9th International Triticale Symposium
May 23-27, 2016. Szeged, Hungary

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Book of Abstracts

Edited by
Lajos BONA, Katharine V. COOPER

Cereal Research Non-Profit Ltd.
International Triticale Association
Eucarpia Cereal Section
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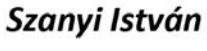

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Preface

Triticale researchers, agronomists and other cereal specialists are coming together for the International Triticale Symposium from many parts of the world with various ideas and practice, but there is one thing in common for sure: triticale is our largely favored species and everyone in the community believes, that there is a promising future for this young and valuable crop. Approximately 25-30 years ago, when triticale production had commercially started, we did not presume that triticale would reach the four million hectares that it has today. It is interesting to learn that triticale became a typical European crop – more than 85% of the world production is produced by European farmers. We consider that triticale has a great future in other continents too, especially for marginal soils, and in low input production systems. On this 9th Symposium, in Szeged, Hungary, scientists and specialists came together from thirty countries to exchange ideas and learn from each other.

Hungary is a leading country in triticale research and production. It is fifty years now that Arpad Kiss, a pioneer researcher in triticale developed the first varieties registered in the world. Kiss was born one hundred years ago in 1916, thus we dedicate this Symposium to his memory, as well as to the other pioneers of triticale development.

The Organizers – the Cereal Research Non-Profit Ltd., Szeged, the International Triticale Association, the Eucarpia Cereal Section, and the Association of Hungarian Plant Breeders hope that you enjoy the Hungarian hospitability and have an interesting, professional and pleasant personal time during the Symposium.

Dr. Lajos Bona
Chair, Organizing Committee

Dr. Geert Haesaert
President, Int. Triticale Association

PLENARY SESSION

The importance of cereals and triticale in the Hungarian agriculture. Renewing the Hungarian agricultural research and innovation system

Feldman Zs

Deputy Secretary of State for Agricultural Economy, Ministry of Agriculture of Hungary

Cereal production has always been the most dominant sector of Hungarian crop production. Actually it covers roughly 60% of the total value produced by the crop sector. The two main crops are wheat and maize, covering around 1 million and 1.3 million hectares, respectively. Smaller crops include barley (300 thousand hectares), triticale (120 thousand hectares), oats (50 thousand hectares) and rye (30 thousand hectares).

The Hungarian cereal balance sheet is constantly in surplus, we produce more than we use internally even in the worst years. The average cereal production amounts to 12-17 million tons from which we use 9-9.5 million tons. The surplus is exported, the average amount of cereal export varies between 3 and 7 million tons per year. We may see some shifts in respect of some sectors of Hungarian agriculture in the future, but the importance of the Hungarian cereal sector will remain high.

Concerning triticale, the total area sown in Hungary is around 120 thousand hectares from which we harvest 400-500 thousand tons with an average yield of 3-4 tons per hectare. Total Hungarian cereal area is 2.7-2.8 million hectares which means that there is room for improvement for smaller crops like triticale, it fits well in the Hungarian crop rotation. As for the future possibilities of this crop, the main deciding factor will be its relative profitability compared to other large field crops (feed wheat, barley). Finding special uses (industrial or human) of triticale may also affect the future of this crop in Hungary.

Future social, economic and environmental challenges can only be answered with the help of a strong and dynamic agricultural research background. The setting up of the National Agricultural Research and Innovation Centre in 2014 was an important step towards the renewal of the Hungarian agricultural research system. The concentrated organizational structure and the complex profile of the institution permit to launch projects that deal with more complicated problems. Besides the enhancement of international agricultural research collaboration, in the years to come, the most important task is to promote the partnership between science and practice. The Ministry of Agriculture of Hungary is committed to help the development and adoption of a long term agricultural research and innovation vision, which is the key element of success.

Centenary of a triticale pioneer: Arpad Kiss (1916-2001)

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Arpad Kiss was born in Budapest, and graduated at the Agriculture University Mosonmagyaróvár, West Hungary. After army service and captivity, first he worked at the Plant Breeding Institute of the Hungarian Academy of Sciences (1950-1957). His interest was focused on the genetics and breeding of cereals, particularly wheat/rye hybrids. Working with G. Redei, who immigrated to the USA in 1956, they found a strong genotype dependence in the crossability of various wheat and rye genotypes. Their fundamental work was successful in developing primary octoploid and hexaploid triticale stocks.

In the 1950s, when Lisenko visited Hungary, Kiss attended his seminar displayed courage by standing up and opposing him. For this debate, he lost his job at the Institute of the Academy and was transferred to the Institute of Ministry of Agriculture, Kecskemét. Fortunately, this institute was located in a sandy soil area, where he could continue his research on and development of triticale. He discovered early that the hexaploid forms would be more useful agronomically than the octoploids, saying "I quit the breeding of octoploids because I heard the negative results of others". From his nursery, in 1968, the world's first released triticale cultivars for commercial production appeared in 1968 as T-No.57 and T-No.64. Kiss established modern triticale breeding with his secondary hexaploids, since they were as competitive on marginal soils as rye, but contained 30-50% more protein. He had many fruitful international relationships with triticale breeders from Poland to CIMMYT. By 1969-1970, Kiss developed more than ten secondary hexaploid lines and sent them to the Cereal Research Institute, Szeged for further tests in various locations. In 1970, the politicians decided to terminate extensive triticale breeding in Hungary. Kiss was forced to donate his valuable advanced materials to Polish scientists in 1970. Also, in 1970, his dwarf cultivar, Bokolo, was patented in Germany. Again, no interest was shown even toward this from Hungarian authorities. His friend, *Charles Jenkins* (1921-2011) who was also among the founder of this species, wrote in a personal letter to me in 2003: "In the very early stages of triticale development, the following names stand out: *Muntzing (Sweden), O'Mara and Metzger (USA), Nakajima (Japan), Pissarev (USSR), Kiss (Hungary), Sanchez-Monge, (Spain), Pienaar (South Africa) and Wolski (Poland)"*.

After his retirement he wrote papers and books, and persevered through these difficulties by his faith and love towards his work and towards people around him. At age 85, Arpad Kiss died on April 5, 2001 – a brave pioneer in tough times.

23 years research work devoted to triticale – An overview

Lelley T

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My first encounter with triticale was in 1967, when I visited Dr. Árpad Kiss in Kecskemét. I followed a proposal of my mentor at that time, Professor Barna Győrffy, director of the Institute of Genetics of the Hungarian Academy of Science in Budapest. I was a newcomer to cytogenetics, searching for a topic for a doctorate study. After touring Dr. Árpád Kiss´ nursery, back in his lab, he showed me, by microscope, the higly disturbed meiotic metaphase of triticale with a number of univalents having lost their orientation. This of course resulted in sterile gametes or aneuploid progenies. He put me the question: how could we find out whether those univalents originated from the wheat or the rye genome? In 1968 I received the Degree of Dr.sci.agr. from the Agricultural University of Gödöllő (Hungary) for a thesis with the title: *The analysis of the karyotype of triticale*. This was at a time when in Hungary the leading scientific ideology in Genetics was *lysenkoism*, a kind of *lamarkism*, and chromosomes were declared to be capitalistic propaganda. Studying the morphology of the chromosomes of Dr. Kiss´ hexaploid triticale, I came to the conclusion that six of the seven rye chromosomes were larger than the largest wheat chromosome in the triticale complement with specific, easily identifiable morphology, and the smallest rye chromosome carried a satellite on its short arm. For the next 22 years, now working in the Plant Breeding Institute of the University of Göttingen in Germany, I became a triticale addict. First triticale taught me cytogenetics. Systematic production of primary triticale genotypes using inbred lines of rye revealed specific interactions between the wheat and the rye genomes in triticale. Orthogonal crossing programs with primary triticale genotypes combined from specific rye and wheat genotypes allowed the study of general and specific combining ability of the wheat and rye genomes, though the term “genome combining ability” was highly criticized by population geneticists. Later, large scale crossing experiments between selected primary triticale genotypes leading to recombination, either only in the wheat or only in the rye genome, were compared with crossing progenies derived from crosses different in both wheat and rye genome. They clearly showed that cross combinations heterozygotic only in the wheat genome yielded the best breeding lines. Unfortunately, my research on triticale was not attractive enough for a further university career in Germany, thus in1992 I left Göttingen for Vienna, the University of Agricultural Sciences, changing my research area to wheat breadmaking quality, to the issue of the 1BL.1RS translocation and, finally to oil seed pumpkin. In my present talk I would like to briefly discuss some of my most interesting findings concerning triticale and to make my great adherence to the plant understandable. On the other hand I will also discuss the reasons for my skepticism concerning the euphoric expectations towards triticale in the 1980s.

Nanocarrier-cargo technology for engineering nucleus and mitochondria of triticale microspore

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Keywords: triticale, organelles, genetic engineering, gene editing, double haploid

The haploid single cell microspore is an ideal target for engineering its genomes and regenerating a new doubled haploid plant to feed into a breeding program. Delivery of new genetics or proteins for editing the nuclear genome in the microspore has been made easier with the adoption of a nanocarrier-cargo technology. Short peptides with the property to translocate across cell barriers and target specifically subcellular localizations are the nanocarriers. They form hydrogen bonds with cargo molecules such as nucleic acid and protein, and transport them specifically to subcellular localities such as the nucleus and the organelles. The cargo can be designed using nucleic acid and proteins, forming blocks that conjugate in a relatively predictable manner, such as observed with ssDNA binding proteins (e.g. RecA, Rad51, SSB and VirD2) and impacting the integrity of stable integration of donor DNA. Nanocarrier mediated nuclease protein transduction opens new possibilities for creating, with precision, site targeted mutation in the nuclear genome. Progresses in the delivery of Talen and Cas9/gRNA for editing targeted gene will be reported. Similarly, a mitochondrial editing method has been developed allowing site targeted insertion of donor DNA sequences. While the methods are being developed, applications are also considered which demonstrate the value of these methods for trait development in elite triticale lines.

Triticale in the large genebanks: state of the art

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Keywords: ex-situ conservation, seed longevity, evaluation data, phenotypic variation

Plant genetic resources play a major role in global food security. The most significant and widespread means of conserving plant genetic resources is *ex situ* conservation. Most conserved accessions are kept in specialized facilities known as genebanks. World-wide 7.4 million accessions are stored in about 1,500 *ex situ* genebanks. The largest collections by crop are wheat (860,000 accessions), rice (780,000 accessions), barley (470,000 accessions) and maize (330,000 accessions).

With respect to triticale, it has been assessed, that there are about 37,500 accessions conserved in the global seed banks. The largest collection is located at CIMMYT (Mexico). Because triticale, like other cereals, is maintained in the form of seed, longevity of seeds is of particular importance for protection. Here we provide data on long term stored triticale accessions.

In addition to the accurate preservation of germplasm, the evaluation of the collections is also a very important task to faciliate further utilisation. Thus genes may be identified which may later be used in breeding programmes for crop improvement. At the Gatersleben genebank evaluation data for 680 accessions are available including the traits: growth habit, winter hardiness, tillering, ear emergence, plant height, number of spikes per square meter, grain yield per square meter, grain number per spike, grain yield per spike, thousand grain weight, disease resistance, protein content and lysine content. A huge variation was obtained for most of the traits investigated. Trait distributions and correlations will be presented.

SESSION I.
GENETICS, BIOTECHNOLOGY AND BREEDING

Session chair:
Harpinder S. Randhawa

Challenges in cereal development: breeders' aspects and responses

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Keywords: traditional breeding, genetic resources, prebreeding, yield improvement, yield gap

Traditional breeding has contributed significantly to the accumulation and preservation of favourable alleles for better adaptation and agronomic performance of cultivated crops. From among the traits having direct influence on yield performance, harvest index and plant height have reached the optimum range in most regions. However, after the successful period of the green revolution, small grain cereal yields – especially wheat – have been stagnating or decreasing in Europe over the last two decades. Differences between alleles at multiple loci have become relatively small in the elite gene pool. It has become evident that cereal breeders must face these new challenges if they are to find new ideotypes suitable for new management systems and to overcome adverse climatic conditions to narrow the increasing yield gap, while also improving the yield. The complex nature of new challenges implicates the need for combining traditional breeding methods with new breeding technologies. To meet these challenges, prebreeding programmes have been established to use gene bank collections, determine natural variation and generate new genetic variability. This will include a new assessment of the existing small grain cereal genetic resources in order to improve the sustainability, safety and quality of cereal-based production.

Triticale is one of the best genetic resources in terms of widening small grain cereal genetic variation mainly for biomass and grain yield production. Its stress resistance plays an important role in resistance breeding for increasing yield stability under changing climatic conditions. Through the spread of agriculture into marginal lands, triticale has been characterized as a cereal crop for adverse environments. Triticale has now also become competitive under high input conditions in certain regions.

According to Hans Braun (2014) triticale would be "Norman Borlaug's unfinished business". Cereal breeders continue to make great efforts aiming at developing new varieties of 50% higher yield potential 20 years hence.

Achievements and trends in the breeding of triticale in Bulgaria

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Keywords: competitive varietal trial, Bulgarian triticale cultivars, triticale breeding

Breeding of triticale (×*Triticosecale* Wittm.) in Bulgaria has a history of more than 50 years. As a result of experience in the breeding of this crop, the hexaploid secondary winter triticale forms are primarily used in Bulgaria. During the last decade 11 cultivars were registered, which were distributed according to the specific soil and climatic conditions of the country. With the aim of determining their specific response to the growing conditions, their development was been followed in a competitive varietal trial over 9 years. The indices date to heading, plant height, number of productive tillers per square meter, absolute and relative yield, number of grains per spike, weight of grains per spike, 1000 kernel weight and test weight were assessed. Based on the obtained results, the main trends demonstrated by the investigated indices were formulated. The eleven cultivars studied were of later date to heading in comparison to the mean standard (formed by the values of the cultivars Vihren and Rakita) and followed a tendency toward lower plant height. In contrast to the standard cultivar Lasko and cultivar Presto, the yield from cultivars Kolorit, Akord, Respekt, Bumerang, Irnik, Dobrudzhanets, Doni 52 and Blagovest was formed mainly by the greater number of grains per spike and the 1000 kernel weight, while the number of productive tillers was of secondary importance. Cultivars Atila, Lovchanets and Borislav were exceptions to this tendency. During the investigated 9-year period, all cultivars exceeded the mean standard and Lasko with respect to yield by 9-20 %, and to Presto by 5-13 %. These results make triticale breeding in Bulgaria very promising, with a trend towards a continuing increase in the productivity potential of this crop.

Genetic mapping of disease resistance and agronomic traits using SNP markers in a triticale

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Keywords: triticale, breeding, genomics, doubled haploid, disease resistance, *Fusarium*

A doubled haploid (DH) population from the cross TMP16315/AC Ultima was evaluated for various traits at three locations in Canada (Beloeil, Ottawa and Lethbridge). In total, ten traits were measured, of which, four [namely FHB incidence (FHBi; Type-I resistance), FHB severity (FHBs; Type-II resistance), FHB Index/Visual Rating Index (FHBv), and DON content (DON; Type-III resistance)] were measured at Beloeil and Ottawa, while the remaining six traits [ergot tolerance (ERG), plant height (PHT), lodging (LDG), grain protein content (GPC), thousand kernel weight (TKW) and grain yield (YLD)] were measured at Lethbridge. High-throughput genotyping was performed with the Wheat 90K Infinium iSelect SNP Assay and the Rye 10K SNP Assay. A total of 5274 high quality polymorphic SNP markers were used for linkage mapping. These markers mapped on all 21 Triticale chromosomes with a marker density of 2.09 SNP/cM. The high-density genetic map along with phenotypic data was used for QTL mapping which identified a total of 44 QTLs, with positive additive effects from both parents. These QTL mapped on 17 chromosomes, which included QTLs with main (additive effect; 37), epistasis (4) and additive × environment (A*E; 3) interaction effects. The contribution of a single QTL effects was of low magnitude for most traits (additive effects ranges from 0.20 to 5.22) except ERG (additive effects 15.42 to 17.19) and YLD (additive effects 402.69 to 454.75) related QTLs. A negative correlation between FHBv and DON was negative at Beloeil. In contrast, a positive correlation was found at Ottawa. FHBi, FHBs, FHBv and ERG were negatively correlated with YLD and TKW, whereas PHT positively correlated with LDG, DON, ERG, GPC and YLD. Of all QTL identified, four regulate lodging as well as DON accumulation confirming the correlation coefficient analysis results and indicates that LDG can influence DON accumulation after the establishment of pathogen. Careful selection and pyramiding of QTL alleles identified in this study can be useful for improving FHB resistance, GPC, YLD and other studied traits in triticale.

