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PROGRESS IN DEVELOPING TRITICALE AS AN ECONOMIC CROP

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PREFACE

This report summarizes the progress made and some of the problems encountered in the Triticale program at CIMMYT during the past year and a supplement to the reports prepared in 1968 and 1969. Since copies of the previous reports are no longer available it was necessary to review or repeat some sections to provide a better continuity of developments in the Triticale program. It is directed primarily to research workers associated with the improvement of triticales as a commercial crop. It is hoped that these reports will help to stimulate the exchange of ideas and information among research workers in all parts of the world. Reports, sug gestions and informal data from others interested in triticales would be appreciated.

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INTRODUCTION

Triticale is an artificial genus created by scientific man in an attempt to produce a new cereal with a new combination of characteristics which will outperform present-day cereal crops, at least under certain ecological conditions. Two "species" of triticales have been produced by scientists, namely, hexaploid and octaploid triticales. The hexaploid triticales (genomes AABBRR) are derived from crossing one of the tetraploid wheat species (genomes AABB) with rye (genome RR). The octaploid triticales (AABBDDRR) are formed from crossing a species of hexaploid wheat (AABBDD) with rye (RR). To date no one has succeeded in producing a tetraploid Triticale (AARR).

When a cross between wheat and rye is made the F_1 plant is sterile. However, when the F_1 seedling is adequately treated with colchicine (or certain other chemicals) and its chromosome (genomes) makeup is doubled to form the new amphidiploid (amphyploid), the resultant F_1 Triticale plant is partially fertile. This then opens the door to possible future genetic improvement.

Triticales are not new. A natural occurring Triticale was described by Wilson in a report to the Botanical Society of Edinburgh in 1875. In 1890 Rimpau succeeded in crossing wheat and rye and producing a fertile hybrid — a Triticale. Nevertheless, the absence of an effective technique for doubling the chromosomes following crossing, restricted interest and research in triticales until the development of the effective colchicine method in 1937. The development of an effective embryo culture technique in the 1940's added new impetus to Triticale research.

Since 1937 a large amount of research has been done to explore the possibilities of developing a commercial Triticale. To date no variety has been developed which will compete satisfactorily with the other small grains. But the struggle to do so prevails and progress continues.

Among the leaders in Triticale research have been Dr. A. Muntzing in Sweden who has spent the past 32 years in developing octaploid triticales, and in more recent years has also worked with hexaploids. Dr. Sánchez Monge in Spain has spent much of his research effort since 1952 in developing hexaploid triticales. Dr. A. Kiss and colleagues in Hungary and Dr. N. V. Tsitsin and co-workers in Russia have spent much of their professional career on the development of both octaploid and hexaploid triticales. Japanese researchers, especially Dr. H. Kihara and co-workers, have also contributed much to our basic knowledge about triticales.

In the Americas limited early work was done on triticales by Drs. J. G. O'Mara and E. R. Sears during the 1930's and 1940's. However, the first Triticale research and breeding program of any scope undertaken in the Americas was that established in 1954 at the University of Manitoba under the leadership of Dr. L. M. Shebeski. The project was led by Dr. B. C. Jenkins, subsequently by Dr. L. E. Evans and is currently led by Dr. E. N. Larter.

The aforementioned formalized research on triticales at the University of Manitoba was launched with the establishment in the Plant Science Department of the Rosner Research Chair in Agronomy with funds provided by the Samuel and Saidye Bronfman Family Fundation. Subsequently, additional funds became available to help support the work from the Manitoba Department of Agriculture and Conservation, The National Research Council of Canada, the Manitoba Pool Elevators, and United Grain Growers.

In December of 1964 provisions were made to establish an expanded cooperative program on Triticale breeding between the Plant Science Department of the University of Manitoba and CIMMYT, with additional financial assistance provided under a Research Grant from the Rockefeller Foundation.

This report provides a brief history of the CIMMYT Triticale program, its research progress up to the present time, and its objectives and hopes for the future.

CIMMYT's TRITICALE RESEARCH PROGRAM

History

CIMMYT's (or rather its predecessor organization the Office of Special Studies of the Mexican Ministry of Agriculture) interest in triticales dates back to 1958 when Dr. Norman E. Borlaug, attended The First International Wheat Symposium at the University of Manitoba. While there he observed the Triticale breeding materials, and also had an opportunity to discuss the problems and opportunities for progress in Triticale improvement with Drs. L. M. Shebeski and B. C. Jenkins. No action was taken to initiate research in Mexico on triticales at the time, however, since all of the available scientific manpower was then deeply engaged in trying to produce the first high-yielding dwarf wheat varieties. This objective was not achieved until 1962 when the semi-dwarf wheat varieties Pitic 62 and Penjamo 62 were released. In 1962 the Mexican National Institute of Agricultural Research was established and the Office of Special Studies having completed its mission was dissolved. This provided an opportunity for Dr. Norman E. Borlaug to explore the possibilities of using the wheat research and production experience and plant materials on an international basis. It also provided an opportunity to reconsider the Triticale challenge.

During November 1963 among a series of experimental wheat lines received from Dr. J. A. Rupert from Chile and sown in CIANO (Ciudad Obregon, Sonora) were three hexaploid triticales. These triticales had been obtained two years before by Dr. Rupert from the Plant Science Department of the University of Manitoba. The triticales made extremely vigorous growth in Sonora, but were extremely late, very tall and highly sterile. Nonetheless, it was decided to make a few crosses to the dwarf Mexican wheats to attempt to correct some of these defects. During March 1964, Ings. Ricardo Rodriguez and Marco Quiñones made a number of crosses between the aforementioned triticales and several Mexican dwarf wheats, including several crosses with an unnamed dwarf Nainari, derivative designated $P4160_E$. These crosses, made 8 months before the Triticale program was officially launched, were to play a considerable role in the future development of the triticale breeding program.

The present CIMMYT Triticale research program is a direct outgrowth of the cooperative breeding program established in December 1964 between the University of Manitoba and CIMMYT. At that time a winter breeding nursery involving most of the Canadian material was sown during November in CIANO at 28° latitude and 30 meters elevation and an aggressive crossing program was launched. Following harvest most of the material was returned to Canada for summer plantings, but part remained in Mexico to be sown during May at Toluca at 18½° latitude and 2,500 meters elevation. From that time up to the present there has been a continuous, free, two-way flow and exchange of Triticale breeding materials between the Canadian and Mexican programs. Both programs have profited enormously from this exchange.

The establishment of the cooperative Triticale program between the University of Manitoba and CIMMYT greatly expanded the research on triticales and gave new dimension and orientation as well as an increased rhythm to the program. These changes resulted primarily from three different events, namely:

1) It was the first time a Triticale breeding program had ever come directly into contact with large, aggressive, diversified bread wheat (*Triticum aestivum*) and durum (*T. durum*) wheat breeding programs. This contact provided unique opportunity to diversify the genetic base of AABB and AABBDD genomes to the triticales, both through a planned program of crossing to Mexican wheat varieties with the triticales and through inadvertent, promiscuous outcrossing, which was to prove so important as will be pointed out later in this report.

2) It permitted growing two generations of all Triticale breeding materials each year, hence doubling the rhythm of the entire breeding effort.

