype-environmental relationships prevent us from making planned use of this ecological plasticity and diversity in wheat improvement?"

# DOES OUR LACK OF KNOWLEDGE ON GENOTYPE-ENVIRONMENT RELATIONS HINDER WHEAT IMPROVEMENT?

(Abstract)

I. M. Atkins

I would simply like to raise the point and ask the question; Are we growing the best type of wheat plant for our environment? Could a more efficient type of plant be found or developed? I do not know the answers but will cite a few examples where changes have brought better yields.

Carleton, when he introduced the durum wheats, was sure that they would find a place in Kansas - but they did not. Kansas grew spring wheats, durum wheats, soft wheats and all were unsatisfactory. Even though Kansas is now the number one wheat state, as late as 1889 a bulletin was published by the Kansas Experiment Station on "Arguments for and against growing wheat in Kansas".

The introduction of the hard red winter wheats into Kansas by Mennonite settlers solved the immediate problem in Kansas and in the Southwest and established wheat as a successful crop. Today we essentially are growing the same type of plant that was introduced in the 1870's. Could this be improved in some way to make it even more successful, at least for specific areas?

Orville Vogel led the way for most of us, and has been more successful than most of us, in thinking of a different type of plant for the commercial wheat crop. This new type of plant has now also been unusually successful in Mexico and from there to other near-tropical areas.

A very striking example can be cited in rice. Texas grows more rice acreage than any state, yet light conditions along the Texas Coast are much poorer than in California and Arkansas. For many years average yields in Texas were the poorest in the United States. With horse drawn machinery, rice average yields in 1920 were only 1,530 pounds per acre. With mechanization and increased fertilizers the yield had risen to 2,400 pounds in 1950. A team effort of research people at our Rice Research Center at Beaumont from 1950 to 1967 have laid the groundwork, extension people have carried the word; and an educated, high type of farmer has brought average yields to 2,400 in 1960, to 4,000 in 1965 and in the past year to 5,004 pounds per acre. Texas yields in 1967 were 27% over 1966 and greater than those of Japan and other intensively cultivated areas.

How has this been brought about? A steady stream of improved varieties which have solved many of the hazards of production; plus the most efficient fertilization, weed control, insecticides, fungicides, cultural methods, etc. Plant breeders produced first improved standard varieties. The rice plant approaches a perennial in habit. By producing very early varieties, plant breeders now have adapted types that can be harvested in July, flooded and fertilized and a second crop harvest in October. They are now changing the plant type to one with erect narrow leaves which do not shade each other and therefore more efficiently utilize the sunlight. They are also "taking apart the leaves" so to speak to find which color of leaf is more efficient in manufacturing plant food.

Maybe we should take a look at our wheat plant?

# DOES OUR LACK OF KNOWLEDGE ON GENOTYPE-ENVIRONMENTAL RELATIONS HINDER WHEAT IMPROVEMENT?

Charles F. Krull and Norman E. Borlaug

As many know, our group does not have much respect for variety X location interactions. Such interactions do exist and can be measured, but we feel that varieties can also be developed that are consistent in their performance.

Such an opinion is not based on a few academic studies, but on experience from moving large numbers of breeding lines between countries as well as from results of the international spring wheat yield trials. There are now data from 10 sets of international yield trials. Of these, 4 trials were carried out in the Americas and 3 in the Near East. More recently these were combined into a world-wide test of which some data are available for three consecutive years. These trials combined represent over 150 yield tests in both hemispheres ranging from 35°S to 61°N., long day and short day conditions, fertilized and unfertilized and irrigated as well as dryland conditions. This undoubtedly represents the largest systematic yield testing of genotypes that has been attempted in any crop.

Varieties have been found that tend to do well throughout the spring wheat regions of the world. Sites in which they do not perform well can usually be explained on the basis of disease susceptibility rather than lack of adaptation. Pitic 62 has been the outstanding example of such varieties, but several other Mexican dwarfs show the same pattern. Pitic 62 not only has had the highest yield average over many sites and years, but is also among the highest yielders at the majority of sites. The consistent high yields of these varieties is further substantiated by the fact that between 12 and 13 million acres of them are being grown on the other side of the world from where they were bred.

Thatcher, Selkirk and other U.S. - Canadian wheats have also been consistent in their yield - they are almost invariably the lowest yielders. Such performance might be expected under short day, irrigated conditions, but these yields have generally been disappointing in even those areas where these varieties are of commercial importance.

It is becoming increasingly clear that varieties that have been bred for optimum conditions - particularly as regards fertilizer use - also tend to be superior under sub-optimum conditions. That is, varieties that do well with heavy fertilization tend to do at least as well as other varieties without fertilizers. Such performance is not unique to the group of spring wheats included in the international yield trials, but seems to be a widespread and often misunderstood plant breeding principle that applies to many crops. Examples in other crops would be the new dwarf rice varieties and new high yielding sorghum hybrids that are vastly superior with heavy fertilization and also yield as well as older types without fertilizer. Even in corn improvement where variety X location interactions have received so much attention, new prolific hybrids that were bred for dense populations and intensive management are proving to be superior under a wide range of conditions.

In summary, broadly adapted, high-yielding varieties can, and have been produced in wheat. The consistently high performance over a broad area increases the usefulness of varieties and facilitates the exchange of germplasm between crop breeders. It also indicates that greater efficiency will be achieved with strong cooperative regional and international programs in contrast to local, uncoordinated efforts.

## THE USE OF REGRESSION ANALYSES TO MEASURE GENERAL ADAPTATION IN WHEAT

(Abstract)

V. A. Johnson, S. L. Shafer, and J. W. Schmidt

The general adaptation of twelve hard red winter wheat varieties grown in regional performance nurseries was studied by regression analyses. The yields of individual varieties in relation to nursery mean yield was utilized for computation of linear regression coefficients following the scheme reported by Finlay and Wilkinson in 1963. The regressions permitted comparisons of predicted varietal performance over a range of environments. Statistical analysis of thirty years of regional data by this method was utilized in the study.

The performance characteristics of varieties in the southern regional performance nursery indicated that some varieties are relatively better yielders in austere environments whereas others make their best relative performance in high yielding in more optimal environments. Pawnee and Early Blackbull illustrate the first group and Comanche the second. Some newer varieties fall into a third grouping in which varieties are superior in performance over the entire environmental range. This group includes Scout and possibly Gage and Caddo.

In northern regional trials Yogo appears to be relatively superior to Cheyenne and Warrior when the general yield level is less than sixteen bushels per acre. It is relatively poorer than these varieties in the higher yielding environments. The variety Lancer was superior to all other varieties with which it was compared when the general yield level exceeded twenty-five bushels per acre.

# PERFORMANCE OF TALL AND SEMI-DWARF SPRING AND DURUM WHEATS AT 5 RATES OF NITROGEN FERTILIZATION UNDER DRYLAND AND IRRIGATED CONDITIONS

(Abstract)

Vanrat Sompaew and D. G. Wells

Chris was compared with two red seeded semi-dwarfs from Mexico and Leeds was compared with two durum semi-dwarfs at 0, 30, 60, 90 and 120# of N per acre at a constant level of 40# of P per acre on dryland and 110# of P per acre under irrigation. Seeding rate was 48# per acre in 3 row plots with rows one foot apart and 8 feet long. Fertilizer was broadcast and plowed under. The original level of fertility at Brookings on the dryland site was very high. Foliage diseases were controlled with Manzate D and green bugs with an insecticide. The traits measured were seeds per head, heads with seed, fertility, lodging, percent protein, weight of 200 seeds, seed yield, straw yield and plant height. Stands of seedlings were determined. Stands were irregular due to lower germination of some entries. A late frost at Brookings reduced stands of 2 of the semi-dwarfs. Stands represented seeding rates of about 22 to 33 lbs. per acre.

The test at Brookings, seeded April 4, received no rain for 60 days so the plants were stunted, tall and semi-dwarfs differing by about 6". Chris tillered more than the semi-dwarfs but Leeds did not. Seeds per head were similar (26 to 28) for all entries. Penjamo 62 excelled in seed size. Yields of the semi-dwarfs and Chris were similar. Penjamo 62 and Chris averaged 29 bushels per acre. One of the durum semi-dwarfs SDI6617 increased in yield with rates of N, exceeding Leeds by 20% at 120# per acre of N due to more heads bearing seed. The semi-dwarfs were lower in protein than the tall varieties.

The test at Redfield, seeded May 8, was irrigated twice in July. The semi-dwarfs were 12" to 15" shorter than the tall checks. No serious lodging occurred. Seeds per head across N rates ranged from 28 to 35. Penjamo 62 averaged 28% more grain yield over all N rates because of having larger seeds and more seeds per head than Chris while having fewer heads with seed. Mean squares for grain yield for varieties and varieties x rates were not significant for the durums while the rates mean square was significant. However, at the 120# rate of nitrogen, the semi-dwarf SDI6617, (Y+54-N104 xLD357)$Tc_2$, outyielded Leeds 71 to 58 bushels per acre due to more heads and more seeds per head. The durums averaged less yield than Leeds over all rates of N. Protein levels, increasing with N rates, were 1 to 2% lower for the red seeded semi-dwarfs than Chris but were similar for the 3 durums.

# PROTEIN IN WHEAT - WHO WANTS IT?

Louis P. Reitz

The major cereals provide over 40 million tons of protein annually to human beings. Wheat contributes one-fifth of the total world supply of protein or nearly as much as all animal products combined.

In many countries wheat constitutes 70% or more of the diet and the protein balance is not maintained. This is especially critical for young children. Any increase in the amount of total protein or of the most limiting essential amino acids (lysine and theonine) would be an automatic means for improvement of cereal diets. While the estimated cost for chemical supplementation is low (24 to 93¢ per year per child for lysine), it is obvious that it would be more desirable and more effective to direct nature to make the change than for man to do it.

About one billion people in the world have a diet high in content of high quality protein. Do these people represent a market for high protein wheat? The answer is far from clear. However, we can look at the U.S. position in two ways although neither is free from compounding effects: a) the range in protein desired for various wheat products, and 6) the protein premiums paid in the marketplace.

Soft wheats with more protein would meet trade opposition. This is especially true in the eastern states. Where heavy fertilization has contributed to higher levels of protein and where the Atlas wheats have been grown the trade has objected strenuously. In fact, lower protein has been requested and sought at premium prices. Soft wheats occupy about 20% of the U.S. acreage.

Hard red spring and durum wheats are grown on 20% of the U.S. acreage and provide some of our highest protein grain. The hard red winter and hard white wheats, grown on 60% of our acreage, are, in general, marginal in protein for desired processing.

From 1949 to 1966 the average protein in Kansas wheat was just over 12%. The highest year showed an average of 14.1% (1956) and the lowest was 10.7% (1961). In North Dakota, the average is about 2 1/2% higher.

During the last three crop years the premium schedule for government loan rates has been 3¢ per bushel for each percent of protein above 12 with a maximum of 18¢ premium per bushel. This is backed up by open market bidding although the actual premium varies greatly from time to time. In Minneapolis the average premium each year from 1960 to 1965 ranged from 6 to 17¢ per bushel for 15% protein DNS over the base price. Montana spring wheat of 14% protein showed a premium every year during a 22-year period at Great Falls; 16% protein wheat had a premium ranging in amount from 1/20 to 1/2 the base price. At Kansas City, No. 1 Hard of 13% protein was 17, 4 and 5¢ above the base price during a month in the fall of 1965, 1966 and 1967.

There are many inconsistencies in price premiums. Local millers may have too much protein in the wheat most readily available to them and will pay no premium at all. I have heard of cases where low protein wheat for bread flour was given the higher local price. Many buyers, especially foreign buyers, specify "ordinary" protein and hope for the best. They complain nevertheless when the grain is below their idea of what they really need.

Historically, economically, and for best nutrition a positive approach to the protein problem seems entirely valid. The only exception is for specialty goods where low protein is required for the production of acceptable products by present technology. If more efficient production is to be achieved, a more effective mechanism for converting nitrogen fertilizer and soil nutrients into grain is needed. There is a great challenge and a real opportunity to:

1 - Breed wheats with higher protein and good yield.
2 - Breed wheats with improved amino acid ratios but preserve wheat's unique gluten.
3 - Breed wheats with more efficient photometabolism.
4 - Devise management systems to increase the efficiency of nitrogen use.
5 - Protect plants from nutrient-robbing effects of microbes and diseases.

# YIELD AND PROTEIN CONTENT

(Abstract)

R. J. Baker

It is generally conceded that there is a negative relationship between yield and protein content in wheat. Existing information would indicate that, while part of this negative relationship is due to the nature of the wheat plant, part is due to the repulsion linkage of genes for high protein with those for high yield. In fact, a negative genetic correlation should be expected when a high yielding variety is crossed with a high protein variety in hopes of producing a line which is high in both.

Computer simulation of a ten locus model in which nine additive genes were controlling yield and one additive gene was controlling protein showed that, even with linkage intensities of 30 percent between loci, substantial improvement of both traits is unlikely. It is suggested that more effort on breaking up linkage blocks and concentrating on the gradual improvement of both protein and yield would help overcome the problems posed repulsion linkages.

# RELATIONSHIPS BETWEEN GRAIN NITROGEN AND PLANT DEVELOPMENT

(Abstract)

F. H. McNeal

We have sampled various plant parts of several spring wheat varieties for nitrogen content over a 2-year period. As maturity approaches the nitrogen in stems, leaves, and head chaff decreases, indicating translocation to the developing kernels. Percentages of total nitrogen in top growth that is translocated to kernels has varied from a low of 56.3% in C.I. 13636 to a high of 76.6% in Thatcher. The year, location and variety seem to influence translocation.

In 1966 we obtained r values at an irrigated and a dryland location of 0.89 and 0.92 respectively, for grain nitrogen content vs. the total weight of tops (Table 1). We also obtained r values of 0.88 and 0.93 between grain nitrogen percent and the grain to straw ratio.

A regression equation was developed and used to predict the grain nitrogen content of 7 varieties studies. An r value of 0.91 was obtained by correlating the predicted values with those actually obtained.

The amount of top growth is one of the keys to nitrogen content. A large amount of top growth with a small grain yield will usually result in grain with a high nitrogen content, assuming nitrogen availability. On the other hand, a grain yield that approaches the straw yield will usually be lower in nitrogen content.

Table 1. Correlation coefficients at two Montana locations in 1966.

| Variable | Irrigation | Dryland |
|---|---|---|
| | r | r |
| Grain N content with total top weight | 0.89** | 0.92** |
| Grain N percent with grain to straw ratio | 0.88** | 0.93** |

** Significant at P = .01.

# CAN WE BREED HIGHER PROTEIN IN WHEAT?

(Abstract)

V. A. Johnson, P. J. Mattern, and J. W. Schmidt

Cooperative research by the Agricultural Research Service and the Nebraska Agricultural Experiment Station has demonstrated the feasibility of breeding higher protein hard winter wheat. We have utilized Atlas 66 as a high protein source in crosses with hard wheats from which a number of experimental lines have been selected that possess 2-4 percent more protein in their grain than hard winter wheat varieties. These protein increases could be achieved without reduction in grain yield.

Our high protein selections possess several, but not all, of the specific quality and agronomic traits necessary in commercial varieties. We believe that high protein is compatible with acceptable milling and baking quality and that commercially acceptable high protein hard winter varieties can and will be developed.

The high protein trait from Atlas 66 is closely associated with adult leaf rust resistance. With few exceptions, high protein selections from Atlas 66 crosses with Comanche and Wichita also possessed the leaf rust resistance of the Atlas 66 parent. Other investigators have made similar observations.

We have been unable to demonstrate that differential nitrogen uptake by the plant is involved in high grain protein. Significant differences in the plant nitrogen content of varieties have been demonstrated but in no case were such differences related to the protein of the grain. We conclude that high grain protein in the Atlas 66 derived lines results mainly from more efficient and more complete translocation of nitrogen from the plant to its grain during kernel development. The superiority in grain nitrogen content of the Atlas 66-derived lines could be measured from the early stages of kernel development.

We have been able to reduce significantly the protein content of the grain of varieties by removal of all leaf blades at heading time. The protein content of the high protein lines was more sharply reduced than the lower protein varieties by leaf removal. This suggests a possible phynologic contribution of the leaf rust resistance of Atlas 66 in addition to the probable genetic linkage with a high protein gene.

Amino acid analyses of the grain from high protein Atlas 66 x Comanche lines revealed substantial differences in the level of lysine, methionine, and threonine. Some lines possessed as much or more lysine and methionine than Comanche; others were lower in these two amino acids. Threonine was more frequently deficient in the lines than lysine or methionine. It does not appear that the high protein trait need be associated with a less favorable balance of essential amino acids.

# GENETIC AND ENVIRONMENTAL CONTROL OF NITRATE REDUCTASE IN WHEAT AND ITS INFLUENCE ON INCREASED PROTEIN PRODUCTION

(Abstract)

L. I. Croy and E. L. Smith

In view of the current interest in world protein production and the long-time interest in higher wheat protein, we believe it is important to vigorously study the nitrogen reduction system in wheat. We believe that study of this biochemical system in the plant should help us better understand and increase protein production of wheat.

Research to date indicates that there is a good correlation between the Nitrate Reductase activity (NR) and protein production in wheat. Also increasing the level of N available to the wheat plant is conducive to higher NR levels and higher grain protein. Increased temperature above an optimum reduces NR activity and a variety interaction with temperature has been observed. The inheritance of NR in corn appears to be simple, probably controlled by two gene pairs.

We propose to conduct further search to identify wheat genotypes having high NR levels and high protein levels. Also genetic studies will be conducted to determine the inheritance of NR in wheat. We will continue studies on the effect of timing and levels of nitrogen fertilizer application on NR and grain protein. Environmental effects, especially temperature and moisture levels, will be evaluated further for their effects on NR and grain protein production.

# INCREASING THE PROTEIN CONTENT OF HARD RED WHEATS

D. W. Sunderman

Developing wheats with increased protein content has been a minor aim of plant breeders for many years. The average protein content has been raised slightly while the yields of varieties have increased considerably.

Reasons for the small increase in protein content are as follows:

1. The heritability of protein content is very low making selection for high protein in early generations rather unreliable.

2. Varieties with high protein content (Atlas 66 and 50) had many undesirable quality characteristics, some associated with protein, making selection rather difficult.

3. High protein content is highly correlated with large loaf volume. Varieties exhibiting exceptionally large volume often have inferior bread grain and texture and are discarded, since these characteristics are generally considered more important than protein count.

4. Protein content is the least important factor considered when releasing a new variety. If the variety protein content is equal to that of current varieties, it is acceptable.

5. Maintaining quality of varieties at the present level, while increasing yield, and disease resistance have been the primary objectives of plant breeders.

Although protein content of new spring wheat varieties has not increased, most of them produce more pounds of protein per acre as shown by their performance in the 1967 International Spring Wheat Yield Nursery grown under irrigation at Aberdeen, Idaho (Table 1). Thatcher and Selkirk, though not appreciably different in protein content produced less total protein per acre than Chris, Crim, ND 824 and NP832.

The performance of these varieties has not been tested under conditions of adequate moisture and limited protein. Tests will be started in 1968 to determine if the yield-protein relationship will remain the same when available nitrogen is limited.

Table 2 shows protein-yeild-quality relationship of commercial Idaho winter wheat varieties and three high protein Idaho selections. Under irrigation with adequate nitrogen, the selections had a higher yeild, protein content and total protein than Tendoy. On dryland, where nitrogen was a limiting factor, yield of selections with the higher protein contents was lower, and only one of the selections produced more total protein than Tendoy.

Questions which must be answered before a concerted effort is made to increase wheat protein content of dryland varieties grown in Idaho are:

1. In low moisture areas where applied fertilizers reduced yields and test weights, should a variety be developed which would use available nitrogen more rapidly than present varieties?

2. Would a high protein wheat yield as well as varieties requiring less nitrogen when nitrogen is a limiting factor?

Table 1. Yield and quality obtained on varieties grown at Aberdeen, Idaho, on irrigated land fertilized with 100 pounds of nitrogen.

| Variety | Test wt. lbs/bu | Yield bu/A | Protein % | Protein lbs/A | Sed. | Flour yield | Abs. | Peak min. | M.T. | Mix-ing time | Dough1/ type | Leaf volume | Bread characteristics1/ Ext. | Grain | Texture | Color |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Thatcher | 61.1 | 71.3 | 16.8 | 719 | 42 | 72 | 65 | 4.0 | 100 | | | | | | | |
| Selkirk | 59.8 | 67.0 | 17.0 | 683 | 48 | 69 | 64 | 5.0 | 40 | 1.4 | 6 | 840 | 5 | 7 | 7 | 5 |
| Austin | 60.6 | 65.1 | 17.5 | 683 | 60 | 69 | 66 | 6.5 | 80 | 1.4 | 6 | 790 | 5 | 8 | 8 | 5 |
| Chris | 61.3 | 73.8 | 17.0 | 753 | 50 | 69 | 66 | 5.5 | 60 | 1.5 | 6 | 815 | 5 | 8 | 8 | 5 |
| Crim | 60.8 | 80.2 | 17.4 | 837 | 54 | 71 | 67 | 5.5 | 60 | 1.9 | 6 | 800 | 5 | 7 | 7 | 5 |
| ND 824 | 63.1 | 87.1 | 17.0 | 888 | 58 | 69 | 67 | 8.0 | 20 | 2.6 | 9 | 840 | 5 | 7 | 7 | 5 |
| NP 832 | 62.5 | 85.9 | 17.0 | 876 | 55 | 68 | 66 | 8.0 | 40 | 2.6 | 9 | 745 | 5 | 7 | 7 | 5 |

1/ Higher number indicates better quality.

