TRITICALE:
First Man-Made Cereal

Edited By

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First Man-Made Cereal

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Material as printed in this Symposium was neither edited nor proofread by this Association. Material was printed as presented by contributors.

ISBN 0-913250-06-6

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PREFACE

Triticale is the first man-made cereal produced by cross-breeding of wheat (Triticum) and rye (Secale). It has been shown to have superior nutritional qualities over wheat and baking qualities over rye. Under certain ecological conditions its yield outperforms that of wheat or rye. Although plant scientists have made striking progress in improving triticale lines, the potential uses of this new cereal as food and feed have only recently been explored by cereal chemists, nutritionists, and food technologists. We have little comprehensive information on triticale.

To provide such information, a symposium on triticale was sponsored jointly by the American Association of Cereal Chemists (AACC) and the International Union of Food Science and Technology held in conjunction with the 58th annual AACC meeting (November 4-8, 1973, St. Louis, Missouri). The symposium papers and several invited articles, presented in this book, deal comprehensively with subjects ranging from the genetic and agronomic characteristics of triticale to its biochemistry, nutrition, and utilization.

The book provides up-to-date information on triticale not only for triticale researchers but also for persons working with crop, livestock, food, and feed. Moreover, with the pressures of increasing population and rising affluence, the demand for food and feed grain is becoming more acute each year. The information on this new cereal will be appreciated by the public, and the book should be a valuable addition to every public library.

I thank all the authors for their excellent contributions. It is also my pleasure to acknowledge the useful suggestions and generous help from Professor Paul J. Mattern of the University of Nebraska, Mr. Raymond J. Tarleton, Executive Vice-President and Mr. David M. Kastler, Director of Publications of the AACC. My thanks also go to Mrs. Ann Gleason and Mrs. Frances Moore for their secretarial assistance.

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FOREWORD

Two or three years ago, triticale was a word known only to a few plant breeders and even fewer cereal chemists. Today, it crops up in conversation whenever food scientists or technologists meet. The farming communities in several countries are aware of its presence although not necessarily its true significance and an awareness of its existence is percolating through to the general public. Triticale is news.

When a major development in world food-supply appears in the offering, the time required for its development and evaluation can be quite long. While the experiments continue, there is a danger that over-optimistic rumors may exaggerate its potential and precipitate (by reaction) criticism based on misunderstanding of the real claims of the situation. It is therefore appropriate to assemble and discuss the state of knowledge to check oscillation of opinion. There have been previous symposia on triticale but this is the first to look beyond the genetic and agronomic characteristics of this crop to its nutritional and technological potential. For this reason its proceedings assume a special importance.

Triticale is a new cereal which could not have arisen by a natural process - that is, without the intervention of man. Fertile triticale is about as probable as the production of fertile mules. It is true that natural crosses between wheat and rye have been observed as botanical curiosities for nigh on a hundred years but the resulting grain was essentially infertile. Modern plant genetics has provided techniques which produce the necessary doubling of chromosomes to produce a fertile plant. While this is a major step forward, it is not immediately obvious (at least to a chemist like myself) that back-crossing is capable of producing a range of characteristics upon which the plant breeder can play a veritable symphony of genetic possibilities. But perhaps I go too fast. Let us look first at the likely advantages.

Rye is the poor man's wheat. It will grow in arid sandy soils and under climatic conditions which wheat will not tolerate. Under these conditions it has been valued more for its hardiness than for its inherent technological characteristics. Its protein is almost valueless from the bread baker's point of view but its relatively high lysine content has conferred a certain nutritional advantage over wheat which has hitherto been undervalued because the prime motive of the average consumer is gustatory satisfaction rather than nutrition. A cereal which combines some of the milling and baking qualities of wheat with some of the nutritional characteristics of rye is at the worst, an interesting development, and at the best a revolution in fulfilling human needs. But this is not the whole story. Rye tends to offer both higher lysine and higher protein contents than wheat, but it also has a flavor characteristic which is different and may well prove a desirable bonus to the other characteristics which the cross makes possible.