3) It permitted growing alternate generations under two widely different environmental conditions, i. e. CIANO and Toluca, and CIANO and Winnipeg. This facilitated identifying lines with day-length insensitivity, wide adaptation and a broader spectrum of disease resistance.

The CIMMYT Triticale breeding program was jointly handled during 1964 and 1965 by Dr. Norman E. Borlaug and Ings. Marco Quiñones and Ricardo Rodriguez. In 1966 Dr. Charles Krull, Ings. Marco Quiñones and Jose Luis Maya took over the task of developing the Triticale program as a separate part of the then formalized international CIMMYT small grain breeding program. In 1968 the leadership of the program was taken over by Dr. Frank J. Zillinsky, the present leader, assisted by Ing. Alfonso Lopez and Dr. George Varughese. Ings. Jorge Villagomez and José Daniel joined the Triticale project in 1969.

During the span of the CIMMYT Triticale program important assistance has been provided in the biochemistry and cereal technology aspects by Drs. Evangelina Villegas and Arnoldo Amaya. Valuable assistance has been provided by Drs. S. Rajaram and Santiago Fuentes in the field of disease resistance and in embryo culture of new F_1 wheat-rye embryos.

Research Objectives

The objective of the CIMMYT Triticale breeding program from the outset was to develop types that would yield as much as or more grain than the best cultivars of wheat, oats and barley. To realize this objective it was recognized that it would be necessary to manipulate many genetically controlled factors and thereby overcome several formidable, and in at least two cases, seemingly unsurmountable barriers that had held back breeding programs for the past 40 years, namely, 1) partial sterility and 2) shrivelling of the grain endosperm. In general the overall objective was approached with the following order of research priorities:

The Attack on Factors which Directly Negate High Grain Yield:

1. An attempt to correct sterility and develop triticales equal in fertility to the best bread and durum wheats.
2. An attempt to overcome grain endosperm shrivelling and improve grain plumpness and test weight.
3. An attempt to introduce early maturity genes, since all of the Canadian triticales were extremely late when grown under Mexican conditions, i. e. short days.
4. An attempt to introduce dwarfing genes, since all Canadian triticales were extremely tall-growing and susceptible to lodging when grown under heavy fertilization and irrigation.

The Attack on Factors Affecting Yield Stability:

5. An attempt to introduce genes for photoperiod insensitivity; thereby permitting flexibility in dates of sowing.
6. An attempt to introduce genes to widen the zone of adaptation.
7. An attempt to introduce genes to broaden the spectrum of disease resistance.

The Attack on Factors Affecting Grain Utilization:

8. From the outset emphasis was given to searching for Triticale lines with high levels of protein combined with high levels of lysine, which hopefully would result in the development of cultivars of high nutritional value.

Improving the Yield of Triticales

If Triticale is to become commercially competitive with other cereal grains it must be at least equally productive in grain yield, have adequate resistance to disease infection, desirable grain type and nutritional quality suitable as feed for animals and a food for humans. Partial sterility and shrivelling of the endosperm were the major factors responsible for the low yields in spite of an apparently highly vigorous plant growth pattern. Grain yields in Mexico among Triticale strains in yield trials through 1968 were only slightly more than one half of that obtained from the adapted wheat varieties.

Strains from selections of cross X 308 (Armadillo) were included for the first time during the summer of 1969 at El Batan and Toluca. The average yields were well above those previously obtained at either Toluca or CIANO, Table 1, despite an unfavorable soil condition at El Batan caused by residual effect of the herbicide atrazine. The decreased yields of the wheat checks indicate perhaps an even greater detrimental effect of the residue on this crop.

The international Triticale yield nursery (ITYN) grown at CIANO during the winter of 1969-70 provided the first favorable opportunity to evaluate the yield potential of the fertile lines from cross X 308. This test contained the best lines selected during 1968 from the X 308 (Armadillo) cross. The Navojoa 69-70 tests contained the latest reselections from the same cross. All tests were conducted at nitrogen fertilizer applications of 60 kg/ha which is about one half of the recommended rate for wheat. Higher levels of nitrogen would have resulted in complete lodging throughout the nursery.

Although average yields in triticales have increased substantially during the past two years they are not yet competitive with the best commercial dwarf Mexican wheat varieties. The present strains have several shortcomings which must be corrected to increase yields to a level comparable to the best wheats. Among these are endosperm shrivelling during maturation, susceptibility to lodging, low tillering capacity, shattering and preharvest germination. They also lack the broad adaptation of the Mexican dwarf bread wheats. Crosses between the Armadillo strains and other triticales are now in the F_3 and F_4 generations. It is hoped that strains selected from these populations will provide the additional increment of yield necessary to equal that of the wheats.

TABLE 1. Yields of the best Triticale strains compared with the best wheat varieties in tests located in the states of Mexico and Sonora during 1968 through 1970.

Location and year	Triticales			Wheat checks		
	No. of strains	Ave. yield kg/ha	Yield of top strain kg/ha	No. of checks	Ave. yield kg/ha	Yield of top variety kg/ha
CIANO (Son.) 1967-68	22	2663	3196	3	4213	5207
Toluca (Mex.) 1968	23	2691	3190	—	—	—
Batan & Toluca 1969 *	10	3229	3972	3	3544	3645
CIANO (Son.) 69-70 **	10	4492	4990	3	5417	6220
Navojoa (Son.) 69-70	18	5066	6282	4	5321	6491
Toluca (Mex.) 1970	39	3934	4853	2	3564	3716
El Batan (Mex.) 1970	39	4578	5193	2	3916	4786

* Identical tests were grown at Toluca and El Batan in 1969. The data from the two tests were averaged for this table.

** The International Triticale Yield Nursery 1969-70 (ITYN).

Improving Fertility in Triticales

The greatest yield increment in triticales during the past 3 years resulted from the discovery of a few highly fertile plants in the F_3 progeny of cross X 308. Progenies of these selections have been used extensively as parents in the breeding program at CIMMYT and have been sent out to breeding and research institutions to many countries around the world. Observations on these selections and on the progeny of crosses involving these selections have revealed that this improved fertility is genetically controlled and can be transmitted readily to its progeny.

The pedigree listed for cross X 308 is [(Triticale Ghiza x Triticale-Carleton durum) x (Triticale-persicum x Triticale-durum)] [(Triticale-dicoccoides) x Triticale-persicum]. It is a series of single and double crosses in which each of the original parents were crosses between a triticale and a tetraploid *triticum* species; only two of these have been identified - Ghiza and Carleton durum. Progenies from this cross are now designated as Armadillo strains.

Observations on the fertile selections indicate a strong possibility that a Mexican dwarf bread wheat was involved as a parent in its pedigree as an outcross. The following characteristics among the progeny of these selections appear to have had their origin from the Mexican bread wheat parent: a short bread wheat like spike, small plump kernels, shorter plant height, erect and non-decumbent early growth habit, insensitivity to day-length, earlier maturity, segregation for brown necrosis on the neck and glumes of some selections having resistance to stem rust. The above characteristics occur only among selections from cross X 308. Brown necrosis occurs on the necks, glumes and straw of many Mexican bread wheats which have derived their resistance to stem rust from the varieties Hope and H-44.