Table 2. Yield and quality data obtained on winter wheat grown under irrigation at Aberdeen for 2 years and on dryland at Tetonia in 1967.

| Variety | C.I. or Cross no. | Test wt. lbs/bu | Yield bu/A | Protein % | Protein lbs/A | Sed. | Flour yield | Peak min. |
|---|---|---|---|---|---|---|---|---|
| Irrigated | | | | | | | | |
| Itana x Atlas 66 | A589A-133 | 62.2 | 73.8 | 15.3 | 673 | 47 | 67.8 | 4.3 |
| | -135 | 61.6 | 75.1 | 15.0 | 676 | 46 | 69.2 | 4.5 |
| Td 3x 7Lee 2x Cns x Au | A615-5-1 | 63.1 | 76.1 | 14.7 | 671 | 55 | 69.1 | 5.5 |
| Tendoy | CI 13426 | 61.9 | 70.6 | 13.9 | 589 | 44 | 69.9 | 4.8 |
| Dryland | | | | | | | | |
| Itana x Atlas 66 | A589A-133 | 62.6 | 48.2 | 13.1 | 379 | | | |
| | -135 | 62.5 | 50.8 | 13.0 | 396 | | | |
| Td 3x 7Lee 2x Cns x Au | A615-5-1 | 62.7 | 52.9 | 13.5 | 428 | | | |
| Tendoy | CI 13426 | 63.1 | 59.4 | 11.7 | 417 | | | |
| Itana 65 | CI 13846 | 62.4 | 56.3 | 11.5 | 388 | | | |

# THE EFFECT OF INCREASING THE NUMBER OF CHARACTERS UNDER SELECTION ON EXPECTED GENETIC GAIN FOR OTHER CHARACTERS

E. C. Gilmore

I would like to say at the outset that ideas expressed in this paper are not original. Most breeders are aware of the implications of increasing the number of characters under selection. I would hope, however, that the example set forth in this paper might lead us to think anew of the relative importance of characters under selection and the consequences of adding new characters to the standard variety acceptability.

Expected genetic gain (G) expressed as a function of heritability and the selection differential is

$$G = H\,(\overline{P}_s - \overline{P})$$

where H, the heritability, is the regression of genotypic value on phenotypic value, and $(\overline{P}_s - \overline{P})$, the selection differential, is the difference between the means of the selections and the population from which they were selected. When truncation selection is practiced for a character having a normal distribution, $(\overline{P}_s - \overline{P})$ equals $k\sigma_p$ where k is a function of the proportion of the population saved, which is frequently called the selection intensity. As the percent of the population saved increases, k decreases and the selection differential decreases, reducing expected genetic gain.

When equal emphasis is placed on selection of n characters which have no genetic correlations and x is the proportion of the population saved, the selection intensity for one character equals $\sqrt[n]{x}$ .

Let us assume that milling and baking quality of a variety can be completely defined by milling percentage, flour ash content, mixing time, loaf volume, and crumb texture. Certainly breeders and cereal chemists wish quality were so easily defined. Let us also limit selection for agronomic characters to yield, test weight, and straw strength, which make a total of eight characters under selection. Let us also assume there are no genetic correlations among these eight characters. If only one out of 100 lines tested is saved, the selection intensity for one character then becomes $\sqrt[8]{.01}$ or 56%. Under the conditions we have described the selections for this character would be a random sample from the upper 56% of the distribution, and the mean of these selections would be .70 standard deviations higher than the mean of the distribution. In comparison, if milling and baking quality were ignored, the mean of the selections would be 1.33 standard deviations higher than the mean of the distribution. The genetic advance for each character would depend on the heritability of the character and the selection unit used, but the above changes in selection intensity illustrate the fact that addition of characters being selected rapidly makes the mean of the selections for one character approach the mean of the population.

Genetic correlations among characters complicate calculation of the effect of simultaneous selection, and for this discussion it should be sufficient to point out that desirable genetic correlations tend to increase genetic advance and undesirable correlations tend to decrease it.

The question to which we should address ourselves is not "Is selection for milling and baking quality an impediment to improvement in other areas?". It could not be otherwise unless all milling and baking characters had a very high desirable correlation with agronomic characters. Rather, the question is "What are proper relative weights to place on all characters under selection so that the maximum benefit to society may ensue?". That this be done is of paramount importance if wheat improvement is to reach its potential.

## STUDIES ON QUANTITY AND QUALITY OF WHEAT PROTEIN

(Abstract)

R. E. Heiner

Random selections of Minn. II-54-30 were made to compare its protein electrophoretic pattern with that of good quality wheats and also to attempt to select a variant within the population that would have acceptable baking quality. Preliminary data suggests that the protein from the original line, when compared electrophoretically with other lines and varieties, differs in one major protein band. It appears that a structural protein is absent in II-54-30. A few selections have been identified as having an unusual level of protein. These selections are presently being evaluated to determine if the increased protein content is associated with an altered electrophoretic pattern. In addition, an $M_2$ population of Chris that has been treated with ethyl methanesulfonate is being screened for high and low levels of protein. Of the 600 $M_2$ plants examined, 58 have protein values higher than 18%. Sixteen have good seed characteristics and 5 are excellent in this regard. Two were noted as having 20% protein with good seed characteristics. The average protein content for the control population is approximately 15.5%.

# WHEAT DISEASES AND QUALITY

K. F. Finney

We have found that soil-borne-mosaic virus, wheat-streak-mosaic virus, and scab are diseases that affect the quantity and quality of wheat protein.

Virus Diseases--Remarks about the two virus diseases pertain to experiments reported by Finney and Sill in Agronomy Journal, 55:476-478, 1963. Fifty-six tests represented several wheat varieties, several locations, and 4 crop years.

Grain samples from wheat plants infected by soil-borne-mosaic or wheat-streak-mosaic virus had milling properties that were inferior to, protein quality and mixing properties that were equal to, and water absorption, protein content, and "as received" loaf volume that were distinctly superior to those of the corresponding controls. Forage samples of winter wheat varieties susceptible to and infected by wheat-streak-mosaic virus were significantly higher (0.1% level) in protein content than those of healthy controls.

Scab--About 15 pounds of scab infected H. R. W. wheat was separated by hand into what appeared to be a 100% scabby sample and a normal or brown sample of wheat. The normal (brown) and scabby wheat samples were present in the original mixture in the ratio of 4 parts of normal (brown) to 1 part of scabby (white).

Proteolytic activity indicated that the brown sample was about 16 days preripe, whereas the scabby (white) sample represented a stage of development of about 22 days preripe. In addition, the scabby wheat contained about twice the water-soluble protein content of the brown wheat. These data for proteolytic activity and water-soluble nitrogen tie in consistently with previous studies of the laboratory concerning the chemical and baking properties of wheat harvested at various stages of maturity. Accordingly it appears that the 100% scabby wheat simply was killed at a sufficiently early stage of maturity (22 days before ripe) before appreciable gluten protein synthesis had occurred, thereby accounting for the inability of the protein in the flour milled from 100% scabby wheat to retain the carbon dioxide produced during fermentation. Previous studies have shown that baking characteristics usually are about normal (compared to ripe samples) as early as 16 days preripe, and above normal 10 to 14 days preripe.

# CAN AMINO ACID RATIOS BE ALTERED? HOW? WILL QUALITY SUFFER?

R. C. Hoseney

I think we can start with a positive statement that yes - the ratio of amino acids in wheat can be altered. Wheat is a biological system, and all biological systems can be altered.

A logical approach to altering the ratio would be to find a wheat with a more desirable amino acid ratio and then use it as a parent in breeding programs. The data, although somewhat limited, suggest that such a wheat may not exist in our present varieties.

The proteins in wheat can be divided into two general classes, the endosperm and non-endosperm proteins. This separation is made when wheat is milled into flour. The endosperm proteins contain about 2.2% compared to the 4.4% lysine in the non-endosperm proteins. Thus, we would have a high-lysine wheat if we significantly raised the percentage of the non-endosperm matter in wheat. However, this likely would lower the milling quality of the wheat and would not give us a more nutritious endosperm. The endosperm proteins also can be divided into 2 groups, namely gluten proteins and water- and salt-soluble proteins. The water- and salt-soluble proteins are essentially the same proteins found in the bran, and thus contain about 4.4% lysine. The gluten protein contains only about 1.1% lysine. The gluten proteins can be divided into 2 groups, gliadins and glutenins, but these do not vary much in lysine content. The ratio of water-soluble to gluten protein varies. In general, the percent of water-soluble protein is higher at the lower protein contents. Thus, the lower the protein content of wheat the higher the percentage of lysine. This must be taken into account when searching for a high-lysine variety.

A second way to obtain a high-lysine wheat would be to find a mutant that will block the synthesis of one or both of the gluten proteins but permit the synthesis of the water-soluble proteins. This evidently is the mode of action of the two mutants in maize described by Dr. Mertz and coworkers at Purdue. The synthesis of zein, which corresponds to gliadin in wheat, has been retarded while the synthesis of globulin proteins has been increased.

On the basis of what has been learned from the high-lysine maize and what we know about wheat protein, I think we can postulate some things about a high-lysine wheat obrained in a manner comparable to that for maize. It would have a white, chalky, non-vitreous endosperm, a low test weight (due to a low density kernel), and probably a low yield when considering weight and not bulk. If it was sent to a quality lab for evaluation, the report would read "Considering the protein content, this is one of the poorest varieties we have ever tested". Such mutants probably have occurred, but have not been recognized.

Another type of mutation could change the amino acid make-up within a specific protein. While this type likely does occur, its effect on the overall lysine content of wheat probably would not be significant. For example a change of from 3 to 4 lysine residues per molecule of a gliadin protein (50,000 molecular weight) would only change the lysine content of that protein from 0.8% to 1.1%. Based on such a change, the increase of lysine in the flour would be 0.04%.

The effect of the above changes on quality would depend on whether the emphasis is on baking performance or nutrition. From a nutrition standpoint, the quality would be greatly improved. From the point of view of the baker the quality probably would be poor. We probably would lose the properties that make wheat so uniquely suited for leavened products.

## PROTEIN CONTENT

E. G. Heyne

Is protein content heritable? Yes, protein content is heritable as well as protein quality. The physical properties of high protein wheats generally available for breeding purposes are not satisfactory for hard wheats. Crosses with Atlas 50 and 66 and Kaw indicate that if the population size is sufficient high protein lines with suitable hard wheat milling and baking properties can be obtained. Selections with 1-2 percent more protein than Kaw were isolated that had good milling properties and baking properties that were equal or better than Kaw.

# PROTEIN, FERTILIZATION, YEAR, AND BAKING ABSORPTION

W. C. Shuey

There is evidence to show that the protein content of the wheat is inversely proportional to yield for specific selections. This can be partially overcome by fertilization; however, varieties respond differently to additional nitrogen, and the protein synthesized is of different quality.

Table I shows the response of 3 varieties to 3 levels of nitrogen and the effect on wheat protein and baking absorption. Variety A - showed very little response to increased nitrogen in wheat protein content or baking absorption. Variety B - showed an increase in wheat protein content with an initial increase in baking absorption and then a decrease. Variety C - showed an increase in both protein content and absorption with increased amounts of nitrogen. The data show that not only did the varieties respond differently to the amounts of nitrogen applied, but the baking absorption capacity response was different.

Table II shows the response of Variety A to fertilization at 2 locations and 2 crop years. Not only does variety play a role in response, but also year and location. Careful perusal of the data reveals that a variety may respond similar to a different variety grown at one location when it is grown at several locations and in different crop years.

The data presented show that: (1) protein can be increased by breeding (Variety A versus Varieties B and C), (2) amount of nitrogen, location, and crop year can alter the amount of protein, and (3) the composition of the protein must be altered under these conditions since the baking absorption responses were different.

TABLE I

SAME LOCATION, YEAR, AND METHOD OF APPLICATION

| Treatment | Variety A | | Variety B | | Variety C | |
|---|---|---|---|---|---|---|
| | Wht. | Bake | Wht. | Bake | Wht. | Bake |
| lbs. of N | Pro. | Abs. | Pro. | Abs. | Pro. | Abs. |
| 0 | 18.4 | 70.9 | 13.2 | 64.4 | 13.3 | 64.7 |
| 100 | 18.0 | 70.6 | 14.7 | 67.6 | 14.4 | 66.6 |
| 200 | 18.2 | 70.9 | 15.3 | 67.0 | 15.8 | 68.5 |

TABLE II

SAME METHOD OF APPLICATION

| Treatment | Location A | | | | Location B | | | |
|---|---|---|---|---|---|---|---|---|
| | 1966 Crop | | 1967 Crop | | 1966 Crop | | 1967 Crop | |
| | Wht. | Bake | Wht. | Bake | Wht. | Bake | Wht. | Bake |
| lbs. of N | Pro. | Abs. | Pro. | Abs. | Pro. | Abs. | Pro. | Abs. |
| 0 | 18.4 | 70.9 | 15.0 | 65.7 | 18.5 | 70.9 | 11.9 | 59.0 |
| 100 | 18.0 | 70.6 | 15.4 | 67.3 | 21.0 | 70.9 | 16.8 | 68.2 |
| 200 | 18.2 | 70.9 | 16.6 | 67.0 | 19.1 | 70.9 | 17.2 | 66.3 |

# LYSINE DIFFERENCES IN THE WORLD WHEAT COLLECTION

(Abstract)

P. J. Mattern, D. A. Whited, V. A. Johnson, and J. W. Schmidt

Lysine is usually considered the amino acid most likely to be limiting in wheat. If genetic sources with higher lysine contents could be identified it should be possible to make substantial improvements in the nutritional quality of wheat.

The Nebraska Experiment Station in cooperation with the Agricultural Research Service is systematically analyzing all of the common wheats in the World Collection maintained by the U. S. Department of Agriculture to identify new sources of high protein and high lysine. The research is being supported by the Agency for International Development, U. S. State Department. More than 2000 wheats from the Collection have been analyzed to date.

Lysine is analyzed in an acid hydrolyzate with an amino acid analyzer which has been modified with four short columns for basic amino acids. Samples are run sequentially in about eight minutes. Protein is determined by the Udy dye-bind method. These samples which show promise are also rechecked for protein by the Kjeldahl procedure.

The correlation of protein with lysine (expressed as percent of dry weight) over the entire range of protein encountered among 2079 wheats was +0.81. However, the correlation of lysine with protein within 2% protein increments is relatively modest - ranging from +0.46 in the 13.0-14.9% protein level to only +0.03 at the 17.0-18.9% protein level. This would indicate that lysine variation within restricted ranges of protein is largely random.

A low negative correlation of -0.48 was obtained when lysine as a percent of protein was correlated with protein. The correlations were even lower when correlations were based on samples within restricted protein ranges.

Our data indicate that level of lysine is influenced by protein level but that protein can account for only a portion of the lysine variation we have encountered. Thus, it would seem that selection for high lysine in wheat may be feasible.

The protein and lysine contents of selected wheats from the World Collection are shown in Table 1. The mean protein content of 2079 wheats from the World Collection was 13.6%. Lysine expressed as percent of protein averaged 3.04%. The lowest lysine encountered was 1.77% in a 14.3% protein wheat from Russia. Seven of the wheats included in Table 1 appear to have promise as possible sources of high lysine. None is abnormally low in protein and two are higher in protein than the average of the 2079 wheats analyzed.

Whether these wheats have promise for breeding higher lysine will depend upon whether their high lysine values are real or only apparent. The effect of environment on lysine level is not known.

We are optimistic that wheats with superior levels of lysine will be found. Improved lysine level combined with high protein would constitute a major step in the improvement of the nutritional value of wheat.

Table 1. Protein and lysine content of selected wheats from the World Collection.

| Sample No. | Origin | % protein1/ | Lysine % of dry wt. | Lysine % of protein |
|---|---|---|---|---|
| 22 | Arabia | 12.1 | 0.44 | 3.66 |
| 15 | USA | 12.5 | 0.46 | 3.65 |
| 667 | China | 12.5 | 0.45 | 3.58 |
| 610 | Sweden | 13.3 | 0.47 | 3.57 |
| 20 | Spain | 15.1 | 0.52 | 3.44 |
| 1335 | USA | 14.1 | 0.47 | 3.36 |
| 1180 | USA | 13.2 | 0.44 | 3.33 |
| . | | | | |
| . | | | | |
| . | | | | |
| $\bar{x}$ (2079 samples) | | 13.6 | 0.40 | 3.04 |
| . | | | | |
| . | | | | |
| . | | | | |
| 229 | | 14.3 | 0.25 | 1.77 |

1/ Dry weight basis.

# WHAT IS THE IMPORTANCE OF THE RACE CONCEPT AND NON-SPECIFIC, GENERALIZED AND HORIZONTAL RESISTANCE VS. SPECIFIC SPECIALIZED VERTICAL RESISTANCE, AS RELATED TO DISEASE AND INSECT RESISTANCE?

(Abstract)

E. L. Sharp

Vertical specialized or specific resistance in a host is directed against some physiologic races of a pathogen but not others. In many cases genes for resistance in the host are known to have counterparts or corresponding genes for virulence in the pathogen. The race concept is founded on this type of resistance. Vertical resistance reduces the initial inoculum. It is relatively easy to work with, usually gives clear cut differences even in the host seedling stage and is often monogenic in inheritance. Vertical resistance has been most often used by plant breeders and has been combined into resistant varieties by a number of pathways including pairs of genes, multiple genes and multilineal varieties.

Horizontal, non-specific or generalized resistance operates against all physiologic races and usually results in a moderate degree of resistance. It reduces the infection rate, is probably best exemplified in the resistance of some potato varieties to late blight, but is applicable to other host-pathogen systems. Some attributes of horizontal resistance are difficulty in obtaining infection, reduced sporulation, lengthened incubation period, slow growth of lesions and a shortened infectious period for infected tissue. The genetic nature for this type of resistance is not well known. It is probably polygenic and additive in action and single genes are difficult to identify. Field resistance tends to be horizontal resistance.

Advocates of horizontal resistance view it as a longer lasting resistance and suggest that breeding for vertical resistance may lead to a multitude of races and reduction of horizontal resistance originally present in a plant host population.

At Montana State, considerable study has been directed toward determining the genetic systems of the wheat variety P.I. 178383 which condition resistance to *Puccinia striiformis* (stripe rust). The results are summarized in Table 1.

Table 1. Summary of stripe rust infection types conditioned by major and minor genes of wheat variety P.I. 178383.

| No. and type of resistance genes | Mean infection type at $15/_{24}{}^{\circ}$F. | at $2/_{18}{}^{\circ}$C |
|---|---|---|
| None | 4 | 4 |
| one minor | 2 | 3 |
| two minor | 0 | 2 |
| three minor | 00 | 1- |
| one major[a] | 00 | 00 |

[a] The major gene is epistatic to all minor genes.

P.I. 178383 is near immune to a Bozeman isolate of stripe rust. One major near dominant gene conditions the reaction. In the absence of the major gene, 3 recessive additive genes conditioning rust reaction can be detected. These minor genes all condition more resistance at a higher temperature profile. Different genotypes of <u>P. striiformis</u> are being evaluated in an attempt to determine if the resistance conditioned by the minor genes is vertical or horizontal. A stripe rust resistant wheat variety (Crest) developed from Westmont X P.I. 178383 by conventional methods contains only the major gene from P.I. 178383.

# WHAT IS THE IMPORTANCE OF THE RACE CONCEPT TO WHEAT BREEDING?

L. E. Browder

The importance of the race concept to wheat breeding is dependent upon the wheat breeders race concept. The concept that race is a stable, hard and fast, ultimate means of classification negates its usefulness completely. But if one understands race as a term to be a flexible, artificial means of categorizing certain combinations of genes for virulence, then the race concept may still be of value. The North American Wheat Leaf Rust Workers' Committee has established that races may be identified equally well on any set of differential host varieties if the information has been published so that others may understand the meaning of race numbers and if the "set" is designated in the race designations. Thus, we may have UN races, NA61 races, NA65 races, and others as well as International Standard races, which are the classic races.