The wealth of possibilities now open to the plant breeder creates special problems. There is already evidence that on land unsuited to wheat, certain strains of triticale will outyield rye by almost 100%. A cereal with improved technological and nutritional characteristics and with the promise of this kind of abundance is a scientific prize which inevitably recalls Dean Swift's aphorism.

However the range of potential characteristics raises serious problems for the plant breeder. He must obviously aim at yield and disease resistance associated with dwarfing character. But the choices thereafter are large. Should the protein character of bread wheats be sought? Enough has already been done to show that triticale bread of excellent quality is possible although it seems unlikely that it will ever acquire the full character of the best strong wheats. Shall we seek high protein and high lysine for nutritional reasons, or extensible gluten for cakes and biscuits, or perhaps more important, the intermediate properties which seem desirable for chapatties or tortillas? Must the breeder back his hunches as to how this material is likely to be used, or can the food technologist provide criteria to guide him?

That is what this conference is really about and the papers which follow are the measure of its success.

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TRITICALE AND DEVELOPING NATIONS

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The CIMMYT - Manitoba Triticale Project

The Triticale Project began to germinate in 1954 when the Rosner Research Chair was endowed at the University of Manitoba by the Bronfman Family Foundation. In 1963 the Manitoba program was extended into a nursery at Ciudad Obregon, Mexico. In 1965, using Manitoba's breeding stock, CIMMYT (the International Maize and Wheat Improvement Centre) in Mexico began what subsequently blossomed into the extensive and fruitful Triticale Project currently being carried out as a cooperative effort between CIMMYT and the University of Manitoba.

In 1971, the Triticale Project was expanded and accelerated by a 5-year research grant of $3.25 million from the Government of Canada. This grant originates in the budget of the Canadian International Development Agency, the Canadian equivalent of USAID, and is managed by the International Development Research Centre (IDRC) which has its headquarters in Ottawa.

International Development Research Centre

IDRC is a public corporation created by an Act of the Canadian Parliament in 1970. It is an autonomous body with a 21-member Board of Governors, eleven of whom are Canadians, ten from other countries. The non-Canadian governors include two Africans, two Asians, one Caribbean and one Latin American.

IDRC's objectives, in the words of the Act, are "to initiate, encourage, support and conduct research into the problems of the developing regions of the world, and into the means for applying and adapting scientific, technical and other knowledge to the economic and social advancement of those regions". Though most of its financial support is received from the Canadian Government, IDRC operates much like a private foundation and is free to receive monies from any source provided these monies are to be used in a manner consistent with the Centre's objectives.

In the Triticale Project, IDRC's own financial resources are used (1) to provide supporting technical services to the Triticale Project, (2) to support a program of outreach and the dissemination of applicable results and relevant information, and (3) to encourage and support triticale research, demonstration and testing programs by scientists in and of the developing nations.

Triticale Project - objectives

At the outset it was agreed that the Triticale Project is intended to develop triticale varieties to complement rather than to replace the other cereal grains; to provide a new crop well adapted to a wide variety of conditions; a crop capable of increasing and improving the quality of the diet of many less developed nations.

The advent and introduction of the high yielding varieties of wheat and rice throughout Asia gave cause for cautious optimism that given reasonably favorable climatic conditions, the production of cereal grains in developing countries could be significantly increased. The crop failures which occurred during 1973 in West Africa and elsewhere served to emphasise how precarious is the present balance between human need and crop availability. Even before these tragic events took place, the Council of FAO at its 59th meeting in December 1972 expressed grave concern over the trend in agricultural production which showed a global increase of only one to two percent in 1971 against an essential target increase of 4% per year.

As others in this symposium will doubtless testify, the Triticale Project promises to fulfill the most optimistic expectations of those scientists at Manitoba, CIMMYT and elsewhere who had the courage to commit themselves and their scientific skills to the development of triticale as a significant cereal crop. One cannot possibly overpraise the remarkable progress made by the scientists at CIMMYT and Manitoba. The mutually sustaining research program they have cooperatively conceived and created is indeed a unique and exemplary model.