Use of intergeneric crosses in cereals and in particular for increasing the genetic diversity of triticale

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Keywords: primary triticale, intergeneric cross, crossability, molecular markers

Many species or even genera from tribe *Triticeae* may intercross, either spontaneously as for the origin of durum wheat and later bread wheat, or by human action as with triticale. The result may involve the whole genomes (polyploidization as for examples previously cited), only some whole chromosomes (addition lines), part of chromosomes (e.g. 1B-1R translocation 1B-1R) or extremely small parts of chromosomes (introgression of disease resistance gene for example). These possibilities have been widely used for breeding small grain cereals for many traits including disease resistance, grain quality, frost or drought resistance or for genetic diversity increase (e.g. crossing durum wheat and *Aegilops* i.e. synthetic wheat).

However, such crosses are not straightforward and many difficulties have to be be overcome: poor crossability and seed setting, absence of or poor endosperm development requiring in vitro embryo rescue, poor germination of hybrid seeds, necrosis, meiotic instability and sterility.

For triticale, a synthesised cereal, no natural genetic diversity is to be expected, and wheat by rye crosses should be made in order to increase triticale genetic diversity. A few Asian wheat cultivars carry recessive crossability genes enabling intergeneric crosses. Several of these genes have been identified and located (Kr1, Kr2, Kr3 Kr4 and more recently Skr). However Asian wheat is not well-adapted to European growing conditions, therefore we decided to introduce crossability into some French wheat varieties. The long backcross process, with selfing and test crosses with rye at each generation, was achieved for eleven French wheats in recent years. We recently succeeded with the introgression of Skr into the French cultivar “Barok” more rapidly by the use of molecular markers allowing Marker Assisted Selection. The markers are unfortunately not close enough to the trait to be diagnostic markers but we are now able to produce primary triticale for more extensive use of rye diversity and to study these kinds of intergeneric crosses.

The research was partly supported by GIE TRITICALE.

Reproductive barrier between common wheat and rye depends on ploidy level of the hybrids

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Keywords: reproductive isolation, complementary genes, wheat-rye hybrids, embryo rescue, chromosome doubling

In crosses between common wheat Chinese Spring (CS) and rye inbred line L2 abortion of the shoot apical meristem (SAM) during the differentiation of the hybrid embryo leads to embryo lethality. Development of the hybrid embryos with "lethal" genotypes progresses until the transition stage. There are no visible differences between embryos from incompatible (CS x L2) and compatible (CS x L6) crosses until 10 days after pollination (DAP). At this time the shoot apical meristem is visible as a dimple on the flattened face of the embryo. The primary meristematic region later forms the shoot-root axis of the embryo. Following this stage, differences become apparent. Since the root meristem is not affected, degradation of the SAM apparently starts after the shoot-root axis has been formed. This suggests that the interaction between the incompatible wheat and rye alleles leads to the malfunction of loci involved in maintaining the SAM. Such kind of embryo lethality is the result of a negative complementary interaction between wheat and rye loci. These loci were named *Eml-R1* and *Eml-A1*. *Eml-R1* locus has two alleles which are either compatible (*Eml-R1a*) or incompatible (*Eml-R1b*) with the wheat genome. Rye *Eml-R1* and wheat *Eml-A1* loci were mapped on chromosomes 6R of rye and 6A of wheat, respectively. The genome location of the wheat and rye *Eml* loci indicates that embryo lethality in wheat-rye hybrids is the result of an interaction between wheat and rye homoeo-alleles. The arrest of SAM in cross Cs x L2 can be easily overcome by embryo rescue of abnormal embryos in age of 14-16 DAP. Two types of amphidiploid plants: fertile and sterile were produced by colchicine application in callus culture. On this basis, a model for studying the differences in interaction and expression of incompatible genes for both parents of identical genetic background but different ploidy level will be discussed.

The research was supported by the DFG: BO 1423/17-1/603175.

Results and challenges of *in vitro* androgenesis techniques for triticale breeding

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Keywords: androgenesis, breeding, doubled haploid, triticale

The genetically pure lines and varieties play important roles not only in agricultural production, but also in the applied research, breeding. In small grain breeding, the doubled haploid (DH) plant production is in the focus of different practical breeding and pre-breeding programs.

In triticale breeding three haploid induction methods are published and used such as chromosome elimination technique (i), anther- (ii) and isolated microspore (iii) culture. Last years, in vitro androgenesis induction via anther- and microspore culture was improved by our research group to produce DH lines followed by practical using these DH line in breeding. These *in vitro* techniques were improved from large scale of breeding materials. Based on three-year data, anther culture was proved an efficient method to produce large quantity of green plantlets from breeding materials, while phenomenon of albinism limited the efficiency of isolated microspore culture.

The produced anther culture-derived plantlets (~2000 green plants/year) acclimatized well to the field conditions, most of the microspore-derived plants survived the winter period and the spontaneous DH plants produced fertile spikes. The DH lines have been integrated into our triticale breeding program.

According to some critical opinions, the genotype influences the efficiency of anther culture and isolated microspore culture (number of embryoids and green plantlets produced in anther culture and isolated microspore culture) and the colchicine treatment can increase the ratio of doubled haploids.

This research was realized in the frames of TÁMOP 4.2.4. A/1-11-1-2012-0001 „National Excellence Program – Elaborating and operating an inland student and researcher personal support system" The project was sponsored by the European Union and co-financed by the European Social Fund (project number: A1-MZ-PD-12-0070) by the GOP-1.1.1-11-2012-0044 and HUSRB/1002/214/045.

Evolution of the CIMMYT Triticale Breeding Program and recent achievements in Mexico

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Keywords: triticale, breeding, seed production, forage, grain feed

The CIMMYT program has contributed significantly to the spread of spring triticale globally, with more than 200 cultivars released by different National Programs worldwide. In 2001, it was all but destroyed after the appearance of the "Pollmer" race of yellow rust which defeated the resistance of more than 85% of the advanced germplasm. After successfully re-building the program using resistance sources identified in very few elite line, transferred from primary hexaploid or octoploid types or introgressed from bread wheat, we abandoned our early vision that triticale could be a replacement for wheat, as human food, in marginal areas and started to breed triticale as a forage/feed crop that can be highly competitive with other species like barley, oats, maize or others. A recent major investment from the Mexican government engaged CIMMYT into the promotion of triticale as a low-cost, input-use efficient green forage or grain feed option to enhance the economic viability of livestock operations in non-tropical regions of the country. With the most important factor limiting triticale adoption in Mexico being the availability of seed commercially, we established an ambitious basic seed production and distribution program using the outstanding, widely adapted, cultivar Bicentenario TCL08. Some 40 tons of high quality seed were produced and distributed to dozens of growers in 13 states, with some becoming successful secondary seed producers, greatly contributing to the spread of this cultivar across the country. Additional efforts were conducted to promote the competitiveness of this crop compared to well-established forages, to encourage large industrial users of forage or feed grain to include triticale operations and to link producers with industrial users. While grain yield remains a major breeding objective, forage yield and quality attributes have been included in the selection process to address the new research goals. Extensive, multi-location, forage quality characterizations have been conducted to document the quality attributes of triticale silage and serve as reliable tool for promotion of this forage in livestock operations. It is our hope that the described approach adopted in Mexico to substantially increase the area of triticale can be generalized to other countries where this crop can play a positive role in enhancing the viability of livestock operations.

The research was supported by the Mexican Ministry of Agriculture, SAGARPA, in particular through its livestock unit: "Coordinación General de la Ganadería".

Transgressive segregation for foliar/total biomass and grain yield in winter by spring/facultative triticale crosses

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Keywords: triticale, transgressive segregation, biomass, grain yield

Transgressive segregation is the main mechanism by which genetic progress can be achieved in non-hybrid, self-pollinated crops such as triticale. The main objective of this research was to evaluate and quantify transgressive segregation for foliar and total biomass and grain yield in 26 triticale families generated from crosses between spring and facultative genotypes to a common winter parent evaluated at seven locations in northern Mexico, including favorable and stress-affected environments. Individual and combined analyses of variance were performed as well as orthogonal contrasts between families and specific parents were studied, for each variable. Significant differences between families were detected for total biomass and grain yield in all environments and between environments/treatments for all traits. Several families with significant transgressive segregation (superiority to the best parent) for one or several traits, stable across environments, were identified and selected. Results will be presented that demonstrate the promising potential of spring by winter crossing in breeding programs for the production of progenies with significant genetic improvement compared to their parents.

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The germplasm development in DANKO triticale program

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Each breeding program is looking for new sources of genetic variation.This increases the opportunity to enrich the gene pool by new genes, which may improve the qualitative and quantitative traits. The most frequently used source for crosses are domestic and foreign varieties and breeding lines. According to breeders' opinions, such crosses give a greater chance for a new variety. However, this leads to a narrowing of the genetic pool, because many breeders use the same variety and lines in their breeding programs. The enrichment of the gene pool of triticale can be obtained by crossing with rye and wheat, octoploids and wild species. Valuable sources may also be translocated forms obtained by research institutes.

In 2003-2015, a total of 9553 cross combinations were made in the winter triticale program. Of these, 4898 (51%) were complex combinations and 4655 (49%) were of simple type. Many combinations – 1018 (10,6%) contain wheat in their pedigrees, 840 (8,8%) – wild species, 582 (6%) – translocated forms, 98 (1%) – octoploid forms and 71 (0,7%) – rye

In the same period, in spring triticale, 2278 cross combinations were made: 937 (41%) were of complex and 1341 (59%) of simple type. In their pedigrees 133 (5,8%) contain wheat. No other components were used.

The percentage of selections in different stages of breeding from 2004 until 2009 is presented. This is an example of one program situated at Choryń. In those years 37% of cross combinations have been selected from F1 to F2. In F6 (trials) 11% of combinations were selected, in F7 – 4%, F8 – only 1% and 0,6 % have been included in official trials.

Markers towards pollen sterility genes in triticale with CMS Tt

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Keywords: triticale, DArT, cytoplasmic male sterility, pollen sterility

Cytoplasmic male sterility (CMS) is widespread among higher plants and results from an interaction between nuclear and mitochondrial genomes leading to impairment of pollen production. The phenomenon facilitates the production of hybrid seed (i.e. in rye, maize, or rapeseed) [1]. The CMS from *Triticum timopheevii* (cms Tt) is the most promising system for hybrid breeding in triticale. However, currently little is known about the genes responsible for pollen fertility restoration and maintenance of pollen sterility in the species [2]. Nevertheless, analysis of F2 mapping population [3] unveiled that several nuclear genes with relatively weak phenotypic effects code for the trait. The genes conferring pollen fertility mapped to the chromosomes 6A, 6B and 6R [3] with additional ones on the chromosomes 1B, 3A, and 3B [3], respectively. Moreover, our unpublished data using RIL4: MS 114(5)-2-1 x Borwo mapping population showed that putative genes responsible for pollen sterility mapped to the chromosomes 3A, 5B, and 7B. RIL5 [DB1 x RB1] mapping population and phenotypic data were employed for the identification of a pollen sterility QTL as well as molecular markers linked to the trait. One hundred and seventy RIL5 plants were genotyped with DArTseq markers. The phenotype of the RIL5 lines was evaluated based on BC1F5: DB1 x [RIL5: DB1 x RB1] where the number of seed per spike was determined. A genetic map was built in MultiPoint Ultra Dense software. Composite interval mapping (CIM) was performed in WinQTL Cartographer whereas association mapping in TASSEL.

A total of 637 skeletons and 2705 redundant markers felt into 22 linkage groups. The groups were 4.3 to 182 cM long and included from 19 (LG21) to 327 (LG9) markers. Based on the known map positions of wheat DArTseq's, eight and seven linkage groups were allocated to the A and B genomes, respectively. Assignment of remaining seven linkage groups to the chromosomes was difficult due to the lack of information about DArTseq markers localization. CIM allowed the identification of a single QTL most probably reflecting pollen sterility gene/s acting in cms Tt system. The QTL mapped to the chromosome 4A. The maximum of the LOD function equaled to 6.2 with LOD cut-off values equal to 2.5. The DS3610112TC11 marker was 0.2cM away from the QTL maximum. This marker has two redundant counterparts: DS3604977AG23 and DS4348966GC15. The QTL explained 32% of the phenotypic variance of the trait. Association mapping identified numerous markers responsible for pollen sterility. The markers were assigned to 4A, 1B, and 3B chromosomes but they failed to pass Bonferroni test.

Summing up, pollen fertility and pollen sterility in triticale with cms Tt are conferred by numerous QTLs located on distinct chromosomes.

Minimizing albinos among DH plants derived via in vitro anther cultures

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Keywords: triticale, anther culture, albinos plants, optimization, silver, copper

The frequency of albinos regenerating from culture could be affected by many factors including the age of the culture, the presence of a callus phase during embryo formation as well as by ingredients present in the culture (i.e. $CuSO_4$, $AgNO_3$, etc.). It is documented that copper sulfate may positively regulate plant regeneration and green plantlets formation whereas silver nitrate may intensify the embryogenic callus production and stimulate callus growth during in vitro procedures. The age of tissue cultures, as well as callus stage, may result in an increased number of mutants.

The objective of the study was to verify whether varying concentration of $CuSO_4$ and $AgNO_3$ in the tissue culture medium and the age of the tissue cultures, could reduce the number of albinos and increase the proportion of green regenerants of similar in type to parental plants. For such purposes, anther cultures of triticale (x *Triticosecale* spp. Wittmack ex A. Camus 1927) were used.

DH triticale plants (Mungis x Presto) were used as a source of explants. Anthers from stressed spikes were placed on solid induction medium 190-2 supplemented with 2 mg/l 2,4D and 0.5 mg/l kinetin. The induction media were prepared in nine different variants (M1-M9) concerning the concentration of $CuSO_4$, $AgNO_3$ and time of androgenesis induction (4, 5, 6 weeks). The regeneration medium (190-2 with 0.5 mg/l NAA and 0.5 mg/l kinetin) was the same for all variants. Next plantlets were transferred to Erlenmeyer flask with rooting medium (190-2 with 2 mg/l IAA). After acclimatization plants were grown to maturity in the greenhouse.

In our study, we cultured 7200 anthers on induction media. The androgenesis in anther cultures resulted in the formation of 15 to 43 green depending on media variant. The highest number of regenerants was found in the case of media: M5 (3.69 regenerants per 100 anthers), M7 (4.13), M8 (3.85) and M9 (5.50) supplemented with 10 μM of $CuSO_4$ and 2-10 mg/l $AgNO_3$. The number of green regenerants was almost double the the number of regenerants achieved under conditions without these ingredients (2.24). The optimum time of induction process was 5 weeks when observed the highest frequency of green regenerants per 100 anthers (5.50) was observed.

In summary, the presence of optimized concentrations of $CuSO_4$ and $AgNO_3$ plus the 5 weeks induction process used in triticale tissue cultures may enhance the efficiency of green plant regeneration and reduction of the number of albinos.

Genetic map of triticale based on DArTseq markers

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Keywords: triticale, DArT, molecular marker, genetic map

Triticale *(x Triticosecale* Wittmack) is a relatively young synthetic allopolyploid created by hybridization of wheat and rye within the last 150 years. There is a growing interest in its breeding due to its high yield potential demonstrated under marginal growing conditions and its possible contribution to raising cereal production globally [1]. Triticale is also being considered for hybrid breeding based on cytoplasmic male sterility (cms) Tt or Pampa [2]. Some hybrids were recently released in France (personal communication). However, there is a gap in understanding of the genetic background of cms in triticale. It is not known how many genes participate in pollen sterility preservation and pollen fertility restoration in both cms systems, as well as their precise location, and putative function is not evident. Thus, genetic maps based on specially designed mapping populations are required to identify QTLs responsible for the trait and allowing the identification of molecular markers useful for MAS.

The first genetic map of triticale-based on DArT, SSR and AFLP markers was described by Tyrka et al. [2011]. Later Alheit et al. (2011) presented a triticale map based exclusively on DArT markers. The maps were not based on hybrid materials and could not be applied for studies of genes conferring pollen sterility/fertility trait in cms Tt. With the development of Next Generation Sequencing technologies highly saturated genetic maps based on RILs could be evaluated.

HT352 x Borwo RIL6 mapping population encompassing 182 individuals was genotyped with DArTseq. The genetic map was constructed using MultiPoint UltraDense commercial software. There were 563 (6446) DArTseq skeleton (total) markers on the map. It has 23 linkage groups with the shortest spanning over 2,93 and the longest over 224,28 cM. On average, the markers were distributed every 1,82 cM. Despite the high saturation of the maps, some gaps were also present. The largest one was detected in the LG21 and was 42,93 cM long. Due to the way parental forms of the mapping population were selected it could be used for the identification of pollen sterility and pollen fertility QTLs for further breeding purposes.