The gene-for-gene relationship is generally accepted to be the basis for pathogenic specialization. As such, this imposes certain limitations and implications on race identification studies. These studies are studies of the parasite race nomenclature and are based on pathogenicity to known host genes for resistance, or known host varieties. Infection-types of host:parasite interaction are observed and information concerning parasite is inferred. The accuracy of inferred information is directly related to accuracy of knowledge of host materials.

The practical use of information concerning pathogenicity to host genes for resistance brings the question of how many genes for resistance can be successfully manipulated in combination in breeding programs.

This is the number of genes for pathogenicity we need to consider and relate to one another in studies of pathogenic specialization. If we use only one gene for resistance only one parasite gene need be followed in a parasite population; if two or more are used, then all the corresponding genes for pathogenicity need to be studied, each independently and in association with one another.

Studies of parasite populations known as race surveys have long been conducted; data obtained were translated into pathogenicity combinations including the entire differential set studied, or races. This treatment tends to obscure information concerning combinations involving less than the whole set, individual virulence gene frequencies and association of pathogenicity to two or few genes for resistance.

There are three parameters which these studies seek to estimate: 1) virulence frequencies, 2) virulence associations, and 3) virulence distributions. These parameters can best be estimated directly, from original data rather than by extracting them from race data. The numbers of combinations which need to be studied may eventually limit the practicality of assigning race numbers to them at all. This whole area of work in wheat leaf rust work presently is in a state of transition. Some better ways of presenting data need to be found.

I would recommend that we consider pathogenic specialization data in the form which the phenomenon functions in nature--ie genes for host reaction and genes for parasite pathogenicity, and that we use survey data to decide which genes for resistance to use rather than what races to breed against.

Finally, a word of caution, we should never assume to equate adult plant resistance to rust with generalized resistance. Such resistances have proven to be quite specific in several cases.

# REPORT OF THE SIXTH CONFERENCE OF THE NORTH AMERICAN WHEAT LEAF RUST RESEARCH WORKERS COMMITTEE

February 4-5, 1968

Manhattan, Kansas

L. E. Browder

The committee and visitors met informally for dinner and discussion on February 4. An agenda was set for the February 5 meeting. The discussion centered around genes which "modify" the effect of other genes, the specific or non-specific nature of such genes and methods of demonstrating their specificity or non-specificity.

The committee convened at 8:30 a.m. on February 5. Discussion began concerning principles of applying information of specific host:parasite relationships to disease control and the kinds of host materials which are of value in studying parasite populations. The general categories of host lines having: (1) "Universal Resistance", (2) known single genes for resistance, (3) combinations of known genes for resistance, and (4) genes for adult plant resistance were considered. Increased knowledge of the resistance genotypes of host materials increases the potential value of studying the North American differential set for *Puccinia recondita* f. sp. *tritici*. The decision was made to meld lines containing certain single genes for resistance from the International Standard Differential varieties with two lines, each having one gene from Exchange ("E" and "L"), and the variety Aniversario (of unknown genotype for resistance) into a North American 1968 (NA68) differential set. A report describing this set and a key for nomenclature of virulence combinations will be published soon. All workers are encouraged to submit host materials for consideration as candidates for the Test Variety program of the NA committee. This may be done by contacting me.

A statistical tool for evaluating association of parasite genes for virulence and derivation of information about genotype of the host lines from data obtained in surveys was discussed as well as the potential value of virulence association data in choice of specific resistances for disease control. Improvements in methodology and equipment used in making surveys so as to provide better data more efficiently were discussed.

Dr. E. G. Heyne met with the committee to discuss nomenclature of genes for specific leaf rust resistance in wheat and the symbolization of host:parasite genotype interactions. The committee resolved to recognize Dr. Heyne as a "clearing-house" for the assignment of gene numbers in the LR series. All workers are urged to contact him before publishing new numbers for genes for leaf rust resistance. The need for designating "intangible" genes temporarily in some cases is recognized. Symbols other than numbers should be used in these cases. A uniform means of designating host genes and alleles was deemed beneficial and such a designation system was agreed upon. A slightly different system from that previously used was developed to accomodate expanding use of automatic data processing equipment.

The group then toured the Wheat Leaf Rust Laboratory and observed some equipment recently developed for use in making surveys of pathogenic potential.

The committee then reconvened in conference to discuss the value and use of non-specificity in rust control. Possible mechanisms and the measurement including early testing of non-specificity were the chief topics considered.

The deposit of cultures of P. recondita f. sp. tritici in the Plant Rust Collection of the American Type Culture Collection was considered and deemed of great importance to future scientists for comparisons as well as providing reserves of today's working cultures and voucher cultures for published research. All rust workers are encouraged to make use of this collection. Cultures may be deposited as "Restricted" and "Red Label" cultures where their distribution is carefully controlled to avoid escape of dangerous cultures.

Some of the previous work of the NA Committee has been published in three papers:

1. A COMMITTEE OF NORTH AMERICAN WHEAT LEAF RUST RESEARCH WORKERS. 1959. A proposed modification of the system of wheat leaf rust race identification and nomenclature. Plant Disease Reptr. 43:613-615.

2. A COMMITTEE OF NORTH AMERICAN WHEAT LEAF RUST RESEARCH WORKERS. 1961. The North American 1961 set of supplemental differential wheat varieties for leaf rust race identification. Plant Disease Reptr. 45:444-446.

3. Young, H. C. Jr., and L. E. Browder. 1965. The North American 1965 set of supplemental differential wheat varieties for identification of races of Puccinia recondita f. sp. tritici. Plant Disease Reptr. 49:308-311.

Reprints of these papers are available through the secretary.

Committee members present at the sixth conference were W. Q. Loegering, Chairman; D. J. Samborski; J. F. Schafer; H. C. Young, Jr.; and L. E. Browder, Secretary.

# BREEDING FOR RESISTANCE TO BARLEY YELLOW DWARF VIRUS IN WHEAT

(Abstract)

Paul J. Fitzgerald and J. R. Thysell

Barley yellow dwarf studies at Brookings are directed toward locating useful sources of tolerance or resistance to the BYDV in wheat, the development of resistant breeding lines, and the study of the inheritance of resistance to the virus. Concurrent with these efforts have been several special studies to determine factors affecting symptom development and the effect of the virus on yield and quality. A special study is in progress to measure the effects of aphid number and plant age on the response of individual plants to infection with the BYDV.

Screening of lines for resistance began in a modest way in 1963 in the greenhouse. The program has expanded to include field comparisons for all final evaluations. Evaluations in the greenhouse based solely on foliar symptoms have not been effective in identifying the most resistant or tolerant lines as measured by field performance. Comparisons between control and inoculated plants at or near maturity with regard to head size, height, and general vigor have been useful in identifying sources of tolerance. More than a dozen lines tested in 1964 greenhouse trials were considered to have some potential as parental material. An additional 14 lines were selected from a screening trial in field plots in 1965. Subsequent tests have reduced the number of promising lines, but crosses have been made involving many of these BYDV-tolerant lines and some of the current hard red spring wheat varieties. Some of the crosses have produced progenies that survived testing as $F_2$ plants in the greenhouse, as $F_3$ lines in field plots, and as $F_4$ lines in a replicated yield trial in 1967. The yield trial also included several selections from the Rockefeller-Mexican Program. Summarized results are presented in Table 1. The performance of some of these lines is encouraging when compared to the 60-75% tolerance reported by H. C. Smith from the best New Zealand wheats. The disturbing note is that Crim and Chris have shown much poorer performance in several previous trials in other years. Additional testing will be required to determine the level of tolerance the lines will exhibit under different environmental stresses.

A different approach to breeding for resistance to the BYDV has been undertaken by utilizing adapted varieties that have complimenting reactions to infection with BYDV with regard to their yield components. Two hard red spring wheats in the 1965 BYD trials were selected because of the following reactions:

| Variety | Kernels/head | | 1000-kernel weight - g | |
|---|---|---|---|---|
| | Control | Inoculated | Control | Inoculated |
| Minn **-54-30 | 26.7 | 26.3 | 30.17 | 27.86 |
| ND 456 | 28.5 | 17.5 | 28.14 | 28.09 |

**These varieties were crossed and their progeny was advanced to the $F_3$ generation before testing. Parental lines and the $F_3$ progeny were heavily infested in the seedling stage with viruliferous Rhopalosiphum padi aphids. Approximately 100 primary tillers from each parent and 500 from the $F_3$ progeny were harvested from infested and control plots for individual head analysis. Preliminary analyses suggest a close approximation to a normal distribution curve. A partial summary of these data is presented in Table 2. The more critical analysis in 1967 indicates that the parental lines did not respond in the manner as in the 1965 trial from which they were selected. It is encouraging, however, that several lines from the progeny exceed the mean of the progeny control for seed number and seed weight. If differences observed are heritable rather than chance variation or escape of infection, prospects seem good that BYDV-tolerant lines may be developed from adapted varieties or selections.**

Table 1. Performance of selected spring selections inoculated with barley yellow dwarf virus in field plots at Brookings, S.D. 1967.

| Selection | Yield in bushels/acre | | Percent control | Standard error1/ (adjusted t) |
|---|---|---|---|---|
| | Control | Inoculated | | |
| From Brookings Program | | | | |
| 6526A-23 | 34.2 | 29.6 | 86.5 | NS |
| Crim | 38.8 | 32.2 | 83.0 | NS |
| Chris | 30.6 | 24.8 | 81.2 | NS |
| 6516A-13 | 38.4 | 30.6 | 79.7 | NS |
| 6516D-12 | 30.2 | 24.0 | 79.5 | NS |
| 524A-20 | 33.8 | 26.2 | 77.5 | * |
| 6529A-22 | 30.6 | 23.4 | 76.5 | NS |
| 6524A-22 | 36.0 | 27.2 | 75.6 | * |
| 6531A-24 | 34.6 | 25.8 | 74.6 | NS |
| 6516D(SB) | 33.2 | 24.6 | 74.1 | * |
| From RF-Mexican Program: | | | | |
| S4027 | 30.4 | 33.2 | 109.9 | NS |
| S3981 | 26.0 | 24.0 | 92.3 | NS |
| Mex 30 | 30.4 | 27.6 | 90.8 | NS |
| S3987 | 25.6 | 22.8 | 89.1 | NS |
| $T_2$PP-An64 | 24.0 | 21.2 | 88.3 | NS |
| Penjamo | 30.6 | 26.4 | 86.3 | NS |

1/ * = Treatment means are different at the .05 level of significance.
NS = No significant difference between treatment means.

Table 2.--Partial summary of individual head analyses from hard red spring wheat parental and $F_3$ progeny plants infested with viruliferous aphids.

| Variety and Generation | Treatment | Number of kernels | | | Weight of kernels | | | mean of control | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Total heads | Range | Mean | Total heads | Range g | Mean g | No. of kernels | Weight of kernels-g | Both kernel no. and kernel wt. |
| Minn.II-54-30 | Control | 87 | 17-51 | 33.1 | 87 | 0.451-1.750 | 1.066 | 41 | 36 | 33 |
| $P_1$ | Inoculated | 84 | 2-49 | 25.7 | 84 | 0.050-1.600 | 0.624 | 12 | 3 | 3 |
| ND456 | Control | 86 | 21-46 | 33.7 | 86 | 0.701-1.700 | 1.313 | 46 | 40 | 35 |
| $P_2$ | Inoculated | 78 | 4-38 | 20.1 | 78 | 0.101-1.500 | 0.551 | 5 | 2 | 2 |
| 6651A | Control | 463 | 14-68 | 36.4 | 456 | 0.140-3.570 | 1.261 | 194 | 226 | 151 |
| $(P_1XP_2)$ $F_3$ | Inoculated | 469 | 1-56 | 25.0 | 481 | 0.019-1.711 | 0.565 | 29 | 21 | 9 |

# SEEDLING AND ADULT PLANT RESISTANCE TO STEM RUST

D. R. Knott

I have tended to be skeptical about the importance of adult resistance, partly because there have been so few good studies that tested both seedling and adult plant resistance. Hope and H44 are considered to be good examples of varieties having adult plant and perhaps horizontal resistance, but many studies on them were done only in the field. I began a study of these two varieties because I was interested both in their genes for resistance and the relationship of the genes to adult plant resistance.

Backcrosses of both varieties to Marquis were studied. For seedling resistance to race 56 each variety had a single dominant gene on chromosome 2B (XIII). A line carrying only this gene, Sr 1, was not as resistant as Hope and H-44. In field tests with race 56, Sr 1 proved to condition moderate resistance. However, a second gene, Sr 2, was clearly segregating. Alone it provided moderate resistance to race 56. Only families segregating for both Sr 1 and Sr 2 had plants that were as resistant as Hope and H-44. The gene Sr 2 had no detectable affect in seedlings. However, at the seeding stage also it was found that only families segregating for both Sr 1 and Sr 2 contained plants as resistant as the parent. Thus in seedlings Sr 2 modifies the resistance conditioned by Sr 1 while at the adult plant stage the two genes act independently but their effects are additive.

Both varieties also carry a recessive gene that conditions good resistance to race 15B-IL. Its location has not yet been determined.

The results show conclusively that Hope and H-44 do have adult plant resistance. It is inherited in a normal fashion and it is reasonable to assume that there is a corresponding gene for virulence in the pathogen. The rather broad resistance of these two varieties is probably due to the number of genes that they carry - at least three genes in addition to genes they obtained from Marquis.

# QUANTATIVE LEVELS OF RESISTANCE TO STRIPE RUST

(Abstract)

W. K. Pope

Wheat selections and populations as observed under stripe rust (puccinia striiformis) at Moscow, Idaho since 1960 show many combinations where crosses of susceptible or moderately resistant wheats produce segregates more resistant than the best parent. These genes act by dosage, are relatively ineffective alone, but produce additive increments of resistance in most, but not all non-allelic recombinations.

The five varieties Cheyenne (res.), Hussar (res.), Idaid (res.), Comanche (Int.) and white club (sus.) will produce additive resistance in all combinations by two's. The highly susceptible Lemhi 62 functions as a missing ingredient with moderately resistant bolden producing highly resistant derivatives that persisted further $F_1$ plants in 1967 with additionally resistant derivatives of the Idaid x Omar combination.

Many highly resistant varieties are multigene such as Hohenheimer whose resistance could not be maintained in a fast backcross to the fully susceptible Lemli. In contrast in a backcross of resistant Cheyenne to Hohenheimer, it has been easy to maintain a higher than Cheyenne level of resistance by maintaining presumably only a part of the Hohenheimer resistance.

All highly resistant wheats including those with very dominant genes have had more than one gene for resistance. Dominant and recessive resistance have been distinguished only by segregation patterns and not by phenotype.

# PHOTO SYNTHETIC AND YIELD RESPONSES OF GAINES AND HADDEN WHEATS TO INFECTION BY SEPTORIA NODORUM.

(Abstract)

A. L. Scharen

Photosynthesis, measured as $CO_2$ absorption, was measured in heads and flag leaves of Gaines and Hadden wheats. The effect of infection by Septoria nodorum on rates of photosynthesis was determined daily for 2 weeks after inoculation at the flowering stage. Yield was measured and related to disease symptoms and photosynthesis. Heads and flag leaves of Gaines absorbed $CO_2$ at an average rate of 5.98 mg per hour during the test period. Severe infection reduced photosynthesis by 46% and yield by 57%. Heads and flag leaves of Hadden absorbed $CO_2$ at an average rate of 2.62 mg per hour. Moderate infection reduced photosynthesis by 14% and yield by 23%.

High rate of photosynthesis are characteristic of high yielding varieties. Changes in photosynthetic ability of varieties when infected by S. nodorum were correlated with the seed yield of those varieties. Measurement of photosynthetic ability may be useful in selecting lines with high yielding potential in breeding programs. Maintenance of photosynthetic ability, and consequently yielding ability, in spite of infection by a pathogen may be helpful in selecting lines with resistance or tolerance to certain diseases.

# INHERITANCE OF STEM RUST RESISTANCE IN SEVERAL VARIETIES OF WHEAT

F. J. Gough and N. D. Williams[a]

We have worked at Fargo, North Dakota on the culture (genotype)-specific form of resistance of Triticum to Puccinia graminis f. sp. tritici Eriks. & E. Henn. Culture 111-SS2 of race 111, the most widely avirulent race known, was used as the standard test culture. In every variety previously studied as many, and usually more, genes for resistance were indicated by the use of culture 111-SS2 than had been indicated by the use of a more widely virulent culture. However, culture 111-SS2 did not indicate all of the genes for resistance which some varieties possessed. For example, Sr 5 and a gene in T. dicoccum Schubl. 'Khapli', believed to be Sr 14, were not discernible with the use of culture 111-SS2.

Objectives of the program were: a) to demonstrate the presence or absence of a gene-for-gene relationship, b) to develop a series of wheat lines, each monogenic for a different gene for resistance, to be used to differentiate cultures of P. graminis f. sp. tritici and as sources of resistance in breeding programs, and c) to select tester cultures of P. graminis f. sp. tritici which would differentiate genotypes of wheat varieties, selections, and hybrids. Ideally, the cultures would have different single genes for avirulence each corresponding to a different gene in the series of monogenic wheat lines.

The first objective has been accomplished. The second will never be to our full satisfaction since almost all varieties are resistant to culture 111-SS2, and because new sources of resistance useful in breeding programs occasionally become available. The third objective has received no concentrated effort.

From crosses of T. aestivum ssp. vulgare (Vill., Host) Mac Key 'Marquis', 'Reliance', and 'Kota' with T. aestivum ssp. compactum (Host) Mac Key 'Little Club', three, three, and four lines, respectively, were isolated. Each line was believed to have a single gene for resistance. Subsequent crosses of each line with Little Club confirmed that all except one derived from Kota (Kt-A) had a single gene for resistance. Kt-A had two genes for resistance. The derived lines were intercrossed and those from Marquis and Reliance were crossed with lines having the genes for resistance from substitution lines Hope 1D, Red Egyptian 2B, and Thatcher 2B. The lines

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a/ The authors gratefully acknowledge the many contributions to this work by the late Dr. Mario Rondon, Dr. L. A. Berg, Mr. Hossein Kaveh, and Mr. Melvern Anderson.

derived from the substitution lines were developed by Dr. W. Q. Loegering. Relationships among the genes for resistance are shown in Table 1.

Several varieties of *T. durum* Desf., two of *T. dicoccum*, and one selection of *T. timopheevi* Zhuk. were crossed with *T. durum* 'Marrocos 9623'. Subsequent segregating generations were tested to determine the number of genes which conditioned resistance culture 111-SS2, and to isolate lines with single genes for resistance (Table 2). The most apparent feature of the data in Table 2 is the number of times that three genes for resistance were indicated by culture 111-SS2. One possible explanation is that the culture had three genes for avirulence which corresponded to three loci in the host varieties. However, this hypothesis weakened by the data obtained from Marquis, Reliance, and Kota which indicated that these three varieties may possess as many as six non-allelic genes for resistance.

Table 1. The relation of genes for resistance to culture 111-SS2 of Puccinia graminis f. sp. tritici in lines derived from Marquis and Reliance to those in Kota and in lines derived from substitution lines Hope 1D, Red Egyptian 2B, and Thatcher 2B.

| Derived line a/ | Gene relationship |
|---|---|
| Mq-A, Rl-A, Kt-B, and Hope 1D | Single gene in common |
| Mq-B | Single gene, probably linked with Sr 9a on Red Egyptian 2B |
| Rl-B and Thatcher 2B | Single gene in common, Sr 16 |
| Mq-C and Rl-C | Single gene in common, not linked with or allelic to genes in other derived lines |
| Kt-A | Two genes, one may be the same as the one in Mq-C and Rl-C. Neither gene allelic to Sr 9a nor the gene in Hope 1D. The cross between Kt-A and Rl-B not obtained. |
| Kt-C | Single gene, not linked with or allelic to genes in other derived lines |
| Kt-D | Single gene, cross not obtained with Rl-B, not linked with or allelic to genes in other derived lines |

a/ Mq-A, Mq-B, and Mq-C were derived from Marquis. Rl-A, Rl-B, and Rl-C were derived from Reliance. Kt-A, Kt-B, Kt-C and Kt-D were derived from Kota.

Table 2. The number of genes in durum, emmer, and timopheevi wheats which condition resistance to culture 111-SS2 of *Puccinia graminis* f. sp. *tritici*.

| Species and variety | No. of genes for resistance |
|---|---|
| *T. durum* | |
| Acme[c] | 3 |
| Arnautka[d] | - |
| Beladi 116[c] | 3 |
| C. I. 7805[d] | - |
| C. I. 8155[a] | 3 |
| Iumillo[b] | 3 |
| Kubanka[b] | 1 |
| Mindum[a] | 3 |
| P. I. 94701[a] | 3 |
| P. I. 192168[a] | 3 |
| Spelmar[a] | 3 |
| St 464[b] | 3 |
| Tremez preto[d] | - |
| Tremez rijo[c] | 2 |
| *T. dicoccum* | |
| Khapli[a] | 3 |
| Vernal[b] | 1 + 2 modifiers |
| *T. timopheevi*[d] | - |

a Selected single gene lines intercrossed and crossed with susceptible *T. durum* 'Marrocos 9623'.

b Single gene lines selected from $F_4$ and backcross-$F_3$.

c $F_2$ and backcross-$F_1$ tested.

d Cross made but segregating generations not tested.