As Dr. Zillinsky will probably describe, CIMMYT bears the major responsibility for the synthesis and breeding of triticale lines of high yield capability, high fertility, superior nutritional value, and satisfactory kernel characteristics.

The Manitoba program concentrates upon some of the more fundamental aspects, including the transfer of new germ plasm from winter triticales to spring types, one objective being to select fertile hybrids displaying a spring habit combined with the greater tillering capacity and spike size of the winter parent. Manitoba is also examining crosses of hexaploid wheats with dwarf ryes in order to produce large heads of grain supported by short straws.

The cytogenetic implications of fertility in wide-crosses and the cytogenetic, physiological and biochemical aspects of endosperm shrivelling are all being studied at Manitoba.

The Manitoba group is also concentrating its attention upon enhancing triticale's resistance to ergot (Claviceps purpurea). The most stable triticales currently extant are hexaploids derived from a diploid rye (Secale cereale) and a tetraploid durum wheat (Triticum durum). In common with other wide genetic crosses the early triticale lines displayed a high incidence of infertility, a defect which is of much lower consequence in advanced lines. Grains in which some sterility may occur, and cross-pollinated grains such as rye, are more susceptible to ergot infection because their florets remain open longer than those of self-pollinated plants. Consequently, rye and triticale are more often infected than wheat. Among the wheats, T. durum is more often infected with ergot than the hexaploid T. aestivum.

The higher fertility of advanced triticale lines together with the identification of ergot-resistant wheat varieties in Kenya which are being crossed with triticales, promises significant improvement in ergot resistance in the foreseeable future.

Though triticale, in common with its parents wheat and rye, will probably be used as animal feed and forage, the primary objective of the Triticale Project is to provide more food for hungry peoples. Consequently the Triticale Project is as much concerned with how triticale will be used as with how it will be grown. In order to explore its potential use, IDRC formed a Working Advisory Group on triticale utilization three members of which, Dr. Bushuk the Chairman, Dr. Villegas and Dr. Hawthorn are participants in this symposium. In his capacity as Vice President of the International Union of Food Science and Technology, Dr. Hawthorn has formed an international committee on triticale composed of IUFoST members. It is the hope that the international community of cereal chemists, food scientists and technologists will not only explore the tolerance and behaviour of triticales when subjected to conventional processing technologies, but will be sufficiently innovative to devise new technologies better suited not only to the properties of triticale but, equally important, to the technical and economic constraints and opportunities of the developing countries where it will be grown. IDRC is currently supporting several projects related to the development of new milling, baking and other processing technologies to be applied to triticale and other cereal grains of importance in the less developed world.

Outreach Program

As is briefly mentioned above one of IDRC's primary responsibilities is to encourage applied research into the adaptability and utility of triticale in developing countries. The purpose is not to replace cereal grains which are well established and agronomically productive but rather to introduce triticales onto marginal lands such as light, sandy and acid soils, to which wheat and other traditional cereal crops are ill-adapted.

IDRC is supporting triticale outreach projects in Ethiopia and Algeria and others are being negotiated in East Africa, Latin America and Asia. In consultation with the scientists at CIMMYT and Manitoba, IDRC expects, during the next few years, to subvention a network of inter-communicating triticale projects comparable to the IDRC networks currently devoted to the improvement of (a) cassava and (b) the cereals and legumes of the semi-arid tropics. It is perhaps worthy of mention that while the outreach project in Ethiopia has been operative only since August 16, 1972, yields of triticale exceed those of the highest yielding bread wheat, the best triticale having produced more than five tons per hectare.

Nutritional Importance of Cereal Grains

Cereal grains and food legumes provide, on average, more than 70% of the dietary calories and protein of all the peoples of Asia, Africa and Latin America.

It is readily evident that the contribution made by cereals and legumes to the energy and protein intakes of the poorest peoples of these continents must be much in excess of 70%.

