HYBRID WHEATS -- Problems, Potentials and Progress

FORECASTING WHEN HYBRID WHEATS MAY BE AVAILABLE FOR COMMERCIAL PRODUCTION WOULD BE PREMATURE, BUT INTENSIVE RESEARCH BEING CONDUCTED AT STATE AND USDA EXPERIMENT STATIONS AND BY COMMERCIAL SEED COMPANIES SOON SHOULD DETERMINE THEIR FEASIBILITY AND THE TYPE OF HYBRIDS THAT EVENTUALLY MAY BE PRODUCED.

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THE SUPERIORITY of plant hybrids over their open pollinated or pure line varieties has been shown in corn, sorghum and several other crops. Economical production of hybrid seed was possible only after solutions were found to several major seed production problems. One of the most effective aids, particularly in the normally self-pollinated species, was the discovery and utilization of cytoplasmic male sterility.

Japanese scientists recently discovered cytoplasmic male sterility in crosses involving the *Aegilops* and *Triticum* species. The latter was used as male parents in the original crosses and in successive backcrosses. Kihara (4) obtained male-sterile wheat using *Aegilops caudata* L., and Fukasawa (2) developed male-sterile durums using plants having *Aegilops ovata* L. cytoplasm as the female parent. Wilson and Ross (8) developed male-sterile wheat by backcrossing *Triticum timopheevi* Zhuk., a wild emmer, to the pollen parent Bison, a hard red winter wheat variety. *Aegilops caudata* and *Aegilops ovata* are related to *Aegilops cylindrice* Host, "goatgrass" or "joint grass," a winter annual weed sometimes found in wheat.

Aegilops caudata and *Aegilops ovata,* although distantly related to wheat, differ distinctly and have 7 and 14 pairs of chromosomes, respectively. *T. timopheevi,* which is more closely related to common wheat, *T. aestivum* L., resembles wheat more than do the Aegilop species. *T. timopheevi* has 14 pairs of chromosomes, as compared with 21 pairs in wheat.

Although these wild species differ from wheat in chromosome numbers and in plant characteristics, such as the free threshing of grain, Figure 1, wheat plants or lines can be developed which have the 21 pairs of wheat chromosomes and differ from the wheat pollen parent only in being male-sterile, Figure 2. The normal wheat flower as it appears in the spike after the outer chaff has been removed is shown in Figure 3, and the normal wheat flower, removed from the spike, is compared with flowers of male-sterile wheat having *Ae. ovata* and *Ae. caudata* cytoplasm in Figure 4.

The name hybrid is often applied erroneously to some of our commercial varieties of wheat. Most of them are advanced generation selections resulting from crosses of two or more varieties, and are pure line varieties which breed true from one generation to the next. Interest in the possibility of producing hybrid wheat, as in sorghum, soon followed the discovery of cytoplasmic male sterility. The possibilities of hybrid wheat were enhanced by the fact that Fukasawa (3) also found that *T. dicoccoides* Korn.,

Figure 1. Left to right—The head and grain of normal male-fertile wheat; a head of male-sterile wheat and grain produced on male-sterile wheat when cross-pollinated by wheat, and the head and grain of *Aegilops ovata* and *Triticum timopheevi*. *Ae. ovata* and *T. timopheevi* are not free-threshing.

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variety Kotschyanum Perc., would restore pollen fertility to *T. durum* steriles having *Ae. ovata* cytoplasm. Further stimulus was added when Schmidt *et al* (5) found a wheat line derived from the cross of *T. timopheevi* x wheat which possesses 21 pairs of chromosomes and the capability of restoring fertility to male-sterile wheat having *T. timopheevi* cytoplasm.

The Kansas Agricultural Experiment Station reported that R. W. Livers had found a restorer in the original *T. timopheevi*-Bison material. Thus, the "tools" are available for producing hybrid wheat: (1) male-sterile line, (2) fertile lines for use in increasing and maintaining the seed of male-sterile lines and (3) pollen restoration lines used as the seed wheat will be available to the wheat producer.

PROBLEMS

The amount of hybrid vigor expressed by wheat hybrids still is mostly unknown. In the past, it was necessary to produce first generation wheat hybrids by hand-crosses. As a result, few hybrid plants have been included in evaluation studies and results of these may be inconclusive. Literature concerning hybrid vigor in wheat, reviewed by Briggle (1), indicates that hybrids between some wheat varieties are no more and sometimes less vigorous than their parents, while hybrids of other varieties have shown as much hybrid vigor as that found in sorghum and corn. It is now possible to produce relatively large amounts of hybrid seed and the vigor of wheat hybrids soon will be determined.