# REACTION OF CERTAIN WHEAT VARIETIES AND SELECTIONS TO LEAF RUST - OKLAHOMA, 1967

H. C. Young, Jr., T. A. Kucharek,
J. M. Prescott and L. L. Singleton

Seeding reaction tests of 82 wheat varieties and selections plus 30 differential varieties and selections were made with 21 isolates of Puccinia recondita f sp tritici during February and March, 1967. The tests were made in the greenhouse at approximately 20° C. The tests with individual cultures were not made concurrently and, therefore, a certain amount of variation in reaction was expected due to light and temperature fluctuations. In all cases, the number of plants with off-type reactions was noted. Those varieties or selections with off-type reactions were considered mixed or segregating for reaction to one or more cultures. Approximately 15 to 20 seedlings were tested with each culture and the reaction listed was the reaction expressed by the majority of plants. If a variety or selection was segregating, a false reaction might have been indicated with such a small number of plants.

The response of most of these same varieties and selections to leaf rust in the field also was recorded. No artificial inoculations were made on the field plantings.

These data have been assembled and distributed with the thought that they would be of interest to other pathologists and breeders concerned with leaf rust problem in wheat.

## Reaction to Leaf Rust Culture

| Entry No. | Variety or Cross | C.I. or Sel. No. | Source | 2-NA65- | | | 5-NA65- | | | | 6-NA65- | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 9 | 27 | 27 | 3 | 19 | 19 | 27 | 3 | 19 | 19 | 25 | 27 | 28 |
| 1. | MA /1 | 4898 | LR INT | 0' | 0-0' | 0' | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 2. | CI | 3756 | DIFF | 0'-1 | 0'-1 | 0' | 0'-2 | 0'-1 | 0'-2 | 0'-2 | X | 2-4 | X | 3-4 | 2-4 | X |
| 3. | BV | 3778 | " | 0' | 0'-2 | 0'-2 | 0'-1 | 0'-1 | 0'-2 | X | 4 | 4 | 3-4 | 4 | 4 | 3-4 |
| 4. | WST | 3780 | " | 0' | 0'-1 | 0' | 0'-1 | 0'-1 | 0'-1 | 0'-2 | 0'-2 | 0' | 0'-1 | 0'-1 | 0' | 0'-1 |
| 5. | LS | 3779 | " | 0' | 0'-2 | 0'-2 | 0' | 0'-1 | 0'-1 | 0'-2 | 3-4 | 4 | 3-4 | 3-4 | 4 | 3-4 |
| 6. | MI | 3332 | " | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 7. | HS | 4843 | " | 2-4 | 3-4 | 3-4 | 3-4 | 3-4 | 4 | 3-4 | 4 | 4 | X | 4 | 3-4 | 4 |
| 8. | DO | 3384 | " | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3-4 | 4 | 4 | 4 | 4 | 4 |
| 9. | DLR | 13373 | NA SUP | 0'-1 | 2-4 | 2-4 | 0'-2 | 2-4 | 3-4 | 2-4 | 0'-3 | 4 | 3-4 | 2-4 | 2-4 | 2-4 |
| 10. | LEE | 12488 | DIFF | 3-4 | 3-4 | 2-4 | 0'-1 | 0'-2 | 0'-2 | 4 | 2 | 0'-2 | 0'-2 | 2-4 | 2-4 | 3-4 |
| 11. | WBN | 12992 | " | 0' | 0' | 0' | 0' | 0-0' | 0' | 0' | 0' | 0' | 0' | 0' | 0' | 0' |
| 12. | SVL | 12595 | " | 0' | 3-4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 0' | 4 | 4 |
| 13. | ECH | 12635 | " | 0' | 0'-2 | 0'-1 | 0'-1 | 0' | 0' | 0'-1 | 0'-1 | 0' | 0' | 0' | 0'-2 | 2-4 |
| 14. | ARS | 13228 | NA UR | 0' | 0' | 0' | 0' | 0' | 0' | 0-0' | 0-0' | 0' | 0' | 0-0' | 0' | 0' |
| 15. | AG | 13523 | " | 0'-2 | 0' | 0'-1 | 0'-1 | 0' | 0'-2 | 0' | 0' | 0'-2 | 0' | 0' | 0' | 0'-2 |
| 16. | AIV | 12578 | " | 0'-2 | 0'-2 | 0'-2 | 0'-2 | 0'-1 | 0'-2 | 0'-2 | 0'-2 | 0'-3 | 0'-2 | 2-3 | 0'-2 | 2-3 |
| 17. | LCO | 14047 | " | 0' | 0'-1 | 0' | 0'-1 | 0' | 0'-1 | 0'-2 | 0'-1 | 0'-1 | 0'-2 | 0' | 0' | 0'-2 |
| 18. | TF | 13483 | " | 0' | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' |
| 19. | WK | 13659 | " | 0' | 0'-2 | 0' | 0-0' | 0-0' | 0' | 0'-1 | 0'-1 | 0' | 0'-1 | 0' | 0' | 0' |
| 20. | WD2 | 13628 | NA TV | 0' | 0-0' | 0' | 0-0' | 0' | 0'-1 | 4 | 0' | 0'-1 | 0' | 0' | 0' | 0' |
| 21. | WBN2 | 14018 | " | 0' | 0' | 0' | 0-0' | 0-0' | 0' | 0-0' | 0-0' | 0' | 0' | 0-0' | 0' | 0' |
| 22. | WK2 | 14049 | " | 0' | 0' | 0' | 0-0' | 0-0' | 0' | 0'-2 | 0-0' | 0'-1 | 0' | 0'-1 | 0' | 0' |
| 23. | L.R. | 13651 | " | 0' | X | 0' | 0'-1 | 0'-1 | 0'-3 | X | 3-4 | 3-4 | 3-4 | 0'-4 | 4 | 4 |
| 24. | LANI | 14021 | " | 0'-1 | 0'-1 | 0'-2 | 0'-1 | 0' | 0'-2 | 0'-1 | 0' | 0'-2 | 0'-2 | 0'-2 | 0' | 0'-2 |
| 25. | LF | 14022 | " | 0' | 0'-2 | 0'-2 | 0' | 0'-2 | 0'-3 | 0'-2 | 0' | 0' | 0' | 0' | 0' | 0'-1 |
| 26. | ANEX | 14020 | " | 0' | 0'-1 | 0'-3 | 0' | 0' | 0' | 0'-1 | 0' | 0' | 0' | 0' | 0' | 0' |
| 27. | FREX | 14019 | " | 0' | 0' | 0'-1 | 0' | 0'-2 | 0' | 0' | 0' | 0' | 0' | 0' | 0' | 0' |
| 28. | WTR | 12110 | OK TV | 4 | 4 | 3-4 | 0'-1 | 0'-2 | 3-4 | X | 4 | 3-4 | 0'-2 | 4 | 4 | 3-4 |
| 29. | WSL | 13090 | " | 2-4 | 3-4 | 2-4 | 3-4 | 2-4 | 2-4 | 2-4 | 4 | 2-4 | X | 2-4 | 3-4 | 4 |
| 30. | TP | 14154 | " | 0' | 0' | 0'-1 | 0' | 0' | 0' | 0-0' | 0' | 0' | 0' | 0' | 0' | 0' |

Continued--

| Entry No. | Variety or Cross | C.I. or Sel. No. | Source | 2-NA65- | | | 5-NA65- | | | | 6-NA65- | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 9 | 27 | 27 | 3 | 19 | 19 | 27 | 3 | 19 | 19 | 25 | 27 | 28 |
| 31. | KR/HF | S63R5003 | OK TV | 0' | θ-0' | 0' | 0' | 0' | 0' | 0' | 0' | 0'-1 | 0' | 0' | 0' | 0' |
| 32. | 5WI/TF | 13853 | " | 0' | 0-0' | 0' | 0-0' | 0-0' | 0' | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' |
| 33. | I.B.J/TF | S60R7919 | " | 0' | 0-0' | 0-0' | 0-0' | 0-0' | 0' | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' |
| 34. | CNN | 8885 | CK | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 35. | CCH | 12517 | " | 3-4 | 4 | 4 | 0'-2 | X | X | X-4 | 4 | X | X | 4 | 4 | 4 |
| 36. | WI | 11952 | " | 3-4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3-4 | 4 | 4 | 4 |
| 37. | TMP | 12132 | " | 3-4 | 4 | 4 | 4 | 4 | 4 | 4 | 3-4 | 4 | 4 | 4 | 4 | 4 |
| 38. | BSN | 12518 | " | 4 | 4 | 3-4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 39. | T*SP/A*E2/PN | 13020 | " | 0' | 0'-1 | 0'-2 | 0'-1 | 0'-1 | 0'-1 | 0' | 0' | 0' | 0'-2 | 0' | 0' | 0'-1 |
| 40. | MQL/2ORO2/TM4/T*SP/A*E2/PN3/PNC | S589063 | " | 0'-1 | 2-4 | 0' | 0'-1 | 0'-2 | 0'-2 | 0'-1 | 0' | 0'-1 | 0'-1 | 0' | 0' | 0'-1 |
| 41. | KV2/FZ/HG3/W38/WBS2/FF4/3TB 2/HOPE/HS5/ARS | P5396A4-11-4 | IND | 0' | 0' | 0' | 0' | 0-0' | 0' | 0' | 0' | 0' | 0' | 0' | 0' | 0' |
| 42. | (UNKNOWN) /2 | P5517B5-5-1P-3-1 | " | 0'-1 | X | 2-4 | 0'-2 | X | X | X | X | X | 0'-1 | 0'-2 | 0'-4 | X |
| 43. | (UNKNOWN) /2 | P5824A1-1-3 | " | 0' | 0' | 0-0' | 0-0' | 0' | 0' | 0-0' | 0-0' | 0-0' | 0' | 0-0' | 0' | 0' |
| 44. | WBS/A.B2/AIV | 13227 | " | 0'-1 | 0'-2 | 0' | 0'-2 | 0' | 0'-2 | X | 0'-1 | 3 | 2-3 | 0'-2 | 0' | 0'-3 |
| 45. | AIV/2PNC | S62R8530 | OK | 0'-2 | 0'-1 | 0' | 0'-2 | 0' | 0'-1 | 0'-3 | 0' | 3-4 | 2-3 | 0'-1 | 0' | 2-3 |
| 46. | BI/CCH2/ATN | T59C773 | TEX | 0' | 0'-2 | 0'-2 | 0' | 0' | 0'-3 | 0'-2 | 0' | 0' | 0' | 0' | X | 0' |
| 47. | ATL50/FW1123 2/SUWON92/NRN66 | S61R8529 | " | 0-0' | 0-0' | 0'-1 | 0-0' | 0-0' | 0' | 0' | 0' | 0' | 0-0' | 0' | X | 0' |
| 48. | PSK | 14153 | OK | 0' | 0' | 0'-1 | 0'-1 | 0' | 0'-1 | 0' | 0' | 0'-2 | 0'-1 | 0' | 0' | 0'-1 |
| 49. | MQL/ORO2/PN3/FTN | S61R8538 | " | 0-0' | 0' | 0'-2 | 0'-2 | 0'-1 | 0'-2 | 0'-1 | 0' | 0'-2 | 0'-1 | 0' | 0' | 0'-2 |
| 50. | BP | PI203084 | FOR INT | 0' | 2-4 | X-4 | X | 0' | X-4 | X | 0' | 0'-2 | X | 0' | X | 0' |
| 51. | (UNKNOWN) /2 | S61R8541 | IND | 0-0' | 0-0' | 0-0' | 0-0' | 0' | 0-0' | 0' | 0-0' | 0-0' | 0'-1 | 0-0' | 0' | 0-0' |
| 52. | 2TMP2/T*SP/A*E | S646395 | OK | 0' | 0'-1 | 0' | 0'-2 | 0' | 0' | 0' | 0' | 0'-1 | 0'-1 | 0' | 0' | 0'-1 |
| 53. | " | S646408 | " | 0'-1 | 0'-1 | 0'-1 | 0'-1 | 0'-1 | 0'-1 | 0'-1 | 0' | 0'-1 | 0'-2 | 0' | 0'-1 | 0'-1 |
| 54. | KAW3/TMP2/T*SP/A*E | S646253 | " | 0'-1 | 0'-1 | 0' | 0'-1 | 0' | 0'-1 | 0' | 0' | 0'-1 | 0'-1 | 0' | 0' | 0'-1 |
| 55. | 64KRANSADOR | | FOR INT | 4 | 2-4 | 2-4 | 4 | 2-4 | 2-4 | X | 4 | 4 | 4 | 0'-3 | 2-4 | 4 |
| 56. | 2TMP2/T*SP/A*E | SC60123-9-3-2 | OK | 0'-1 | 0'-1 | 0' | 0'-1 | 0'-1 | 0'-1 | 0' | 0' | 0'-1 | 0'-1 | 0' | 0' | 0'-1 |
| 57. | WI4/(WI3/T*SP/A*E2/PN)F1XR | S64C984 | " | 0'-1 | 0'-1 | 0'-1 | 0'-2 | 0'-1 | 0'-1 | 0'-1 | 0' | 0'-1 | 0' | 0' | 0' | 0'-1 |
| 58. | " | S64C1028 | " | 0'-1 | 0'-2 | 0' | 0'-1 | 0' | 0' | 0' | 0' | 0' | 0' | 0' | 0' | 0'-2 |
| 59. | ML | 13369 | TEX | 3-4 | 4 | 0'-2 | 4 | 2-3 | 2-4 | 2-4 | 2-4 | 2-4 | X | 0'-2 | X | 2-4 |
| 60. | (UNKNOWN)/2 | P568B6-2-3P-2 | IND | 4 | 4 | 4 | 4 | 4 | 0' | 4 | X | 2-4 | X-4 | 4 | 4 | X |
| 61. | (UNKNOWN)/2 | P568C3-5 | IND | 3-4 | 3-4 | 4 | 0' | 3-4 | 4 | 4 | 4 | 4 | X | 2-4 | 0'-4 | 4 |
| 62. | (UNKNOWN)/2 | P5752A1-1P-2 | IND | 2-4 | 4 | 4 | 3-4 | 4 | 4 | 4 | 4 | 4 | X-4 | 3-4 | 4 | X |

Continued --

| Entry No. | Variety or Cross | C.I.or Sel.No. | Source | 2-NA65- 9 | 27 | 27 | 5-NA65- 3 | 19 | 19 | 27 | 6-NA65- 3 | 19 | 19 | 25 | 27 | 28 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 63. | IVCL(12034)/CMN2/PN3/CCH | K63322 | KAN | 3-4 | 2-4 | X-4 | 4 | 0' | 0' | 0'-3 | 4 | 0'-2 | X | X | 3-4 | 2-4 |
| 64. | " | K63326 | " | 0'-2 | 0'-2 | 0'-2 | 0'-1 | 0'-2 | 0' | 0'-2 | 2-4 | 0'-2 | 0'-2 | 0'-4 | X | X-4 |
| 65. | 38MAB0427 | PI116015 | FOR INT | 0'-1 | 2-4 | 3-4 | 4 | seg. | 4 | 4 | 3-4 | 3-4 | 2-4 | X | 4 | X |
| 66. | ARGENTINA C9556 | PI117490 | " | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 0'-4 | 4 | X |
| 67. | RIETTE/QUALITY | PI225157 | " | 0'-1 | 0'-3 | 0'-2 | 3-4 | X | 2-4 | 0'-2 | Y | 2-4 | X | 0'-1 | X-4 | X |
| 68. | OTT2/SVL/2PN | K62234 | KAN | 4 | X-4 | 4 | 2-4 | X | X | X | 2-4 | X-4 | X-4 | 0'-2 | 0'-4 | X-4 |
| 69. | (UNKNOWN)/2 | PI113954 | FOR INT | 4 | 4 | 4 | 4 | 4 | 4 | 4 | - | 4 | 4 | - | 4 | 4 |
| 70. | TF3/T*SP/S*C2/FW815X2 | GA2892 | GA | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' |
| 71. | BC3896/62 | | " | 2-4 | 2-4 | 2-4 | 2-4 | 2-4 | 3-4 | 2-4 | 3-4 | 3-4 | 3-4 | 2-4 | - | 2-4 |
| 72. | DANNE SEL C-129-16 | S431 | OK | 4 | 4 | 4 | 4 | 3-4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 73. | CCH | 12517 | CK | 4 | 4 | 4 | 0'-1 | 0' | X | X-4 | 4 | X-4 | X | 4 | 4 | 4 |
| 74. | SDY | 13684 | CK | 3-4 | 4 | 4 | 3-4 | 4 | 4 | 4 | 4 | 4 | 4 | 0'-4 | 4 | 4 |
| 75. | SUT | 13546 | CK | 3-4 | 3-4 | 4 | 4 | 3-4 | 4 | 4 | 4 | 2-4 | 2-4 | 0'-4 | 4 | 2-4 |
| 76. | CDD | 13536 | " | 4 | 3-4 | 3-4 | 4 | 3-4 | 3-4 | 4 | 4 | 4 | 4 | 4 | 2-4 | 4 |
| 77. | KAW61 | 12871 | " | 4 | 4 | 2-4 | 4 | 4 | 2-4 | 3-4 | 3-4 | 4 | 4 | 4 | 3-4 | 4 |
| 78. | PKR | 13285 | " | 3-4 | 2-4 | X-4 | 0'-1 | 0' | 0' | 0'-2 | 4 | 2-4 | X | 2-4 | 4 | 3-4 |
| 79. | DANNE SEL C-145B4 | S111 | OK | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 80. | DANNE SEL C-146-4 | S118 | " | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 81. | DANNE SEL C-141-2 | S116 | " | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 82. | DANNE SEL C-204 | S31 | " | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 83. | DANNE SEL C-5-134-8 | S50 | " | 3-4 | 4 | 4 | 3-4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 84. | NRN16/CI12500 2/KAW | K63155 | " | 4 | 3-4 | 3-4 | 4 | 2-4 | X-4 | X | 4 | 4 | 4 | 4 | 3-4 | 4 |
| 85. | DANNE SEL C-140-E | S307 | " | 4 | 4 | 4 | 4 | 3-4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 86. | DANNE SEL C-155-2 | S157 | " | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 87. | DANNE SEL C-132-8 | S286 | " | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3-4 | 4 | 4 | 4 | 4 |
| 88. | SANDO HYBRID | SS684 | " | 4 | 3-4 | 4 | 0'-1 | 0'-1 | 0'-2 | X-4 | 4 | X | X | 4 | 4 | 3-4 |
| 89. | SANDO HYBRID | SS4149 | " | 3-4 | 3-4 | 4 | 0'-2 | 0' | 0'-2 | X-4 | 4 | 0'-2 | X | 4 | 3-4 | X-4 |
| 90. | DANNE SEL C-61-19-1 | S1219 | " | 3-4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3-4 | 4 | 4 | 4 |
| 91. | TMP/AG | S646307 | " | 0' | 0' | 0' | 0'-1 | 0' | 0' | 0' | 0' | 0' | 0' | 0' | 0' | 0' |
| 92. | KAW/AG | S646255 | " | 0-0' | 0'-2 | 0'-1 | 0'-1 | 0' | 0'-1 | 0' | 0' | 0' | 0'-2 | 0' | 0' | 0'-2 |
| 93. | DANNE SEL C-170-6 | S770 | " | 2-4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |

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| Entry No. | Variety or Cross | C.I.or Sel.No. | Source | 2-NA65- | | | 5-NA65- | | | | 6-NA65- | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 9 | 27 | 27 | 3 | 19 | 19 | 27 | 3 | 19 | 19 | 25 | 27 | 28 |
| 94. | OTT/CTT2/CCH/KAW3/TMP | S648735 | OK | 4 | 4 | 4 | 4 | 4 | 3-4 | seg. | 4 | 4 | 4 | 0'-4 | 4 | 4 |
| 95. | I.B.J/CMN2/TF3/I.B.J/CMN2/ T*04/TMP | S648788 | " | segregating | | | | | | | | | | | | |
| 96. | TOLLE | | FOR INT | 3-4 | 3-4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3-4 | 4 | 4 | 3-4 |
| 97. | TMP64 SEL | S65317 | OK | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3-4 | 4 | 4 |
| 98. | TMP64 SEL | 13679 | " | 4 | 4 | 3-4 | 4 | 4 | 4 | 4 | 4 | 3-4 | 4 | 4 | 4 | 4 |
| 99. | I.B.J/CMN2/TF3/I.B.J/CMN2/T*O 4/TMP | S648813 | " | 3-4 | 4 | 4 | 4 | 3-4 | 3-4 | 4 | 4 | 3-4 | 3-4 | X | 4 | 3-4 |
| 100. | SANDO HYBRID | SS736 | " | 4 | 4 | 3-4 | 0'-2 | 0'-1 | 0'-3 | X-4 | 4 | X | X | 3-4 | 4 | 3-4 |
| 101. | I.B.J/CMN2/TF3/I.B.J/CMN2/T*O 4/OTT/CTT2/CCH/KAW | S643966 | " | 0'-1 | X | X | X | 0'-2 | X | X | X | X | X | 0'-1 | 2-4 | 0'-2 |
| 102. | | S649033 | " | 4 | 2-4 | X-4 | 4 | X-4 | 0'-4 | X-4 | 4 | X-4 | X-4 | X | X | X |
| 103. | BEZOSTAJA | | FOR INT | 0' | 3-4 | 2-4 | 4 | 3-4 | 2-4 | 3-4 | 3-4 | 3-4 | 4 | X | 2-4 | 4 |
| 104. | LS/6PD | | CAN | - | 0'-2 | 0'-2 | 0' | 0'-1 | 0'-1 | X | 4 | 3-4 | X-4 | 4 | 4 | 3-4 |
| 105. | 7TC/WST | | " | - | 0' | 0' | 0' | 0' | 0' | 0'-1 | 0'-1 | 0'-2 | 0'-1 | 0' | 0' | 0' |
| 106. | 7TC/AFRICA43 | | " | - | 4 | 2-4 | 0'-2 | 4 | 3-4 | 3-4 | 2-4 | 0'-2 | 0'-1 | 2 | 3-4 | 0'-2 |
| 107. | 6TC/DO | | " | - | 4 | 3-4 | 4 | 4 | 4 | 4 | 4 | 3-4 | X | 4 | 4 | 4 |
| 108. | 6TC/M.E | | " | - | 4 | 3-4 | 4 | 3-4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 109. | 6TC/CTR | | " | - | X | 4 | 4 | 4 | 4 | 4 | 2-4 | X | 4 | 4 | 4 | 4 |
| 110. | 6TC/ECH L | | " | - | 4 | 2-4 | 0'-1 | 0' | X | X | 3-4 | X | X | 4 | 4 | 4 |
| 111. | 6TC/ECH E | | " | - | 2-4 | 2-4 | 2-3 | 0'-3 | 0'-3 | 0'-3 | 0'-2 | 0'-2 | 2-4 | 2-4 | 2-4 | 3-4 |
| 112. | AFRICA43/6TC | | " | - | X | 0'-2 | 3-4 | 0'-2 | X | X | 2-4 | 4 | 4 | 4 | 4 | 4 |

Reaction to Leaf Rust Culture

| Entry No. | 9-NA65- 1 | 1 | 1 | 1 | 13-NA65- 7 | 7 | 13 | 23 | Off Type3/ | 1967 Field Response R | S | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 0 | - | - | - |
| 2. | 3-4 | 2-4 | 3-4 | 3-4 | 3-4 | 4 | 4 | 2-4 | 0 | - | - | - |
| 3. | 3-4 | 2-4 | 3-4 | 2-4 | 3 | 3-4 | 3-4 | 2-4 | 0 | - | - | - |
| 4. | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3-4 | 0 | - | - | - |
| 5. | 4 | 4 | 4 | 3-4 | 4 | 3-4 | 4 | 4 | 0 | - | - | - |
| 6. | 0' | 0'-1 | 0'-1 | 0' | 3-4 | 3-4 | 4 | 4 | 0 | - | - | - |
| 7. | 2-4 | 3-4 | 4 | 2-4 | 2-4 | 2-4 | 0'-2 | 2-4 | 0 | - | - | - |
| 8. | 0' | 0'-1 | 0'-1 | 0' | 4 | 4 | 4 | 4 | 0 | - | - | - |
| 9. | 0'-1 | 0'-2 | 0'-2 | 0'-3 | 0'-2 | 0'-2 | 0' | 2-4 | 0 | 4 | tr | 100 |
| 10. | 0'-1 | 0' | 0'-1 | 0'-2 | 0' | 0'-2 | 4 | 0' | 0 | - | - | - |
| 11. | 0' | 0' | 0-0' | 0' | 4 | 4 | 4 | 4 | 4 | 4 | tr | 100 |
| 12. | 0' | 0' | 0-0' | 0' | 4 | 3-4 | 0' | 3-4 | 0 | - | - | - |
| 13. | 0'-1 | 0' | 0' | 0' | 0' | 0'-1 | 0' | 0-0' | 0 | - | - | - |
| 14. | 0-0' | 0' | 0-0' | 0-0' | 0' | 0' | 0-0' | 0' | 0 | 0 | 0 | 0 |
| 15. | 0' | 0'-1 | 0' | 0' | 0'-2 | 0'-2 | 0' | 0' | 0 | 0 | 0 | 0 |
| 16. | 0'-1 | 0'-1 | 0' | 0'-2 | 0'-2 | 0'-2 | 0'-2 | 0'-2 | 0 | 4 | tr | 100 |
| 17. | 0'-2 | 0'-1 | 0'-1 | 0'-1 | 0'-1 | 0'-1 | 0' | 0'-2 | 0 | 0; | tr | 100 |
| 18. | 0-0' | 0' | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' | 0-0' | 0 | - | - | - |
| 19. | 0' | 0' | 0-0' | 0' | 0'-2 | 0'-2 | 0' | 0'-2 | 20 | segregating | | |
| 20. | 0'-2 | 3-4 | 3-4 | 3-4 | 0'-1 | 0'-1 | 3-4 | X | 3 | 4 | tr | tr |
| 21. | 0' | 0' | 0-0' | 0' | 4 | 4 | 3-4 | 4 | 4 | 4 | 3 | 100 |
| 22. | 0' | 0'-1 | 0-0' | 0-0' | 0'-1 | 0'-1 | 0'-1 | 0'-2 | 17 | segregating | | |
| 23. | X | 3-4 | X | 2-4 | 0'-1 | 0'-2 | 0'-2 | 2-4 | 0 | - | - | - |
| 24. | 0' | 0' | 0'-1 | 0' | 0' | 0'-1 | 0'-1 | 0'-2 | 5 | 0; | tr | 100 |
| 25. | 0' | 0'-1 | 0' | 0'-1 | 0'-2 | 0' | 0-0' | 0' | 0 | 0 | 0 | 0 |
| 26. | 0' | 0' | 0' | 0' | 0' | 0' | 0' | 0' | 2 | 0; | tr | 100 |
| 27. | 0' | 0' | 0' | 0' | 0'-1 | 0' | 0' | 0' | 38 | 0 | 0 | 0 |
| 28. | 0' | 3-4 | 3-4 | 4 | 0'-2 | 2-4 | 4 | 2-4 | 0 | 4 | 70 | 100 |
| 29. | 0'-2 | 2-4 | 3-4 | 3-4 | X | 2-4 | X | 2-4 | 0 | 4 | 70 | 100 |
| 30. | 0' | 0'-1 | 0-0' | 0-0' | 0' | 0' | 0-0' | 0' | 0 | 0 | 0 | 0 |

Continued --

| Entry No. | 9-NA65- 1 | 1 | 1 | 1 | 13-NA65- 7 | 7 | 13 | 23 | Off Type3/ | 1967 Field Response R | S | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31. | 0' | 0' | 0'-1 | 0' | 0' | 0'-1 | 0' | 0' | 1 | 0 | 0 | 0 |
| 32. | 0-0' | 0' | 0' | 0-0' | 0-0' | 0-0' | 0 | 0' | 1 | 0 | 0 | 0 |
| 33. | 0-0' | 0-0' | 0' | 0' | 0-0' | 0' | 0-0' | 0' | 0 | 0 | 0 | 0 |
| 34. | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3-4 | 0 | 4 | 50 | 100 |
| 35. | X | 4 | 4 | 3-4 | 0' | 0' | 4 | X-4 | 0 | 4 | 50 | 100 |
| 36. | 4 | 4 | 4 | 4 | 3-4 | 4 | 4 | 4 | 0 | 4 | 70 | 100 |
| 37. | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 1 | 4 | 70 | 100 |
| 38. | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 1 | 4 | 50 | 100 |
| 39. | 0'-2 | 0'-2 | 0' | 0' | 0'-1 | 0'-1 | 0' | 0'-1 | 8 | 0 | 0 | 0 |
| 40. | 0' | 0' | 0' | 0' | 0'-1 | 0'-1 | 0' | 0'-1 | 41 | 0; | tr | 100 |
| 41. | 0' | 0-0' | 0'-1 | 0'-1 | 0'-1 | 0-0' | 0' | 0'-1 | 1 | 0 | 0 | 0 |
| 42. | X | X | X | 0'-1 | 0' | 0'-1 | 0' | 0'-2 | 1 | 0 | 0 | 0 |
| 43. | 0-0' | 0-0' | 0-0' | 0-0' | 0' | 0-0' | 2-4 | 0' | 31 | 0 | 0 | 0 |
| 44. | 0'-4 | 0' | 0'-1 | 0'-2 | 0' | 0'-1 | 0'-1 | 0'-2 | 2 | 0; | tr | 100 |
| 45. | 0'-3 | 0'-1 | 0'-1 | 0' | 0' | 0'-2 | 2-4 | X | 1 | 0; | tr | 100 |
| 46. | 0'-2 | X | 0'-2 | 0' | 0' | 0'-1 | 0' | 0'-2 | 4 | 0; | tr | 100 |
| 47. | X-4 | 2-4 | 2-4 | 0'-2 | 0'-1 | X | 0' | 0'-1 | 14 | Segregating | | |
| 48. | 0' | 0'-2 | 0' | 0'-1 | 0'-1 | 0'-2 | 0' | 0'-1 | 2 | 0; | tr | 100 |
| 49. | 0'-1 | 0'-2 | 0' | 0' | 0'-2 | 0'-1 | 0' | 0'-2 | 11 | 0 | 0 | 0 |
| 50. | X | X | 2-4 | 0'-1 | 0'-2 | X | 0-0' | 0'-1 | 7 | 2-4 | tr | 100 |
| 51. | 3-4 | 4 | 2-4 | 4 | 4 | 4 | 3-4 | 3-4 | 7 | 4 | tr | 25 |
| 52. | 0' | 0'-1 | 0' | 0' | 0'-1 | 0'-1 | 0' | 0' | 1 | 0 | 0 | 0 |
| 53. | 0' | 0'-1 | 0-0' | 0' | 0'-1 | 0'-2 | 0' | 0'-1 | 0 | 0 | 0 | 0 |
| 54. | 0'-1 | 0'-2 | 0' | 0' | 0'-2 | 0'-1 | 0'-1 | 0' | 0 | 0 | 0 | 0 |
| 55. | 0'-4 | 0' | 0' | 0' | 3-4 | 4 | 3-4 | 4 | 1 | 0 | 0 | 0 |
| 56. | 0' | 0'-1 | 0-0' | 0' | 0'-1 | 0'-1 | 0' | 0' | 1 | 0 | 0 | 0 |
| 57. | 0' | 0'-1 | 0-0' | 0' | 0'-2 | 0'-1 | 0'-1 | 0'-1 | 0 | 0 | 0 | 0 |
| 58. | 0' | 0'-2 | 0' | 0'-1 | 0'-1 | 0'-1 | 0'-1 | 0' | 0 | 0 | 0 | 0 |
| 59. | 0'-1 | 0'-1 | 0' | 0'-2 | 2-4 | 3-4 | 3-4 | 2-4 | 0 | 4 | 5 | 100 |
| 60. | X-4 | 4 | 4 | 0'-4 | 4 | 4 | X | X | 0 | 4 | 1 | 100 |
| 61. | X | 0'-4 | X | X | 3-4 | 4 | 4 | 4 | 0 | 2-4 | 3 | 100 |
| 62. | 2-4 | X | 0' | 4 | X | 3-4 | 2-4 | X | 2 | 0 | 0 | 0 |

Continued --

| Entry | 9-NA65- | | | | 13-NA65- | | | | Off | 1967 Field Response | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | 1 | 1 | 1 | 1 | 7 | 7 | 13 | 23 | Type3/ | R | S | P |
| 63. | 0' | 0'-1 | 0' | 0' | 0' | X | 3-4 | X | 6 | 4 | 1 | 100 |
| 64. | 0'-1 | 0' | 0'-1 | 0'-1 | 0' | X | 4 | X | 14 | 4 | 5 | 100 |
| 65. | 4 | X-4 | 2-4 | X | 3-4 | 4 | 0'-1 | X | 6 | 0; | tr | 50 |
| 66. | 3-4 | 2-4 | 2-4 | 2-4 | 2-4 | 4 | X | 3-4 | 0 | 4 | 5 | 100 |
| 67. | 0' | X | 1-2 | 0'-2 | X | X | X | X | 0 | 4 | 5 | 100 |
| 68. | X | 0'-1 | X | 0'-1 | 4 | 4 | X-4 | X | 3 | 0; | tr | 100 |
| 69. | 4 | 4 | - | X | 3-4 | 4 | 2-4 | 4 | 0 | 4 | 30 | 100 |
| 70. | 0' | 0' | 0' | 0' | 0-0' | 0-0' | 0-0' | 0' | 0 | 0 | 0 | 0 |
| 71. | 0'-3 | 2-4 | 0'-2 | X | X | 3-4 | X-4 | 2-4 | 0 | 4 | 30 | 100 |
| 72. | 3-4 | 4 | 4 | 4 | 3-4 | 4 | 4 | 4 | 0 | - | - | - |
| 73. | 0'-4 | 4 | 4 | 4 | 0' | X | 4 | X | 0 | - | - | - |
| 74. | 4 | 3-4 | 0'-4 | 4 | 3-4 | 4 | 3-4 | 4 | 0 | - | - | - |
| 75. | 0'-4 | X | 4 | 4 | 4 | 4 | 3-4 | 4 | 0 | - | - | - |
| 76. | 4 | 3-4 | 4 | 4 | 4 | 4 | 2-4 | 4 | 0 | - | - | - |
| 77. | 2-4 | 4 | 4 | 3-4 | 4 | 4 | 4 | 4 | 1 | - | - | - |
| 78. | 0'-2 | 3-4 | 2-4 | 3-4 | 0' | X | 3-4 | 2-4 | 0 | - | - | - |
| 79. | 3-4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | - | - | - |
| 80. | 4 | 4 | 4 | 4 | 4 | 4 | 3-4 | 4 | 0 | - | - | - |
| 81. | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 0 | - | - | - |
| 82. | 4 | 4 | 4 | 4 | 4 | 4 | 3-4 | 4 | 1 | - | - | - |
| 83. | 3-4 | 4 | 4 | 4 | 3-4 | 4 | 2-4 | 4 | 0 | - | - | - |
| 84. | 2-4 | 4 | 4 | 4 | 4 | 4 | 3-4 | 4 | 0 | - | - | - |
| 85. | 4 | 4 | 3-4 | 4 | 4 | 4 | 3-4 | 4 | 1 | - | - | - |
| 86. | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 0 | - | - | - |
| 87. | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 0 | - | - | - |
| 88. | X | 4 | 4 | 4 | 0' | X | 4 | X | 0 | - | - | - |
| 89. | 0'-4 | 4 | 4 | 4 | 0' | X | 4 | X-4 | 8 | - | - | - |
| 90. | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 0 | - | - | - |
| 91. | 0' | 0' | 0-0' | 0' | 0'-1 | 0' | 0'-1 | 0' | 0 | - | - | - |
| 92. | 0' | 0' | 0'-1 | 0' | 0'-1 | 0' | 0-0' | 0' | 0 | - | - | - |
| 93. | 4 | 4 | 4 | 4 | 4 | 4 | 3-4 | 4 | 1 | - | - | - |

Continued --

| Entry | 9-NA65- | | | | 13-NA65- | | | | Off | 1967 Field Response | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | 1 | 1 | 1 | 1 | 7 | 7 | 13 | 23 | Type3/ | R | S | P |
| 94. | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | - | - | - |
| 95. | Segregating | | | | | | | | 89 | | | |
| 96. | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 0 | - | - | - |
| 97. | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 0 | - | - | - |
| 98 | 4 | 4 | 4 | 3-4 | 4 | 4 | 4 | 4 | 1 | - | - | - |
| 99. | 3-4 | 4 | 0'-4 | 4 | X-4 | 3-4 | 3-4 | 4 | 1 | - | - | - |
| 100. | 0'-4 | 4 | 4 | 4 | 0' | 0' | 3-4 | X-4 | 2 | - | - | - |
| 101. | X | X-4 | 0'-2 | X | X | X | 0' | X | 4 | - | - | - |
| 102. | X-4 | 0'-4 | 0'-4 | 2-4 | X-4 | 1-4 | X-4 | 2-4 | 0 | - | - | - |
| 103. | X | 0' | 0'-1 | 0-0' | 0'-1 | 2-4 | X | 4 | 7 | - | - | - |
| 104. | 4 | 4 | 4 | 4 | | 4 | - | 4 | 0 | - | - | - |
| 105. | 4 | 4 | 4 | 3-4 | - | 4 | - | 3-4 | 0 | - | - | - |
| 106. | 3-4 | 0'-3 | 0'-2 | 2-4 | - | 3-4 | - | 0'-2 | 0 | - | - | - |
| 107. | 0'-1 | 0' | 0'-1 | 0' | - | 3-4 | - | 3-4 | 2 | - | - | - |
| 108. | 4 | 3-4 | 4 | 2-4 | - | 4 | - | 4 | 0 | - | - | - |
| 109. | 4 | 4 | 4 | 3-4 | - | 4 | - | 2-4 | 0 | - | - | - |
| 110. | 0' | 4 | 4 | 3-4 | - | X | - | 2-4 | 2 | - | - | - |
| 111. | 0'-2 | 2-4 | 2 | 2-4 | - | 3-4 | - | 2-4 | 0 | - | - | - |
| 112. | 4 | 4 | 4 | 4 | - | 2-4 | - | 3-4 | 0 | - | - | - |

/1 Abbreviations used were made according to rules adopted by the National Wheat Improvement Committee as amended by KONZAK. See Agron. J. 52:613, 1960, U.S. Dept. of Agr. Tech. Bull. 1278, p. 131, 1963 and Wheat Newsletter 1965.

/2 Variety name or cross unknown to us at this time.

/3 Number of plants with off-type reactions. In general, over 10 plants with off-type reactions indicates the variety or line is segregating for reaction to one or more cultures.

# ARE OUR VARIETIES OF OATS TOO RESISTANT TO DISEASE?

J. M. Poehlman

In breeding for resistance to disease, protection may be conferred by (a) single (or complementary) major genes, (b) combinations of several major genes, (c) combinations of minor genes, or (d) combinations of both major and minor genes. It is suggested that resistance to highly specialized diseases, such as crown rust (Puccinia coronata avenae Eriks and B. Henn.) may be short-lived in varieties protected by single or complementary major genes. Varieties which have a moderate or intermediate type of resistance conferred by a group of genes, each of which contributes, if only in a minor way, to the defense of the host plant, may retain their protective qualities over a much longer period. Breeding for the moderate type of resistance thus might give more stability to disease resistance and permit greater concentration on breeding for needed improvements in agronomic qualities. Comparisons of the resistance of the Marion variety with varieties carrying Victoria and Bond resistance genes are cited.

# INHERITANCE OF BLUE ALEURONE AND PURPLE PERICARP IN HEXAPLOID WHEAT

(Abstract)

F. E. Bolton and B. C. Curtis

A study of blue aleurone and purple pericarp characters in hexaploid wheat included cytological observations, gamete transmission studies, genetic analyses, histological observations, and pigment characterization.

Two blue aleurone lines, Blue (C.I. 12025) and Pugsley's Male Sterile/Blue Baart (PBB), exhibited significant differences in transmission frequency through the male and female gametes of the chromosomes controlling blue aleurone. PBB exhibited xenia but Blue did not. PBB produced a darker blue seed color than Blue. It was concluded that blue aleurone was controlled by a substituted pair of alien chromosomes in Blue and an alien addition (ditelocentric chromosome) in Pbb. No homology was observed between the alien chromosomes in Blue and in PBB.

The purple-seeded hexaploid, ND2, contains two genes ($P^1$ and $P^2$) for purple pericarp, one of which is dependent on the complementary action of a third gene (S) controlling the purple stem character. Two purple-seeded tetraploid lines, NY1 and NY3, were converted to hexaploids by backcrossing to Wichita, C.I. 11952, a common hexaploid variety. NY1 contains a single gene for purple pericarp which is the same as the $P^2$ in ND2. NY3 contains a third gene ($P^3$) for purple pericarp. The three genes, $P^1$, $P^2$ and $P^3$, are incompletely dominant and show additive gene action. When all three genes are combined in crosses with parents, each of which has purple stem, they segregate independently and the combination of six factors for purple pericarp produces a very dark purple seed. The purple pericarp factors were found to be inherited independently of factors for brown and black glume of the non-purple seeded parent.