The biological complementarity of cereal and legume protein when eaten in combination is well documented. There is convincing evidence to suggest that, because of the higher cash return per hectare to the farmer from the higher yielding cereal grains, the acreage given to food legumes, particularly in Southeast Asia, is contracting. The FAO Production Year Book for 1970 indicates that between the early 1950s and 1970, chickpea production in Asia declined, per capita, from 6 to 3 kg, soybeans from 1.2 to 0.9 kg and lentils from 0.6 to 0.4 kg. It is probable that this drop in legume production is a function of comparatively low yields and low prices.

Though some major new programs of legume improvement in Asia, Africa, and Latin America may eventually arrest and reverse this trend, it appears inevitable, over the short term future, that cereals will become an even more important provider of dietary protein for those Asians, Africans and Latin Americans who subsist close to the margin of nutritional adequacy.

Consequently in current and future cereal breeding programs attention must, perforce, be given to the biological quality of the protein, and in particular to the endosperm and aleurone proteins.

Triticale protein

Among the earlier literature one can find certain misleading information about triticale proteins. Some of the extraordinarily high protein contents reported are attributable to one or both of two factors. In the first place the early triticale lines manifested a high incidence of shrivelled kernels in which endosperm to bran plus germ ratios were low as compared with normal wheats. Since the germ, scutellum, and aleurone are proportionally higher in nitrogen than the endosperm, shrivelled grains give a higher Kjeldahl nitrogen analysis than do plump grains. In addition some authors calculated triticale proteins using a conversion factor of N x 6.25 and expressed their results on a dry weight basis. As members of the AACC are well aware, protein expressed as N x 6.25 at zero moisture gives a value 30% higher than N x 5.7 at 14% moisture.

Some generous overestimates of the biological value of triticale also appeared. These were the outcome of evaluations based upon a test animal (*Microtus pennsylvanicus*) which is demonstrably ill-suited to the assay of cereal proteins. In several reported instances this animal ranked cereal proteins as biologically superior to casein.

Based upon recent and more reliable evidence it is quite unnecessary to exaggerate the biological value of triticale. Triticale can proudly hold up its long, spiked head alongside any of its cereal relatives. The average lysine content of a large sample of wheats from many parts of the world is 179 milligrams per gram of nitrogen. (1). The average for rye is 212 mg/g N. Based upon Dr. Villegas'

1972/73 data obtained at CIMMYT, the average lysine content in triticale is 196 mg/g N, significantly higher than the world wheat average. Furthermore, Dr. Villegas reports advanced triticale lines which show lysine contents equal to opaque-2 maize, but significantly higher in protein. The average protein content of advanced hexaploid triticale lines is of the same order as the mean protein content of the World Collection of common wheats analysed at the University of Nebraska. (2).

The University of Manitoba is planning a comprehensive examination of a large collection of spring and winter ryes, one of the objectives being to seek out high lysine varieties, hopefully some possessed of a prolamin-depressant mutation, by which to increase further the lysine content and the biological value of triticale protein without prejudice to other essential properties.

It was mentioned earlier that one of IDRC's self-appointed responsibilities is to give technical support to the projects it is concerned with, particularly by means of the retrieval, publication and dissemination of relevant information. It was hoped to unveil at this meeting a synthetic review of and commentary upon the literature which relates to the nutritional value of the proteins of triticale, wheat and rye. The review which is now at the printers includes the influence of genetic, environmental, and agronomic factors; the incidence of toxic substances and nutritional inhibitors; and the effects of processing and supplementation upon the biological value of triticale, wheat and rye proteins.

Perhaps I might briefly share with you some of the review's general findings.

First and foremost triticale is destined to take its place as an important new component of the world's spectrum of food and feed grains. Its high yield capability, combined with the satisfactory biological quality of its protein, together with its adaptability to environments unsuitable for wheat, give ample cause for optimism concerning its future production.

The need is now urgent for cereal chemists and food technologists to display imagination equal to that of the plant scientists who gave us triticale, in devising new techniques by which to use the grain in food, feed and forage. It is particularly important that the utilization of triticale in traditional and adopted foods be explored in those countries where land, presently unproductive but potentially amenable to triticale, is to be found.