As soon as the superior yielding capacity of the Armadillo strains was established, factors contributing to this yield increase were investigated. Some characteristics of Armadillo strains actually depress yield. The tillering is poor particularly among the early strains; the spikes are shorter and the seeds are smaller. The grain test weight of these strains is about 3 to 4 kilogram per hectolitre higher. Although they are semi-dwarfs (E1) resistance to lodging is about equal to the normal triticales, but are much more prone to lodging than the dwarf (E2) bread wheats. Satisfactory resistance to diseases is available among both groups of triticales. None of the above characteristics except test weight favor the yield of Armadillo strains over the standard triticales. Test weight accounts for a very small portion of the 40 to 50% observed yield increase. Seed set as a percentage of florets with seeds obtained in CIANO 68-69 were the first determinations which appeared to give Armadillo strains a significant advantage. In subsequent determinations at El Batan (BV-69) and Navojoa (N69-70), these differences diminished, but still favored the Armadillo strains, Table 2. Upon reassessing the determinations obtained in Yaqui 68-69, it was observed that all of the low seed set percentages were obtained on late maturing strains. In that year a serious water stress was created among the later maturing strains due to cutting off irrigation water when the early varieties no longer required it. Water stress was not a factor in the two later generations.

The slightly lower test weight (4.5 kg/hl) and lower seed set percentages (5-15%) among the standard triticales only partially account for the differences in yield. For example, the average yield of seven Armadillo strains in a replicated test at Y 69-70 (ITYN) was 4.5 tons per hectare

Above: *Seed of one of the early normal lines in the CIMMYT breeding program, having poor fertility and poorly developed endosperm.*

Below: F_4 *progeny of cross to Armadillo, the selection which provided the fertility and seed type to the present crosses. Fertility and seed type can be transmitted readily to the progeny of crosses.*

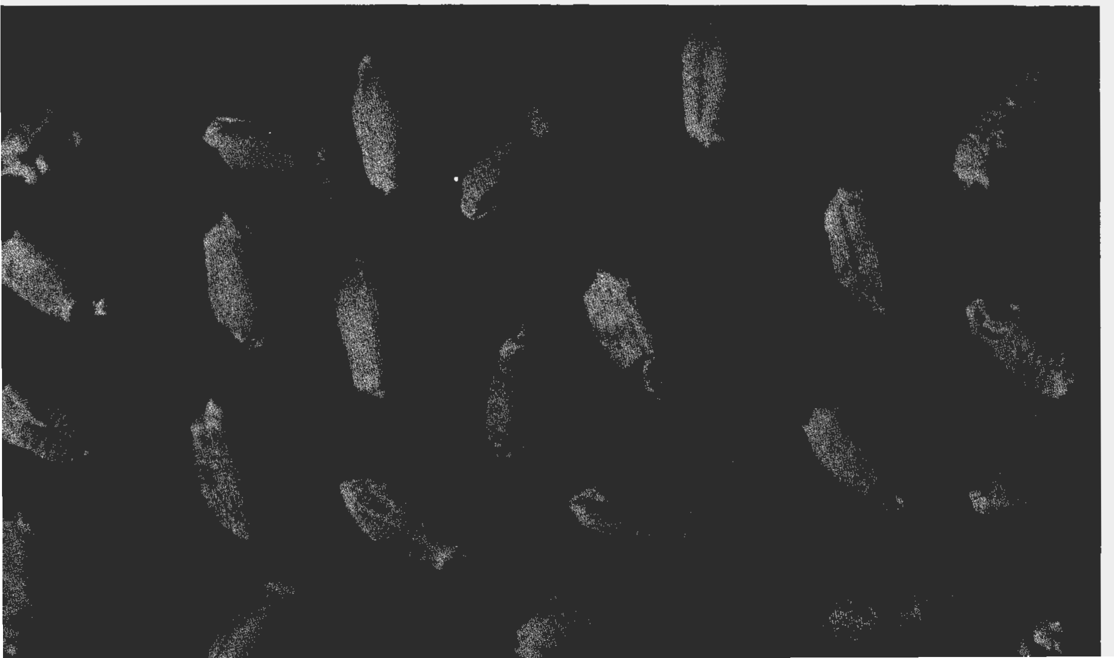

TABLE 2. A comparison of percent seed set among wheat varieties and Triticale strains grown in Mexico at 3 locations:

Variety or Strain	Percentage of florets with seeds			
	Y 68-69 *	BV-69 *	N-69-70 *	3 sta. Average
Inia 66 (Bread Wheat)	79.6	93.0	85.4	86.0
Tobari 66 (Bread Wheat)	79.0	95.0	84.3	86.1
Aningha (Durum Wheat)	68.2	No info.	80.9	73.0
X 308-27Y strains (Triticale)	77.0	80.3	83.2	80.2
X 308-14Y strains	80.2	76.2	86.2	80.8
UM 940 (Triticale)	59.6	66.2	71.9	65.9
Rosner (Triticale)	58.0	79.0	75.0	70.7
Standard triticales	57.9	68.0	70.3	65.4

* Y68-69 = The CIANO Exp. Sta. Yaqui Valley., Sonora, Mexico.
BV-69 = El Batan Sta. near Mexico City, Mexico.
N-69-70 = Navojoa sub-sta. Mayo Valley. Sonora, Mexico.

while the yield of Rosner in the same test was 2.6 tons, or about 57% of the Armadillo strains. All other factors being equal, the differences in test weight and fertility should account for not more than 15 percent of the reduction in yield. A clue to the reason for the discrepancy was obtained by comparing the differences in the average number of seeds per spike counted in obtaining fertility data with the average number of seeds per spike retained in the threshed sample, Table 3. When fertility determinations are made, all florets which produce seeds, regardless of how poorly the seeds are developed, are considered to be fertile. The grain from spikes threshed in a head thresher are subjected to an air blast to separate the chaff and straw from the grain. Very poorly developed grains are blown out with the chaff. The effect is to reduce yield by weight of the grains lost and to increase test weight on the retained sample. Table 3 provides an estimate of the proportion of seed retained per spike after threshing relative to the total number of grains produced. Compared to the bread wheat check Inia 66 (100%), the Armadillo strains varied from 78.5 to 100.8% in the proportion of seeds retained, with an average of 94.1%. The standard type triticales varied from 61.5 to 75.0%. These estimates are more in line with the actual grain yields obtained than was possible from the fertility and test weight determinations alone.

Most of the sterility observed in the adapted wheat varieties occurred in underdeveloped florets on the central portion of the spikelet. This appears to be a natural mechanism for adjusting seed production to the environment. Sterility in the primary and secondary florets of wheat is seldom observed. Among triticales strains, empty primary and secondary florets occur more frequently.

