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Studies on Hybrid Wheat[1/]

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A number of different cytoplasmic male sterile-fertility restoration systems in wheat have been derived from interspecific and intergeneric crosses. Some have limited usefulness. Apparently effective fertility restoration and non-restoration have been reported for timopheevi type male sterility with all components at the 42 chromosome level. There is no reason to believe that these systems now identified are unique. Others will undoubtedly follow as research in this area is intensified. All of these reports have created new interest in hybrid wheat.

Today we would like to limit our discussion to the Nebraska male sterile-fertility restoration system reported last fall. Until recently the line from which both male sterile and restoration lines arose carried only the designation 1279A9-III-4 x Nebred, Nebr. 542437. Dr. L. P. Reitz has supplied the following information from USDA records at Beltsville:

Slide 1 -- Derivation of Nebr. 542437.

The first three crosses were made by Dr. J. Allen Clark in 1936 and 1937, the first at Arlington Farms, Virginia, the second at Bozeman, Montana, and the third at Washington, D. C. Male sterile or partially male sterile plants were used as females in each cross. About 72 rust resistant plants were selected from a 3rd year bulk at Langdon, North Dakota. These plants exhibited various degrees of sterility or fertility. These lines were distributed to Wisconsin, North Dakota, Minnesota, Montana and Nebraska. A number of crosses were made with lines 2, 4, 7, 12, 13, 16 and 21 by Dr. Karl S. Quisenberry at Lincoln in 1941. They were used both as male and female parents. Seed set was generally low but a few crosses produced high seed set. In 1942 there is a note that two F_1's involving lines 12 and 21 in crosses with Nebred and Cheyenne were sterile.

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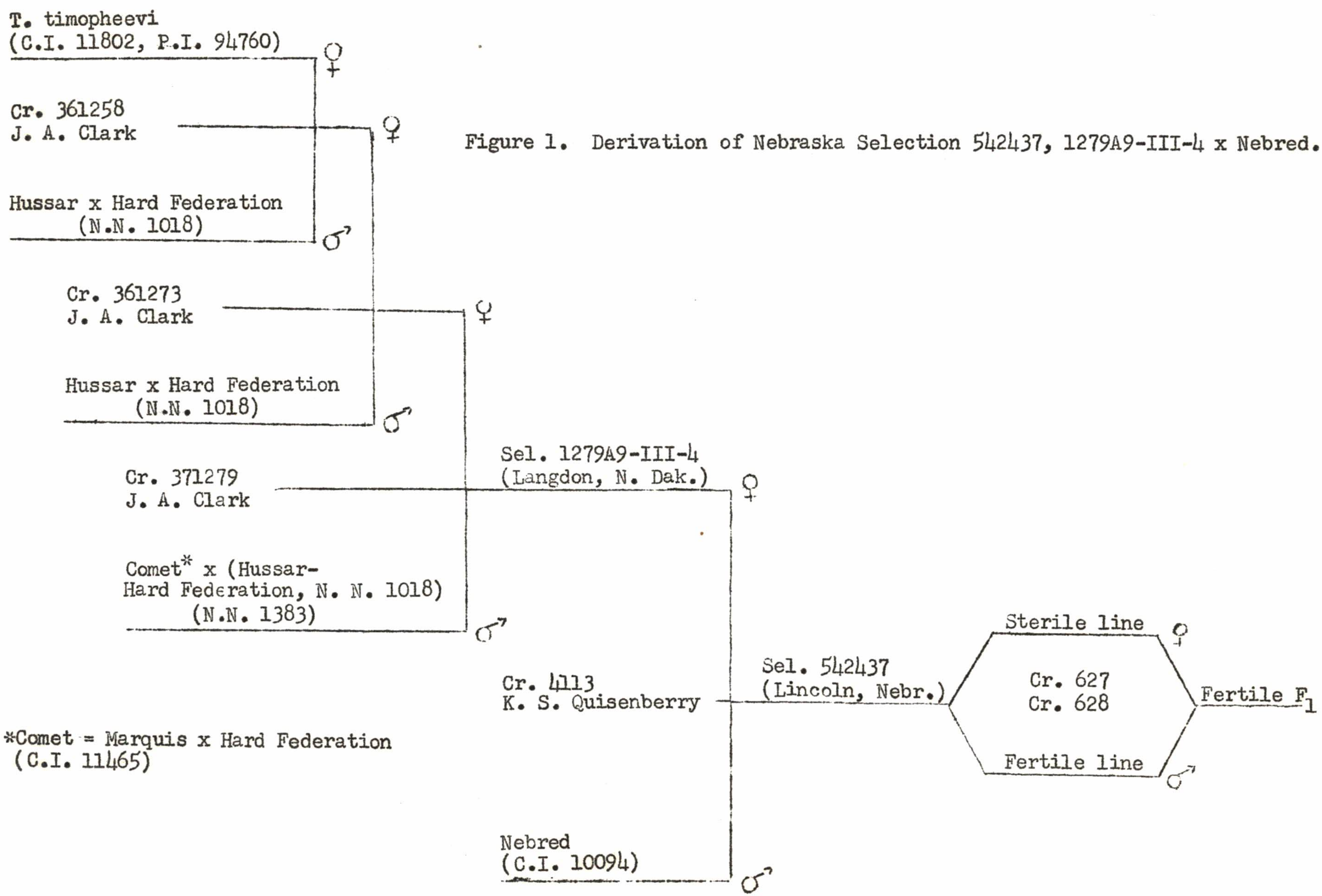