The effect of medium composition on somatic embryogenesis from mature embryos of triticale cultivars with various resistance to Parastagonospora nodorum

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Keywords: triticale, embryogenic callus induction, plant regeneration, mature embryos, Parastagonospora nodorum blotch

Triticale is an important cereal crops grown under a wide variety of climatic and agricultural conditions around the world. Fungal pathogens, especially *Parastagonospora nodorum*, represent the most relevant biotic stresses for cereal. *P. nodorum* this pathogen reduces the assimilative area of plants with adverse effects on quantity and quality of grain yield. High level of resistance of triticale cultivars to the above pathogen is a rare feature. The purpose of the study was to support conventional methods of resistance breeding using the biotechnology tools of somatic embryogenesis. This study was undertaken to improve callus induction and plant regeneration from mature embryos of five triticale winter cultivars varying in resistance to *P. nodorum*. In the first part of this research, the influence of three types of auxins [2,4 dichlorophenoxyacetic acid (2,4-D); 3,6-dichloro-o-anisic acid (dicamba);1-naphthaleneacetic acid (NAA)] and the effect of maltose vs. sucrose were evaluated. The phenotypic assessment of *in vitro* culture was tested on the basis of the percentage of producing embryogenic callus and plant regeneration. The results demonstrated relatively high embryogenic potential of all winter triticale cultivars used in the study. Inducing media with dicamba and sucrose have a role in embryogenic callus growth but the highest efficiency of plant regeneration was obtained on a medium without auxins. The results of this study can be applied to triticale mature embryo culture for breeding, transformation and other biotechnological objectives.

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Genetic characterization of triticale doubled haploids

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Keywords: triticale anther culture, doubled haploids, genetic heterozygosity, molecular markers

Androgenesis is the process of induction and regeneration of haploids and double haploids originating from male gametic cells. Due to its high effectiveness and applicability in numerous plant species, this process has an outstanding potential use in plant breeding and commercial exploitation of doubled haploids (DH). Using DH production systems, homozygosity is achieved in one generation, eliminating the need for several generations of self-pollination. However, androgenesis can be highly stressful and thus lead to different genetic and epigenetic changes in derived plants. In order to avoid heterozygosity, distinguishing between desired doubled haploids and redundant heterozygous diploids are important. Nowadays, DNA markers are commonly used for homozygosity testing and assessment of plant origin. The aim of the study was to evaluate genetic variation of 27 double haploids obtained through *in vitro* anther culture (5 parental DH lines and 22 derived from them) using ISSR and *Vrn* allele-specific molecular markers. Fourteen ISSR markers were tested and five of them (UBC811, UBC808, UBC856, UBC807, ISSR17) were shown as high polymorphic relating to triticale genotypes. The percentage of polymorphism across the triticale lines ranged from 80.0 to 95.0 %. According to ISSR-analysis the majority of DH lines derived from one line showed high genetic similarity. In particular, 16 doubled haploids originated from one line DH-27-1-08-1 grouped in one cluster. However, significant differences were depicted among some lines. In particular, DH-(7-16)-1-11-1 and its "parental" line DH-50-1-08-2 (on the basis of which DH-(7-16)-1-11-1 was originated) were placed in different clusters of a phylogenetic tree. Allelic variation in *Vrn*-genes was analyzed using allele-specific DNA markers. Two alleles (*Vrn-A1a* and *vrn-A1*) were detected at *Vrn-A1* locus and three alleles (*Vrn-B1a*, *Vrn-B1c*, and *vrn-B1*) were found at *Vrn-B1* locus. All double haploids carried the recessive allele at the *Vrn-B3* locus. This analysis revealed that two lines DH-31-1-08-1 and DH-(7-16)-1-11-1 were not completely homozygous. Heterozygosity in the line DH-31-1-08-1 is apparently due to somatic rather than androgenetic origination. However, this explanation is not applicable to DH-(7-16)-1-11-1, because this double haploid carried alleles *Vrn-B1a* and *vrn-B1*, while the original line DH-50-1-08-2 contained the *vrn-B1* allele only. Therefore, the occurrence of heterozygous forms could be explained by somatic rather than androgenetic origination and may be due to somaclonal variability that takes place during *in vitro* cultivation.

Phenotypic variability for glaucosity in Romanian triticale germplasm

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After many decades of breeding, triticale has become a higher biomass and grain yield producing crop than wheat. Triticale inherited a better resistance to abiotic stresses, such as heat and drought, from its rye parent. Some traits like: a good stand establishment of the crop, early growth in the spring, a better growth at the low temperatures than wheat and the high albedo of canopy, resulting from plant glaucosity, generate the superior performance of triticale despite unfavorable weather conditions resulting from global climate change.

The present study is focused on characterization of glaucosity in the Romanian triticale germplasm tested in advanced and preliminary trials and the relationship between albedo, assessed by glaucosity of the plant and the yield of 13 genotypes, sown as normally and later than usual, across three experimental years (2013-2015).

The range of glaucosity among the 249 genotypes analyzed was large, but the most of them exhibited a medium or high level of glaucosity, with the exception of a few genotypes (8%) characterized by rather low glaucosity. It is of interest to note that all the triticale varieties tested in Romania, which originated from countries located in humid areas of Europe, were characterized by a low glaucosity. These findings suggest that high glaucosity may be associated with the selection of genotypes for high performance under temperate climate conditions of low rainfall and frequent periods of drought and heat stress during the vegetation period.

Our data for yield performance of 13 Romanian triticale varieties, tested in three years, in two different conditions, normal and late sowing time, show the advantage of the more glaucous genotypes. The later sowing time was chosen, in order to assess the yield performance of genotypes when the growth of plants is delayed, such as when weather conditions do not permit sowing at the usual optimal time. With late sowing, lower biomass is achieved and it is of interest whether more glaucous genotypes achieve a higher yield than genotypes of lower glaucosity. The correlation between yield obtained in normal and late sowing times, indicated such a classification of genotypes and also that the short straw varieties tend to have a higher level of glaucosity in the late sowing than taller types.

The relationship between yield, in normal and late sowing and the degree of glaucosity, show the same trend but the correlation was stronger in the late sowing time. In the stress conditions, with low biomass, the influence of glaucosity seems to be greater. The late sowing, simulating an autumn drought, could be a technological measure to induce a low biomass within genotypes tested and to assess their response to frequent drought and heat stress occurring in the next part of the vegetation period.

Recent changes in temperate climate conditions have been experienced in Romania, increasing the length of the drought period in the spring and drought and heat periods during grain filling. In such conditions, selection of triticale genotypes of high glaucosity, is considered a useful tool to improve the level of yield and yield stability.

Evaluation of response to leaf and stripe rusts in Romanian winter wheat and triticale germplasm

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Leaf rust caused by *Puccinia triticina f. sp. tritici* is the most prevalent disease from the rust complex in wheat areas across Romania, but impact of *P. striiformis f. sp. tritici*, in favorable conditions for development of attacks, also produces significant damage. When triticale was introduced to our agriculture, varieties expressed a high level of resistance to disease but with increase in the area sown in the regions less favourable for wheat, occurrence of susceptibility to rusts is to be expected and quantified. For instance, in 2014, under unusual cool and wet spring weather conditions, heavy attacks of powdery mildew and yellow rust on triticale varieties was first reported**.** To face the current challenge of increased demand for food supply under the influence of global climatic change on pathogen evolution, erosion of race specific resistance gene(s), narrowing the variability for resistance, development of new germplasm with improved resistance remains the most reliable, cheapest and most environment friendly strategy to control diseases in these important staple food crops. Hence, at NARDI Fundulea, screening of resistance to rusts represents an objective of utmost importance in wheat and triticale breeding. In wheat, the varieties released in recent decades are generally characterized by adult plant resistance (APR), conferred mainly by the presence of *Lr34* resistance gene, molecularly validated. A research project to introduce other pleiotropic adult plant resistance (PAPR*)* genes, such *Lr46* and *Lr67* into adapted wheat lines, but less susceptible to leaf rust is in progress. The aim of this study is to characterize, under artificial inoculation with current pathogenic isolates, the level or resistance to leaf and stripe rusts in modern Romanian and foreign wheat and triticale germplasm. The response to leaf rust under artificial field inoculation has been evaluated in 255 wheat and 208 triticale genotypes. According to these results a higher vulnerability to local leaf rust isolates originated from wheat, was found in wheat genotypes, as compared to those of triticale. The values recorded for severity of leaf rust attack (%), ranged from 0 to 100% (47% of susceptible spreader, on average) in wheat and between 0 and 50% (10% of susceptible spreader, on average), in triticale. Inoculations performed with *P. striiformis,* previously isolated from naturally infected plants revealed in triticale a large variability of severity, ranging from 1 (very resistant) to 9 (very susceptible) (4.0 on average), while the frequency of attack was 40.4% (N=220). In comparison, wheat genotypes were characterised by a relative lower frequency of attack (F=22.0%, N=150) and severity (Severity=1.4%, on average). Results registered in the present study regarding the response to leaf and stripe rusts in wheat and triticale, could be determined by differences of virulence in the experimental pathogenic isolates, but these findings need to be confirmed in a further research, based on *Lr* and *Yr* gene differentials. Future approaches in breeding of wheat and triticale include a more systematic marker assisted selection (MAS) for partial resistance type against both rusts with a higher emphasis on searching for reliable sources of resistance to stripe rust in triticale.

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Initial material of winter triticale for breeding of winter hardiness varieties

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Keywords: winter triticale, winter hardiness, frost tolerance, yield capacity, facultative varieties

Yield stability of winter crops is essential to the economies of many countries. Due to good adaptability, which is determined by winter hardiness, drought tolerance and disease resistance, winter triticale gives 20% more stable yields compared with wheat sown immediately following corn, soybean or sunflower crops; on poor soils; and with late sowing dates. The combination of high adaptability, yield capacity and grain quality is a key issue in winter triticale breeding. The evaluation of new varietal diversity from Ukraine, Russia, Belarus, Poland and other countries in terms of frost tolerance with freezing under controlled conditions in frost chamber revealed the amplitude of tolerance from 2.5 to 8.5 points at the critical freezing temperatures from –13.5°C to –19.0°C. A wide range of variability requires careful assessment during selection of varieties for production and breeding.

In the forest-steppe, varietal composition of winter triticale bred in Ukraine is represented mainly by highly frost-tolerant genotypes (7-8 points): *Raritet*, *Amos, Nikanor, Shalanda, Chornobryvets,* and *Obriy Myronivskyy*. Facultative varieties *Pidzymok Kharkivsky, Yaroslava* and *Khl 2-8* were created for planting after corn and soybean on late dates. When sown within the usual timeframe in autumn, they cannot develop high winter hardiness. For good overwintering and accurate assessment of their frost tolerance, later sowing dates are required: the first or second week of October in Kharkiv region. Accessions *Sonet, Sirs 57, Tsekad 22* and others created in the conditions of Stavropol Territory, Siberia (Russia) also can be used in breeding as sources of frost tolerance. Their frost tolerance reaches 8.5 points; the critical freezing temperature is –19.0°C; level of overwintering 92-100%. Climatic changes lead to instability of conditions in the overwintering period. There are sharp temperature shifts causing thaws. Snow cover in winter forms and melts 3-4 times. In such circumstances, it is important to have triticale with increased resistance to snow mold (*Fusarium nivale (Fr) Ges., F. culmorum Sacc., F. graminearum Schwabe*). Varieties *Shalanda, Raritet* and *Amos* (Ukraine) have such features. *Nikano, Etel, Markiian* (Ukraine)*, Svyatozar, Kapral* (Russia) and *Mayak* (Belarus) are noticeable for intensive spring regeneration.

All the above-mentioned winter triticale accessions combine high adaptability to biotic and abiotic factors and yield capacity. Under optimum conditions, they give grain yields of 8-10 t/ha.

First transgenic triticale is already over 20 years old

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Keywords: transgenic triticale, transgene stability

In 1995, first transgenic triticale plants expressing *bar* gene and *uid*A gene were reported (Zimny et al. 1995). Since then many studies were performed on this triticale. We examined the location of the introduced foreign genes on chromosomes in various transformation events. The position of T-DNA insertion appeared to be random within the nuclear genome. In four independently transformed lines T-DNA insertion sites were mapped by in situ hybridization to four different chromosomes in 3 different genomes (Pedersen et al. 1997).

The segregation pattern of the *bar* and *uid*A gene in different plants, measured by herbicide application or x-gluck test was not always the expected one.

Transgene expression was often unstable, as we observed a decline of the gene expression in following generations. To stabilize transgenic lines, double haploids were regenerated via androgenesis. These lines were used as pollen donors to study outcrossing rate of Triticale. Based on the results on pollen flow, as well as experiments on outcrossing, we came to the conclusion that the range of pollen flow exceeds the distance of outcrossing in triticale by many times (Zimny et al. 2013). We selected also pairs of isogenic lines that differ by the presence of the inserted sequences only.

Comparative studies are one of conditions for the assessment of risks associated with the introduction of GMOs into the environment. The analysis of the metabolome of triticale grain from lines containing the transgene was carried out using FTIR spectroscopy. No differences in the regions of the spectral characteristic of fatty compounds, phenolic compounds, proteins, and in the fingerprint region has been recorded.

After 23 years of experiments it can be concluded that for such a long period of time transgenic lines were stable for the introduced genes and represent an excellent experimental material for variety of basic as well as applied research.

SESSION II.
CROP MANAGEMENT AND AGRONOMY RESEARCH

Session chair: Gheorghe Ittu

A further expansion of the growing area of triticale needs an increase in input-response efficiency

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To date triticale is a well known small-grain cereal and with a yearly production of more than 17 million tons in 37 countries it is a well-established crop in many agricultural regions worldwide. Its reliability and magnitude of production on all soil types especially under conditions in which other crops perform poorly as well as its versatility in use (food, feed, forage, etc.) encourage farmers to grow triticale. Nevertheless with the increasing acreage of triticale and the frequent presence of triticale in farmers cropping systems more cultural problems came up.

As triticale would remain competitive compared to other cereals under a broad range of growing conditions input of new productive and robust varieties are essential. New test methods are necessary to screen new genotypes efficiently for characteristics as drought and disease resistance.

Due to climate change drought becomes more and more an issue worldwide. Drought tolerance will become an important varietal characteristics even in regions with a moderate climate as NW Europe. Mitigation of the genepool of triticale to genotypes with a better water use efficiency will be necessary.

Triticale became more vulnerable to diseases during the last decade. Since the end of the ‘90 many genetic backgrounds showed an increased susceptibility to powdery mildew while the last 5 years triticale became as susceptible to stripe rust much as wheat. Besides the incorporation of broad acting resistance genes new strategies to control diseases in triticale (e.g. cultural as well as adequate fungicide treatments) impose to safeguard the production level of triticale at an economic acceptable level.

Introduction of dwarfing genes in the genetic background of many triticale varieties reduced triticale’s competitiveness against weed population significantly. Especially in more intensive cropping systems with a high ratio of small-grain cereals the use of herbicides is desirable. But very often herbicide combination from wheat can’t be adapted as such in triticale. Screening for selectivity is needed even on varietal level.

An adequate uptake of nutrients is important in each cropping system. In many systems phosphorus is and becomes more and more an issue. In many soils P uptake is blocked through interaction with calcium and iron ions while in many NW European countries P input is limited by legislation. Also a more nitrogen uptake efficiency is necessary to reach an acceptable economic yield level without leaching and running off too much nitrate to ground – and/or surface water respectively.

Triticale has potential as forage crop including grazing and fodder for preservation. Crop husbandry measures as well as intercropping of triticale with legumes can increase feed quality. In many countries the interest in triticale is growing as forage crop. Especially organic growers will use triticale as fodder crop.

Evaluation of yield and water-holding capacity of straw from triticale and wheat

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Keywords: triticale, wheat, straw, water-holding capacity

Traditionally straw is used as forage or as bedding material in animal production. Straw has a high absorbing power and is not expensive compared to other bedding materials making it ideal for litter housing systems. Straw yield is affected by many environmental and cropping factors, such as water availability, fertilization, seeding density, seeding date and crop protection measures. In addition, the genotype might determine the straw yield potential. Therefore, different cereal cultivars will have different straw yields.

Despite the numerous positive aspects of triticale, the interest of Belgian farmers in triticale is low. This reserve is amongst others fueled by the assumption of triticale straw having a lower water-holding capacity compared to wheat straw. Research has shown that the water-holding capacity of straw, is mainly determined by the harvest- and preservation techniques (Deininger et al. 2000).

For two successive growing seasons yield and water-holding capacity of straw from wheat and triticale cultivars was collected at the experimental farm of Ghent University and University College Ghent.