Cooperation with Cereal Chemists and Nutritionists

A final conclusion from the review deserves special mention. In the past, and in general, cooperation with and support for the plant breeder by the nutritional scientist has fallen far short of what is essential if new cereal varieties of improved biological value are to become a widespread reality.

The methodology and standards related to biological evaluation of new cereal lines is at best contradictory, at worst chaotic. To bring about a markedly closer cooperation among plant scientists, analytical chemists and nutritional scientists, IDRC is seeking the assistance of the Protein Advisory Group of the United Nations, in concert with the appropriate international scientific unions. The objective is an internationally recommended and widely acceptable system of analysis and biological evaluation by which to screen and select early, intermediate and advanced generations of new cereal grains and legumes of superior biological value. The plant breeder cannot be expected to produce new varieties of improved biological value if he is not provided with adequate analytical tools of selection.

The plant scientists at CIMMYT, Manitoba and elsewhere have, in triticale, provided a remarkably imaginative and creative contribution to the world's cereal crop. We owe them a respectful debt of gratitude.

We now look to the cereal chemist, the food technologist and the nutritional biochemist to make a comparable contribution, and to transform triticale from a productive plant to a satisfying food, in order that triticale will, in the words of the prophet, provide seed for the sower and bread for the eater.

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TRITICALE PRODUCTION IN THE UNITED STATES[1]

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Predictions that triticale varieties have the potential to produce very high grain yields have whet the interest of growers, processors, consumers, and scientists over the past 10 to 12 years. A recent article in the New York Times[2] reported on presentations made at the International Symposium on Triticale, Lubbock, Texas, September 18-19, 1973. The article states, "A new food grain high in protein, a cross between rye and wheat, is producing a new sparkle in the eyes and causing the mouth to water at the aroma of breads, cakes, and cookies baking at Texas Tech University," and further, "The grain can be grown in any country where wheat is grown. Triticale has the ability to produce two or three times per acre more grain than wheat or rye."

The New York Times article is similar to many that have appeared in the popular press, and it is clear why readers can become excited about triticales. What is the current status of this potentially new crop? The purpose of this report is to summarize the data available on the productive capacity of triticale varieties and selections which have been tested in the United States to date. The first triticale variety, Rosner, was released by the Canada Department of Agriculture in 1968. Private industry has marketed several varieties since 1968, and a number of more recently developed selections have been tested. Briggle[3] summarized information available on triticale to 1968, and Lebsock[4] reported on triticale performance in the United States for 1967-1971. Data from 1972-1973 provide the basis for this report.

Method of Summarizing the Data

Cooperators from 28 states provided the data from replicated yield tests. Triticales were compared with wheat, barley, rye, and oats in 226, 53, 50, and 48 tests, respectively. More than 30 triticale varieties or selections were included among various tests, and most tests included more than one entry of triticales and of the cereal crops used as checks. Both winter- and spring-habit triticales were included. Test conditions included dryland, irrigation, fertilizer rates, seeding rates and dates, but no attempts were made to group data according to similar growing conditions. The highest yielding triticale was compared with the highest yielding cereal check in each test, thus the average triticale production for an individual state for 1971 and 1972 may have been based on more than one triticale entry.

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[1] Much of the data presented here are preliminary in nature and subject to new interpretations. They should not be used without permission of appropriate State Agricultural Experiment Station officials.

[2] Anonymous. College Testing a New Food Grain. New York Times (November 18, 1973).

[3] Briggle, L. W. Triticale - a Review. Crop Sci. 9:197-202 (1968).

[4] Lebsock, K. L. Triticale Performance in the United States, 1967-1971. PSR-32-72. Agricultural Research Service, Beltsville, Maryland (1972).

Data reported on protein content are from the same cereal check and triticale entries which ranked highest in yield within a test.