Figure 1. Derivation of Nebraska Selection 542437, 1279A9-III-4 x Nebred.

*Comet = Marquis x Hard Federation
(C.I. 11465)

During the next few years the materials were grown as bulks. Winter kill eliminated much material. Others were discarded because only small quantities of seed were harvested. In 1946, cross 4113 was head selected. Elimination by Drs. Reitz and Johnson pared this to two lines by 1953-54. In 1954 the remaining line, 2437, was designated for germplasm. It was retained because of excellent stem rust resistance and good straw characteristics.

Other lines from these crosses and of Dr. R. G. Shand's lines were of more than passing interest when Wilson and Ross reported male sterility following the substitution of a common wheat nucleus for the timopheevi nucleus in a backcross program using T. timopheevi as female and Bison wheat as a non-restorer male.

These Nebraska lines had been seeded in the field in the fall of 1961 for rust studies. Later these Nebraska lines were sent to Hays and also planted in the greenhouse at Lincoln when male sterile seed was received from Hays. During the greenhouse pollinating season at Lincoln, one plant of Nebraska 542437 was observed to be completely male sterile, the other plants were fertile. The sterile plant was used in crosses to Bison, its fertile sister plants and to a number of other strains and varieties. The same line was observed to have sterile and fertile plants in the field in 1962. F_1 plants from crosses of sterile x Bison, a non-restorer identified by Wilson and Ross, were male sterile in the growth chamber in the fall of 1962 while F_1 plants from the cross of sterile x sister fertile plants were fertile.

All of the crosses made in 1962 are being grown in the greenhouse this winter. In addition an F_2 population of 350 plants from the sterile by fertile F_1's and about 100 plants from the cross (sterile x Bison F_1) x (sterile x fertile F_1) are being grown. These should give us some idea of the inheritance pattern in this material as well as seed increase for distribution.

The following series of slides relate only to the Nebraska male sterile-fertility restoration materials plus Bison as the non-restorer component.

Slide 2. Head from sterile x Bison F_1 showing opening of sterile forets.

Slide 3. Flower parts of sterile x Bison F_1 showing shrivelled anthers.

Slide 4. Empty pollen grains from the sterile x Bison F_1.

Slide 5. Metaphase I from sterile x Bison F_1 showing 21 pairs of chromosomes.

Slide 6. Flower parts from sterile x fertile F_1 showing swollen anthers.

Slide 7. Pollen grains from sterile x fertile F_1.

Slide 8. Metaphase I from sterile x fertile F_1. Again 21_{II}.

Slide 9. Metaphase I from a similar plant showing either poor association or early desynapsis leading to univalents.

Meiotic indices (on basis of about 1000 pollen quartets per plant) may be of interest. One plant, 3605, had the lowest meiotic index of 46. Other indices in order from plant 3606 through 3611 are 90, 97, 96, 96, 92 and 90. A sterile x Bison F_1 plant that was checked had 96% normal dyads (200 checked). This compares well with the original sterile plant which had a meiotic index of 96.

Irregularities noted were univalents which appear to arise from desynapsis since the percentage of cells with univalents at metaphase I is higher than the meiotic indices indicate. The plant with the low meiotic index had a chromosomal fragment. Bridges do occur at anaphase in both sterile x Bison F_1 and sterile by restorer F_1. Thus an inversion is suspected. However, this could be associated with the stem rust resistant character and not with this system itself.