The purple pigments are located in the cross cell layer of the pericarp whereas the blue pigments are in the aleurone layer. The red color of common wheat was also present in the testa of both the blue aleurone and purple pericarp parents. The combination of two genes for purple pericarp and a substituted chromosome for the blue aleurone, along with the tannish-red testa produces a bluish-purple to grayish-black seed color. Three distinct seed color lines were developed which are phenotypically different from the common red and white wheats.

The pigments of the aleurone and pericarp producing the blue and purple colors were characterized as anthocyanins, although positive identification of the glycones and aglycones was inconclusive.

# GENETIC MALE STERILITY IN HEXAPLOID WHEAT

L. W. Briggle

Seed of a stock segregating for male sterility was obtained from C. A. Suneson who in turn had received it from A. T. Pugsley of Australia. This proved to be a very heterogeneous population for various plant and seed characters when grown in the Beltsville greenhouse during the winter of 1962-63. Several plants were male sterile or partially fertile. Some plants which appeared to be male sterile produced 1 or 2 seeds per spike - presumably selfs. Seed from this latter class (1 or 2 seeds per spike) was saved and the plants grown in the greenhouse in 1963-64.

One vigorous plant from a selfed (?) seed was completely male sterile and produced several spikes. Pollen from 'Chancellor' was sifted over the exposed stigmas and a very good seed set obtained.

$F_1$ plants were fertile. The $F_2$ population segregated for male sterility, but did not fit a logical pattern. Spikes on male sterile $F_2$ plants were bagged and some pollinated with Chancellor. Those bagged and not pollinated did not set seed.

Backcross plants (from male sterile $F_2$ plants backcrossed to Chancellor) were fertile, and corresponded to an $F_1$ generation. The $F_2$ segregated for male sterility. Each $F_2$ population was very small (15-20 plants) but about 50 $F_2$ populations were grown. Male sterile plants numbered from 1 in an $F_2$ population to 7 in another $F_2$. Male sterile $F_2$ plants were bagged and some backcrossed again to Chancellor. Plants in 8 $F_2$ families set seed on "male sterile" plants which had been bagged but not pollinated. These families were discarded.

The second backcross population (equivalent to an $F_1$) was fertile. Again the $F_2$ segregated. Partially fertile plants occurred in some $F_2$ families, and very few male sterile plants in others. Still other families had normal 3:1 ratios of fertile to male sterile plants. Again individual $F_2$ populations were rather small, but many were tested. This procedure was used in preference to growing one or a very few large $F_2$'s in an attempt to select stable $F_2$ populations approaching 3:1 segregation patterns for further backcrossing.

Ratios obtained from some second backcross $F_2$ families are as follows:

| | | Fertile | Sterile |
|---|---|---|---|
| W66-67 | 33A | 49 | 19 |
| " | 33B | 17 | 6 |
| " | 33E | 18 | 3 |
| " | 33G | 18 | 7 |
| " | 33M | 71 | 20 |
| " | 33P | 19 | 7 |

Twelve fertile second backcross $F_2$ plants, chosen at random, were used as male parents in another backcross to Chancellor. Some of the twelve were expected to be heterozygous for the male-sterility gene, so that when used as the male parent one could determine whether the male sterile characteristic was transmitted by male gametes. Male sterile plants did occur in some of the $F_2$ populations grown. Populations again were small, but segregation ratios were as follows:

| | | Fertile | Sterile |
|---|---|---|---|
| W66-67 | 34A | 14 | 3 |
| | 34D | 18 | 3 |
| | 34G | 12 | 4 |
| | 34L | 12 | 3 |
| | 34N | 8 | 4 |
| | 34P | 14 | 5 |
| | 34U | 8 | 9 |
| | 34CC | 13 | 1 |
| | 34EE | 12 | 2 |

These results indicate that a gene (s) for male sterility is involved, rather than cytoplasmic male sterility. The fact that $F_1$ populations are always fertile and that segregation occurs in $F_2$ is also indicative of gene male sterility. Male sterility appears to be conditioned by a single recessive gene, but larger populations are needed before definite conclusions can be made.

Chancellor seems to have a compatible genetic background for the male sterile gene to be expressed. A number of third backcross $F_2$ families presently growing in the Beltsville greenhouse have essentially the plant characteristics of Chancellor and I hope will segregate in a 3:1 ratio for fertility and male sterility. Expression of male sterility in the original stock received from Suneson apparently was affected by modifying genes. Perhaps these modifiers have been removed by backcrossing to Chancellor, which in effect is transferring the male sterile gene into a Chancellor line.

Further backcrossing to Chancellor is contemplated, along with rigid selection for stable expression of male sterility. At the same time further genetic studies will be conducted.

# POLLEN RESTORATION FROM THE WORLD WHEAT COLLECTION

K. P. Porter and T. G. Wright

## Restoration from the World Wheat Composite:

Restoration research at the Southwestern Great Plains Research Center has included a search for additional sources of restoration in the World Collection of Common Wheats. Crosses of male-sterile Bison x a composite of the World Wheat Collection (W.W.C.) were made in isolated field crossing blocks in 1964 and 1965. Forty fertile or partially fertile $F_1$'s were selected from a total of 5000 $F_1$'s in 1965 and 1966. The fact that 99 percent of the $F_1$'s set a negligible amount of seed is evidence that seed set on the selected plants resulted from self- rather than from cross-pollination.

Detailed data were not taken on 11 $F_1$'s selected in 1965. However, the average number of seed produced on open pollinated spikes of their $F_2$ progeny varied from 15.9 for the least fertile to 32.7 for the most fertile $F_2$ population. It was obvious the populations segregated for pollen-fertility.

Seed set data were taken on 29 $F_1$'s selected in 1966, Table 1.

Table 1. Mean number of tillers and seed set on selected $F_1$ plants, male-sterile Bixon x World Wheat Collection 1/

| Plant character | Mean of 29 plants | Range |
|---|---|---|
| Tillers/plt. | 20.6 | 2 - 41 |
| Wt. of seed/plt, gram | 15.3 | 2 - 35 |
| Wt. of seed/spike, gram | .76 | .4 - 1.2 |
| No. seed/spike | 23.3 | 11 - 34 |

1/ Fertile or partially fertile plants selected from 2500 $F_1$ plants in 1966.

Many of the selected plants were highly fertile.

The $F_2$ populations of the 29 $F_1$ plants were grown in the field in 1967. About 75 spikes of selected populations and of fertile Bison were bagged prior to flowering. Mean percent seed set on bagged and exposed spikes of each populations are shown in Table 2.

Table 2. Mean percent seed set on spikes of $F_2$ populations, male-sterile Bison x W.W.C. and on spikes of Bison.

| $F_2$ Row No. | Mean Percent Seed Set | |
|---|---|---|
| | Bagged Spikes | Exposed Spikes |
| 2843 | 44 | 81 |
| 2852 | 66 | 91 |
| 2854 | 40 | 79 |
| 2858 | 53 | 79 |
| 2860 | 68 | 90 |
| 2865 | 63 | 80 |
| 2878 | 56 | 63 |
| Bison | 84 | 91 |

Frequency distributions in percent seed set classes of both bagged and exposed spikes for the least and most fertile $F_2$ population and for Bison are shown in Figure 1. Population 2860 was segregating from amber to dark red seed color.

No conclusion was attempted from these data concerning the mode of inheritance of restoration. The data indicate that useful genes are involved.

Plants from seed of the most fertile bagged heads are being grown for test crosses in the greenhouse. In addition, eighty of the more fertile of 1000 $F_3$ head rows (originating from the 11 $F_1$'s selected in 1965) are being increased and evaluated in the field.

Seed of a composite from the $F_2$ and $F_3$ populations, 1967, are available from J. C. Craddock, Beltsville. Seed of individual populations should be available in 1968.

Lines from Nebraska Lot 1, Dekalb's *T. Timopheevi* x Marquis[3], 'Kansas' (*T. Timopheevi* x Marquis[3]) x Bison, fertile $F_2$, $F_3$, plants of MS Bison x W.W.C., and Primépi have been intercrossed in several ways in an effort to combine restoration genes from several sources.

Restoration from Hairy Chaff Types:

Hairy chaff was a characteristic of some $F_1$'s. It appeared that some hairy chaff wheats possessed good restoration genes. A number of hairy chaff types from our W.W.C. were test crossed to male-sterile Bison but only one gave partially fertile $F_1$'s. To make a complete search, seed of all hairy chaff types (700) were obtained from J. C. Craddock. To date, test crosses of male-sterile Lee and single plant selections from 149 hairy chaff spring wheats have been grown.

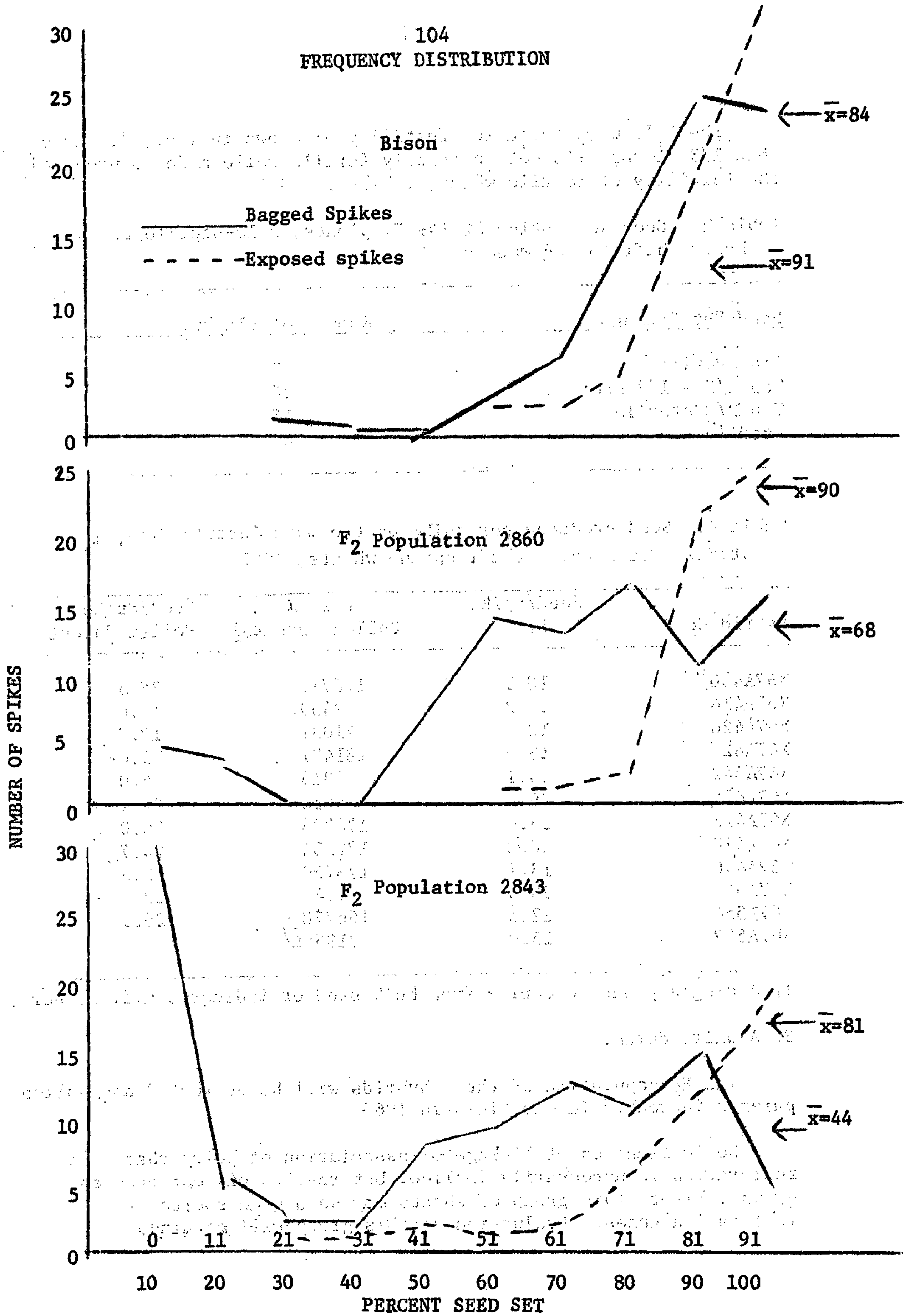


Figure 1. Frequency distributions of bagged and exposed spikes in seed set classes of 2 $F_2$ populations and Bison grown in field. Bushland, Texas, 1967.

The $F_1$'s were rated for fertility as shown in Table 3. More than 1/3 of the $F_1$'s were partially fertile while a few approached the fertility of fertile wheat, Tables 3 and 4.

Table 3. Seed set rating of 149 $F_1$ plants, male-sterile Lee x hairy chaff spring wheats.

| Seed Set Rating | Number of Plants |
|---|---|
| Tip sterile | 13 |
| Top 1/3 - 1/2 sterile | 36 |
| Top 2/3 sterile | 18 |
| Sterile | 82 |

Table 4. Seed produced per spike on the more fertile $F_1$'s, male-sterile Lee x hairy chaff spring wheats, 1967.

| Hybrid No. | Seed/Spike $F_1$ | P.I. No. Pollen Parent 1/ | Seed/Spike Pollen Parent |
|---|---|---|---|
| X67A406 | 18.9 | 178717 | 28.6 |
| X67A414 | 26.2 | 192459 | 18.6 |
| X67A426 | 18.9 | 171031 | 18.7 |
| X67A429 | 15.5 | 181427 | 13.0 |
| X67A442 | 16.1 | 4315 | 16.0 |
| X67A455 | 26.3 | 4910 | 24.4 |
| X67A471 | 25.6 | 170994 | 26.0 |
| X67A478 | 18.8 | 172534 | 24.7 |
| X67A496 | 13.1 | 178769 | 12.6 |
| X67A511 | 23.4 | 4544 | 23.6 |
| X67A554 | 22.5 | 166778 | 26.9 |
| X67A557 | 15.0 | 91955 2/ | |

1/ A single plant selection from bulk seed of indicated P.I. number.

2/ A white durum.

The $F_2$ population of these hybrids will be evaluated and pollen parents increased in the field in 1968.

No implication of linkage or association of hairy chaff and restoration is necessarily implied, but results of test crosses grown indicate this group of wheats may be a good source of restoration genes. Evaluation of this group will continue.

Restoration from 'Primépi':

'Primépi', as reported by Oehler and Ingold 1/ appears to have good restoration potential. Results of test crosses grown at Bushland supports their findings, Table 5.

Table 5. Mean seed set on Primépi hybrids grown in greenhouse, 1967.

| Hybrid or Parent | Number of Plants | Percent Seed Set Lateral Florets | No. of Seed in Central Florets |
|---|---|---|---|
| Caddo x Primépi | 10 | 83.3 | 4.6 |
| MS Caddo x Primépi | 9 | 81.3 | 2.1 |
| Primépi x Caddo | 7 | 82.3 | 1.5 |
| MS Tascosa x Primépi | 10 | 81.1 | 2.3 |
| Caddo | 4 | 77.8 | 2.0 |
| Tascosa | 5 | 87.6 | 4.2 |
| Primépi | 2 | 81.0 | 1.5 |

1/ Oehler, E., and M. Ingold. 1966. New cases of male-sterility and new restorer source in T. *aestivum*. Wheat Information Service No. 22:1-3.

# MALE-FERTILITY RESTORATION PROBLEMS IN HYBRID WHEAT

S. S. Maan and K. A. Lucken

Our hybrid wheat investigations include a search for new and more suitable cytoplasmic male-sterility-fertility restoration systems, and attempts to improve the male-fertility restoration of common wheat with T. timopheevi cytoplasm.

The cytoplasm of T. zhukovskyi has produced male sterile common wheats. Lines with male-fertility restoring factor(s) from T. zhukovskyi appear promising for anther size, anther shape, anther extrusion, and abundance of pollen.

The cytoplasm of two diploid wheats T. monococcum and T. boeoticum has produced male-sterile durum plants. Lines with male fertility restoring factor(s) from diploid wheats are being tested. One addition line with mst-common wheat + a chromosome pair from T. boeoticum is about 70% fertile.

The possible effect of T. araraticum cytoplasm on male-sterility is being investigated.

Studies of the T. timopheevi male sterility-fertility system include chromosomal location of male-fertility restoring genes in several R-lines, and the development of 'single gene' or chromosome substitution lines in the genetic background of the variety Chris. For this a male sterile monosomic set of the variety Chris is being used. We hope the use of a male-sterile monosomic set and 'single gene' lines will allow study of dose effects of restorer gene(s), and also the evaluation of individual chromosomes of R- and B-lines for their influence on male-fertility restoration. If dose effects are favorable, increase of restorer gene dose may be possible by the 5B-method (transfer to a homeologous chromosome) or by a system of compensating nulli-tetras involving ditelocentrics such as: $19'' \; 1A'' \; 1D^{O} \; 1A^{L''} \; 1D^{S''}$ or $19'' \; 1A'' \; 1B^{O} \; 1A^{L''} \; 1B^{S''}$, assuming the gene is on $1A^{L}$. On the other hand, if a chromosome arm has an inhibiting effect on the expression of a gene for male-fertility, easy-to-restore compensating nulli-tetra di-telocentric female lines may be a possibility, such as: $19'' \; 7A''' \; 7D^{O} \; 7D^{L''} \; 7A^{S}$, if short arm of 7D has an inhibiting influence on male fertility restoration.

If male-fertility promoting or inhibiting effects of individual chromosomes in a R-line or a B-line can be ascertained, then cytogenetic methods can be used to develop desirable chromosome combinations in male and female lines for completely fertile hybrid wheats.

# GENETICS OF FERTILITY RESTORATION IN VARIOUS MALE-STERILE CYTOPLASMS

P. Menge, E. R. Ausemus, W. H. Althaus

Primépi was a popular variety in France about 20 years ago. It is a descendent of the old variety Bon Fermier which descended from Noe.

We received Primépi during the summer of 1966 with the report that it contained a single dominant gene for complete restoration. Primépi has been crossed with 33 male-sterile spring wheats, most of these are hard red spring wheats from the United States and a few from the Mexican breeding program. The $F_1$'s were planted and observed for fertility in the greenhouse and most of them were found to be as fertile as the standard parent varieties. A duplicate planting was made in the field but, it was planted so late that the data obtained was not reliable.

The $F_2$'s were planted in the greenhouse during the fall of 1967 with fertility readings being taken in January, 1968. We get some sterility in the greenhouse at this time of year due to light conditions, however, the fertility readings on the $F_2$'s indicated that the restoration was due to a single dominant gene. These are preliminary data based on a small number of plants. This simple type of inheritance agrees with the report of M. Ingold at the Eucarpia meetings held in Switzerland in 1967.

Primépi was crossed with 23 winter wheat male-sterile varieties, 11 hard red, 6 soft red, and 6 foreign varieties. The fertility of the $F_1$'s of all of these crosses was as good or better than the standard parent varieties when grown in the greenhouse. The anthers and pollen shedding was excellent with the exception of 1 or 2 varieties. Primépi crosses with Scout, Gage, and Kaw male-steriles were the best pollen shedders with good anther extrusion and large anthers. Primépi has given us better restoration of the soft red winter wheats than any of our other restorers.

We will be glad to supply a limited amount of seed from the $F_1$ or $F_2$ plants to anyone interested. Address inquiries to Northrup, King & Co., 1500 Jackson St. N.E., Minneapolis, Minnesota 55413, attention Mr. Wm. Althaus.

## ENVIRONMENTAL EFFECT ON MALE FERTILITY RESTORATION

(Abstract)

Peter Salm

The effects of environment on fertility restoration were estimated by uniform yield trials of restored $F_1$ hybrids at several locations in 1967. Latitude had the most pronounced effect on fertility. Sterility increased when going from south to north. The northern locations are often characterized by cool temperatures, long days and rapid plant development. One or all of these factors may be contributing to the greater sterility levels observed in the hybrids.

This type of uniform trial, utilizing a partial restorer and A-lines of different restoration requirement, offers an effective means of monitoring the sterility level of a region. Locations 200 - 300 miles apart have shown significant differences in restoration requirements in these tests.

A hypothetical model indicating sterility levels by location, and the number of restoration genes required is proposed.