Improving Grain Type

Seed shrivelling is one of the major problems still confronting Triticale breeders. Subsequent to fertilization, endosperm development tends to be more or less abnormal in all triticales. This defect is accentuated during

TABLE 3. Fertility determinations and some seed characteristics on Triticale strains, hybrids, and wheat varieties grown at Navojoa 1969-70

Identity	No. of seeds per spike	No. of seeds retained after threshing	% seed retained at threshing	% fertility	No. of seeds/ spikelet	Weight of seeds per spike	Weight per 1000 grains	Proportion of seeds retained vs. total spikelets	Seeds retained as % of Inia
A. *Wheats*									
Inia	50.4	46.0	91.3	85.4	2.80	2.11	46.8	77.9	100.0
Tobari	47.4	42.5	89.6	84.3	2.96	1.55	36.6	75.5	96.9
Aningha	44.2	38.3	86.6	80.9	2.43	2.15	56.2	70.0	89.8
B. *Armadillos*									
Beaver	91.6	88.2	96.2	77.2	3.27	4.11	46.6	74.2	95.2
Badger	73.2	58.8	80.3	90.1	2.93	3.19	54.3	72.3	92.8
308-Y-23M	100.6	88.3	87.7	86.3	3.38	3.33	37.7	75.6	97.0
„ -6Y	81.6	68.5	83.9	86.1	3.16	3.48	50.9	72.2	92.6
„ -7Y	77.4	60.8	78.5	78.0	3.05	3.33	48.0	61.2	78.5
„ -14Y	99.4	91.6	92.1	83.5	3.76	3.97	43.4	76.9	98.7
„ -14Y	95.6	87.2	91.2	86.2	3.39	3.84	44.1	78.6	100.8
„ -11Y	111.4	105.9	95.0	81.3	4.10	4.37	41.3	77.2	99.1
„ -27Y	87.2	75.2	86.2	83.2	3.16	3.06	40.7	71.7	92.0
„ -27Y	79.8	74.4	93.2	79.3	2.73	2.87	38.6	73.9	94.8
„ -Y-2M	109.0	96.7	88.7	76.5	3.66	4.04	43.4	67.8	87.0
C. *Old hexaploids*									
UM 940	86.8	68.9	80.4	71.9	2.61	2.67	38.8	57.8	74.1
JFR-6TA	107.2	73.1	68.2	70.3	2.97	3.90	53.4	47.9	61.5
D. *New amphiploids*									
HR-5 A2	27.7	9.7	35.0	31.5	1.32	0.40	41.3	11.0	14.1

TABLE 3. (Cont.)

Identity	No. of seeds per spike	No. of seeds retained after threshing	% seed retained at threshing	% fertility	No. of seeds/ spikelet	Weight of seeds per spike	Weight per 1000 grains	Proportion of seeds retained vs. total spikelets	Seeds retained as % of Inia
DR-28-6Y A3	72.6	29.6	40.7	66.9	2.50	1.58	53.5	27.2	34.9
Hybrids Group 1									
ISN 795B (DR-28-6Y) x UM-962 F_1	63.8	30.7	48.1	59.9	1.80	1.72	56.1	28.8	36.9
ISN 803B (DR-28 x Arm)	85.6	39.6	46.2	76.1	2.89	2.41	60.8	35.1	45.0
Hybrids Group 2									
ISN 529 (Wheat x Arm) x Arm F_1	62.8	31.4	50.0	68.2	2.51	1.90	60.7	34.1	43.7
ISN 537 (Badger x Calidad) x Arm F_1	58.6	31.6	53.9	67.8	2.44	1.71	54.2	36.5	46.8
Hybrids Group 3									
Maya T-6 x Arm 2 F_1	51.2	28.5	55.6	56.4	2.06	1.66	58.2	31.8	40.8
Maya II x Arm 2 F_1	95.0	41.1	43.2	73.1	3.34	2.03	50.3	31.6	40.5
Maya II x Arm 2 F_1	81.2	27.7	34.1	74.2	3.12	1.74	62.8	25.3	32.5
Hybrid Group 4									
UM-940 x Arm F_2	107.6	93.8	87.2	77.5	3.35	4.46	47.6	67.5	86.6
Hybrids Group 5									
(Arm x rye) x Arm F_1	96.0	55.2	57.5	75.9	3.40	2.56	46.4	43.6	55.9

grain maturation. The most serious abnormalities occur in the original crosses of durum wheat and rye. It is highly probable that the failure to produce viable seeds from the cross without employing embryo culture techniques is largely a direct result of abnormal development of the endosperm. Crosses between bread wheat and rye also result in badly shrivelled seeds, but an occasional seed develops sufficiently well to germinate without employing embryo culturing techniques.

Once the amphiploid is formed following treatment of the F_1 polyhaploids with colchicine, endosperm development is somewhat less abnormal than in the original cross. The early generations of the amphiploids produce poorly developed seeds. Usually the germination of these seeds is poor and seedling vigor is low. Improvement in seed type can currently be obtained by crossing to other triticales having good grain type particularly to Armadillo, and subsequently selecting strongly for better seed type in each succeeding generation. It is highly probable the most of the better seed types now present in the breeding program have evolved from crosses to the Armadillo strains.

The Triticale selections have been screened for better grain type since the program was started in Mexico in 1965. The most significant improvement for plumper grain was obtained concurrently with the isolation of the fertile strains from cross X 308 in 1968. The original Armadillo selections averaged about 3 kg/hl heavier test weight than the best strains in the 1968 yield tests (68.5 kg/hl vs. 65.8). Test weights among reselections from the original Armadillo strains continue to improve. The average test weight of the better Armadillo strains in the Navojoa 69-70 tests was 70.4 kg/hl with the top strain at 73.7.

In an effort to improve grain quality, over 5,000 samples from segregating populations in the Triticale nursery at Navojoa 69-70 were screened for grain type. About 125 strains were retained to serve as a basis for further seed improvement. The elite grain types will be used in crosses to other triticales, as well as to establish an outcrossing population among the selections.

Susceptibility to Lodging

The triticales in the breeding program, including the Armadillo strains which provide the basis for improvements in yield, fertility and grain type, have weak straw. This is currently the most serious limiting factor to higher yields. Lower nitrogen applications have had to be used in replicated yield trials. At the lower nitrogen application levels the yields of the best triticales approach those of the bread wheat checks. However, at the higher nitrogen applications, i. e. 120 kg/ha recommended for the dwarf wheats, the triticales lodge severely and yield either only slightly more or even less than when fertilized with 60 kg/ha of nitrogen. The wheat yields continue to increase at these heavy rates of fertilization. Maximum yields of triticales obtained at Navojoa 69-70 have barely reached 7 tons per hectare, while those of the best wheats have frequently exceeded 9 tons (Y69-70). Little progress in maximum yields can be expected until a substantial improvement in lodging resistance is obtained.

Response to Nitrogen Fertilization

An experiment was established at CIANO 1969-70 by Dr. R. Laird to determine the most appropriate nitrogen fertilizer application to be used in Triticale yield trials. Two Triticale strains were used at nitrogen levels from 0 to 300 kg/ha, in increments of 60 kilos. Residual nitrogen in the soil was removed by growing sorghum on the plot area for 4 months prior to preparing the tests. Unfortunately two major problems were encountered which decreased the realiability of the experiment. The seeding had to be delayed by 6 to 8 weeks after the optimum seeding time due to rain. Very poor germination among the triticales reduced the stand to about ⅓ of the normal plant density.