Seed set (growth chamber) averaged between 1.5 and 1.8 seeds per 2 florets. Total seed set per plant averaged over 200. This is reasonably good for our growth chambers. In addition, the best first spikes were used for cytological preparations and for pollen sources for backcrosses. Differences in maturity among plants were observed in the growth chamber. Sterile heads in the field

appeared to be taller and possibly earlier than their fertile counterparts. Outcrossing to other materials could account for this.

The assumption has been made by many that T. timopheevi is the sole source of both sterility and restoration. This may or may not be the case. Without the knowledge of the chromosomal set-up at the various crosses one cannot interpret the evaluation of either system very well in this material. Dr. Nyquist, Univ. of California, reported sterility when Hard Federation and Ramona were used as female parents in crosses with C.I. 12633. A bulk from the cross of Warrior x Concho (Hard Federation derivative) likewise produced many sterile plants in the field in 1961 at Lincoln. Hard Federation figures prominently in the pedigree of this material. Comet, Marquis, Hussar and Hard Federation as well as other wheats such as Nebred and Cheyenne will be or have been used in further crosses to determine their contributions. Crosses between T. timopheevi and other tetraploid wheats need to be restudied. Effective restoration may, in part, be due to cumulative or modifying factors from the recurrent parents. We may be in for surprises as well as disappointments. The identification of Bison as a non-restorer by the Ft. Hays group was of key importance to our work and may be of real significance in future investigations.

Very little information is available regarding the extent of hybrid vigor in wheat. Most of the information is from space-planted nurseries. The data on the following slides similarly is on space planted material. However, they are indicative of what might be expected to occur in hybrid populations.

Agronomic characteristics of Seu Seun 27, BlueJacket and their F_1 hybrid.

Variety	Yield Grams per plant	Yield Bushels per acre	Heads per plant	50-kernel weight grams	Plant height cm.	Flowering date in May
Seu Seun 27	6.26	60.0	9.4	1.25	83	21.9
BlueJacket	6.90	66.2	9.1	1.44	125	26.8
F_1 Seu Seun 27 Bluejacket	7.60	73.0	9.6	1.52	112	22.0
LSD .05		7.11				
C.V.		8.33%				

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Here are shown the data from the only field experiment.

Seu Seun 27 is a Korean semi dwarf wheat.

BlueJacket is a tall hard red winter wheat.

Since plants per area were kept constant, variation contributing to yield is limited to heads per plant, kernels per head, and kernel weight. Information is not available for kernels per head. The F_1 exceeded the parents in heads per plant and kernel weight and registered a significant increase in yield. The F_1 yielded 110% of the better parent.

Agronomic characteristics of Comanche, Atlas 66 and their F_1 hybrid.

Variety	Yield Grams per plant	Yield Bushels per acre	Heads per plant	1000-kernel weight grams	Flowering date in April
Comanche	5.4	34.4	10.4	41.15	6
Atlas 66	9.1	58.5	11.5	40.65	2
F_1 Atl 66 x Cmn	8.8	56.7	11.6	45.47	4
LSD .05		11.8			
C.V.		13.6%			

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Atlas 66 is a North Carolina soft red winter wheat that is high in grain protein content.

Comanche is a hard red winter wheat.

Again data are not available for number of kernels per head. Since kernel weight is up and the heads per-plant component scarcely exceeds the better parent, the F_1 must have been deficient in kernel number.

Yield of grain is only 97% of the better parent.

The F_1 was intermediate in flowering but probably somewhat taller.

Agronomic characteristics of Wichita, Atlas 66 and their F_1 hybrid.

Variety	Yield Grams per plant	Yield Bushels per acre	Heads per plant	Plant height cm.	Flowering date1/
Wichita	7.09	45.3	6.0	153.3	6.5
Atlas 66	6.26	40.3	5.5	152.8	10.7
F_1 Wi x Atl 66	7.72	49.6	6.4	165.9	9.6
LSD .05		N.S.			

1/ Flowering date code, April 21 = 1.

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The same parent, Atlas 66, was crossed with Wichita, a low protein hard red winter wheat.

While the F_1 exceeded both parents in yield the differences were not statisticall significant.