Triticale Compared with Wheat

Data from triticales and wheats grown in 1971 and 1972 are summarized in Table I. Average data from the 28 states showed that triticales yielded 14% less grain than wheat. Triticale yields expressed as a percent of wheat ranged from 41% in Maryland to 248% in Georgia. Both extremes occurred in states where wheat is a relatively unimportant crop, and where yields of both triticale and wheat were too low to encourage their production. Perhaps the most significant comparisons between wheat and triticale can be made in states where wheat has been a major crop. In states that produce more than 500,000 acres of wheat per year, triticale exceeded wheat only in Missouri (13%). In Kansas, the largest producer of hard red winter wheat, and in North Dakota, the largest producer of hard red spring wheat, triticale yielded 90 and 93% of wheat, respectively. In Washington, average data showed triticales yielded 93% as much grain as wheat; however, four of the five tests where spring-sown. Triticale yielded only about 74% as much grain as winter wheat in 1971 in Washington. Triticale compared less favorably with wheat in other important wheat growing states; Colorado (66%), Texas (76%), Ohio (83%), Minnesota (85%), and Oklahoma (86%).

TABLE I

Comparison of Triticale with Wheat in Yield of Grain in the United States, 1972-1973

State	Number of tests	Average yields, lb/acre		Triticale in % of wheat	
		Triticale	Wheat	Range	Average
Alabama	11	1,381	1,103	70-389	125
Arizona	1	5,766	8,101	-	71
Arkansas	9	2,522	3,297	50-112	77
California	5	2,983	4,404	46- 80	68
Colorado	20	2,449	3,733	43- 95	66
Florida	5	1,815	1,348	98-223	135
Georgia	2	2,253	909	174-446	248
Idaho	4	3,792	4,826	68- 96	78
Indiana[a]	1	2,874	2,046	-	140
Kansas	37	2,561	2,847	71-124	90
Kentucky	3	3,544	2,991	97-141	119
Louisiana	10	1,719	2,150	52-112	80
Maryland	4	1,029	2,513	15- 60	41
Minnesota	4	2,826	3,307	70- 93	85
Mississippi	6	1,539	2,316	53- 79	66
Missouri	8	2,462	2,184	90-137	113
Montana	2	3,364	3,777	62-124	89
Nebraska	3	2,362	2,803	80- 92	84

TABLE I. Continued . . .

New Mexico	10	2,872	2,556	67-322	112
North Dakota	13	2,327	2,496	83-118	93
Ohio	2	2,849	3,425	76- 93	83
Oklahoma	17	2,604	3,036	50-156	86
South Carolina	7	1,684	2,011	63-118	84
Texas	14	1,011	1,322	50-143	76
Virginia	5	2,347	3,164	53-132	74
Washington	5	3,147	3,450	77-150	91
Wisconsin	3	1,850	1,904	90-102	97
Wyoming	15	2,745	3,162	55-172	87
Average, 28 states	226	2,365	2,737	-	86

[a]Spring planting.

Triticale Compared with Barley, Oats, and Rye

Data in Table II show that triticale averaged about 13% less grain per acre than barley in 53 tests grown in 13 states. In North Dakota, the largest producer of barley in the United States, triticale was 18% less productive than barley.

TABLE II

Comparison of Triticale with Barley in Yield of Grain in the United States, 1972-1973

State	Number of tests	Average yield, lb/acre		Triticale in % of Barley	
		Triticale	Barley	Range	Average
Alabama	6	1,558	1,064	119-200	146
Florida	5	1,815	1,878	76-148	97
Georgia	1	2,927	3,158	-	93
Indiana	1	2,874	3,265	-	88
Kansas	2	2,264	2,462	61-168	92
Kentucky	2	3,636	3,195	102-127	114
Mississippi	1	2,214	2,730	-	81
Missouri	6	2,329	1,450	119-209	161
New Mexico	10	2,872	4,666	43-112	62
North Dakota	13	2,372	2,833	65-115	82
Ohio	1	2,974	4,188	-	71
Oklahoma	2	2,096	2,336	-	90
Texas	3	1,445	1,161	92-172	124
Average, 13 states	53	2,315	2,656	-	87