Four triticale and four wheat cultivars, two with short straw type and two with long straw type, were selected with a high yield potential and a low disease susceptibility. The selected wheat cultivars were Elixer, Henrik, Sokal and Sahara. The triticale cultivars were Borodine, Vuka, Joyce and Remiko. Both wheat and triticale varieties were grown on the same field in a randomized block with cultivar as the treatment and crop husbandry measure as the blocking factor. The dry matter content of the straw was determined immediately after threshing the grains, 24 and 72 hours later. After 72 hours the straw yield and water-holding capacity was measured.

For both growing seasons the triticale varieties resulted in a significant higher straw yield compared to the straw yield of the wheat varieties. The water-holding capacity of the triticale straw was higher or at least at the same level as the water-holding capacity of the wheat varieties.

Rotational diversity effects in a triticale-based cropping system

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Keywords: triticale, wheat, canola, peas, crop, competitiveness

A study was conducted at four locations across AB and SK, and one location at Normandin, QC from 2008 to 2013. The objective of this study was to determine the effect of cropping sequences of varying levels of diversity including continuous triticale and triticale grown in combinations with wheat, oats, canola, pea, and intercropped combinations. An analysis without Normandin data indicated that triticale yield, seed mass, test wt., and protein concentration was less for a continuous triticale, cropping sequences including triticale and a cereal, and triticale that is intercropped when compared with more diverse cropping sequences. Triticale grain yield responses were as follows: continuous triticale, triticale-cereal, and triticale intercropped with pea yielded 3.5 t ha^{-1} < triticale-pea yielded 3.6 t ha^{-1} < triticale-canola and canola-triticale-pea yielded 3.9 t ha^{-1}. Moreover, along with improved yield the canola-triticale-pea yields were more consistent than other treatments. Triticale biomass yield was greatest for canola-triticale-pea (11.4 Mg ha^{-1}) compared with other less diverse triticale cropping sequences (1.1 Mg ha^{-1}). Weed biomass was not affected by cropping sequence and cropping sequence effects were relatively more variable among sites for grassy weeds. Analysis of data from Normandin only, revealed cropping sequence effects, with one exception. Triticale grain yield for continuous triticale and triticale-triticale-canola (2.8 t ha^{-1}) was less than the triticale-pea and triticale-oat (3.1 t ha^{-1}) sequences, with intermediate yields for the other cropping sequences. Canola yield and other selected canola responses were not affected by the cropping sequence.

The research was supported by Agriculture and Agri-Food Canada's Agricultural Bioproducts Innovation Program (ABIP).

Effect of meat and bone meal (MBM) and composted slaughterhouse wastes on triticale yield and element composition

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Keywords: animal waste compost, meat and bone meal (MBM), triticale, fertilizer

The use of animal wastes as organic fertilizers has been a proven practice for a long time, although currently it is permitted only under controlled conditions to prevent the spread of infections and diseases. After heat sterilization, the wastes originating from animal bodies are excluded from the scope of hazardous materials, which creates an opportunity for further processing, e.g. composting, drying, grinding, granulation. Wastes and sewage sludge of animal production and meat industry become utilizable with this process. These products are also suitable for agricultural land application as organic fertilizers or soil amendments.

In order to study the effect of such materials, field experiments were set up in Őrbottyán, Hungary on calcareous sandy soil in 2002. Three different slaughterhouse waste composts as well as a meat and bone meal (MBM) were applied in five different doses (0, 25, 50, 100, 200 $t \cdot ha^{-1}$ fresh compost or 0, 2.5, 5, 10, 20 $t \cdot ha^{-1}$ MBM) on a single occasion in the first year, thus residual effects were studied in the subsequent years. The composts increased organic matter, total N, P, S and Zn contents of the soil. Increasing rates of MBM resulted in elevated NO_3-N and NH_4-N contents in the ploughed layer. Triticale (*X Triticosecale* spp.) was grown in the experiment from 2004 to 2010.

In the favourably wet year of 2004, the residual effect of the 200 t ha^{-1} dose of mature and immature compost resulted in 1.6 and 9.0 t ha^{-1} above-ground yield increase, respectively. Semi-mature compost and MBM, applied in November 2002 increased triticale biomass 1.5-2.0-fold in 2004. Effects were lower in subsequent years, but immature and semi-mature composts significantly increased the grain yield even 7-8 years after its application. Depending on their composition, the applied materials had different effects on the element content of triticale. Mature compost decreased Na and increased Mo concentration of the triticale straw and grain. In case of immature compost, incorporation of Ca, Mg, Na and Sr declined, while that of Cu rose with the application rate. Semi-mature compost stimulated the uptake of N, K, S in both grain and straw as well as Zn and Fe in grain. MBM significantly increased N and K contents in the straw as well as N and S in the grain of triticale.

The research was supported by ATEVSZOLG Co., Hungary

Studies on the value of triticale cultivars for organic farming in Poland

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Keywords: triticale, organic farming, grain and biomass production

Triticale (*Triticosecale* Wittmack.) has a very large role in Polish agriculture. Poland is a world leader in cultivation of triticale. Currently, the area of triticale in Poland is about 1.3 million hectares. Winter triticale occupies 1 million ha, and spring triticale about 300 thousand hectares. Triticale is mainly used as animal feed. Its grain is used in the feeding of poultry and other monogastric animals. The advantage of triticale grain over other cereal grains is its relatively higher protein content with preferred amino acid composition, which results in its high nutritive value. Triticale can be grown on lighter soils and lower pH, which predominate in Poland. Triticale produces relatively high biomass. Under Polish conditions, biomass of triticale can be a valuable source of bulk feed in the form of silage, hay for feeding ruminant animals.

The aim of the research, performed in 2014-2015, was to determine the suitability of triticale varieties for cultivation on organic farms, both for grain and biomass. Materials used were 9 varieties of triticale, registered in Poland. The trials were established at two locations: Radzików and Chwałowice, on certified organic fields. During the growing season the resistance to major fungal diseases was determined. In addition, some agronomic features such as heading date, resistance to lodging and plant height, were described.

After harvest the following parameters were determined: grain yield, grain moisture, TKW and hectolitre weight. Also, grain chemical composition was appreciated (protein, fat and ash contet) as well as the presence of ergot alkaloids and *Fusarium* fungi infestation. Mycotoxin content in grain (DON – deoxynivalenol, NIV – nivalenol, ZEA – zearalenone) was determined. In the biomass trial, total yield, yield and content of dry matter were determined. Chemical analysis of biomass, (protein, fat, crude fiber content) was performed.

The research was supported by The Polish Ministry of Agriculture and Rural Development in the frame of Organic Farming Support

Comparison of agronomic characteristics and disease resistance of four F2 hybrids of triticale and their parents

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Keywords: Triticale, hybrids, heterosis, agronomic characteristics, disease resistance

Resistant varieties to Fusarium Head Blight and Septoria Tritici Blotch are among the main objectives of the cereal breeding program at the Université de Lubumbashi where experiments on small grain cereals are conducted to find varieties with good performance. This study is based on the comparison of morphological and agronomic characteristics of four F2 hybrids of Triticale (*X Triticosecale*) obtained during 2013 and their parents. Results indicate that the manifestation of heterosis in F2 hybrids appears for some characteristics such earliness, plant height, spike length and thousand kernel weight and number of spike per m². There is also a better expression of disease resistance in F2 hybrids.

Characterisation of the weed suppressive potential of winter cereal cultivars: the role of above-ground competition versus allelopathy in wheat, triticale and rye

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Keywords: IPM, benzoxazinoid, competition, *Triticum aestivum*, *Triticosecale, Secale cereale*

Current weed management practices in Northern Europe are based primarily on the use of effective herbicides but an increase in the number of herbicide resistant weed phenotypes and a complete lack of new modes of action have led to an urgent need for more integrated weed management tactics. A better understanding of crop-weed interactions would help to achieve this goal. Hence, we studied the weed suppressive potential of 72 commercial cultivars of winter wheat (*Triticum aestivum*), winter triticale (*Triticosecale*) and winter rye (*Secale cereale*) with a specific focus on the relative contribution of above-ground competition and allelopathy. As an indicator of allelopathic potential (AP), the quantity of twelve secondary plant metabolites belonging to the chemical group of benzoxazinoids (BX) were analysed in root and shoot tissue of 33 wheat, 11 triticale and 28 rye cultivars. The total content in root and shoot tissue differed significantly between species with rye containing the highest levels of BX, followed by triticale and wheat with the lowest levels of BX. In addition, the proportion of the twelve BX differed significantly between the species, with rye having the highest levels of non-methoxy-substituted BX and triticale with the highest levels of methoxy-substituted BX. Investigated traits related to above-ground competitive potential (CP) were plant height, ground cover before canopy closure and leaf area index of the cereal cultivars. No stable correlation between AP and CP could be identified and therefore cultivars were assigned to 4 groups: high AP and CP, high AP and low CP, low AP and high CP or low AP and CP and arranged according to descending weed suppressive potential. Finally, 4 cultivars of each cereal species, representing each combination of weed suppressive potential, were chosen for further trials studying their actual weed suppressiveness in the presence of weed.

The effect of Gérce alginite and nitrogen application on triticale yield and element composition in a field trial set up on an acidic sandy soil

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Keywords: alginite, triticale, soil amendment, field experiment

Alginite is an oil shale rock discovered and mined in many places throughout the world. However alginite in the Carpathian Basin has its own composition in unique quality. It is suitable for direct agricultural application. The largest mine is located in Gérce, Hungary. Preliminary studies showed significant positive effects of Gérce alginite on soil qualities and on crops. Our hypothesis was that due to its weakly alkaline pH, significant amounts of Ca, Mg, K, S, P contents and its clay fraction, alginite will improve the quality of the acidic sandy soil studied, thus it will increase the yield and affect the composition of triticale.

The experiment was set up in the framework of one of the oldest long-term field experiments in Hungary, in Nyírlugos on acidic sandy brown forest soil. The soils of the selected plots received four different N doses: 0, 50, 100, 150 $kg \cdot ha^{-1} \cdot year^{-1}$ N applied continuously for five decades, thus the plots were acidified and depleted in Ca, Mg, K, P elements. Alginite was applied in a 100 t/ha dose once at the beginning of the experiment in 2011 autumn. The alginite contained 15% moisture, 15% $CaCO_3$ and 4.6% organic material, as well as 0.15% N, 386 $mg \cdot kg^{-1}$ AL-K_2O, 216 $mg \cdot kg^{-1}$ AL-P_2O_5 macro nutrients and 5% Ca; 3.6% Al; 2.9% Fe; 1.9% Mg; 0.82% K; 0.15% P; 0.12% S elements. With the 100 $t \cdot ha^{-1}$ dose, 4.2 t Ca; 3.1 t Al; 2.4 t Fe; 1.6 t Mg; 694 kg K, 128 kg P, 105 kg S per hectare was loaded into the ploughed soil layer.

As it was expected, alginite application caused physical and chemical improvement of soil which was followed by higher yields. With the application of alginite, grain yield and above-ground biomass weight almost doubled in the first year, 2012. The effects were lower, but still significant in 2013, when grain yields remained below 1 $t \cdot ha^{-1}$. Since no chemical weed control was applied in the experiment between 2012 and 2014, air-dried weed mass was approximately 50% of the triticale above-ground air-dried weight at harvesting in 2013. The year 2014 was favorably wet. Due to the application of both N + alginite, the grain and straw yield of triticale increased 5-fold, reaching 10.5 $t \cdot ha^{-1}$ air-dried biomass on the 150 $kg \cdot ha^{-1} \cdot year^{-1}$ N-treated plots. Air-dried weed mass was slightly increased by alginite. In 2015 N-fertilization increased, while alginite treatments slightly decreased the yields, since fungal infection was more pronounced on those plots. Alginite treatment increased Mg, Mo and reduced Mn, Zn, Ba content of triticale grain. Ca, Mg, S, Mo concentration increased in straw, while incorporation of Mn, Zn, Ba, Cu, Ni, Co elements was inhibited by alginite.

The research was supported by Alginit Ltd., Hungary.

Hungaro durumrye – the first food triticale variety

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Keywords: human consumption, triticale, Hungaro durumrye

'Hungaro durumrye' is the first food triticale variety that combines favorable qualities of parent species durum wheat and rye, and it also has properties of food wheat. The method used with the breeding of *Hungaro durumrye* – crossbreeding of secondary hexaploid triticale varieties – makes the recombination of properties possible, as a result of which a high number of different hybrids are created. With this method, it is possible to improve the flour quality and bakery properties of the triticale, since the secondary hexaploid triticales may also have genes from the D-genome of the hexaploid *Triticum aestivum*. With the help of mcGISH technique, 14 rye chromosomes could be detected from the 42 chromosomes of *'Hungaro durumrye'*. Whole chromosomes or segments of the D genome could not be observed. During testing chromosomes in mitosis/metaphase, it may be that the size of the translocated segment falls beyond the sensitivity limit of the mcGISH. The name *'Durumrye'* was initiated by the breeder. The National Food Chain Safety Office (NÉBIH) that performs Varietal Certification issued a resolution about the use of name, which made it possible to name and distribute it under the name of *'Hungaro triticale'* variety *'Hungaro durumrye'*. Later the 'Hungaro Durumrye Ltd.' (www.hungaro-durumrozs.hu) was established for the human use of the '*Hungaro durumrye'* variety. The gluten content of '*Hungaro durumrye'* is 25-28% and its flour quality is suitable for milling (B1, B2). Its protein content is the same or higher than that of wheat, and the amount of essential amino acids is also higher. It has higher phosphorus, potassium, copper, magnesium and zinc content than wheat. '*Hungaro durumrye'* has twice the E, B1, B2 and B4 vitamin content than wheat. Its nutrition-physiological importance is enhanced by having double the dietary fiber content compared to wheat flour, and its total carbohydrate content approaches 10% lower, which suggests a lower energy content. The white and whole grain flour of *'Hungaro durumrye'* has an increasing popularity among consumers, bakers, pasta producers and confectioners. The uniqueness of its products lies in their distinct, unique and delicious taste. The production and distribution of *'Hungaro durumrye'* organic-flour and bakery products and pastas made from it have already started. The excellent resistance qualities and weed suppression ability of this variety allow it integration into organic production. This variety also has outstanding winter hardiness and drought resistance. Its yield potential reaches that of the best standard fodder varieties and its ripening period is also the same. *'Hungaro durumrye'* offers new possibilities to increase environmental friendly food grain production and to produce healthy food products.

‘Quirinale’: a new winter type triticale variety

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Keywords: triticale, breeding, variety

ENEA has always dedicated effort to the breeding of cereals, among which triticale. Research activities carried out aim to obtain new, higher yielding varieties, with improved nutritional traits and increased biomass production, thus representing a valid alternative to oats and barley, both for livestock use and for the production of alcoholic beverages and bio ethanol. In addition, high quality triticale genetic material could be exploited as ingredient in the food industry for the preparation of innovative health value added food products. In 2006, approximately 100 spike progenies were collected from the plateau of Leonessa in Central Italy at an altitude of 1000 m a.s.l., after being subjected to selective pressure by biotic and abiotic stresses for over 20 years. The original batch went through various cycles of selfing and was gradually reduced to 15 lines, maintaining those proving stability of the phenotypical traits, and characterised by higher number of kernels per spike and better resistance to different biotic and abiotic stresses. Selected lines were crossed between themselves and the obtained material was further evaluated in collaboration with ISEA srl, an Italian seed company, applying the pedigree method. Following test plots, three of the newly obtained lines resulted the top yielders with productivity around 7t/ha, quite higher when compared to the best performing commercial variety ‘Agrano’ used in the trial, that was limited to 5.9 t/ha. Among these, one line (n°14) was proposed to the Italian authority responsible for the registration and maintenance of vegetal varieties for evaluation. During two years of agronomic evaluation, our line scored an average yield around 6.00 t/ha, about 10% more compared to the commercial varieties, (namely ‘Catria’ and ‘Bienvenue’) utilised by the authorities for a comparison. Results obtained allowed the registration of line n° 14 with the name ‘Quirinale’ as a new variety at the National Varietal Italian Registry (2013 co-ownership ENEA/ISEA). ‘Quirinale’ is a winter type variety, around 120-130 cm tall, characterised by prostrate growth habit, showing resistance to abiotic and biotic stresses. ‘Quirinale’ has no limitations with regard to the area of cultivation. Its fields of application may be different, from animal husbandry, both for the composition of feed or as fodder, to biomass for biogas production. Besides the success achieved with ‘Quirinale’, more triticale lines are still under study aiming at a combination of high homozygosity level and good productivity. The registration of a high yield high quality variety as ‘Quirinale’ will provide an important contribute to promote the expansion of the cultivation of triticale in Italy. Thanks to the higher content of protein and essential amino acids (lysine and threonine) compared to other cereals, a new scenario is opening for this crop, with the perspective of its use being adopted by the bakery and pasta making industry. However it should be noted that the cultivation of triticale will become economically sustainable only when its yield will exceed those of common and durum wheat by 10% and 30% respectively.