Whether hybrid wheat seed can be produced economically is not yet known. Wheat is a self-pollinated crop with a small percentage of crossing occurring naturally. Male-sterile plants, however, may set a substantial amount of seed from wind-blown pollen. Wilson and Ross (7), at Hays, Kansas, obtained an average of 71% seed set on male-sterile plants placed between strips of wheat at flowering time. The ratio of pollen parent to the male-sterile seed parent required to obtain adequate seed set in crossing blocks is one of several factors that will determine the cost of hybrid seed.

The ratio of the amount of wheat seeded to that harvested may be placed at 1 to 50, as compared with 1 to 1,000 for sorghum. This unfavorable ratio places an additional economic limitation on the cost of hybrid seed. Difficult as these problems appear, they may be found less serious or they may be alleviated by research. Such research will be directed toward improved cross pollination potentials of male-steriles and increased dissemination of pollen from pollen parents by breeding and selecting for appropriate flower characteristics. Economic problems might be circumvented in part by using second generation seed of appropriate hybrids, if pollen fertility and dissemination are adequate to eliminate practically all sterility in the second generation.

Other possibilities include composites of first generation seed and appropriate varieties or the incorporation of hybrid seed into multilineal varieties. Composite hybrids

Figure 2. Male-sterile wheat having *Ae. ovata* cytoplasm, center, is compared with its fertile counterpart, right, and to a plant of *Aegilops ovata*, left. The male-fertile line shown can be used to maintain the male-sterile line, but it will not restore male fertility. Other lines which will restore pollen fertility must be used as the pollen parent to produce fertile hybrids.

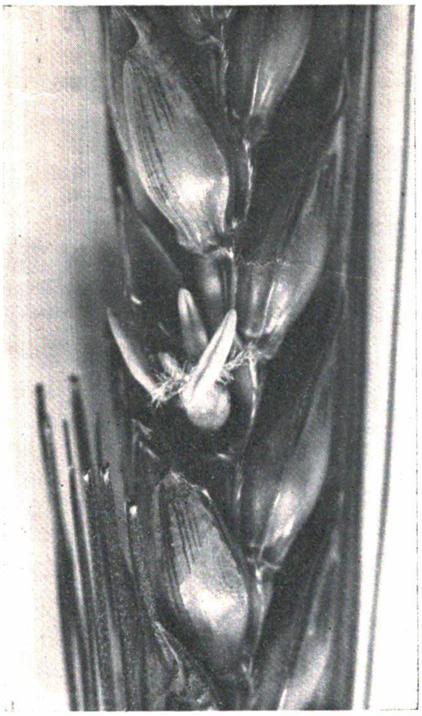

Figure 3. The flower of a normal male-fertile wheat plant as it appears on the spike after the outer chaff has been removed. Greatly enlarged.

probably would be less uniform and less vigorous than the first generation hybrid, but seed costs should be much lower.

Problems common to the breeding of pure line varieties also must be reckoned with in hybrids. One of these is the milling and baking quality. Both the cytoplasms and the restoration factors proposed for use in the production of hybrid wheat come from wild species related to wheat. This could result in the production of poor quality grain if inadequate attention is given quality characteristics. High-yielding hybrids may tend to have lower grain protein percentage, and even greater attention may need to be given the quantity and quality of protein of hybrids than has been given to that of pure line varieties.

POTENTIALS

The potentials of hybrid wheat by the utilization of male sterility justifies intensive research. In addition to increased grain yield, possible increases in forage production or grazing value would be an added bonus. Resistance to some diseases and insects controlled by dominant genetic factors are more easily fixed in hybrids than in pure line varieties. This principle may apply equally well to other desirable characteristics controlled by dominant genes. Wheat will cross with certain relatives, such as diploid rye and some of the wheatgrasses. This fact raises speculation as to the utilization of male - sterile wheats in producing improved grass or wheat-like forages, some of which may be sterile vegetative hybrids from crosses of wheat and its relatives. Uniformity or high seed yield of forage hybrids might not be important requirements, but other forseeable problems preclude suggesting definite methods of breeding or estimates of probability of success for such hybrids.

Even if all efforts to utilize male sterility in producing hybrid wheat or forages should fail, its use in improving pure line varieties will be invaluable. The primary objective in breeding new pure line varieties of wheat is the combination of desirable qualities of one variety with those of another. Recombinations of characteristics occur at the highest frequency in the first segregating generation progeny. Recombinations of some characteristics, such as earliness and a high degree of winterhardiness, rarely may occur in populations originating from a few first generation plants. Male sterility makes possible large first generation populations and it can be used to maintain the variability needed in subsequent generations for the occurrence of such recombinations.

PROGRESS

Research was initiated at the Southwestern Great Plains Field Station, Bushland, Texas, in the fall of 1958, when male-sterile spring wheat varieties having *Ae. caudata* cytoplasm were obtained from B. C. Jenkins, Division of Plant Science, University of Manitoba, Winnipeg, Canada.