# ENVIRONMENTAL EFFECTS ON MALE STERILITY AND MALE FERTILITY RESTORATION

(Abstract)

Gregory Vazquez

Relatively large differences in the number of days to flowering are observed in materials sensitive to day length, whereas nonsensitive materials show only slight variations in flowering when grown in areas of varying day lengths. The variations in the vegetative period seem to be associated with varying levels of restoration of fertility, especially in materials sensitive to day length. There is a general tendency for less restoration of fertility as the number of days to flowering decreases. The high fertility at Ciudad Obregon, Mexico may be due to longer stigma and pollen viability, whereas, this characteristic may be much reduced in areas having short growing seasons such as Casselton, North Dakota.

The environments of Ciudad Obregon, Mexico, Toluca, Mexico and Casselton, North Dakota are somewhat different. The environments of Obregon and Casselton are commonly characterized by having contrasting temperatures and relative humidity, particularly during the flowering period. However, observations conducted during the last few seasons indicate that the average high and low temperatures and relative humidity in Cuidad Obregon and Casselton are very similar, with Toluca being a little cooler and wetter than the other two. Nevertheless, restoration appears to be much easier in Cuidad Obregon than in Casselton with Toluca being somewhat intermediate.

It may be suggested that unless minor climatic differences are responsible for these tremendous variations of levels of restoration observed; there exists the possibilities that these differences may be due to the length of the growing period of day length sensitive materials grown at variable latitudes. There is also the possibility that modifier genes acting differently control these variations. An extensive reciprocal recurrent selection program for restoration within groups and among groups planted at different locations, might eventually unite sufficient modifier genes that are capable of restoring under any set of environmental conditions.

# ENVIRONMENTAL EFFECTS ON FERTILITY RESTORATION IN WHEAT.

E. L. Smith and W. L. McCuistion

Variation in fertility restoration resulting from environmental differences is not unique to wheat. This phenomenon has been reported in corn, sorghum, and several other crops. From observations made at the Oklahoma Station it appears that certain meterological conditions during the flowering period account for a considerable amount of the variation observed in percent seed set of restorer lines and crosses being evaluated in our hybrid wheat program. Temperatures in our glass greenhouse have occasionally exceeded 90° F. during the flowering period. Following these periods a sharp increase in percentage of sterile florets has been noted. Rather moderate temperatures and high relative humidity appear to be desirable for maximum expressing of fertility restoration.

In a study just completed at Stillwater, the degree of fertility restoration was noted on restorer material derived from Nebraska 542437 stock. The material was evaluated for two years under the following environments: 1) glass greenhouse, 2) fiberglass greenhouse, and 3) field nursery on the Agronomy farm. The material consisted of 6 Lot 1 and 7 Lot 2 restorer selections and the $F_1$ hybrids between each of these selections and male sterile Bison.

During this study there was no noticeable environmental effect on the sterile system. Bison ms remained completely sterile in the three environments. There was however, a great deal of variation in fertility restoration of the restorer selections and testcrosses as measured by percent seed set (Tables 1 and 2). There was little association in percent seed set from one location to another. For the glass and fiberglass greenhouses the response in fertility restoration was somewhat similar from one year to the next. However, this was not the case for the material grown in the field.

Considering the reaction of all restorer material involved in this study, the fiberglass greenhouse was the most critical environment for measuring fertility restoration and had a fair degree of correlation from one year to the next. Of the three environments, the fiberglass greenhouse appears to be the most suitable for the early phases of restorer line development.

TABLE 1.--CORRELATION COEFFICIENTS (r) OF SEED SET

| Location | Lot 1 | Lot 2 | Checks |
|---|---|---|---|
| **Correlation Between Years** | | | |
| 1965 vs. 1966 Field | 0.33 | 0.35 | 0.88** |
| 1965 vs 1966 Glass Ghse. | 0.92** | 0.67 | 0.58* |
| 1965 vs 1966 Fiberglass Ghse. | 0.81* | 0.76* | 0.86** |
| **Correlation Between Locations, 1966** | | | |
| Field vs. Glass Ghse. | -0.59 | 0.13 | 0.64** |
| Field vs. Fiberglass Ghse. | 0.34 | 0.34 | 0.24 |
| Glass Ghse. vs. Fiberglass Ghse. | 0.30 | 0.52 | 0.83** |

TABLE 2.--PERCENT SEED SET OF 5 MS x R TESTCROSSES IN THREE ENVIRONMENTS

| Testcross | Field | Glass Ghse. | Fiberglass Ghse. |
|---|---|---|---|
| 5892-25 $F_1$ | 81.0 | 91.4 | 79.0 |
| 5893-2 $F_1$ | 74.4 | 55.6 | 79.6 |
| 5892-7 $F_1$ | 68.8 | 84.3 | 42.7 |
| 5892-9 $F_1$ | 67.2 | 61.1 | 83.0 |
| 5892-2 $F_1$ | 57.1 | 55.3 | 55.9 |

# PROBLEMS INVOLVED IN TRANSFER OF FERTILITY RESTORING GENES INTO LINES OF COMMON WHEAT

(Abstract)

Max A. Urich, W. R. Grace & Co.

Selections from the Kansas and Nebraska sources of fertility restoration were used as base material in our program for the development of common wheat lines with fertility restorer genes. The $F_1$ plants of most crosses (restorer selection x common wheat line) showed 60 to 90% fertility as measured by seed set. Large $BC_1$populations of all crosses were grown in a fiberglass greenhouse during the fall of 1967. In most populations it was impossible to find any plants with over 50% fertility. Some populations were completely sterile. This indicates (1) an extremely sterile environment in our fiberglass greenhouse, (2) the difficulties encountered in a backcross program for fertility restoration, and (3) some type of complex interaction involving Triticum timopheevi cytoplasm, restoration genes, genes from the common wheat recurrent parent, and the environment which causes an apparent breakdown of fertility restoration

Varying degrees of fertility have been noted in two of our male sterile lines after showing good sterility for several generations. This again indicates the complexity of the male sterility - environmental interaction.

# SUMMARY OF WHEAT HYBRID PERFORMANCE TRIALS IN KANSAS

R. W. Livers

A five-year Kansas experiment, which will be completed in 1968, is concerned with field performance of hard red winter wheat hybrids compared with their parents. Data the first year were obtained on eighteen hybrids involving seven parents. In succeeding years there have been 36 hybrids, all possible single-crosses of nine parental varieties. These have been grown in four replications at Hays from hand-crossed seed planted at the rate of forty-five pounds per acre in single-row plots three feet in length bordered on all sides by a full stand of wheat. In addition to this experiment a five-variety diallel trial has been grown since 1965 at Hays, Hutchinson and Manhattan with the same plot arrangement.

There are several questions which are being answered by the information which is accumulating. In the first place, there can be no doubt that there is a substantial amount of hybrid vigor in grain yield when the best available hard red winter wheat varieties are intercrossed. In the four crops to date the average of all hybrids at Hays has been 37 bushels per acre, 32% more than the parent variety average. The best hybrid has averaged about 43 bushels, a 31% advantage over the best variety.

In maturity the hybrids have been close to the midparent value, but with a definite trend toward earliness. They have averaged about 1/2 day earlier than the midparent, suggesting partial dominance of earliness. Earliness has had little or no effect upon yield except in the stem rust year, 1965, when earliness was of some benefit.

Height, seeds per head, seed weight and pounds per bushel are characters which have consistently exceeded the midparent value in hybrids. Sometimes this appears to be a dominance effect from the better parent and sometimes there has been a minor heterotic effect.

There has been striking heterosis for number of heads per plot, straw yield and grain yield. Measured from the midparent values these have been 120%, 126% and 132% respectively. Head number has been strongly and positively associated with yield in three years out of four; and straw yield has been closely related to grain yield in two years but appeared unrelated in the other two years.

Correlations between midparent and hybrid values for yield from 1964 to 1967 have been -.23, .83, .66 and .28. These correlations are not homogeneous, and they suggest that sometimes parent yield is a good predictor of hybrid performance, but that often it is not. Parent-hybrid correlations for some characters including maturity, height, seed weight and bushel weight have been quite high.

From the 1964 and 1965 crops mixogram data were secured. There was close and consistent relationship between hybrids and midparent values for mixing time and mixing tolerance.

Yield data from $F_2$ populations are available for comparison with $F_1$'s from the Hays crop of 1966 and 1967. In 1966 yields were very low. The $F_1$ hybrids exhibited the usual 30% increase, but the $F_2$'s were almost exactly equal to the parents. In 1967 the yield level was quite high. The average of 36 $F_2$'s was 7% better than the yield of parent varieties. This compares to an advantage of 35% for the $F_1$ hybrids. In neither year was any $F_2$ significantly better than the best variety.

In the hybrid study involving three Kansas locations there has been a moderate amount of interaction between genotypes and stations, and between genotypes and years. However, the consistent performance of hybrids in different sites and years is a more impressive feature of the experiments than occasional interactions. Generally speaking, the two additional stations give data which agrees with Hays data both in degree of heterosis and in superiority of certain hybrid combinations.

Data on general and specific combining ability from diallel analyses are not yet available at the time of this writing.

4-YEAR RESULTS WITH WHEAT HYBRIDS AT HAYS, KANSAS

| | 1964 | 1965 | 1966 | 1967 | AVERAGE | |
|---|---|---|---|---|---|---|
| AVERAGE YIELD OF ALL HYBRIDS | 37.3 | 48.1 | 12.9 | 50.9 | 37.3 | |
| AVERAGE YIELD, PARENT VARIETIES | 31.0 | 35.1 | 9.4 | 37.7 | 28.3 | |
| DIFFERENCE, BUSHELS PER ACRE | 6.3 | 13.0 | 3.5 | 13.2 | 9.0 | |
| % ADVANTAGE OF HYBRIDS | 20% | 37% | 37% | 35% | 32% | |
| YIELD OF BEST HYBRID | 45.0 | 57.1 | 16.9 | 62.8 | 42.8 | * |
| YIELD OF BEST VARIETY | 34.0 | 44.2 | 13.3 | 46.0 | 32.6 | ** |
| DIFFERENCE, BUSHELS PER ACRE | 11.0 | 12.9 | 3.6 | 16.8 | 10.2 | |
| % ADVANTAGE OF HYBRID | 33% | 29% | 27% | 37% | 31% | |

* Average of hybrid with best 4-year yield performance.
** Average of variety with best 4-year yield performance.

PERFORMANCE OF HYBRIDS IN PERCENT OF MID-PARENT VALUES

| | 1964 | 1965 | 1966 | 1967 | MEAN |
|---|---|---|---|---|---|
| DATE HEADED | 99% | 97% | 100% | 88% | 96% |
| HEIGHT | 104% | 102% | 104% | 105% | 104% |
| HEADS PER PLOT | 109% | 126% | 124% | 122% | 120% |
| SEEDS PER HEAD | 105% | 101% | 101% | 104% | 103% |
| SEED WEIGHT | 106% | 107% | 102% | 107% | 105% |
| LBS. PER BU. | 100% | 102% | 101% | 101% | 101% |
| STRAW YIELD | 117% | 130% | 128% | 128% | 126% |
| GRAIN YIELD | 122% | 137% | 129% | 138% | 132% |

Simple correlations between grain yield and other characters observed in wheat hybrids grown at Hays, Kansas.

| | 1964 | 1965 | 1966 | 1967 |
|---|---|---|---|---|
| DATE HEADED | .07 | -.35* | .21 | -.03 |
| HEIGHT | .22 | -.34* | .39* | .71** |
| HEADS PER PLOT | .52** | .25 | .43** | .78** |
| SEEDS PER HEAD | .34* | -.26 | .73** | .50** |
| SEED WEIGHT | .24 | .62** | .09 | .21 |
| LBS. PER BU. | .13 | .83** | .49** | .19 |
| STRAW YIELD | .82** | .03 | .26 | .80** |

3-year average yields of 9 parents & 36 wheat hybrids at Hays, Kansas.

| | Tmp | Pkr | Sut | Tcs | Cch | Ot | Pn | Bsn | Cnn |
|---|---|---|---|---|---|---|---|---|---|
| Triumph | ---- | 34.0 | 33.3 | 34.1 | 31.9 | 35.2 | 34.9 | 34.4 | 36.7 |
| Parker | 34.0 | ---- | 34.8 | 40.3 | 34.9 | 38.1 | 38.3 | 37.7 | 38.4 |
| Scout | 33.3 | 34.8 | ---- | 43.2 | 37.7 | 35.3 | 38.3 | 44.7 | 39.5 |
| Tascosa | 34.1 | 40.3 | 43.2 | ---- | 35.6 | 38.7 | 40.3 | 37.8 | 39.7 |
| Concho | 31.9 | 34.9 | 37.7 | 35.6 | ---- | 37.1 | 36.4 | 31.9 | 36.5 |
| Ottawa | 35.2 | 38.1 | 35.3 | 38.7 | 37.1 | ---- | 36.7 | 38.3 | 36.0 |
| Pawnee | 34.9 | 38.3 | 38.3 | 40.3 | 36.4 | 36.7 | ---- | 37.7 | 36.3 |
| Bison | 34.4 | 37.7 | 44.7 | 37.8 | 31.9 | 38.3 | 37.7 | ---- | 38.3 |
| Cheyenne | 36.7 | 38.4 | 39.5 | 39.7 | 36.5 | 36.0 | 36.3 | 38.3 | ---- |
| Average | 34.3 | 37.1 | 38.4 | 38.7 | 35.3 | 36.9 | 37.4 | 37.6 | 37.7 |
| Parent | 22.0 | 28.0 | 32.1 | 23.5 | 28.5 | 29.6 | 26.9 | 28.3 | 27.6 |

# HETEROSIS OF YIELD AND SEED WEIGHT IN 44 SPRING WHEAT CROSSES IN 1965 and 1967

C. L. Lay and D. G. Wells

Yield and kernel weights were studied of hand made crosses of 22 spring wheats with Lee and Rushmore in 1965 and 1967. The $F_2$ generations also were studied in 1967. $F_1$ and parental seed was produced in the greenhouse and was uniformly plump. $F_2$ seed came from the field and was plump. A split plot design in 4 replicates was used. In 1965 whole plots were of one row 170 cm long divided into subplots 20 cm long separated by oat hills in 5 cm long spaces. Rows were 31 cm apart. In 1967 two rows were added to a whole plot, one row for each $F_2$. Plots were overseeded and thinned to a rate of 30 kg/ha (27#/acre). Diseases were chemically controlled. Rainfall was abundant in 1965. In 1967 there was drouth stress broken by one irrigation and then natural rainfall.

For yield in 1965 and 1967, the $F_1$'s for Lee crosses in relation to the high parents ranged respectively from -18 to +108% and -14 to +61%. For seed weight in 1965 and 1967, the $F_1$'s in relation to the high parent ranged respectively from -13 to +10% and -3 to +13%. $F_2$ yields in relation to the high parents ranged from -36 to +15%. $F_2$ kernel weights ranged from -9 to +7% in relation to the high parent.

For yield in 1965 and 1967, the $F_1$'s for Rushmore crosses in relation to the high parents ranged respectively from -19 to +62% and -30 to +23%. For seed weight in 1965 and 1967, the $F_1$'s in relation to the high parent ranged respectively from -9 to +10% and -7 to +5%. $F_2$ yields in relation to the high parents ranged from -42% to -9% while seed weights ranged from -7% to +5%.

The 2 testers in hybrids differed significantly only for kernel weight in 1967. For kernel weight in 1965 and yield both years, they were similar. The 22 tested entries differed in GCA for both trials both years. There were SCA differences in yield but not kernel weight in 1965. No SCA differences were found in 1967. Tested lines in both years for both traits were significantly different at the 1% level of P. Testers for both traits were similar in 1965 and significantly different in 1967. Rushmore in 1967 averaged 23% higher in yield than Lee. In 1965 Lee and Rushmore yielded 2021 and 1989 kg/ha. In 1967 the yields were 3296 and 4287 kg/ha respectively.

The highest yielding $F_1$ in 1965 was 66% over Chris, the best commercial variety in the test. In 1967, Canthatch yeilded a little more than Chris. The best $F_1$ was 36% over Canthatch.

The correlations for 1965 between yields of the two sets of hybrids, of yields of Rushmore and of Lee hybrids with their seed weights and between seed weights of the two sets of crosses were all highly significant. However, there was no significant correlation between yields of the high parents and the hybrids in both series of crosses.

Correlations were not significant between years in the yields of crosses involving Lee or Rushmore.

# THE PROSPECTS FOR HYBRID WHEAT IN SASKATCHEWAN

D. R. Knott

In some earlier work at Saskatoon 7 $F_1$ hybrids were tested and the maximum increase in yield over the better parent was 11%. The best hybrid also yielded 11% more than Thatcher.

More recently diallel crosses were made among 6 varieties of fairly diverse origin but all basically hard red spring wheats. The varieties were chosen so as to provide a good measure of the inheritance of yield, maturity, rust resistance and quality in $F_1$ hybrids. Enough seed was produced to test the hybrids in short rows with seeds planted 2" apart. Of the 15 hybrids, the plants of one developed progressive necrosis and died and the plants of a second showed moderate chlorosis. The latter cross was, therefore, eliminated from consideration.

The yield of the 13 remaining hybrids ranged from 4% below to 24% above the better parent. The only two significant increases above the better parent occurred for crosses where the parents had lower yields than expected. The best hybrid was only 6% above the best parent.

In heading the hybrids tended to be nearer to their earlier parent than to their later parent. Hybrids involving the early variety Garnet all headed within a day of Garnet.

The protein content of the hybrids tended to be near or even below that of the lower parent with a couple of exceptions.

Rust resistance behaved as expected.

The hybrids were tested in $F_2$ both to see if a useful degree of heterosis was present and also to give a prediction of the degree of heterosis in $F_1$. The average yield of the $F_2$'s was exactly equal to the average of the parents.

Correlations between midparent values and $F_1$ and $F_2$ values were highly significant for weight per 1,000 kernels, days to head and height were significant for protein and yield. The yield correlation between the mid-parent $F_1$ values would have been much better except for the unexpectedly low yields obtained for two of the parents, Garnet and Manitou. This resulted in low mid-parent values. It appears, therefore, that a pretty good idea of $F_1$ performance can be obtained by looking at the parent values. Estimates of general combining ability were much greater than for specific combining ability.

Our attempts to produce good restorer lines has convinced me that the present genes are not adequate. None of the $F_1$'s we have tried are fully fertile.

# COMBINING ABILITY STUDIES IN DURUM WHEAT

J. N. Widner and K. L. Lebsock

A ten parent diallel was conducted at two locations in North Dakota during 1965. Heterosis percentages ranged from 184% to 81% of the higher yielding parent. The highest yielding hybrid outyielded its higher parent by 30% and the standard variety Wells by 16%.

Estimates of general and specific combining ability were obtained by the analysis designated by Griffing as Model I, Method 4. Number of tillers/2 feet, kernels/head, 200 kernel weight, and grain yield all had highly significant mean square values for general combining ability. Only 200 kernel weight had a highly significant mean square value for specific combining ability. The percent general to specific combining ability for these characteristics as calculated from the variance components are as follows:

| | % GCA | % SCA |
|---|---|---|
| Tillers/2' | 42.4 | 2.7 |
| Kernels/head | 41.5 | 16.5 |
| 200 kernel weight | 48.1 | 29.5 |
| Grain Yield | 23.3 | 24.6 |

The estimates of general combining ability effects indicate 61-130 to be the highest in general combining ability. This parent was also involved in the crosses that produced the highest yielding hybrid and the highest increase in heterosis above the higher parent.

The correlation coefficient (r = .16) between yield of the mid-parent and the hybrid indicates parental yields do not safely predict the yield of the hybrids. The highest yielding hybrid in this study came from a cross of Langdon and 61-130 which ranked 4th and 9th respectively in yield. The lowest yielding hybrid came from a cross of Wells and 60-45 which ranked 1st and 5th respectively in yield.

DIALLEL ANALYSIS IN DURUM WHEAT - 1965

| PARENTAL LINES | PARENTAL YIELD G/PLOT | $F_2$ YIELD G/PLOT* | $F_1$ YIELD G/PLOT* | ESTIMATES OF GENERAL COMBINING ABILITY EFFECTS |
|---|---|---|---|---|
| 61-130 | 147 (9) | 192 (9) | 245 | 10.6 |
| LEEDS | 217 (2) | 218 (1) | 244 | 9.9 |
| WELLS | 240 (1) | 209 (2) | 243 | 8.6 |
| AKMOLINKA | 139 (10) | 195 (7) | 240 | 5.1 |
| 60-120 | 217 (3) | 204 (3) | 237 | 2.6 |
| LANGDON | 199 (4) | 204 (4) | 236 | 1.1 |
| TEHUACAN | 164 (7) | 197 (6) | 234 | -1.7 |
| RAMSEY | 178 (6) | 192 (10) | 233 | -2.6 |
| CAPPELLI | 157 (8) | 197 (5) | 229 | -6.4 |
| 60-45 | 182 (5) | 195 (8) | 211 | -27.1 |

* MEAN OF FIVE REPLICATIONS.