Table 4 provides a comparison of the yields of triticales vs. two wheat varieties at the different nitrogen levels. At the lower nitrogen levels 0 to 120 kg/ha the triticales were more or less competitive with the two wheat varieties. At intermediate nitrogen levels, the grain yields of the triticales dropped off sharply and actually decreased at the high levels while the wheat varieties Inia 66 and Yecora 70 continued to increase in yield. The rate of increase in the variety Inia 66 declined and finally levelled off more quickly than did Yecora 66. The grain yield of Yecora 70, a new triple dwarf wheat variety, continued to increase through the 150 to 300 kg/ha levels, falling off gradually at the upper levels.

TABLE 4. Response to nitrogen of two Triticale strains grown at CIANO, Ciudad Obregon, Sonora during 1969-70.

Nitrogen application kg/ha	Yield of grain in tons per hectare				
	Triticales			Wheats	
	T-909	T-14	Average	Inia 66 *	Yecora 70 *
0	0.958	0.803	0.880	0.565	0.695
60	1.909	2.095	2.004	1.600	1.850
120	3.222	2.886	3.054	3.200	3.400
180	3.317	3.467	3.392	4.100	4.900
240	3.668	3.594	3.631	4.300	5.700
300	3.277	3.503	3.390	4.300	6.000

* Wheat yields were calculated from neighboring comparable test plots using nitrogen increments of 50 kg/ha.

Comparative response to nitrogen.
Triticales 0-120 N = 18.1 kg. grain/kg. N.
Inia 0-150 N = 23.3 kg. „ /kg. N.
Yecora 70 0-150 N = 23.4 kg. „ /kg. N.
Test sown "late" — Jan. 15, 1970. Data supplied by Dr. R. Laird.

The poor germination of the triticales and delayed seeding reduced yield considerably from those obtained at Navojoa 69-70 seeded in November where a 60 kg/ha nitrogen application resulted in average yields of 4.5 tons per hectare. Lodging was severe in the November seedings at 60 kg/ha N level, but did not occur in the January plantings with application of less than 200 kg/ha N. Since the Triticale yields from the January plantings began to fall off before lodging occurred, some other factors are involved in reducing response to nitrogen at levels above 120 kgs.

Armadillo strains having shorter straw are a first step towards triticale strains which will eventually compare in height and straw strength to the Mexican dwarf wheats.

Improving Lodging Resistance

For triticales to be competitive with wheat at the higher levels of production it is essential that the lodging resistance be improved. This can be accomplished by improving straw strength, decreasing plant height or both. Several strains of Triticale have been selected which have stiff straw. The most promising strain was selected from a bulk outcrossing population in the Toluca Nursery 1968. Progenies from this plant grown in subsequent generations indicated that the original selection was heterozygous and most probably an F_1 plant. Strains selected from the progeny of this plant have been named "Beaver" and vary in height from double dwarfs (E_2) to tall. All progenies tend to possess better than average resistance to lodging and have been used frequently in crosses to the Armadillo strains. The most advanced populations are now in the F_4 generation. There appears to be no difficulty in recovering selections possessing strong straw and good fertility among the segregating progenies.

Improvement in straw strength without resorting to additional dwarfing was undertaken because of difficulty in maintaining fertility and good test weight in the dwarf selections from crosses involving the double dwarf UM 940. The possibility that the dwarfs from this source carry cytological abnormalities, such as chromosome deficiencies, substitutions or translocations is being investigated by Dr. P. J. Kaltsikes, University of Manitoba. Increased sterility associated with increased degrees of dwarfing, however, need not necessarily be due to chromosomal abnormalities. It

A short fertile lodging resistant F_2 plant from the cross Beaver x Armadillo growing at Toluca, 1970.

may be polygenic as in the case of the Norin dwarfing complex in wheat. The original obstacles encountered in incorporating dwarfing genes from Norin 10 into tall Mexican wheats was similar. Only semi-dwarf (E_1) segregates with good fertility and more or less acceptable grain type could be isolated from the original single crosses between Norin 10, or Norin 10-Brevor and tall Mexican varieties. All double dwarf (E_2) segregates and especially the triple dwarf (E_3) segregates were highly sterile and possessed very shrivelled grain. Subsequent recrossing of the least defective double and triple dwarf segregates followed by applying strong selection pressure for fertility and grain plumpness, resulted in the development of the excellent double dwarf Sonora 64, possessing complete fertility and excellent grain type.

A third and fourth cycle of crossing and continued strong selection pressure for better fertility and grain type has recently produced the triple dwarf (E_3) varieties Yecora 70, and Saric 70 with good fertility and good grain type. It is highly probable that similar results will evolve with aggressive imaginative breeding in triticales.

Dwarfing

a) *Dwarf bread wheats*

The use of dwarfing genes in the breeding of bread wheats and durums has proved to be the most successful mechanism for improving lodging resistance. New amphiploids arising out of crosses between dwarf (E_2) durums and tall ryes are taller than some of the selected triticale hexaploids previously developed from dwarf wheats. This indicates that the single pair of dwarfing genes are not capable of overcoming the genes for tallness contributed by the rye varieties. It was apparent that more dwarfing genes were needed to reduce plant height in the hexaploid triticales. Crosses were made between dwarf bread wheats (E_2 and E_3) and fertile triticales of normal (N) height. Crosses were also made between hexaploid and octaploid triticales. The F_1 plants approached the hexaploid triticale parents in height, but segregation for height was evident in the second generation. To overcome the high degree of sterility in the first two generations, the hybrids were sown in alternate rows among fertile hexaploid triticales in order to permit outcrossing. By the third generation there was sufficient fertility among Triticale-like progeny to set seed without the need for the Triticale pollen source. Fertile hexaploid Triticale plants of E_2 and E_1 stature occur regularly among the segregating progeny.

Snoopy rye, the progeny of a single dwarf plant discovered in a population of Gator rye in October, 1969. Since the original plant was outcrossed considerable variability and disease resistance was observed among the progeny.

b) *Dwarf ryes*

The major problem in reducing the height in triticales is the presence of genes for tallness contributed by rye varieties. An obvious solution is to replace these height genes with dwarfing genes in the rye genome. A search for dwarf ryes among collections of spring ryes from around the world resulted in the discovery of a dwarf rye in a heterozygous (outcrossing) population of rye strains received from Dr. Darrell Morey of the Coastal Plains Experiment Station, Tifton, Georgia. Populations of self-fertilized ryes were received from Dr. Morey in 1968. Following two generations under open pollination, a single dwarf plant was discovered among a population originating out of the variety Gator. Dwarf segregates from the progeny of this plant are being used to create new dwarf triticales of both hexaploid and octaploid types. Crosses are also being made between the dwarf ryes and fertile semi-dwarf hexaploid triticales to create variability among the rye chromosomes. It is expected that this new source of dwarfing, now referred to as Snoopy, will be distrbiuted throughout our hexaploid and octaploid triticales within a few generations.

Other Factors Influencing Yield

Triticales are subject to most of the problems common to wheat and rye. A few are more serious than in either wheat or rye. This is probably due to the narrow genetic base upon which this crop has been developed. Among the characters which significantly limit yield in triticales are susceptibility to diseases, low tillering, particularly among early maturing Armadillo strains, narrow adaptation range, shattering, pre-harvest germination, poor germination, and low seedling vigor.