Male-sterile winter wheat varieties, *Ae. ovata* and *T. timopheevi* cytoplasms, respectively, were obtained in 1960 and 1962 from the Kansas Agricultural Experiment Station. Since the *T. timopheevi* steriles were obtained only recently, results of research in Texas are limited at this time to those of the *Ae. caudata* and *Ae. ovata* cytoplasms. Work with these cytoplasms has consisted primarily of backcrossing the spring wheat steriles to winter varieties to transfer the *Ae. caudata* sterility to winter wheat and to increase and develop additional steriles of Texas varieties having *Ae. ovata* cytoplasm. Several wheat varieties and lines have been evaluated for pollen restoration, but all have produced male-sterile progency in crosses

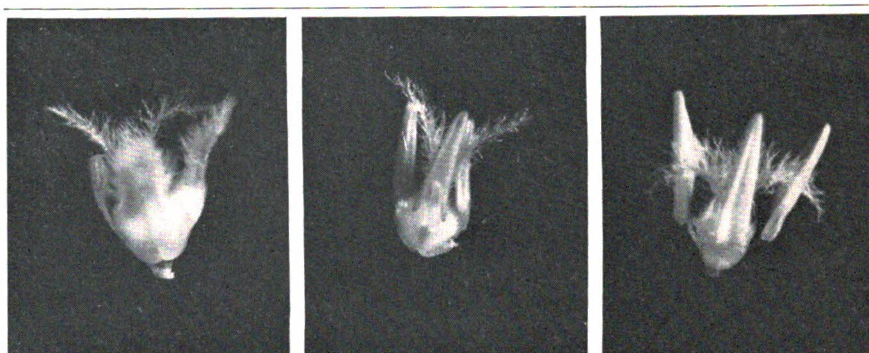

Figure 4. Left to right—Flowers of male-sterile wheats having *Ae. caudata* cytoplasm, *Ae. ovata* cytoplasm and a flower from normal male-fertile wheat. The normal flower has three plump anthers (pollen sacs) and a two-branched feathery stigma that leads into the globular ovary at the base. Flowers of *ovata* steriles are similar to the normal flower, but the anthers are pinched and nonfunctional. Flowers of the *caudata* steriles commonly develop abnormal stigma-like female parts (pistillodes) and may be female-sterile as well as male-sterile. Flowers of *T. timopheevi* steriles, not shown, are similar to those of *ovata* steriles.

TABLE 1. SEED SET IN THE GREENHOUSE ON MALE-STERILE WHEAT PLANTS WHEN POLLINATED, USING THE APPROACH METHOD, WITH WHEAT AND WHEAT RELATIVES, 1962

Cytoplasm of male sterile	Number of flowers pollinated	Pollinator	Percent seed set
Ae. caudata	441	Wheat	20
Ae. ovata	370	Wheat	36
Wheat[1]	600	Wheat	50-60
Ae. ovata	285	*Agropyron elongatum*	17
Ae. caudata	116	*Agropyron elongatum*	0
Ae. ovata	60	*T. dicoccoides*[2]	61
Ae. ovata	290	Tetraploid rye	0
Ae. caudata	157	Tetraploid rye	0
Ae. ovata	148	*Elymus* (species ?)	0
Ae. caudata	380	*Elymus* (species ?)	0
Ae. ovata	423	8x *Triticale*	13[3]
Ae caudata	131	8x *Triticale*	0

[1]Emasculated male fertile wheat. Number of florets estimated. Number of seed obtained indicated 50 to 60% seed set.

[2]Variety Kotschyanum.

[3]All seed obtained were badly shriveled and did not germinate. The 8x *Triticale* used in this cross was obtained from N. F. Jensen, Cornell University.

with *Ae. caudata and Ae. ovata* male-steriles.

Results of crosses made in the greenhouse in 1962, Table 1, suggests that a higher seed set may be expected on *Ae. ovata* than on *Ae. caudata* steriles, and that emasculated flowers of male-fertile wheat may set seed more readily from cross pollination than male-sterile wheats of both *Ae. caudata* and *Ae. ovata* cytoplasms. The relatively [redacted] production of some type of forage hybrid. It may not be possible in Texas to obtain proper "nicking" of flowering of male-sterile wheat with the flowering of wheatgrass species and many other problems also are involved.

Excellent seed set obtained on male - sterile wheats, *ovata* cytoplasm, when pollinated by *T. dicoccoides,* is attributed to the abundance of pollen shed by this species. This was the initial step taken to transfer the pollen-restoration and pollen-shedding characteristics of this species to wheat lines to be used as pollen parents. As was expected, no seed were obtained on male-sterile wheat pollinated by tetraploid rye or an unidentified species of *Elymus,* wild rye, even though both pollinators shed great quantities of pollen on the male-sterile wheat flowers. A relatively high seed set was obtained on *ovata* steriles when pollinated with an 8x *Triticale,* but all seed obtained were badly shriveled and did not germinate.