# METHODS OF EVALUATING COMBINING ABILITY POSSIBLE PROCEDURES

E. L. Smith, W. O. McIlrath, and C. R. Glover

A number of wheat workers have demonstrated that general combining ability variances are more important than specific combining ability variances for yield as well as other agronomic characters. This suggests that we should look first for high general combining ability in our hybrid wheat material. However, specific combining ability effects should not be ignored. In the final analysis we will have to make use of these non-additive effects in selecting parental combinations which give rise to superior hybrids.

A combining ability study involving adapted and foreign varieties was recently conducted at the Oklahoma Station. In this study general combining ability variances for yield were some 12 times greater than specific combining ability variances. For tillers/plant, kernels/plant, 1000 kernel weight, heading date, and plant height, general combining ability variances were also well in excess of specific combining ability variances. However, it is of considerable interest to note that in all characters examined, variances associated with specific combining ability, although relatively small, were statistically significant.

Extrapolating from findings in other crops, we can assume that general combining ability will be relatively more important than specific combining ability in material previously unselected for combining ability. Specific combining ability will become more important in material which has been previously selected for general combining ability. Considering this as well as the nature of the problems encountered in A- and R-line development, the following procedures might be useful in evaluating hybrid wheat material for combining ability.

Preliminary general combining ability estimates should be obtained on varieties and experimental lines before or concurrent with their conversion to A- and R-lines. This can be accomplished through the use of hand-made crosses involving two or three high-performing adapted varieties as testers. Diallel or partial diallel crossing system can also be used. In most programs, preliminary estimates of general combining ability have already been obtained for many commercial varieties and promising lines.

It appears that A-lines can be developed more rapidly than R-lines. Therefore, more A-lines than R-lines will be available, at least initially. With this situation we can employ a partial diallel mating system for a more extensive evaluation of general and specific combining ability effects. With this method (Table 1) four or five R-lines will serve as testers for 10 or so A-lines.

In addition to general combining ability, we will also evaluate for specific effects and search for promising A-line X R-line combinations. As more R-lines become available the model can be reversed so that four or five A-lines are used as testers for a larger number of R-lines.

This type of mating system has been used with sorghum and other crops and appears to be well suited for work with wheat. Also this model provides a means of obtaining additional information on variance components.

Table 1. -- PARTIAL DIALLEL MATING SYSTEM

| A-Lines | R-Lines | | | |
|---|---|---|---|---|
| | W | X | Y | Z |
| 1 | W1 | X1 | Y1 | Z1 |
| 2 | W2 | X2 | Y2 | |
| 3 | W3 | X3 | | |
| 4 | W4 | | | |
| 5 | W5 | | | |
| 6 | W6 | | | |
| 7 | W7 | | | |
| 8 | W8 | | | |
| 9 | W9 | | | |
| 10 | W10 | X10 | Y10 | Z10 |

# POLLEN PRODUCTION AND POLLEN SHEDDING OF SPRING AND DURUM WHEATS

(Abstract)

L. R. Joppa, F. H. McNeal, and M. A. Berg

The amount of seed set by cytoplasmic male sterile lines of wheat is determined by amount of available pollen, relative flowering date of the male and female lines and area of stigma exposed by the female. The present study was designed to investigate the relative pollen shedding ability of varieties of spring and durum wheats and the relationships between pollen shedding and other varietal characteristics.

The varieties differed in amount of pollen shed, number of pollen grains/anther, % anthers extruded, tillers/plot, fertile florets/plot, fertile florets/tiller, yield and kernel weight. The amount of pollen shed was positively correlated with % anthers extruded and tillers/plot but negatively correlated with fertile florets/ tiller.

Path coefficient analysis indicated % anther extrusion had the largest direct effect on pollen shedding. Pollen shedding ability of a variety can be predicted on the basis of fertile florets/plot, pollen grains/anther and % anther extrusion.

# THE EFFECT OF TEMPERATURE AND RELATIVE HUMIDITY ON THE VIABILITY OF HARD RED WINTER WHEAT POLLEN

(Abstract)

R. E. Watkins


Three varieties of hard red winter wheat - 'Warrior', 'Wichita', and 'Triumph' - were grown in controlled environment chambers at four temperatures each at three levels of relative humidity to determine the effects of temperatures and humidity on pollen viability and longevity. The temperatures were 65, 75, 85, and 95°F, and the relative humidities were 20, 50 and 80%. Pollen viability was determined through the use of the vital stain, tetrazolium bromide, in a sugar-gelatin mixture.

The results indicate that both temperature and humidity have an important effect on the longevity and viability of wheat pollen. Approximately 15% of the pollen grains were still viable after 40 minutes of exposure at 65°F and 50% relative humidity. While only about 18% were viable after 5 minutes at 95° and 50% humidity. At a constant temperature the pollen longevity was greater at the higher relative humidities. This study indicates that relatively low temperatures and high humidities are necessary for extended longevity of wheat pollen.

# POLLEN DISPERSAL

(Abstract)

E. G. Heyne

Pollen dispersion measured by Kramer-Collins spore traps and by glass rods indicated pollen would move at least 200 feet. However, highest seed sets were obtained on the down-wind side of the source and within 10 feet. Temperatures and other environmental conditions were poor for wheat pollination and maximum seed set was only 42%. There appear to be two peaks for pollen dispersion per day sometime in the morning before 11:00 a.m., and again in the afternoon when air temperatures decreased. Very high correlations were obtained between pollen per cubic foot per day and the average seed set per date of exposure.

Wheat cultivars appeared to differ in amount of pollen per anther. In 1966, 12 cultivars varied from about 1300 to 1600 per anther from the middle spikelets.

# MAXIMIZING CROSS POLLINATION

(Abstract)

D. E. Glenn

As early as 1965 we expressed confidence that a satisfactory level of cross pollination could be obtained in drill strips up to 16 feet in width, using a ratio of 1 male to 2 females. To date, we have seen nothing to change this opinion. Our data shows that we have obtained 80% cross pollination on a field average basis, though results have sometimes been difficult to duplicate.

Probably the most important factor in obtaining a satisfactory level of cross pollination is the proper timing of the blooming of male and female. Best results have been obtained where the sterile blooms about two days earlier than the pollinator. However, exposing the unfertilized stigmas for several hours or days may create some disease problems. The most serious that we have encountered is the formation of ergot bodies at the more northernly United States locations.

We are attempting to study the amount of isolation required for $F_1$ crossing fields. Results from 1967 showed insignificant levels of crossing at distances of 250 yards to 300 yards from the pollen source.

# MINIMUM SEEDING RATES IN WINTER WHEAT

(Abstract)

Arthur Klatt

One of the basic problems associated with hybrid wheat is the high cost of seed, not only from the farmer's aspect but also the producer. As a possible means of reducing the seed expenditure, a seeding rate study was conducted at Ft. Collins, Colorado in 1967. Two adapted, high yielding varieties, Scout and Lancer, were tested under 4 rates of seeding (3#, 6#, 9#, and 15#/Ac.).

The yields of Scout ranged from 54.7 bu/Ac at the 3 lb/Ac rate up to 71.4 bu/Ac at the 15 lb/Ac rate. Lancer yields ranged from 57.2 bu/Ac at the 3 lb/Ac rate up to 63.1 bu/Ac at the 6 lb/Ac rate. There was no significant difference in yield of Scout at either the 9 or 15 lb/Ac rate, however, the 3 lb and 6 lb/Ac rates were significantly lower in yield. The yield of Lancer did not differ significantly at the 6, 9, or 15 lb/Ac rates, however, the 3 lb/Ac rate again decreased yield. When the grain yields of the two varieties were averaged, no significant difference occurred between the 6, 9, and 15 lb/Ac seeding rates.

This test indicates that maximum or near-maximum yields can be maintained at seeding rates that are much lower than the 30 to 50 lb/Ac seeding rates commonly used in this area. Yield component studies showed that the yield levels are maintained at the lower seeding rates mainly by an increased number of tillers per plant and larger head size.

# IMPROVED SEEDING PRACTICES FOR HYBRID WHEAT

(Abstract)

F. C. Stickler

There is general agreement that seeding rates will be reduced with hybrids because of higher seed costs. However, it is still not known whether rates will be sufficiently reduced to require new concepts of seed metering and other changes in planting equipment design.

There is much experimental data indicating that the prevailing rates in most localities can be reduced without materially affecting yield. However, there are important "side issues" to the seeding rate question (particularly in the Hard Red Winter and Soft Red Winter areas) that may limit the extent of reduction. These are:

1. Reduced ability of thin stands to compete with weeds.
2. Wind and water erosion problems arising from incomplete ground cover.
3. The desire to pasture the wheat during the fall and winter.
4. Delayed maturity of the crop.
5. Less winter survival, presumably because of less material protection.

These are not insurmountable problems, but they are factors to consider in assessing the future needs for planting equipment. Although unit-planters may meet the planting requirements of the plant breeder and/or seedsman, they are not the answer for the commercial wheat grower.

More uniform seed distribution and improved fertilizer application practices may help capitalize on the increased tillering capacity of hybrids.

# SYSTEMIC AND NONMERCURIAL FUNGICIDES IN RELATION TO HYBRID WHEAT

(Abstract)

Earl D. Hansing

About 70% of the wheat seed in Kansas is now treated with mercurial fungicides before planting. With the eventual change to hybrid wheat little or no seed will be treated with mercurial fungicides. Systemic fungicides likely will be used during development of the hybrids. Vitavax 75, an oxathiin fungicide applied as a seed treatment, will control loose smut, bunt, and some seed rots and seedling blights. Then either nonmercurial fungicides or combinations of them with systemic fungicides will be used for seed distributed to farmers. They are more expensive but also more effective than mercurial fungicides for control of seed rots and seedling blights. Since seed will be more expensive the grower will want to have it treated with the best fungicides so as to obtain maximum stand of plants and yield.

# HYBRID WINTERHARDINESS NURSERY

V. A. Johnson

The winter survival of 16 winter wheat hybrids was evaluated in replicated rows at six locations in the hard winter wheat region in 1967. Eight of the hybrids were non-restored ms Bison as a common parent. The other eight hybrids involved NB 3547 or TX 1055 as a fertility restorer parent, crossed with A-line versions of winter wheat varieties ranging in winterhardiness from Parker to Omaha.

Differential winterkilling occurred only at Laramie, Wyoming and Brookings, South Dakota. The average winter survival of non-restored hybrids was slightly less than the least hardy parents. Restored hybrids survived somewhat better on the average than either parent at Laramie but were only equal to the least hardy parent at Brookings where the winter was more severe.

Heads were bagged in restored hybrid rows prior to anthesis to permit measurement of degree of restoration. The data appear in Table 1. Restoration was clearly the most complete at Laramie where there was little difference in degree of restoration provided by NB3547 and TX1055. Overall restoration provided by NB3547 was next at Bushland followed by Brookings, Lethbridge, and Mocassin in that order. Restoration provided by TX1055 was approximately half as effective as NB3547 at Bushland and even less so at the other locations.

Table 1.

| | % seed set on bagged heads | | | | |
|---|---|---|---|---|---|
| Hybrid | Laramie Wyoming | Bushland Texas | Brookings So. Dak. | Lethbridge Alberta | Mocassin Montana |
| Gage x 3547 | 100 | 77 | 74 | 74 | 54 |
| Scout x 3547 | 95 | 75 | 68 | 64 | 57 |
| Bison x 3547 | 72 | 90 | 67 | 53 | 38 |
| Parker x 3547 | 79 | 74 | 70 | 38 | 44 |
| Omaha x 3547 | 62 | 67 | 51 | 55 | 33 |
| Wichita x 3547 | 82 | 83 | 69 | 55 | 54 |
| Bison x 1055 | 64 | 28 | 2 | 2 | 6 |
| Wichita x 1055 | 95 | 49 | 3 | 19 | 16 |

Grain yields were taken at Mead, Mocassin and Lethbridge where all hybrids survived the winter without loss of stand. Performance of restored hybrids in relation to the parents is shown in Table 2. Less-than-complete restoration at these locations undoubtedly had a depressing effect on the performance of hybrids, although seed set from cross pollination probably lessened the effect.

Table 2.

| Hybrid | Hybrid performance as % of parent mean (above line) and best parent (below line). Mead | Mocassin | Lethbridge |
|---|---|---|---|
| Scout x 3547 | 123 / 122 | 91 / 85 | 104 / 90 |
| Gage x 3547 | 101 / 96 | 102 / 85 | 107 / 92 |
| Bison x 3547 | 101 / 98 | 100 / 88 | 116 / 111 |
| Parker x 3547 | 97 / 87 | 97 / 88 | 112 / 111 |
| Omaha x 3547 | 90 / 87 | 84 / 83 | 111 / 110 |
| Wichita x 3547 | 94 / 85 | 93 / 83 | 103 / 92 |

# WINTERHARDINESS IN HYBRID WHEAT

J. M. Poehlman

Winterhardiness in wheat is a complex problem with survival depending upon the interaction of the genotype and the environment. Inherent survival will differ with the class of wheat and the variety within the class. Survival will be affected by the minimum temperatures, duration of exposure, moisture content of the soil, alternate freezing and thawing, snow cover, crop residue on the surface, plant spacing, soil fertility and texture, plant and root development, prehardening, disease or insect injury, and other factors. In general the hard winter wheats have greater resistance than the soft winter wheats to low temperature and drought while the soft wheats have the greater resistance to heaving. This is a basic difference in the adaptation of soft wheats to the Eastern U. S. and the hard wheats to the Great Plains.

The inherent hardiness of hybrid wheats will depend upon the inherent hardiness of the parent strains. It would be expected that the low temperature hardiness of a particular hybrid would be intermediate to that of the parent lines. Hardiness, particularly to heaving, might be increased over the midparent by greater seedling vigor and growth in the hybrid line.

# HARD RED WINTER WHEAT REGIONAL PROGRAM

## Uniform Quality Series

The purpose and organization of the Uniform Quality Series were discussed. A motion to discontinue the Quality Series after the 1968 crop year was approved. Karl Finney of the Hard Winter Wheat Quality Laboratory will evaluate varieties in the 1968 Quality Series as composites only. Cooperating stations are urged to submit advanced lines and varieties for quality evaluation as "special samples". Five pounds of seed would be adequate for full evaluation of special samples.

## Southern Regional Performance Nursery

There were no recommendations for changes in the nursery. Cooperators were urged by the regional leader to ship seed of new entries by parcel post or motor freight. It was pointed out that north-south movement of railway express shipments is very slow. Walter Nelson of the Lind, Washington Station expressed interest in obtaining seed of entries in the southern and northern regional performance nurseries for observation and yield testing at the Lind Station.

## Northern Regional Performance Nursery

No changes recommended.

## Uniform Winterhardiness Nursery

It was suggested by the North Dakota cooperators that the northern and southern materials sections of the nursery should be grown at Williston or Dickinson instead of at Fargo where the winterkilling is usually too high for differential ratings. This change will be affected for the 1969 nursery.

## Soil-borne Mosaic Nursery

No changes recommended.

## Uniform Rust Nursery

Organization and the policy governing the management of the nursery was discussed by R. A. Kilpatrick.

## Regional Report

No changes were recommended for the report except the suggestion that data in 1968 be reported in metric as well as English units in anticipation of eventual conversion to the metric system entirely.

## C.I.Number Assignments

Cooperators were urged to consider requesting C.I. numbers for regional nursery entries. Numbers are assigned only upon request or at the time of release to growers. If C.I. numbers have not already been assigned, this certainly should be considered by the originator at the time an experimental variety is withdrawn from the nursery. Failure to assign numbers could result in the eventual loss of valuable germ plasm.

## Data Retrieval Systems

Computerized retrieval of regional data was discussed by F. H. McNeal. C. F. Konzak discussed a world germ plasm record system.

# TOWARD A WORLD PLANT GERM PLASM RECORD SYSTEM

C. F. Konzak

A program to develop an internationally coordinated system adapted to the storage, retrieval and processing of records and data by computers is nearing the stage of initial field action. The studies involved are being conducted by a working group on international standardization in crop research data recording. This working group was established on the recommendation of a group of scientists assembled at IAEA headquarters in Vienna in December, 1965, at the invitation of the Directors General of FAO and IAEA.1/ Since then the working group has investigated the possibilities for standardization of data recording procedures and is developing a model system for records on accessions of food, feed and fiber plants as a part of these investigations.

Studies of a trial system for storage and retrieval of records by computers were successfully completed in February, 1967 by the coordinator and colleagues with the guidance and assistance of other working group members and the IAEA computer staff. Preliminary recommendations on data recording procedures have been extensively reviewed. Development and review of the format for records is now in the process of final review prior to the launching of field tests. As part of the International Biological program, some standardized procedures have been proposed for records on new germ plasm obtained from plant explorations, from induced mutation research and from hybridization or selection programs as well as for records on existing collection of germ plasm being maintained at stations all over the world.

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1/ Members of the Working Group are: T. T. Chang, Geneticist, International Rice Research Institute, Manila, Philippines; K. W. Finlay, Reader, Waite Agricultural Institute, Glen Osmond, South Australia; E. G. Heyne, Professor of Agronomy, Kansas State University, Manhattan, Kansas, USA; A. F. Kelly, National Institute of Agricultural Botany, Cambridge, U.K.; C. F. Krull, Agronomist, Rockefeller Foundation Programme, Mexico City, Mexico. Advisory members of the Working Group include: S. Borojevic, Institute for Agricultural Research, Novi Sad, Yugoslavia; E. H. Everson, Michigan State University, East Lansing, Michigan, USA: J. MacKey, Department of Genetics and Plant Breeding, Royal Agricultural College of Norway, Vollebekk, Norway; C. A. Watscn, Agricultural Experiment Station, College of Agriculture, Montana State University, Bozeman, Montana, USA; and P. R. Jennings, International Rice Research Institute, Manila, Philippines.

The organization and integration of internationally standarized records has been proposed by way of a coordinated world plant germ plasm record system. FAO headquarters at Rome is the logical location for the coordinating center and central record file. Wide scale field tests of the proposed system are being planned. Holders of a number of the major world collections of wheat germ plasm stocks will be asked to participate in these tests. The system will also be used in plant exploration and adaptation projects of IBP and in programs coordinated by FAO and FAO/IAEA. A project on a germ plasm record system has been included among the U.S. projects participating in the IBP.

In preparation for the planned all out effort on germ plasm registration, U.S. workers could begin to standardize their records in at least three ways that should be compatible with their present work: accession number systems can be established, designations applied to varieties and selections could be made compatible for length (23 spaces) and complete pedigrees for accessions could be recorded according to the standardized system proposed by Purdy et al.

Regional Committee Reports

These were made by K. L. Lebsock, Secretary, Hard Red Spring Wheat Regional Committee, and V. A. Johnson, Secretary, Hard Red Winter Wheat Committee. Germ plasm release policies were discussed at length by the state and federal workers attending the regional programs session.

## RESOLUTIONS

The following resolutions were adopted unanimously by the conference participants.

### REPORT OF THE SPRING WHEAT RESOLUTIONS COMMITTEE

Be it resolved that the members of the Eleventh Spring Wheat Workers Conference, February, 1968, express their appreciation to the following people and organizations: First, to the local arrangment committee and various Departments of the Kansas State University for arrangements, accomodations, and hospitality; second, to the Chairmen of the various sections for the arrangement of the program; third, to the Kansas State University for their promotional activity, and fourth, to the Hard Red Winter Wheat Conference for their invitation to meet jointly. Be it also resolved that we go on record as favoring future joint conferences. Be it further resolved that we express our appreciation to our neighbors in Canada and Mexico for their participation and interest in our conference. Finally, we wish to thank those representing commercial interests in spring wheat research. We hereby also direct the Secretary of this Conference to express our appreciation by letter to the appropriate leaders of the organizations mentioned and enter these resolutions in the official record of this Conference.

Committee: Norman Williams
John Schmidt
Paul J. Fitzgerald, Chairman

**REPORT OF THE RESOLUTIONS COMMITTEE OF THE HARD RED WINTER WHEAT WORKERS:**

Be it resolved that the Hard Red Winter Wheat Workers express their appreciation to the administration of Kansas State University, its Conference Coordinator, and the local arrangements committee, especially its chairman, Dr. E. G. Heyne, for the use of their facilities, their excellent planning, and their hospitality as the host of this conference.

Be it further resolved that the Hard Red Winter Wheat Workers express their pleasure in having met jointly with the Hard Red Spring Wheat Workers in a fruitful and successful conference.

Be it further resolved that the Hard Red Winter Wheat Workers express their recognition of the substantial and stimulating contribution of private research workers participating in this conference.

Be it further resolved that the Hard Red Winter Wheat Workers express their appreciation to Dr. E. G. Heyne and Dr. D. R. Knott for their unselfish contribution of time and effort in developing the Wheat Newsletter into an effective means of communication among wheat workers.

Committee: E. C. Gilmore
R. E. Finkner
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