Diseases:

Although triticales appear to become infested by the same diseases as wheat and rye, up to the present time diseases have not been a serious limiting factor in Triticale improvement. It is very likely that as Triticale production begins on a commercial scale, diseases which find Triticale a suitable host will tend to increase to epiphitotic proportions. It is necessary to keep a close watch on diseases which attack this crop. It is essential that a diverse gene pool be maintained so that selection of disease resistant strains can be rapidly achieved in the eventuality that a disease becomes important.

The Rusts:

1) Stem rust (*Puccinia graminis tritici*) presents no immediate threat to triticales. Practically all strains and early generation populations are resistant to the local races in Mexico. Dr. S. Rajaram (1969-70)* inoculated 468 strains and advanced lines with two virulent strains of wheat stem rust. Strain 15-2, 4, 7, which makes the resistance possessed by Gaza durum (Sr 11), the *timopheevi* gene (Sr-Tt) and that of Yuma durum

* From an unpublished report prepared by Dr. S. Rajaram, February 1970.

ineffective, and strain 151-1, 2, 3, 5, a strain highly virulent on bread wheat varieties, were used because these races render ineffective many of the resistance genes now carried in both durum and bread wheat programs. All of the lines tested were resistant to both strains of stem rust.

It appears that some of the genes for resistance to stem rust have been derived from the rye parents. The current varieties of bread wheat and durum wheat used in the crosses do not possess a degree of resistance equal to that displayed by the triticales derived from these wheats.

More detailed studies in the resistance to stem and leaf rust have been undertaken as thesis problems by Ing. Alfonso Lopez at Chapingo and Ing. Marco Quiñones at the University of Manitoba, Winnipeg.

2) Leaf rust (*Puccinia recondita*). This disease is much more serious than stem rust on triticales. About one-half of the strains in the Triticale nursery at CIANO 1969-70 had an MS or S reaction to the naturally occurring inoculum capable of infecting Inia and Lerma Rojo. Dr. S. Rajaram found that the majority of the advanced lines of Triticale were susceptible in the seedling stage in the greenhouse to race 144-1, 4, 7, of leaf rust of wheat. Crop losses from leaf rust have been relatively light. Infestations appearing rather late in the season have tended to build up slowly and some strains appear to produce the telia stage while the leaves are still green. On these strains, the production of uredospores was very light. It is not known whether the host-pathologen-environment combination was unique to force early teliospore formation, or whether certain strains of triticales are genetically constituted to encourage the development of telia. Early teliospore formation was observed on some strains of triticales at Navojoa and Toluca during 1970. If a genetically controlled mechanism exists for the inhibition of uredospore production it would be a useful means of controlling the build up of epiphytotics.

3) Stripe rust, (*Puccinia glumarum*). This disease occurs more frequently at higher elevations near Mexico City and Toluca than in Sonora at elevations near sea level. Varieties of durum wheat and rye, from which the original triticales were developed, were apparently highly susceptible to stripe rust. In 1965, when the Triticale program was started by CIMMYT, the Triticale nursery was almost wiped out by stripe rust at Toluca. Since then, by incorporating resistance genes from durum wheats, bread wheats and ryes, and by continuous screening for resistance, most of the current breeding material is resistant to the races of stripe rust now prevalent in Mexico.

Bacterial Disease:

A bacterial blight, or stripe, probably caused by *Xanthomonas translucens* sp. caused serious damage to triticales in the nursery at Navojoa during 1969-70. The disease had been observed previously on occasional rye and Triticale plants in 1968 and 1969, but caused very little damage to the infected plants. Damage from the infection at Navojoa during 1969-70 indicates that the disease is capable of destroying susceptible varieties under conditions favorable to bacterial development.

The bacterial infection first became apparent on the leaves at heading time. It is probable that infection actually occurred considerably earlier, but only became conspicuous in the later stages of plant development. The early infections appeared as water soaked spots or streaks along the veins of the leaves. Under high humidity, a milky bacterial exudate forms as droplets along the infected veins. These form a whitish transparent scale upon drying. Under high humidity yellowish granules form on the surface

TABLE 5. The effect of bacterial blight infection on Triticale strains in yield tests at Navojoa 1969-70.

Yield test number	Triticale strains in tests				The strains of Triticale most heavily infected with Xanthomonas**	
	Yield		Test Weight		Yield	Test Weight
	Median * g/plot	Top strain g/plot	Average kg/hl	Top strain kg/hl	Average g/plot	Average kg/hl
I	1153	1383	71.9	73.7	860	69.7
II	1180	1293	70.0	72.4	850	71.0
III	913	1125	71.5	73.5	801	65.9
IV	1028	1387	70.5	73.3	719	69.0
V	940	1218	70.5	73.2	533	61.2
VI	1135	1508	69.5	72.5	787	68.6
VII	1005	1260	69.0	70.4	643	67.6
VIII	833	1068	71.3	73.4	833	66.9
IX	913	1160	69.5	73.0	475	66.9

* Median = the yield of the mid variety when arranged in order of yield.
** Average data on from one to four varieties in each test.

of the leaves as the exudate dries. As the disease progresses, the yellowish-brown translucent lesions elongate into streaks along the veins finally coalescing to form large blotches. Eventually the lesions turn brown as the leaf dies. Prior to the time that the whole leaf has been killed, the translucent longitudinal striping, transparent scale and yellow-brown granules are reliable diagnostic characteristics. Leaves, stems, glumes, and awns can become infected by the disease under favorable conditions.

Infection by bacterial stripe occurred on several strains of triticales being increased in Navojoa during 1969-70. The early infections were observed in mid-January and the susceptible strains were completely defoliated by mid-February. All highly susceptible strains were sister lines from a single fertile short triticale strain X 308-27Y. Many strains from other crosses and also sister selections from cross X 308 were found to be more resistant. Later maturing strains did not appear to become infected until the plants approached heading. Environmental conditions became less favorable for disease development as the season progressed, thus tending to reduce damage on late maturing strains and in late sown plots.

The infestation of bacterial blight at Navojoa 1969-70 provided an opportunity to determine damage to susceptible strains caused by the dis-

Above: *Early symptoms of bacterial blight or stripe are water soaked (translucent) streaks along the veins of the leaf. When humidity is high, milky white globules of bacterial ooze can be observed along the infected veins.*

Below: *As the disease progresses, the leaves, sheaths, stems and spikes are invaded and destroyed. The bacterial exudate forms yellowish crystals upon drying along the stems and leaves. Note the longitudinal striping along the vens of the infected leaf.*

ease. Table 5 provides summary data comparing yields and test weights of strains heavily infected by bacterial stripe with the average of strains under test. Both yields and test weights were reduced by the disease. In only one test did a heavily infected strain approach that of the median variety in yield (test VIII). In test II the infected Triticale strain appeared to suffer less in test weight than infected strains in other tests. The degree of infection varied greatly among strains and among tests. The most heavily infected strains in tests V and IX resulted in both greatly reduced yields and test weights.