Productivity of hybrid triticale depending on nitrogen fertilization doses

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Keywords: hybrid triticale, yield, yield components, nitrogen fertilization, protein content

The main purpose of breeding is to create cultivars which are superior to those currently available. For this purpose, new breeding methods are being searched for. One method is breeding hybrids. One of the key issues for the spread of hybrid cultivation is the need to identify their requirements for agricultural production. Such studies, with a view to determine the impact of the level of nitrogen fertilization on the yields and characteristics of hybrids of winter triticale were carried out in the Agricultural Experimental Station in Kępa, on the Osiny farm in the years of 2013/2014 and 2014/2015. The studies included the following hybrid cultivars: DAST 22/11 F1, CM 12/10 F1, SM 4/11, which were compared against population bred, non-hybrids: *Palermo* and *Wiarus*. Three rates of nitrogen were used: 60, 120 and 180 kg N ha^{-1}, and a control treatment without nitrogen. The studied cultivars differed in terms of yields. The highest yields were recorded for CM 12/10 F1 – 11.3 t/ha, followed by *Wiarus* – 11.2 t/ha, SM 4/11 – 9.9 t/ha, *Palermo* 9.9 t/ha, and DAST 22/11 – 9.4 t/ha. The lines responded differently to the amount of the applied nitrogen.

DAST 22/11 F1 hybrid yielded the highest under the dose of 60 kg N ha^{-1}. Increasing nitrogen rate up to 120 and 160 kg N ha^{-1} caused the decrease of yield levels. CM 12/10 F1 and SM 4/11 F1 hybrids yielded similarly in each studied treatment. Population cultivars: *Palermo* and *Wiarus* yielded the highest under 120 kg N ha^{-1}.

The highest 1000 grain weight was recorded for hybrid – DAST 22/11 – 49.14 g, while the lowest *Wiarus* – 36,7g. There was an interaction between a variety and nitrogen dose in the development of the number of ears. In hybrid DAST 22/11 F1, the highest number of ears was produced from treatments using the smaller amounts of nitrogen: 60 and 120 kg N ha^{-1}, respectively, 640 and 643 ears per m^2. In contrast, CM 12/10 F1 and SM 4/11 F1 hybrids increased number of ears under higher nitrogen rates – 120 and 160 kg N ha^{-1}. For population cultivars, the number of ears per unit area was higher for *Wiarus* than for *Palermo*.

Increasing the dose of nitrogen increased the grain protein and amino acid content. The grains of hybrid DAST 22/11 contained the highest proteins content. Under 180 kg kg N ha^{-1}, the amount of proteins was 13.0%. *Palermo* provided the lowest grain protein content, of 11.5%. Hybrid DAST 22/11 F1 had the highest amino acids content in its grains.

Evaluation of yield stability of triticale genotypes in three environments of northern Tunisia

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Keywords: triticale, grain yield, genetic variability, chemical and stability

Triticale (X *Triticosecale* Wittmack) is, in general, highly productive and may have better disease resistance than other cereals. These are some of the reasons for the increasing interest of farmers for this synthetic crop species in Tunisia. Driven by the demand of adapted cultivars for Tunisia, we have studied the yields and yield stability of seven triticale genotypes from CIMMYT and three local checks. This has been done for three cropping seasons 2012/2013 to 2014/2015 at three locations in North Western Tunisia representing sub-humid (Oued-Beja), semi-arid (Oued-Meliz) and humid (Sedjnéne) climatic conditions. The analysis of variance (ANOVA) revealed highly significant ($P<0.01$) variations among genotypes, localities and years (environments). Our results showed that genotypes LIRON (4.04t/ha) and POLLMER (4.16t/ha) are high yielding followed by COPI (3.96t/ha) in terms of grain while DIS (13.9 t/ha) and POLLMER (13.1t/ha) produce highest biomass yield. Greater number of kernels per spike (41% and 85%) was obtained in 2014/2015 than 2012/2013 and in the sub-humid (Oued Béja) than in humid (Sedjnène) sites, respectively. Average TKW was higher for POLLMER genotype (48.61g) compared to the other genotypes. Analysis using Eberhart and Russel model showed that variety POLLMER had regression coefficients closer to unity (bi= 2.17) and approached acceptable deviation from regression ($S^2di= 0.93$). Therefore POLLMER is identified as a stable high grain yielding variety with high biomass yield under these three areas of northern Tunisia.

SESSION III.
PHYSIOLOGY, ABIOTIC- AND BIOTIC STRESSES

Session Chair:
Edward Arseniuk

Comparative performance of triticale and wheat genotypes for physiological traits, grain yield attributes and nutrient use efficiency

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Keywords: triticale, wheat, chlorophyll, grain yield components, nutrient use-efficiency

The objectives of the present investigation were to study the comparative performance of hexaploid triticale, bread, durum and synthetic wheat genotypes for various characters. Physiological traits associated with stress tolerance and performance, grain yield attributes and nutrient uptake under low and optimum input conditions were investigated. Genotypic and phenotypic variability among ten genotypes of each group was determined for: chlorophyll content and fluorescence, grain yield and its components and nitrogen, phosphorus and zinc uptake and use-efficiency. The effect of various genomes on expression of traits was compared. Results revealed that the mean squares due to genotypes were significant for all the characters except for spikelets per spike. Genotype × fertilizer (G × F) interaction was significant for majority of the characters in *T.aestivum*, *T. durum*, triticale and synthetics. The triticale genotypes were superior and had higher values than *T.aestivum*, *T.durum* and synthetic wheat for grains per spike {i.e. TL 2937 (54.62)}, spikelets per spike {i.e. TL 2908 (26.16)}, days to heading {i.e. TL 2966 (83.00 days)}, days to maturity { i.e. TL 2937 (128.00 days)}, chlorophyll content { i.e. TL 2968 (54.97)}, chlorophyll fluorescence Fv/Fm ratio { i.e. TL 2963 (0.83)} and nitrogen content in grains { i.e. TL 2967 (2.75 g)} under optimum input conditions, revealing the contribution of the "R" genome and the effect of selection on the expression of important traits. Correlation coefficients revealed that the genotypes having high grain yield also had more tillers per plant, high 100–grain weight, lower plant height and higher harvest index under both optimum and low input conditions. But the correlations of grain yield with grains per spike and biological yield was not similar under both conditions. The grains per spike was an important component of grain yield under optimum input conditions, and biological yield under low input conditions. In general the *T.aestivum* group had the best response followed by synthetics, triticale and durum groups for nitrogen, phosphorous and zinc use-efficiencies, though some durum and trticale genotypes performed better for these traits under low and optimum input conditions. This situation may be due to previous high selection pressure on *T.aestivum* and *T.durum* for fertilizer responsiveness.

Tall tales: the influence of plant height on grain yield of triticale

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Keywords: triticale yield improvement, height, harvest index, canopy conductance

Triticale (X *Triticosecale* spp.) varieties grown in Australia have typically been around 1.2-1.3m tall. Recently, some shorter triticales, nearer 0.8m tall, have been released to growers. These new, shorter varieties do not yield any more than their taller counterparts. To investigate why not, we examined the effects of height on biomass and yield of triticale and of bread wheat using lines ranging in final height from 0.6 to 1.3m.

For the Wheat Trial (consisting wheats under strong selection pressure for yield but varying widely for height) there were strong, positive relationships between height and biomass production at anthesis and also at maturity. Surprisingly, at maturity there was no significant effect of height on harvest index despite a large range in final height and the expectation that harvest index should be considerably lower in taller wheats. Consequently, for wheat, grain yield and height were positively associated.

For the Triticale Trial (consisting triticales varying widely for height but not previously under selection pressure for yield) there were again strong, positive relationships between height and biomass production at anthesis and also at maturity. In these triticales there was a small trade-off between height and harvest index (taller triticales had somewhat lower HI), so there was no association (positive or negative) between height and grain yield, despite the large range in canopy height.

Previously we have observed that tall canopies tend to be cooler, indicating greater canopy conductance which should enable better exchange of CO_2 into the canopy to improve productivity. We tested whether the presence of tall plants projecting above the canopy of a short triticale would help to enhance yield. We grew large (30m x 30m) 'swathes' of a short triticale and the same triticale in a 90%:10% mixture with a taller triticale (no change in final plant number) under irrigated, high-input conditions. We observed a 3% yield gain for the mixture, sufficiently encouraging to repeat the study with more intensive measurements in 2016.

Taken together, the results of these studies indicate that (1) height is a significant driver of greater biomass in modern cereals and that (2) strong selection pressure for yield through harvest index seems to have largely overcome the positive effect on harvest index associated with short stature that was a major driver of the 'Green Revolution'.

The research was supported by the Grains Research & Development Corporation of Australia. Britt Kalmeier, AGT triticale breeder, generously provided seed of advanced triticale lines varying in height.

Impact of drought stress on photosynthetic and fluorescence parameters, yield and root growth of triticale

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Keywords: triticale, drought stress, photosynthesis and fluorescence, yield, root system

Triticale combines high productivity from wheat with good disease resistance and adaptability to marginal environments from rye. Therefore, a high drought stress tolerance is expected from triticale. A drought stress experiment was set up, combining one triticale and two wheat cultivars with different drought tolerance levels. Drought stress was applied during the elongation stage or grain filling stage and control plants received optimal irrigation during the complete life cycle. The main focus of this experiment was to study and compare photosynthesis and fluorescence parameters, yield parameters and root growth between cultivars and treatments.

Data revealed triticale to be least affected by drought stress during both developmental stages. In contrast with wheat, no significant differences between control and stress treatments were detected for net photosynthesis (A_{net}), stomatal conductance (g_s), and chlorophyll fluorescence parameters. Drought stress during the elongation stage had the most impact on the number of productive shoots, grain yield and number of grains for both wheat cultivars. For triticale, dry conditions seem to affect apical dominance, causing the plants to produce fresh shoots and buffering the reduced number of spikelets that is formed under stress conditions. Triticale's root system was significantly more extensive, when compared with both wheat cultivars. Although the maximal root length was not the longest, more roots were formed and root dry weight was highest.

Comparative performance of triticale genotypes in North Western Plain Zone for grain yield and its attributes

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The human-developed cereal crop, triticale is gaining importance globally, but little work has been done in India yet. The results of coordinated trials conducted over two years, i.e. 2013-14 and 2014-15 are quite encouraging. Seven triticale genotypes were evaluated against two bread wheat checks HD2967 and WH1105 in RBD design. The plot size of 2.40m x 6.0m comprised twelve rows with 20cm spacing and four replications at the CCS, H.A.U. Hisar research farm. The data of grain yield from each plot (middle ten rows) was obtained and expressed in quintal (100kg) per hectare. The ancillary data on days to heading, days to maturity, height, lodging, grain texture, grain colour and thousand grain weights were also taken. In 2013-14 the mean grain yield at different centres ranged from 44.5 q/ha (Gurdaspur) to 55.8 q/ha (Ludhiana) over two locations, TL 2942 exhibited the highest grain yield (56.6 q / ha) against the bread wheat check HD 2967 (50.9 q / ha). The performance of the test entries was comparable to wheat checks for agronomy and grain characteristics. For thousand grain weight the test entry TL 2998 (49.0 g) and TL 2997 (47.0 g) showed high mean grain weight compared to wheat checks WH 1105 (37.0 g) and HD2967 (41.0 g). It was interesting to note that none of the triticale lines were found to be susceptible against the yellow rust while wheat check HD 2967 showed 20s yellow rust susceptibility. For days to maturity, days to heading, height and grain colour, the triticale lines were on par with wheat checks while the grain threshability of wheat checks was medium and texture was semi- hard whereas in triticale threshability ranged from medium to hard and texture semi-hard to hard .

Methylation changes relative to Al stress in triticale

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Keywords: quantitative MSAP, methylation, aluminum stress, triticale

Aluminum stress is one of the most recognized abiotic stresses of plants growing in soils under acidic conditions. The known mechanism of tolerance is based mostly on the ability of organic acids exuded by roots to chelate toxic Al^{3+} ions via the formation of low molecular weight complexes [1]. In triticale, the major gene coding for aluminum-activated malate transporter (ALMT), is located on the 7R chromosome and explains up to 36% of the phenotypic variance [2]. Additional loci were mapped to the chromosomes 3R, 4R, and 6R [3, 4]. Despite evidence that this trait has a genetic background, one cannot exclude that at least part of the phenotypic variance is dependent on epigenetic mechanisms (i.e., DNA methylation) reflecting the adaptation of plants to stress environment. The aim of the study was to establish if aluminum tolerance in triticale could be co-regulated at the DNA methylation level.

Cytosine methylation for five Al-tolerant (T) and five non-tolerant (NT) lines maintained in control, and Al-stress (20ppm of Al^{3+}) conditions was analyzed using Methylation Sensitive Amplified Polymorphism (MSAP) approach [5]. The method is based on two isoschizomers, *Hpa*II and *Msp*I that are different in their sensitivity to methylation of the recognition sequences 5'-CCGG-3'. The results were evaluated according to the protocol proposed by Wang et al. [6].

Our data demonstrates that both T and NT triticale lines subjected to Al stress exhibit 4% increased amount of demethylation (DM) in roots. De novo methylation (DNM) was detected exclusively in two tolerant lines (L195 and L198), the proportion being 0.23% for each of them. Aluminum stress does not induce changes in methylation pattern in leaves.

Occurrence of triticale diseases in Algeria: Overview of the last decade

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Keywords: triticale, biotic stresses, disease survey, occurrence, severity

Triticale production is expanding in Algeria, and due its tolerance of less favourable soil conditions, it is mostly grown in the northern loamy and sandy soils of the country. Resistance to diseases has been recognized as one of its most important advantages. However, this advantage is diminishing since triticale growing has intensified. In recent decades several biotic stresses have appeared to attack triticale despite triticale appearing healthier than other crops. Disease status is important because most of the triticale production is devoted to animal feed. In our study we are dealing with the occurrence of pathogens identified in most farmer triticale fields of northern Algeria through field disease surveys performed each year. All fields of the region are inspected and sampled for the natural occurance of diseases from conditions representing favorable and semi-arid regions. Disease severity is more apparent in the coastal and interior plains than in the high plateau. Surveys revealed that diseases are variable from year to year and are related to the overall climatic conditions. Globally, the most prevailing diseases were Septoria-like diseases (SLD), leaf rust and, to some extent, yellow rust which was epidemic in the year 2003-2004 and reduced cereal production by 80%. Powdery mildew, root-rot Fusarium or take-all are becoming more prevalent. Overall, 50 to 65% of the fields were infected by SLD, while leaf rust was detected in 48% of the fields. BYDV was also present in all areas but with a low severity; bacterial blight was only found in some coastal area. Since 2005, at a breeding level in the National Wheat improvement Program, we have undertaken a large screening of all cereal collections. As a result we could identify lines that carry simultaneously adult plant resistance (APR) to leaf rust, yellow rust, Septoria leaf blotch and Tan spot at the favorable site and tan spot, septoria leaf blotch, stripe rust on bread wheat; root-rot Fusarium or take all is more prevalent in the semi-arid areas. Stem rust appeared also in some very late genetic material in triticale and in rye planted as border rows in the station.

Yellow rust disease on triticale in Mexico, a different *formae specialis* or just lack of virulence to common wheat Yr genes

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Keywords: triticale yellow rust, seedling and adult resistance, avirulence/virulence formulae

Prior to 1995, Triticale (X*Triticosecale* spp.) was immune to all Mexican yellow rust races, including to isolates with virulence on *Yr9*. In 1996, new virulent isolates, including 94.16 with virulence to *Yr9* and *Yr27*, were identified in Mexico and resulted in the most popular triticale cultivars and a number of advanced lines from the CIMMYT program becoming susceptible. In 2002, a new race which preferentially attacked triticale, namely MEX02.28, was identified. This race had the particularity of completely overcoming the resistance of cultivar Pollmer TCL2001 and that of the great majority of breeding lines from the CIMMYT program. This race became the most prevalent until 2014. Its avirulence/virulence formulae is quite distinct from those prevalent on bread wheat: "*Yr1,3,4,5,8,10,15,24, 26,27,28,31,32 / 2,6,7,9,17,Poll"*. No changes in the population of yellow rust in Mexico had any significance for triticale from 2002 to 2015, with the area of rainfed triticale being only a few hectares. As the cultivated area increased with the diffusion and success of the spring cultivar Bicentenario TCL08, yellow rust became again present in farmer fields at variable levels. Variable levels of infection were also observed in the, until then, highly resistant Bicentenario TCL08, which indicated the possibility of a new race. Preliminary seedling tests in the glasshouse indicated that there was no virulence differences between the Pollmer race and isolates obtained from Bicentenario TCL08. Seedling tests with both isolates (conducted separately) indicated that the majority of the 573 CIMMYT triticale advanced lines tested were seedling susceptible, while most of them were highly resistant at the adult stage in the field, not only to the triticale races, but also to those races which are primarily found on bread wheat.