The lower percentage seed set on *Ae. caudata* steriles, as compared with that on *Ae. ovata* steriles, possibly could be the result of differences in environmental conditions or other factors not associated with differences in cytoplasms; however, the development of abnormal female parts in flowers of male-sterile wheat having *Ae. caudata* cytoplasm, Figure 4, may result in a high percentage of female as well as male sterility.

Percentages of seed set on male-sterile wheat plants grown in a field of wheat and on male-sterile plants placed in fields of diploid and tetraploid rye at flowering time are given in Table 2. Since male-sterile plants grown in the field of wheat were space-planted, many late tillers were produced which flowered after the pollination period and were not pollinated. The first five heads of steriles of both cytoplasms set more seed than later tillers. The *Ae. caudata* steriles set more seed than the *Ae. ovata* steriles since they headed at the same time as the pollinating field, while the *Ae.*

TABLE 2. PERCENT SEED SET ON LATERAL FLORETS OF MALE-STERILE WHEAT PLANTS GROWN IN A FIELD OF TASCOSA WHEAT AT BUSHLAND AND ON PLANTS PLACED IN FIELDS OF DIPLOID AND TETRAPLOID RYE AT FLOWERING TIME, 1962

Pedigree of male-sterile plants[1]	Cytoplasm	Number of plants	Pollinator	Percent seed set: On first 5 heads	Percent seed set: On all heads
MS Selkirk[4] x Tascosa[3]	*Ae. caudata*	73	Tascosa	24	12
MS Crockett[3] x Tascosa[2]	*Ae. ovata*	39	Tascosa	11	8
MS Denton[4]	*Ae. ovata*	1	Elbon rye		6
(MS Rescue[2] x Red Chief) x Tascosa	*Ae. caudata*	6	Elbon rye		1
(MS Selkirk[4] x Triumph[2]) x Tascosa	*Ae. caudata*	4	Abruzzi rye		0
(MS Selkirk[4] x Triumph[2]) x Tascosa	*Ae. caudata*	3	Elbon rye		0
MS Crockett[4] x Tascosa	*Ae. ovata*	6	Tetra Petkus rye		0

[1]Male-sterile Selkirk and Rescue, spring varieties, and male-sterile Crockett and Denton, winter varieties, were supplied by B. C. Jenkins, University of Manitoba, and J. A. Wilson, Kansas Agricultural Experiment Station, respectively. They developed these male-sterile varieties by backcrossing them to male-sterile wheats obtained from Japanese scientists.

ovata steriles were several days later. The delayed flowering of *Ae. ovata* steriles, as observed by Wilson and Ross (6), was apparent in this planting. Only the male-sterile Denton (*ovata* cytoplasm) set appreciable seed when subjected to pollination from diploid rye and no seed were obtained from pollen of tetraploid rye. Since the rye fields used as pollinators had about 1% wheat mixture, some of the seed may be from wheat pollination, but a few plants grown from these seed appear to be hybrids of wheat and rye. Nevertheless, the results obtained indicate less seed set can be expected from rye on male-sterile wheats of these cytoplasms than from wheat pollination. The low seed set, regardless of pollinator or cytoplasm, may be the result, in part, of abnormally high temperatures and low humidities which occurred at flowering time. In addition, the tight chaff characteristic of Tascosa is evident in all the steriles used and it may permit only restricted opening of the flower at flowering time.

Using seed produced in 1962, several small crossing blocks were established to obtain additional information on cross pollination of male-steriles having *caudata* and *ovata* cytoplasms. Pollinators used in these crossing blocks will not restore pollen fertility to the steriles and hybrids from these seed will be sterile. However, if sufficient seed are produced in these crossing blocks, it may make possible the evaluation of hybrid vigor in wheat for forage production. A small crossing block involving steriles of both cytoplasms and the world collection of common wheat as the pollinator has been established in a mass search for pollen restoration factors. Hybrid material from this crossing block eventually may be used for selecting wheats with flower characteristics more suitable for cross pollination or for wheats with greater pollen dissemination capabilities.

Although the apparent female sterility of the *caudata* steriles and the delayed maturity of the *ovata* steriles may be solved by breeding and selection, these two factors may limit their utilization. Fortunately, steriles having *T. timoheevi* cytoplasm appear to be completely female fertile and mature at the same time as the recurrent pollen parent. Recent backcrosses made at Bushland suggest that seed may be set more readily on *T. timopheevi* steriles than on steriles of the other cytoplasms.

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