A highly heterozygous outcrossing population which was sown in mid-October at Navojoa was observed to be heavily infested with bacterial stripe early in February. Plants completely free of disease symptons could be found readily throughout the population. Using this opportunity to screen for resistance to the disease, bags were placed on disease free plants prior to anthesis. This provided a means of identifying the plants at maturity and insured a supply of self-pollinated seed.

Ergot (Claviceps purpurea):

Ergot is a serious disease of rye which also attacks triticales and other cereal crops particularly when environmental conditions tend to induce sterility. The disease is common in most temperate zone areas where rye is grown and where susceptible wild grasses occur. It does not occur to any extent in Mexico. The presence of ergot in the grain is highly undesirable because of a toxic substance called ergotin in the ergot bodies.

In a personal communication Dr. E. N. Larter reported that the wheat variety Kenya Farmer is resistant to infection by ergot. This variety has been crossed to triticales and ryes in an attempt to transfer ergot resistance to triticales. Since the disease does not occur in Mexico it will be necessary to screen for resistance in an environment more favorable for ergot development. This disease is likely to decrease in importance as triticales with greater fertility are developed.

Other Diseases:

Many diseases of cereal crops of importance in wheat growing regions of the world have not yet become serious in Mexico. Among this group are powdery mildew, (*Erysiphe graminis* sp.), glume blotch, (*Septoria nodorum*), ergot (*Claviceps purpurea*) and the smuts. It is highly probable that as the commercial production of triticales gets underway in regions where these diseases are established, this crop will be attacked. Other diseases occur to a greater or lesser extent throughout Mexico, but have not yet become serious on triticales. Among the latter group are yellow dwarf, root rots, speckled leaf blotch and scab. Usually infestations of these diseases do not occur regularly enough in Mexico to permit adequate screening for resistance. It will be necessary either to set up artificial environments to permit screening of triticales against these diseases in Mexico or to send the strains to areas where infestations of these diseases occur regularly. International coopeiation is essential to solve many of these problems.

Adaptation

The current strains of triticales appear to be notoriously poor in adaptation. They appear to be particularly sensitive to changes in latitude. Changes in elevation, temperature, day length, availability of moisture and nutrients, and probably many other factors influence their performance. Triticale has lacked the innumerable generations of natural selection for survival in competition with other species at different environments under which the other cereal crops evolved. To make up for this lack of natural evolution, it will be necessary to establish populations, as genetically diverse as possible, and have them grown and selected in various environments around the world. The best selections from all possible sources will subsequently be brought together and hybridized to establish a second cycle of diverse material. Such a program requires the generous cooperation of many interested scientists around the world.

Cultural Practices

We now know very little about the cultural practice requirements for Triticale. Special attention to agronomy and production practices will enable us to get the most out of our present strains, and provide a basis for better and more productive triticales in the future. Studies on the behavior of triticales under different seeding rates now spacings, dates of seeding, fertilizer application levels, and tolerance to herbicides have been undertaken in a preliminary way by Dr. R. Laird.

Observations on the effect of herbicides for weed control indicate that there are wide differences among triticales on their reaction to herbicides. Research is needed to establish recommended dosage rates, tolerance levels, and to select triticales resistant to herbicides.

Miscellaneous Problems

Several characteristics of triticales have been observed which adversely affect production and seed quality. Some of these can be attributed to the lack of generations of natural selection, others are characteristics inherited from one of the parental species. Solutions to these problems must be found in our breeding programs.

Pre-harvest Germination

Many of the triticales lack after-ripening dormancy essential to prevent seed germination on spikes during maturation. In some lines germination occurs while the spike is still green and the humidity is low. This is an undesirable trait which appears to have been inherited from the rye parent. This problem becomes more serious in humid climates and under adverse harvesting conditions. Under commercial production there is a natural selection pressure towards strains having post harvest dormancy. However, in the CIMMYT Triticale breeding program where the seed is sown twice each year almost as soon as it is harvested, there is a tendency to select against types having dormancy. In the future, screening tests must be developed to effectively identify lines resistant to sprouting in the spike.

Poor Germination and Low Seedling Vigor

Several factors contribute to poor germination either singly, or in combination. Some of this is due to the initiation of germination on the spike during maturation with subsequent loss of germination during drying. Poor embryo and endosperm development may be factors contributing to both low germination and weak seedling vigor. Another cause of poor germination is infestation of the seed by fungi and bacteria. This is particularly severe on the seed produced in the Toluca area under high humidity. Under these conditions the high moisture content in the harvested seed coupled with fungal infection reduces the germination percentage and the seed continues to deteriorate with time unless it is thoroughly dried. Artificial drying of experimental seeds harvested at Toluca and El Batan may be necessary to obtain a vigorous stand in the following generation.

Shattering

Shattering does not appear to be a problem of much importance in the better Triticale lines. Two types of shattering, however, do occur in triticales, but only one of these appears to merit consideration in breeding. Some of the strains tend to have a rachis which becomes brittle and breaks up into sections containing one to several spikelets. As these plants ripen and the spikes dry out, they become highly predisposed to breakage of the rachis, particularly in the upper section of the spike. Only occasionally does neck breakage occur. Many breeding lines are, however, resistant to this type of damage. Exposed kernels on spike are common among the Armadillo strains. Although they appear to be held rather insecurely by the glumes, very little actual loss of seed occurs from these strains in the field. Perhaps the most significant effect of this condition is bleaching of the grain from exposure to light.

Armadillo as Parent in Wide Crosses

Observations on the use of Armadillo strains in crosses have indicated that these strains not only improve the fertility of the progenies in crosses to other triticales but are beneficial in interspecific crosses. The Armadillo strains appear to have 3 distinct advantages over the older triticales in crosses to wheats, octaploid triticales and ryes.

1) Better cross-compatibility.—Some strains of Armadillo have been found to have a high compatibility in crosses to bread wheats and durum wheats. Compatibility data obtained during the 1968-69 season gave the following average seed between Armadillo strains and other species:

Bread wheat x Armadillo "S"	31%
Durum wheat x Armadillo "S"	18%
Armadillo x rye	9%

Some strains were found to be much more cross-compatible than others. Difficulties in germination under field conditions were encountered. Much better results were obtained when the seeds were germinated in Petri dishes on filter paper.

2) Better source of pollen for crossing or outcrossing the sterile F_1 plants. F_1 hybrids between triticales and other species are usually quite sterile. A source of pollen compatible to the partially viable female gametes of the F_1 hybrid plants is necessary to obtain viable seeds.

Not only do the Armadillo strains produce greater quantities of viable pollen but the pollen is more compatible in the production of seeds. This is particularly apparent when the hybrids are grown in alternate rows with triticales to provide a viable pollen source for outcrossing.

3) More viable female gametes in F_1 hybrids. Previous to 1968 most of the failures experienced among wide crosses were due to the inability of obtaining seeds on F_1 plants. In El Batan 1969 and Navojoa-CIANO 1969-70 nurseries seeds were obtained from most of the F_1 hybrids either by backcrossing or outcrossing. This suggests that a larger proportion of the female gametes on the F_1 plants are viable or that they are more compatible with the current pollen sources. These characteristics of the Armadillo strains open the door to the incorporation of greater genetic variability in triticales.