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Examining winter triticale for susceptibility to ergot in Western Canada

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Keywords: winter triticale, ergot nursery, plant disease

Winter Triticale (X *Triticosecale* Wittmack) is a small crop in Canada predominantly used for livestock feed in the form of silage or grain. Susceptibility to ergot is a concern for triticale producers, especially those cutting the crop for silage at the soft dough stage as there is no opportunity to remove ergot sclerotia before livestock feeding. Knowledge gained through the co-operative registration trials for winter triticale and fall rye indicated that significant levels of ergot infection, measured as percent ergot, can occur in Western Canada. Furthermore, there was variation in tested varieties, as well as testing locations which have consistently higher levels of infection. Based on this knowledge, ergot nurseries were initiated at Lacombe, AB and Lethbridge, AB to evaluate winter triticale cultivars sourced from European, Canadian and the United States breeding programs for susceptibility to ergot. Testing over two years (2013-14 and 2014-15) provided variable results between years and locations likely due to extremely dry temperatures in 2014-15. However, some trends were observed across cultivars and using stability analysis, check cultivars were selected based on the stability of percent ergot production and level of susceptibility. A comparison across tested cultivars indicates that, in general, European germplasm can provide Canadian cultivars with an improved source of resistance to ergot. Research in resistance to ergot infection and winter triticale breeding is continuing at AAFC-Lethbridge with the expectation that new ergot resistant winter triticale cultivars will lead to an increase in uptake of this crop by producers.

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Comparison of *Fusarium* toxins accumulation in grain of winter triticale and winter wheat

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Keywords: deoxynivalenol, Fusarium head blight, triticale, wheat, zearalenone

Resistance to Fusarium head blight (FHB) of breeding lines of winter triticale and winter wheat was evaluated in the years 2012–2014 at two locations (Radzików, Poznań). Lines included in the experiments were previously tested and showed increased level of FHB resistance. FHB index was scored based on the FHB severity and FHB incidence. Proportion of *Fusarium* damaged kernels (FDK) was assessed visually. Content of trichothecenes B (deoxynivalenol, acetyl derivatives of deoxynivalenol and nivalenol) and zearalenone in grain was analyzed.

FHB index for triticale was significantly lower than for wheat in 2012 and 2013. In 2014 there was no significant difference between triticale and wheat for FHB index. FDK proportion for triticale was significantly lower than for wheat in 2012 and 2014. In 2014 there was no significant difference between triticale and wheat for FDK. Content of trichothecenes B in triticale grain was significantly higher than in wheat grain in 2012. In 2014, triticale grain also accumulated more trichothecenes, however the difference was not significant. In contrast in 2013, content of trichothecenes was significantly higher in wheat grain than in triticale grain. Triticale and wheat did not significantly differ for zearalenone concentration in grain in 2012 and 2013. In 2014 triticale grain was significantly more contaminated with zearalenone than wheat grain.

Analysis of combined data of three years showed that wheat lines were more highly infected by *Fusarium*. Mean FHB index and FDK were significantly higher for wheat than for triticale. Mean trichothecene content in wheat grain was higher than in triticale grain, while zearalenone content was higher in triticale grain. However, the differences for both toxin types were not statistically significant.

The results showed that in triticale symptoms of FHB (head infection, kernel damaged) were weaker as compared to wheat. However, as regards toxin concentration in grain, there were no differences between two cereals. In certain conditions, toxin accumulation in triticale grain was even higher than in wheat grain.

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Type I and type II resistances to Fusarium head blight in winter triticale lines

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Keywords: disease spread, Fusarium head blight, initial infection, triticale

Resistance of 29 breeding lines of winter triticale to Fusarium head blight (FHB) of type I (to initial infection) and type II (to disease spread) was tested in Radzikow under partially controlled conditions. Check cultivars of winter wheat (resistant to FHB and commercial cultivars) and durum wheat ('Komnata') were included. Additionally in Poznan resistance of type II of 42 introgressive winter triticale lines, with *Triticum monococcum* genes and a bread wheat 'Panda' chromosomes 1D or 3D substituted for chromosome 1A was tested under field conditions. For evaluation of FHB type I resistance triticale and wheat heads were sprayed with *F. culmorum* spore suspension at full flowering. Disease was assessed 7 day after inoculation. The number of infected spikelets was recorded in each of 10 heads per line. In addition, 21 days after inoculation FHB index was assessed. For evaluation of FHB type II resistance triticale and wheat heads were point inoculated with droplet of spore suspension of two *F. culmorum* isolates. Disease was assessed 21 day after inoculation. The number of infected spikelets was recorded in each of 10 heads per line

The mean number of infected spikelets in triticale lines after spray inoculation was 2.07, with range 1.20 – 3.70. Four lines showed high level of type I resistance (<1.40) and three low level (>3.00). The mean for wheat checks was 1.52 infected spikelets, with range 1.00 – 2.20. Mean number of infected spikelets in triticale lines after point inoculation was 1.95, with range 1.10 – 3.70. Three lines showed high level of type II resistance (<1.40) and three low level (>3.00). Mean for wheat checks was 1.73 infected spikelets, with range 0.60 – 5.00. Correlation coefficients between resistance type I and resistance type II was significant (r = 0.493). Both resistance types correlated with FHB index under controlled conditions, however the coefficient was higher for type II – r = 0.538 and r = 0.781, respectively. FHB resistance type I and type II was also correlated with FHB indexes assessed under field conditions in Radzikow and Poznan. Both resistance types correlated with FHB indices in both locations, despite resistance type I and FHB index in Poznan. Coefficients for type II were much higher showing more significant influence of this resistance type to field resistance to FHB. FHB infection of introgressive lines was low. The mean number of infected spikelets was 1.36 with range 1.00 – 2.81. For seven lines the number of infected spikelets was 1.00, and for three lines it was above 2.00. Results were affected by dry conditions after flowering, however some variability of type II resistance was found.

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Studies on morphological traits in triticale

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Keywords: morphological traits, awnless, waxless, winter triticale

The aim of the study is to determine the inheritance of two morphological traits in winter triticale (*Triticosecale* Wittmack): lack of surface wax on the plant (waxless plants) and reduced awns on the ears (awnlet plants), as well as obtaining isogenic lines for awned/waxy coated varieties. The back-crossing procedure was used.

The research is based on winter triticale genotypes with two morphological traits: RAH 366 (waxless plants), RAH 122 (reduced awns) and the varieties of winter triticale: Borwo, Remiko, Subito, Tomko and Wiarus, as well as the male-sterile line MS-114 (5) -2-1 line and maintainer line MF 114 (5) -2-1.

Seeds of studied genotypes were planted in greenhouse after vernalization. Pesticide treatments (spraying against aphids and fungal diseases) were conducted throughout the growing season. Ears of mother plants (except male sterile line) were emasculated and pollinated with pollen collected from ears of two genotypes with morphological traits (RAH 366, RAH 122). In subsequent generations segregation of the traits was examined.

The research is supported by the Polish Ministry of Science and Higher Education in the frame of statutory research

Contribution of proteinaceous toxins in *Parastagonospora nodorum* blotch development in triticale

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Keywords: triticale disease, resistance, *Parastagonospora nodorum*, leaf and glume blotch, proteinaceous toxins

Parastagonospora nodorum is a necrotrophic pathogen of all assimilative green parts of wheat and triticale plants as well as of other cereals and grasses. Oval or lens-shaped, first chlorotic and later in the season red-brown spots develop along the leaf blade and sheath and affect the entire leaf and/or glume and awns. With development of the disease, called *Stagonospora nodorum* leaf and glume blotch, pycnidial sporulation appears on necrotic lesions. Destruction of green plant parts affects photosynthesis adversely, which results in grain yield loss. In recent years a number of reports on proteinaceous host selective toxins produced by *P. nodorum* in affected plant tissue have appeared. These toxins play a crucial role in the induction of tissue necrosis. Toxins interact with specific host genes. Presence of the dominant allele in infected plants leads to necrosis induction, while absence of the dominant allele causes toxin insensitivity. So far, eight pairs of *S. nodorum* toxin/host gene were reported and described. Tests conducted under controlled environment as well as field conditions confirmed that protein toxins are important factors in *P. nodorum* leaf and glum blotch of wheat.

The objective of this project was the examination of the presence of ToxA, Tox1 and Tox3 genes of *P. nodorum* in isolates collected in Poland and evaluation of Polish triticale varieties and breeding lines reactions to semi purified toxin Tox3.

Analyses revealed that genes coding Tox1 and Tox3 toxins are significantly more frequent in triticale than the ToxA gene. The majority of tested isolates contain both Tox1 and Tox3. Seedling leaves of 58 Polish triticale varieties were infiltrated with chromatographically purified preparation of Tox3. 66% of triticale seedlings were susceptible. Toxin resistance was compared with *P. nodorum* phenotypic resistance and significant correlation between these two types of reactions was found.

In upcoming years we are planning to purify more infectors and to continue genotyping of cereal lines.

The research was supported by the Ministry of Agriculture and Rural Development.

Relationships between SPAD values and yield components of triticale genotypes and other cereals grown under Tunisian sub-humid conditions

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Keywords: triticale, oat, barley, grain yield, biomass yield, SPAD and Tunisia

Cereals (Triticale, Barley and Oats) are important forage crops for livestock. Triticale (X *Triticosecale* Wittmack) is now the least used but might prove to be a good alternative to barley and oats. A study was carried out at the experimental station of Béja in the sub-humid area of northern Tunisia during the 2014-2016 cropping season. Ten triticale genotypes, two barley cultivars and one oat cultivar were used. The experimental design was a randomized split block design with three replicates. Results indicated a significant genotype/species effect for plant height (PLH), SPAD values, Biomass yield (BY) and grain yield (GY) For all genotypes, grain yield ranged from 2.61 t/ha to 6.11 t/ha, while biomass yield ranged from 6 to 8.83 t/ha. Average grain yield across triticale genotypes was 4.59 t/ha, highly outyielding the grain yield of barley (3.27t/ha) or oats (1.99 t/ha). Therefore, triticale can be considered a good alternative to barley and oats for grain, hay and silage production in northern Tunisia. SPAD values in Triticale were significantly correlated to GY for the different genotypes ($R^2 = 0.80$; $p < 0.01$). This effect was more pronounced for triticale genotypes than barley and oats for all parameters.

Features of productivity formation of winter triticale in its ontogeny

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Keywords: triticale, stages of organogenesis, weather conditions, cultivation technology

The main aim of modern agriculture in Ukraine is the stabilization of crop production. The increasing of crop areas of triticale is a world trend, especially in Europe. At the present time the main requirements for grain production of triticale is increasing the yields and improving grain quality.

The main focus of this paper was to identify the correlation between elements of growing technology which affect the productivity of winter triticale being the dynamics at stages of organogenesis which depend on weather conditions in the vegetative period.

Field experiments were carried out in conditions of stationary crop rotation on the NULES of Ukraine, Kiev. The biological control of the development and growth of triticale included the regular monitoring of plant development in various stages of organogenesis and given the opportunity to diagnose and manage sowing, set both potential and real crop productivity.

It was shown that the physiological and ontogenetic features of productivity potential and triticale grain quality depend on the environmental conditions and the technology of cultivation. The study included the influence of the cultivation technology including the fertilization, crop protection systems, treatment by physiologically active substances on the level of structure and function organization of agrophytocenoses and the productivity of triticale cultivars.

It was established that the length of the shoot apex of triticale in the treatment with the application of $N_{30}P_{150}K_{150}+N_{60(II)}+N_{60(IV)}+N_{30(VII)}$ constituted 0,58-0,61mm; this development corresponding to the end of II-nd stage of organogenesis. The length of the shoot apex of triticale in the treatments using $N_{30}P_{30}K_{30}$ and $N_{30}P_{120}K_{120}+N_{30(II)}+N_{30(IV)}+N_{30(VII)}$ constituted 0,43-0,47 mm and 0,52-0,56 mm, which corresponds to II-nd stage of organogenesis. The level of frost resistance of plants which had already begun differentiationof the initial ear was high, unlike plants with an undifferentiated cone of growth was high which extreme factors had not influenced.

Physiological and ontogenetic factors contributing to the productivity and quality parameters of triticale, wheat and rye varieties, including environmental factors and agronomic technologies have been identified.

Investigation of resistance to rust diseases in recent triticale cultivars

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Keywords: leaf rust, stem rust, yellow rust, molecular markers

Diseases caused by *Puccinia* species pose a great threat to grain yield both in wheat and triticale. Although the rust resistance of triticale relies on the genetic resources of wheat and rye, due to the very limited use of primary triticales in recent breeding programs, the genetic base of rust resistance in new triticale cultivars is expected to be increasingly vulnerable.

In this study seedling resistances to stem rust and leaf rust were evaluated on 56 triticale cultivars received for the field demonstration trial of 9th International Triticale Symposium held in Szeged, Hungary. Mixture of pathotypes prevalent to Hungary were used both for leaf and stem rust resistance tests. Molecular markers were also used to determine the presence or absence of five leaf rust resistance genes (*Lr9*, *Lr14a*, *Lr16*, *Lr20* and *Lr28*), four stem rust resistance genes (*Sr13, Sr36, Sr38,* and *Sr39*) and four yellow rust resistance genes (*Yr5*, *Yr10*, *Yr15* and *Yr36*) located on A or B genome of wheat.

Out of 56 entries 14% showed resistant (R) and 68% susceptible (S) type of *symptoms* to leaf rust, while rest of entries showed mixed reactions. In stem rust tests, the rate of resistant cultivars (R or MR) was 63%, and that of the S type was 12% (the rest also showed mixed reactions). None of the five *Lr* genes identified by molecular markers showed linkage to resistance. Among *Sr* genes only the *Sr13* (found in 13 entries) showed a possible linkage to resistance as its marker was not present in susceptible cultivars. According to marker test the *Yr10* and *Yr15* resistance genes occurred in a high frequency (36 and 41%) and the rest was low (*Yr5*: 4%) or absent (*Yr36*); resistance to yellow rust was not tested.

It could be concluded, that leaf rust resistance of triticale needs an urgent improvement, whereas stem rust resistance seems satisfactory. However, we have no information of their resistance against the recently appeared stem rust pathogen race Ug99 and its lineages. Data may help breeders to incorporate effective *Lr* or *Sr* genes into new cultivars.

SESSION IV.
UTILIZATION OF TRITICALE – FOOD AND FEED ASPECTS

Session Chair:
Willem Botes

Grain storage carbohydrates – novel targets for triticale grain quality improvement for human health and industrial applications

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Cereal grains that include, rice, wheat, maize, barley, sorghum, millets and others form staple food in human diet. The mode of cereal consumption is ethnically and regionally determined and contribute close to half the calories in human diet. In a cereal grain, carbohydrates are the major storage component, contributor to grain yield and source of energy in human diet and animal feed. In a cereal endosperm carbohydrates are the predominant storage component, followed by protein, lipid and other minor constituents such as phenolic acids, minerals and vitamins. Proteins provide functionality for bread related products, and have been the focus of improvement in wheat, rye and triticale.

In the present situation with a less active lifestyle combined with ease of food availability resulting in over consumption of calories that has resulted in obesity and chronic diseases such as diabetes, coronary heart disease and colorectal cancer. To overcome some of these chronic diseases there is renewed interest to develop cereal grains with grain carbohydrates that are beneficial to intestinal health and improve human health in general. The major storage carbohydrate, starch is an energy dense molecule, made up of repeating glucose units attached to each other in a linear molecule (amylose) and highly branched (amylopectin). Starch is present as a water-insoluble granule composed of one-quarter amylose and three-quarters amylopectin, along with traces of lipids and proteins. In spite of this basic uniform structure of starch, it differs in digestibility depending upon the type of grain, thus the energy or calories contributed by different food groups in human diets also differ. Starch digestibility is the first step in carbohydrate participation in human diet. In a recent study of selected triticale genotypes from Hungary, considerable variation was observed in grain carbohydrates (starch and non-starch polysaccharides) and starch *in vitro* enzymatic hydrolysis. In studies with other cereal starches, such as wheat and barley starch composition and structure has been associated with starch *in vitro* enzymatic hydrolysis. Based on its *in vitro* enzymatic hydrolysis, rate of glucose release and its absorption in the gastrointestinal tract; starch is classified as readily digestible starch (RDS), slowly digestible starch (SDS), and resistant starch (RS). Results show that size of starch granules, amylose to amylopectin ratio and amylopectin chain length distribution determine the extent of starch digestibility or, resistant starch in food. The *in vitro* enzymatic digestibility properties of starch can be used to design diet plans for calorie deficient regions or in the affluent societies (calorie excess) for weight control, disease prevention and management in people with diet related diseases. Triticale with its increased concentration of non-starch polysaccharides and modified starch can be a very valuable crop for improved human health and reduction of chronic diseases. Triticale with highly digestible starch can be used for ethanol production or high calorie animal feed.