No information is available regarding kernels per head and kernel weight. The F_1 was superior in number of heads per plant; at the same time it was taller in height and more nearly like the late parent in maturity.

Mean grain yields, kernels per plot and 1000-kernel weight of Bison, C.I. 13678 and their F_1 hybrid.

Variety	Yield bushels per acre	Kernels per plot	1000-kernel weight in grams
Bison	58.1	4788	37.70
C.I. 13678	34.2	4719	23.06
F_1 Bsn x C.I. 13678	76.1	7055	33.93
LSD .05	12.9	1319	3.57
C.V.	13.3%	13.8%	6.54%

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Bison is a hard red winter wheat with high kernel weight.

C.I. 13678 is Norin 16 x Nebraska 60 Mi-Hope a high yielding semi dwarf wheat deficient in kernel weight.

The F_1 significantly out-produced either parent. In kernel weight the hybrid was not the equal of Bison but much superior to the low parent.

The high yield came from the much greater number of kernels per plot. The reason for this is shown in the next slide.

Agronomic characteristics of Bison, C.I. 13678 and their F_1 hybrid.

Variety	Plant height cm.	Flowering date 1/	Av. no. heads per plant	Av. no. kernels per head
Bison	173.3	12.6	9.2	25.86
C.I. 13678	115.2	7.1	8.5	28.25
F_1 Bsn x C.I. 13678	165.2	8.1	10.7	32.85

1/ Flowering data coded, 1 = April 19.

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The F_1 was superior in both kernels per head and heads per plant. These increases were sufficient to offset the somewhat lower kernel weight.

Dominance for earliness and tall plant height is indicated.

Comparisons of four F_1 hybrids with their parental means and their better parent.

F_1 hybrid	Yield		Component contributing to heterosis
	Percent of mid-parent mean	Percent of better parent	
Atl 66 x Cmn	122	97	Kernel weight
Wi x Atl 66	116	109	Heads/plant
SS 27 x BJ	116	110	Kernel weight Heads/plant
Bsn x C.I. 13678	165	131	Kernels/head Heads/plant

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The yield results are here summarized for the four crosses.

All F_1 hybrids were superior to the mid-parent value in yield but only two were significantly superior to the better parent.

All were as good or better than the better parent in heads per plant.

Where kernel weight of the two parents is good, the F_1 may have better kernel weight.

Only in one cross was information available for the kernels per-head component.

Yield comparison for the F_1 and better parent ranged from 3% below to 31% above.

From these data presented, there is reason to believe that certain combinations might be obtained that could be outstanding in yield. This is not to say that similar combinations could not be isolated from these same crosses as a pure line. However, good hybrids might be obtained more quickly and with less work than comparable pure lines. At least, it is worth further exploration.

It was shown that by appropriate use of parents, earliness, tolerable plant height, etc. can be maintained in the hybrid combinations. Hybrids will place a premium on dominance for such characters as disease resistance, quality, winter-hardiness, etc. They offer considerably greater versatility than now available with pure line varieties.

Optimism regarding the usefulness of hybrid wheat, however, is tempered by these factors:

1. A considerably greater amount of seed per acre planted than for corn or sorghum.
2. A lower average yield per acre for wheat in comparison with corn and sorghum.
3. The highly self-pollinating nature of wheat and its effect on successful hybrid seed production including ergot difficulties.
4. The absence of good information regarding the extent of hybrid vigor in wheat.

Any estimate of the value of hybrid wheat at this point is, therefore, premature. This estimate will be formed over the next few years since hybrid wheat investigations on a larger scale appear to be possible. Not until such information is available can there be a meaningful evaluation.

The production of hybrid varieties must be preceded by the incorporation of male sterility and male fertility restoration and non-restoration factors into appropriate breeding lines followed by field testing of hybrid combinations from such lines. Field testing may begin in a few years. It can be expected to proceed most rapidly in the spring wheat region because breeding cycles or generations for spring wheat are much shorter than for winter wheats. Eventually, hybrids could be the most successful in the Pacific Northwest because of higher potential yields in that area coupled with lower seeding rates per acre and climatic conditions more favorable for hybrid seed production.

From the plant breeding viewpoint, hybrids could have value other than increased yield. For example, hybrid combinations could be developed and put into production more quickly than conventional varieties to meet a new disease threat. However, the producer will be interested only if the hybrid provides a greater return per investment. This return must be sufficient to cover the increased cost of procuring new seed every year.