The Significance of the Highly Fertile Armadillo Strains

The unique combination of characters isolated in the Armadillo triticales opened broad horizons to future improvement of this species. The Armadillo lines combined the following characteristics:

1) A very high level of fertility —never before encountered in any Triticale breeding program.

2) Improved grain plumpness and test weight.

3) High grain yield per hectare.

4) Insensitivity to day length.

5) Earliness.

6) One gene for dwarfness (semi-dwarf E_1).

7) High nutritional quality.

Moreover these characters are easily transmitted by crosses with Armadillo to its progeny.

Nutritional Quality of Triticales

If triticale is to compete successfully with other cereals as a food for humans or as feed for animals, it must be nutritious, palatable and productive. Special quality characteristics, such as color, flavor, texture, gluten strength, etc. may also be required for food products and in industrial uses.

Protein and Lysine Percentages:

Protein determinations provided by Dr. Evangelina Villegas head of the CIMMYT Protein Quality Laboratory, have indicated that range in protein characteristics among triticales in wider than either bread wheat or rye. Protein and lysine analysis on one hundred Triticale strains grown in the crossing blocks at El Batan and Toluca during 1969 showed a range from 12 to 21% protein. The percent lysine in the samples ranged from .36 to .72 percent. Dr. Villegas has pointed out in previous reports that there is a tendency for triticales having shrivelled seeds to be higher in protein. Also that there is an inverse relationship between protein, and lysine in protein. The higher protein samples tend to be lower in lysine. These associations are rather loose and are influenced very considerably by environment and fertility of the soil. An example of high protein and high lysine percentages was obtained from the analysis of the Toluca 1969 crossing block material. Entry No. CB 75 had 18.92% protein and 3.80% lysine in the protein compared to CB 54 with only 11.97% protein and only 3.01 lysine in the protein. The total lysine content of CB 75 was double that of CB 54 (.72 to .36%).

TABLE 6. A comparison of protein and lysine content of Triticale crosses grown at two locations under different levels of nitrogen fertilizer.

Cross number	No. of strains	Average % Protein		Ave. % Lysine in Protein		Lysine in Sample	
		Y68-69*	N69-70**	Y68-69	N69-70	Y68-69	N69-70
X 136	3	16.85	14.84	3.00	3.70	.505	.549
X 160	1	16.30	15.39	3.25	3.12	.529	.480
X 195	5	16.34	15.65	3.16	3.18	.516	.497
X 224	13	17.78	16.03	2.67	3.22	.475	.516
X 281	3	16.59	16.62	2.72	3.03	.451	.504
X 284	6	16.92	14.81	2.56	3.34	.433	.495
X 298	6	16.33	15.27	2.71	3.11	.442	.475
X 308	57	15.63	14.35	2.94	3.20	.459	.459
X 313	18	16.30	14.17	3.28	3.35	.534	.475
X 653	37	16.44	15.19	2.77	3.29	.455	.499
X 674	2	16.58	15.62	2.80	3.30	.464	.515
Ave. all samples	151	16.26	14.96	2.83	3.25	.460	.486

Data provided by Dr. Evangelina Villegas, June 1970.
* Y68-69 = CIANO winter nursery 1968-69 = 120 kg/ha N application.
** N69-70 = Navojoa winter nursery 1969-70 = 60 kg/ha N application.

The influence of environment is very evident from the data presented in Table 5 which compares the protein and lysine content of identical groups of strains from 11 crosss grown at CIANO in 1968-69 and at Navojoa in 1969-70. Nitrogen application prior to seeding was 120 kilograms per hectare at CIANO (Y68-69) and only 60 kilograms at Navojoa (N69-70). Lodging was more serious on the Y68-69 crop. The test weights and seed grades were very similar from the two seasons. The average protein content was higher (16.26% vs. 14.96%) and the percent lysine in the protein lower (2.83 vs. 3.25) in the seed from the CIANO grown crop.

Protein Efficiency Ratings (P.E.R.):

Dr. Fred Elliott at Michigan State University using the meadow vole, *Microtus pennsylvanicus,* in nutritional experiments determined the efficiency with which the protein in different triticales increased body weight. The bioassays were conducted at a 7 percent protein level using milk casein as a check. Each determination was obtained in trials using five replications. Protein efficiency ratings on 10 Triticale strains ranged from 1.72 to 2.90, Table 6. This compares favorably with other cereals. P.E.R. determinations on foods prepared from high lysine corn had an average rating of 1.80. The meadow vole bioassay technique appears to be an extremely useful one in a breeding program as it requires a relative short time and results can be obtained with less than 100 grams of grain. A laboratory for using meadow voles to study nutritional quality is being established at CIMMYT.

TABLE 7. Protein efficiency ratings of 10 Triticale strains grown at CIANO 68-69.

Cross No.	Plot No. Y68-69	Percent Protein *	Percent Lysine in Protein	Percent Lysine in Sample	P.E.R.**
X 674	T-5	17.38	2.88	.500	2.51
X 653	T-29	18.24	2.69	.409	2.32
X 195	T-83	16.64	3.06	.509	1.72
X 224	T-86	17.74	2.92	.509	2.60
X 224	T-95	18.30	2.73	.499	2.06
X 284	T-115	16.64	3.49	.580	2.04
X 308	T-114	15.39	3.58	.551	2.61
X 313	T-245	16.99	3.06	.520	2.32
X 313	T-257	16.53	3.69	.609	2.90
X 653	T-70	16.19	3.27	.529	1.78

Data supplied by Dr. Fred Elliott, Michigan State University.

* Protein and lysine data supplied by Dr. Evangelina Villegas.

** P.E.R. = Protein efficiency ratings — Bioassay Analysis on Meadow Voles at 7% protein. Casein Check = 2.50.

Toxicity

At least three sources of toxic compounds occur in feeds derived from cereal grains. The most serious occurs from the presence of ergot bodies in the grain. This condition is due to a disease caused by *Claviceps purpurea* and is discussed in greater detail in the diseases section. Other toxic substances are produced by certain fungi contaminating the seed at maturation. *Aspergillus, Alternaria* and *Fusarium* are three of the fungi which are known to produce toxins in contaminated cereal seeds. A third source of toxic substances are formed as organic compounds, i.e. resorcinols, within the developing seed. Some varieties of rye tend to produce these compounds in greater abundance than other cereals. The presence of toxicity among some Triticale strains was indicated by the results of feeding experiments on a strain from cross X 653 (T-70) provided by Dr. Fred Elliott. Some voles flourished on the diet while others hardly survived the duration of the test. Since the seed used in the test was free of ergot and other fungi, it is assumed that the toxicity was due to organic compounds such as resorcinols. Strains of voles which are sensitive to specific toxins would be extremely useful in providing a screen against lines containing toxic compounds in the breeding program.

Recent bioassays on 191 Triticale lines grown in Navojoa 1969-70 have shown a very wide range of PER values from 0.07 to 3.88. Lines having very low values apparently contain sufficient toxins or anti-metabollic substances to drastically curtail growth. On the other hand, lines with high values appear to be equal to egg protein in increasing body weight. It is important to determine how other animals and poultry react to the quality of proteins in triticales.