Triticale end-use: nutritional and technological properties of Hungarian genotypes

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Keywords: triticale utilization, human consumption, nutritional and technological properties, bread product

Triticale (X *Triticosecale* Wittmack) is mainly used as an animal feed, and it is also appropriate as food, however the use for human utilization is still uncertain. Cereal foods are an essential part of the daily diet (protein, carbohydrate and dietary fiber). As the population becomes more health conscious, and current trend to try new products has increased the interest in triticale.

In the present study ten hexaploid triticale (cultivars and advanced lines) and one each of wheat and rye genptypes were studied. The samples were compared for important nutritional constituents such as total protein, fat, ash, dietary fiber (DF), starch and minerals. Significant differences in nutrient composition was observed among the analyzed triticale genotypes. As expected the ash content (1,5-1,8%), protein (10,7-14,4%) and fat concentrations (1,0-1,8%) were in intermediate position between wheat and rye. The triticale genotypes contained significantly higher DF (8,9-13,1%) compared to the wheat. In triticale, arabinoxylans (AX) are the main non-starch polysaccharides, nearly 50% of the DF was present as AX (4,9-7,4%). Starch is the major storage polysaccharide in cereals. In triticale, the starch concentration varied from 61,3 to 68,6%, that is similar to the concentration of wheat.

Analyzes of dough rheological properties of triticale flour by Mixolab revealed that triticale flours have poor mixing properties compared to the parent wheat flour. This could be due to the low gluten content in triticale. However, the dough stability and viscosity was acceptable. Protein weakening was slower than rye and starch gelatinization and degradation had lower values compared with wheat.

We measured the nutritional values in bread products as well. Bread made of triticale-wheat flour blend contained 6% more protein and 43% more dietary fiber compared to white wheat bread and was also enriched in some minerals. Triticale dosage did not influence significantly the bread quality (weight, volume, texture, taste).

In conclusion, triticale may be a suitable crop for food industry due to its valuable nutritional composition and acceptable technological values that can be used larger scale in milling products.

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Triticale, a promising green forage crop for organic agriculture

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Keywords: triticale, green forage, protein yield, organic farming

Different types of forage and silage have a high importance in cattle feeding. Winter cereals grown with or without a companion leguminous species are widely used for making silage. These green forage crops can be effectively introduced into crop rotations and, due to their early harvest, they can increase the efficiency of land use. In organic husbandry it is legislatively regulated that only fodder originating from organic crop production ought to be used as animal feed. In the present study, biomass yielding ability, crude protein yield and forage quality of different cereals were examined under organic growing conditions.

Green forage yield and crude protein content of winter cereals (triticale, winter oats, rye, emmer and spelt) and legumes (Hungarian vetch and winter pea) were examined in an organic nursery between 2013 and 2014 using small plots established not using individual crops but also comprising cereal-legume mixtures with four or two components: triticale-oat-pea-Hungarian vetch and triticale-pea. Mixtures were established in two types of cereal: legume ratio, 50:50 and 40:60. Harvest was carried out at the end of the milk stage of the cereals making three different groups (cereals, legumes and mixtures) for the statistical evaluations.

Considerable differences were found between the biomass yields of the different cereal species examined. Evaluating the harvested biomass yields on a dry matter basis of 35%, one of the triticale varieties (Mv Sámán) had significantly the highest yield (56.22 t/ha), while the spelt genotype had the lowest (30.60 t/ha). The Hungarian vetch had a significantly higher yield (20.05 t/ha) than the winter pea genotype, while the triticale-pea mixture with 50:50 ratio gave the highest yield (44.00 t/ha) of all the mixtures. Comparing the two types of mixing ratio within both mixtures, the cereal-legume mixtures with 50:50 ratio had higher yields than the same mixtures but with 40:60 ratio.

With regard to the crude protein yield (t/ha) derived from the biomass yield and protein content of the trial entries, the triticale genotype, Mv Sámán grown as sole crop showed the significantly high value of 1.82 t/ha. Crude protein yield of the legume genotypes varied between 0.81 and 1.09 t/ha which can be explained by their low biomass yield, even though they had high protein content. Regarding mixtures, those with the lower legume proportion (50%) had higher protein yields varying between 1.57 and 1.66 t/ha, than those comprising 60% legume (1.32-1.59 t/ha).

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The effect of added concentrated oat fibre on the chemical composition of triticale breads

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Keywords: triticale, oat, dietary fibre, chemical composition, bread, β-glucan

Cereals constitute the major source of energy and dietary fibre for humans. In recent years, triticale (X*Triticosecale* spp.) has become a popular crop. Besides its high yield potential, triticale also has very good nutrition and functional value and contains high amount of lysine, soluble arabinoxylans, phenolics, vitamins and microelements. Oat and its products due to their nutritional and health properties are very often used as additives to bread flour. The main focus of this paper was to study the chemical composition of triticale bread enriched with concentrated oat fibre. Material for the study comprised of breads made of flour from four triticale varieties with addition of 2,5%, 5%, 10% of oat concentrate (OC). Triticale – oat breads were baked according to ICC Standard No. 131 procedure with modification. Breads were analyzed for the content of protein, ash, lipids, starch and dietary fibre (DF). DF was determined with the standard Uppsala method (AACC 32-25), as a sum of nonstarch polysaccharides (NSP) and lignin. β-glucan content was measured according to the standard method AACC 32-23. Results are reported for dry matter weight. All analyses were made in duplicate. Content of all chemical components, except starch, increased as OC concentration increased. Among the nutrients the most increase was observed for protein and lipid content. For example in bread obtained from control Panteon variety protein content was 14%, while in bread with 10%OC it was 16%. Among the bioactive components, the highest increase was observed for the β-glucan content. Breads with the lowest addition of OC contained two-fold more β-glucan than control breads, which increased to five-fold higher in breads with 10% OC. The soluble fraction of NSP was the second trait that significantly increased with OC increasing concentration. The raising of these two components is related to the increase in viscosity, two-fold more in breads with 10% OC compared to their counterparts. The results showed that the addition of OC improves nutrition and the bioactive value of triticale bread.

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Highly promising yield and quality potential of facultative-winter triticale as a green forage source for dairy production in the Laguna Region of Northern Mexico

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Keywords: triticale, silage, silage quality, dairy production

Water availability is one of the major constraints for forage production in the dairy production area of Coahuila and Durango States in Northern Mexico. Because of its better water-use efficiency and relative low production costs, triticale can be greatly competitive with oats, ryegrass and berseem clover as a winter forage, provided it can produce high quality forage for dairy operations. To demonstrate this potential, an on-farm evaluation comparing the commercial-scale performance of five facultative/winter habit genotypes with a range of phenologies to that of the spring triticale cultivar "Bicentenario TCL08" and of the oat commercial checks "Cuauhtémoc". For each cultivars, plots of ¼ ha were harvested either two or three times (1 or 2 re-growths) at booting stage and the resulting green forage was processed into a commercial silage. Under the two-cuts system, the best genotype, namely the intermediate-winter cultivar AN184, out-yielded the oat check by 302% for dry matter production; Under the same system, the awnless winter cultivar ANPELON and the facultative cultivar AN38 out-yielded the check by 197% and 153%, respectively. AN184 was also the best yielder under the three-cuts system (11.8 t/ha dry matter), followed by ANPELON (9.0 t/ha dry matter). No comparison to the oat check was possible under the three-cuts system as the oat cultivar would not provide any significant second re-growth. All the winter and facultative genotypes were substantially better than the spring check, due to their better phenological adaptability to this production system and environment. In terms of forage quality, and in particular, crude protein per hectare, AN184 was again the best performer, out-performing the oat check by 274% (2.99 vs. 0.80 t/ha). Complete quality profiles were produced, clearly documenting the qualitative superiority of most triticales compared to the oat check. Taken together, these results clearly demonstrate the commercial potential of facultative-winter triticale as an advantageous replacement for most winter forages used in the dairy production area of Coahuila/Durango in Mexico.

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Quality parameters of flour blends using Hungarian triticale varieties

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Keywords: triticale, fertilization, blends, baking quality, wet gluten, extensograph

Due to its advantageous agronomical and nutritional properties, triticale may be used in flour blends for human consumption in many countries. The baking quality of blends depends not just on the proportions of the flours used, but also on their individual quality which may be influenced by fertilizer treatments.

Hungarian triticale varieties, the *GK Szemes* and *GK Rege* were tested in blends. The triticales were grown in Fülöpszállás, Hungary, in a long-term fertilization trial in 2014 and were treated with different amounts of fertilizer ($N_{30}P_{30}K_{30,}$ $N_{60}P_0K_0$). Flour blends were prepared with commercial wheat flour and triticale wholemeal flour in proportions from 0% to 100%. The wholemeal samples were ground by Fluormill A500MSM stone mill. Wet gluten was measured by ICC 106/2. The dough rheological properties were examined by Brabender Farinograph and Brabender Extensograph following the usage of the ICC 115/1 and ICC 114/1 methods (Brabender GmbH and Co. KG, Germany).

Changes of wet gluten and extensograph parameters of the blends were determined. Though there were differences in the baking qualities between the two triticale varieties, the quality parameters in their blends were similar. The quality of blends significantly depended on the fertilizer treatment of triticale in addition to the proportions of the flours. When the $N_{60}P_0K_0$ treated triticale was used in blends, wet gluten and extensibility values were significantly higher, but in the case of resistance to extension (R_{max}) blends with the $N_{30}P_{30}K_{30}$ treated samples gave higher values. The measured values of wet gluten and extensibility were above the expected values (synergism), while in the case of resistance to extension the expected values were higher than the measured values (antagonism).

Based on these results, new bakery products were developed from different blends. Blends with a lower proportion of triticale are suitable to produce white-type bread, pastries, sweet and savoury cakes with a similar or improved flavor, advantageous nutritional value and longer shelf life than the traditional white-type bakery products. Rye-type breads and bakery products can be produced using blends with higher proportions of triticale with altered baking technologies. The trade-mark of these newly developed bakery products is “Szögedi Rozsbuza”.

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Effects of fertilizer active agents on quality parameters of Hungarian triticale varieties in long-term fertilization trials

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Keywords: triticale, fertilizers, N:PK rate, quality, H.I., FQN, extensographic stability

Modern, hexaploid triticale consists of a specific combination of protein and fiber components sourcing from parental species. Less favorable protein characteristics of triticale compared to wheat for specific products, limits its use in the food industry. For that reason, use of triticale for baking industry is proposed as blends, primarily with wheat flour. The quality of the flour blends is influenced not only by the ratio of components, but also by the quality of the flours to be mixed, which in turn is influenced by cultivar, crop year and prevailing climatic and agronomic conditions. The N and PK fertilizer doses used as fertilizer for plant growth can also be important.

In this study, triticale cultivars *GK Rege* and *GK Szemes* were grown on a calciferous meadow soil in Fülöpszállás, Hungary, in a long-term fertilization trial in 2013 and 2014. We analyzed the effects of the ratios of N and PK active agents of fertilizer (0:0; 0:1; 1:0; 1:1; 2:1; 3:1) on the crucial technological quality parameters. Kernel hardness analysis was done by PERTEN SKCS 3100. White flour was produced by means of a Brabender Senior mill and whole-meal samples were ground on a Fluormill A500MSM stone mill. Farinographic quality number and extensographic stability of the flour samples were measured by the standard methods (ICC 115/1; ICC 114/1).

Results reflected that the single-applied PK active agent significantly improved those rheological parameters influencing the stability of the dough (farinographic quality number and the extensographic stability in case of white and whole-meal flour as well). The single application of N fertilizer did not influence the above mentioned traits significantly. The low, 1:1=N:PK rate was the most efficient treatment in this respect resulting in the highest values. The increasing N:PK ratio reduced the stability-increasing effect of PK. The higher N-rates reduced the farinographic quality number and the extensographic resistance to extension within the same N:PK ratio groups. The changes in the white flours were similar to those in the whole-meal flours but at lower levels. Extensographic stability of cultivar GK Szemes was lower than cultivar GK Rege. The proportions of the active agents of fertilizer also influenced the kernel hardness significantly but in the opposite direction as in the case of stability parameters.

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Carbohydrate composition of Hungarian triticale genotypes

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Keywords: triticale utilization, human consumption, carbohydrates, starch structure, fibre composition

In the last decades, importance of triticale have been increasing globally. Although, both parental species are used in the human diet, the utilization of triticale as food is still very limited. According to nutritional survey's cc. 50% of the daily carbohydrate intake comes from different type of cereals. There is a new trends in food uses of triticale that requires a better understanding of the carbohydrates structure.

In this study, eleven hexaploid triticale genotypes (cultivars and advanced lines) along with reference wheat and rye varieties were analyzed for starch concentration, composition (amylose-amylopectin ratio) and amylopectin structure, starch granule size, starch hydrolysis index and non-starch polysaccharides concentrations.

Starch is the major storage polysaccharide in cereals, the concentration in triticale (61,3-70,1%) is close to the value of wheat. The average amylose content of the triticale genotypes is around 24%, which is lower than the control wheat and rye. The starch hydrolysis profile was faster in the case of rye, but some of the triticale genotypes showed favorable properties compared to the wheat line. Triticale contains higher amount of large A-type-granules. The other part of the carbohydrates which is resistant to digestion by the human gastrointestinal tract, called dietary fibres showed values ranging from 10,2 to 14,4%. In triticale, nearly 50% of the dietary fibres present as arabinoxylans (4,9-7,4%), in some genotypes the content was even higher than rye. β-glucan concentration around 1% was similar in all the triticale genotypes. However, the triticale genotypes differed in resistant starch concentration that varied from 2,3 to 9,9%.

The tested Hungarian triticales showed similar carbohydrate composition compared to the parental species, however we found differences between the genotypes. This could open up the opportunity for targeted selection during the breeding process to develop triticale cultivars for added human health benefits.

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Forage yield and quality of spring triticale harvested at booting and milky-dough grain stages in Chihuahua, Mexico

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Keywords: triticale, forage-yield, forage-quality, dairy industry

Because of the robustness and agronomic competitiveness of triticale, there is an increased interest in the Mexican State of Chihuahua for its use as silage in dairy operations, as a complement to maize silage. In 2015, we conducted an evaluation of the forage yield and quality potential of 10 advanced breeding lines originating from CIMMYT, comparing their performance to that of the commercial check Bicentenario TCL08, of the breeding line *Ardilla* and of the forage wheat *Anahuac*. Plots were sown at a seeding density of 160 kg/ha using a randomized complete block design with 3 replications and a fertilization of 160-60-0 kg/ha of NPK. Forage yield data was obtained from cuts at booting and at milky-dough grain stages and samples were analyzed for forage quality parameters in a commercial lab. Results presented in the poster indicated that all triticale had forage yields superior to those of the forage wheat by an average of 14% at booting and 46% at the milky-dough grain stage. Milk production estimates obtained based on parameters from the forage quality profile indicated that triticale forage would result in a 66% increase in production over forage wheat, when cut at booting and 264% when cut a milky-dough grain stage. Additionally, the quality results obtained suggest triticale forage harvested at booting had a good enough quality to be used for cows in full production whereas that harvested at milky-dough grain stage was more suitable for young and replacement cows. In separate experiments, commercial-scale evaluations conducted on farmers' fields in different region of the state of Chihuahua, we obtained results indicating that both spring and facultative triticale genotypes consistently out-performed forage wheat (var. *Anahuac*) in dry matter production when harvested at milky-dough grain stage. Based on all these results, we are able to clearly document the suitability of triticale as a highly competitive forage for the dairy industry in the state of Chihuahua-Mexico.

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Protein and amino acid content in the grains of triticale

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Keywords: protein content, exogenous and endogenous amino acids, cultivars, winter and spring triticale

In Poland, triticale is a cereal used mainly for animal feed (85% of grain harvest). Triticale grains are used in feeding all species of livestock. Therefore, besides the size of the yield, high nutritional quality of grains is also important. To achieve grains of high feed value, farmers should select cultivars of a high amino acid content and favorable grain composition, providing minerals to livestock. Animals must be provided with exogenous amino acids together with feed protein, as they are not able to produce those themselves. Triticale is grown on soils previously occupied by rye. Triticale contains more grain protein than rye and thus increases the amount of protein included in the feed. Triticale protein has a favorable amino acid composition (below oats), and contains the most amount of lysine within basic cereal species. Before deciding on producing grains for fodder purposes, agricultural producers should focus their attention on selecting appropriate cultivars and adjusting cultivation technology according to the environmental conditions.

The study was conducted in 2011-2013 at the Experimental Station of IUNG-PIB in Osiny, on the plots of the area of 45m^2. The study included four cultivars of triticale: *Pizarro, Cerber i Fredro* (a long-straw form) and *Pigmej* (a short-straw form), as well as spring triticale cultivars: *Nagano* and *Legalo*. Protein content of grains (using Kjeldahl method) and amino acid content of triticale proteins (by UPLC method) were determined.

The content of grain protein and amino acid composition of the protein depended on specific triticale cultivar. Spring forms of triticale had a higher protein content in their grains than winter ones. Winter triticale cultivars of *Cerber* and *Fredro* had a 17% higher protein content compared to *Pizarro* and *Pygmej*. In contrast, protein content in the grains of spring triticale cultivars was similar at 12.6%.

Winter triticale cultivars *Cerber* and *Fredro* had a similar content of exogenous amino acids. Their content was higher by 11% than *Pizarro* and *Pigmej* cultivars, which in turn, had a higher content of endogenous amino acids. Among the tested cultivars of triticale, the highest amount of amino acids was recorded for cv. *Nagano*, followed by *Legalo*. The spring forms dominated in the amount of exogenous amino acids by 11.2%, and for endogenous amino acids by 16.1% over the winter forms.

Chemical composition of bread obtained from Polish triticale varieties

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Keywords: triticale, bread, flour, chemical composition, dietary fibre

During the last few decades triticale has become a commercial crop grown in a range of environmental conditions worldwide. Triticale, a hybrid cereal developed by crossing wheat and rye combines the valuable properties of both parental sprcies. Considering the favourable grain composition, this cereal should get more attention as an alternative source of nutrients and health-protective components in human diets, particularly as the consumption of cereal products is currently below the recommended level, and trending downwards. The aim of the study was to determine the chemical composition of triticale breads made of flour of five Polish winter triticale varieties. The results were compared against the control wheat variety. Triticale breads were baked according to ICC Standard No. 131 procedure with modification. All bread samples were characterised for nutrients (protein, ash, starch, lipids) and bioactive components (dietary fibre (DF), total polyphenols (TPC), antioxidant activity (ABTS) and viscosity of water extracts (WEV). All analyses were performed in duplicate. The study revealed that triticale bread is a good source of protein (10.9% vs. 11.2%) and starch (67.5% vs. 65.4%), comparable to wheat bread. The average ash and lipids content in triticale bread was 2.4% and 1.3%, respectively. Triticale bread seems to be also a good source of DF with an average content in the range between 5.2% and 6.8%. The average contribution of insoluble (I-NSP) and soluble (S-NSP) nonstarch polysaccharides was respectively 3.7% and 2%, whereas WEV of analysed samples was in the range 1.5 to 3.1mPas. The obtained results are slightly higher, in the beneficial direction, than bioactive parameters of bread made from wheat flour, which is the main cereal used for breadmaking. The results show that it is possible to obtain bread from some modern triticale varieties, with a favourable chemical composition from a technological and nutritional perspective and it is a reason to justify the promotion of some triticale cultivars for breadmaking purposes.

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Bioactive compounds in triticale

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Keywords: triticale, antioxidant activity, phenolic compounds, total dietary fiber, farming system

The aim of current research is to investigate differences in content of total phenolic compounds (TPC), antioxidant activity (ABTS cation and DPPH radical scavenging activity) and dietary fiber (TDF) of triticale. Three varieties: 'Dinaro', (Poland), 'Inarta', Ruja'(Latvia) and two breeding lines (9405-23 and 0314-29) from breeding program in Priekuli Plant Breeding Institute (Latvia) cultivated under conventional and organic farming conditions were used in the current research.

Influence of genotype and growing conditions were determined for all evaluated traits. The highest TPC and ABTS cation scavenging activity in varieties 9405-23 and 'Ruja' were determined. Comparing farming methods it is possible to observe trend that in samples grown under organic cropping system content of phenolic compounds are significantly lower.

For two varieties (9405-23 and 'Inarta') ABTS cation scavenging activity was lower in samples grown in organic farming system, whereas for variety 'Ruja' no significant differences between samples grown under conventional and organic methods were identified.

The highest DPPH radical scavenging acitivity was in variety 9405-23 and 'Ruja'. Comparing farming systems, for 2 varieties ('Ruja'and 'Inarta') DPPH radical scavenging activity and TDF was lower in samples grown in organic farming system, whereas for breeding line 9405-23 no significant differences between samples grown under conventional and organic methods were identified.

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The heavy metal and mineral compositions of grains of some triticale genotypes

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Keywords: triticale, heavy metal, minerals, ICP-AES

In the current study, mineral and heavy metal contents of several triticale grains were determined by inductively coupled plasma-atomic emission spectrometry (ICP-AES). The phosphorus and potassium contents of triticale grains ranged from 2932.6 mg/kg (Egeyıldızı) to 5667.0 mg/kg (TF5-12) and 5041.4 mg/kg (TMB-15) to 7822.6 mg/kg (TMB-5), respectively. While the highest calcium content was found in the TMB-25 triticale sample (883.3 mg/kg), the lowest calcium content was found in the Karma 2000 sample (304.6 mg/kg). The magnesium contents of triticale samples varied between 1522.2 mg/kg (TMB-1) and 2523.0 mg/kg (Tatlıcak). In addition, iron contents of triticale grains ranged from 49.0 mg/kg (TF5-10) to 4152.7 mg/kg (Egeyıldızı). Zinc concentrations ranged from 34.7 mg/kg (TF5-10) to 100.8 mg/kg (TMB-11). The lowest and highest manganese contents of triticale grains were found in Ayşehanım (27.4 mg/kg) and Egeyıldızı (381.7 mg/kg), respectively. The results presented here suggest that triticale grains could serve as a good source of mineral elements.

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SESSION V.
ECONOMY, MARKETING EXTENSION AND SOCIAL ASPECTS

Session chair:
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Economical aspects of triticale seed and grain production

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Keywords: seed sector, triticale, economic aspects, subsidies

The world population is increasing rapidly. Increase in crop production is immensely important for human and animal nutrition, as well as to establish a balance between food production and population growth. Evaluation of marginal farmlands and selection of suitable plant species are important in crop production. Triticale, which is a hybrid between wheat and rye, was developed over the last 100 years or so, as an alternative crop for human and animal nutrition. European countries like Poland, Germany and France rank first in terms of total production while Belgium and Germany rank first in terms of grain yield. Triticale, which has not yet completed its development process in the market economy, is used mostly as animal feed.

Many important factors are effective in increasing crop production. Therefore, development of higher yielding and better quality new cultivars, certified seed production of these and their usage in triticale production are currently desired. The most important technological input in agriculture is seed, which plays a cardinal role in increasing crop productivity and reducing production costs. Use of certified seed in crop production coupled with appropriate cultivation techniques can provide a yield increase over 20-30% for self-pollinating species and about 100% for cross-pollinated species with hybrid seeds. Development of the seed sector to supply quality seeds is thus an important part of agricultural systems.

Seed crop species, varieties, production costs and price and the subsidies for seed affect certified seed production and seed usage. Depending on region, the economic returns of varieties, with higher adaptability, tolerance to disease and pests, better yield and quality, are higher than the inputs. The seed cost of triticale varieties is less than for wheat. The seed industry in Turkey has made significant progress in recent years. Looking at the estimated cost account considering support in Turkey, there is a difference close to 80% between two crops, except for support. The production cost for triticale grain is 171 USD/t while seed production cost is 310 USD/t. Diesel and fertilizer support (37 USD/ha), certified seed production support (28 USD/t), and certified seed usage support (21 USD/ha) for triticale are important economic factors for the development of seed sector and increase in agricultural production. In this study, the importance of economic instruments in furtherance of triticale seed growing and grain production have been emphasized.

The motivation of research, the extension strategy to create a favorable approval and to evaluate the practical results

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This paper describes triticale in Romania and is homage to those people that believed, worked and demonstrate its utility. In a country with long tradition in wheat cultivation triticale as an economic crop was marked by mistrust. The lack of confidence was canceled when Drs. Perry Gustafson from the University of Manitoba, Canada and R. Glenn Anderson and Bent Skowmand from CIMMYT, Mexico arrived to talk about triticale's future. It was an important moment for triticale evolution in Romania. The 60s was the period of hybridization and hybrid evaluation for practical purposes (i.e. tolerance to Al3+ and salt). The Romanian triticale collection was enriched from the germplasm from Canada, Mexico, Europe, and the former Soviet Union. The main interest in 1970s was to enhance the lodging resistance, to improve the fertility and the seed plumpness using heavy and moderate radiation. The results emphasized the significant influence on plant height ($p<0.1$) and fertility ($p<0.01$). Unfortunately the influence of radiation was short lived as the selected lines lost many of their value-added traits. In 1970 – 1985 triticale yields grown in Timişoara (Chernozem), Făget (Albeluvisol/rich in Al3+), and Gărâna (high land/ DystricCambisol) fields were significantly ($p<5\%$) better in comparison with wheat, rye and hard wheat. In the 1980s work turned to the evaluation of triticale for energy supply and for forage. The results pointed out the value of energy yield (MJ/ha). Cultivars 1123/77, 4586/79, TR5 were of significantly higher energy value ($p<0.01$) in the flowering period than wheat. Taking into account the cellulose energy (MJ/ha) there were differences: at the heading stage between Bucovina 1 rye, 4586/79, T.Tim 7 ($p<0.01$), and TR5 were the best ($p<5$); at milky stage differences ($p< 0.1$), lines 1123/77 and TR5; and at maturity significant differences were observed between lines 1123/77, T.Tim 6, T.Tim 7 and TR5 as well as rye ($p<0.01$). The Department of Animal Nutrition organized experiments on birds, horses, cattle, sheep, and swine with various systems of animal feeding (silage, pellets, green fodder, pasture/grazing). The results were amazing. The strategy for dissemination and extension of triticale to farmers was to involve students and farmers. The most successful extension was driven by students who prepared theses on "triticale". Following three or more years of experiments conducted in Timisoara and Făget they were convinced of the qualities of triticale and convinced their parents and relatives to try it. Our experimental fields in Garana showed the farmers from that area to start cultivating triticale instead of rye. When 25 years of research on triticale were commemorated (1988) a workshop with farmers, students and IAT staff was organized. People from Timisoara participating in the workshop were informed about triticale as a "healthy food", due to its different amino acid content. For this commemoration the Timisoara philatelic group made an envelope and a stamp with specific symbols. The circulation of the monograph "Triticale a New Crop" book was sold out in one week. Now when small farmers from hilly and mountain areas grow triticale we are thankful to students and pioneer farmers for their work in dissemination and to all researchers for their effort to create a future framework for triticale.

Productivity of triticale in Ukraine

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Keywords: triticale, rye, wheat, varieties, production, quality, system of fertilization

Abundance of soil and weather conditions in Ukraine triggers growing interest in triticale as a crop of vast potential.

For the purpose of determining productivity of winter and spring triticale compared to other crops we have conducted numerous field and laboratory studies during 1988-2016.

Field studies were carried out in the form of long-term and short-term trials in different regions of Ukraine to determine the plasticity and stability of triticale varieties compared to other crops and the advantages of triticale, especially its winter varieties, in the regions of critical planting. Triticale varieties have thus been identified based on genotype, morphotype and their tolerance of stressful environmental factors.

Varieties of rye and triticale are highly resistant to phytopathogenic objects and are strong phytocompetitors in comparison with wheat. Varieties of triticale are less susceptible to diseases of leaves, stem and root system than rye, however are more susceptible to diseases of spike. There is a suggestion that the plants' susceptibility to diseases increases as the dose of fertilizer is increased.

Physiologically active substances are antistress agents, which improve the plants' protective functions and are a promising vector to improve the plants’ resistance to adverse environmental factors. The maximum effect of using the antistress agents may be reached through their complex application with fertilizers and pesticides with a simultaneous reduction of pesticide needed.

Quality of cereal grain varies within a wide range depending on species and applied nutrition. We have determined peculiarities of varieties and species of the fractional contents of protein in wheat, rye and triticale. The system of fertilization has a higher influence on grain protein content rather does the cereal species. Different applications of nitrogen changes the gluten content. Wheat and triticale grain may have higher contents of the biologically valuable fractions of albumins and globulin, depending on the rate of fertilizer application. The ratio of specific fractions and additional proteins in particular are of critical importance. Grain of different industrial quality is formed depending on the ratio of prolamines and glutamines.

Australian triticale update: New cultivars, quality aspects and funding outlook

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Keywords: triticale cultivars, breeding, grain and forage, human use quality

Australian farmers continue to want triticale as a reliable, hardy and productive crop. As seedgrowers, we are receiving increasing demand for triticale seed for livestock production: grazing followed by grain harvest, or hay and silage use. Farmers report that other crops (e.g. legumes, wheat, barley, oats) have failed to produce adequate economic return in recent hotter and drier seasons. On our farm at Sherlock, in a drier region with alkaline, relatively poor and rocky soil, we have bred and released 6 spring triticale cultivars. Reduced-awn head types *Tuckerbox* and *KM10* are popular for forage. *Yowie* and *Goanna* are fully-awned grain types, and *Joey* and *Kowari* are brand new cultivars that we are currently seeking commercial partners for. The University of Sydney has recently released a new long season dual purpose cultivar, *Cartwheel* and Australian Grain Technologies (AGT), three spring cultivars, *Fusion*, *Bison* and *Astute*.

The keen interest of farmers and researchers for triticale is unfortunately not matched by the research funding agencies, and it is disappointing to report that funding for triticale breeding and national variety trials (NVT) has ceased.

Recent research by Angela Pattison investigated quality parameters of modern triticale cultivars which relate to processing for human food, such as grain hardness, gluten properties and alpha-amylase.

Triticale does not attract advertising, but may be found in a range of breads and cereal products, if you read the small print. I can vouch for the excellent food value of triticale, given over 30 years of triticale in my diet, but relatively few food companies and health researchers have taken triticale up.

Promotion of triticale as a forage crop

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Keywords: triticale, forage, straw yield, economic return.

Since more than three decades, triticale showed a good adaptation and yield potential but the crop is still at a secondary priority compared to wheat. Developing new performing, adapted and easily adopted genotypes of triticale is a challenge in Algeria. As feed crop, triticale got its place in the cereal/animal systems. Triticale is promoted in Algeria with the aim of reducing maize imports. The crop is mainly grown for forage production (hay, green, silage and mixed to legumes), as grain feed or for dual purpose (forage and grain).

Many new adapted spring cultivars were developped during this last decades (all complete types). In terms of production, triticale outyielded durum wheat and barley by 11% in favourable and semi arid environments. However, bread wheat still outyields triticale (10%) in the sub-humid zones.

Forage production (fresh biomass and dry matter) of triticale gave encouraging results in comparison to barley and oats, when used in mixture with vetch or pisum for hay production, the amount of legume in the mixture was always higher with triticale than with oats or barley.

Triticale produces more straw, commonly fed to sheep, than other crop during dry years (frequent in Algeria) where the free market price is increasing drastically. Straw yield of triticale compensated largely for its low price when compared to barley straw or wheat and gave in general better economic return to farmers (2460 USD/ha for triticale Vs 2240, 2160, 1470, and 1370 USD for bread wheat, durum wheat, barley and hay of oats respectively).

Triticale improvement and production in Poland

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Keywords: triticale research, breeding, cultivar registration, acreage, production

Research and breeding of triticale in Poland began in the 1960s. Triticale breeding in Poland was highlighted by the program of Wolski and collaborators. The most notable release in 1982 was the cultivar *Lasko*. Because of its low winter hardiness, *Lasko* practically was not cultivated in Poland but was registered in other countries e.g. in Germany, France and other European countries. Over the years the cultivar set the standards for grain quality, and could be found in pedigrees of many modern triticale cultivars. From prof. T. Wolski's program in 1984 cultivar *Grado* and in 1985 cv. *Dagro* appeared on the list. At that early stage, triticale research and breeding in Poland was focused predominantly on winter type. However, this situation did not last long. In 1987 spring triticale cultivar of IHAR origin *Jago* and in 1988 *Maja* were registered. With the time being the number of triticale cultivars of both habits, winter and spring, was increasing. New cultivars were added to the list each year, and some older ones deleted. At present, 11 spring type and 42 winter type triticale cultivars are on the registration list in Poland. Among winter type cultivars with a short (e.g. *Bogo*, *Gniewko*, *Grenado*, *Pigmej*) and regular straw length have been developed and registered. Most of the cultivars were developed by recombination breeding but a number of cultivars came from a double haploid technology (e.g. *Borowik*, *Twingo*). Triticale cultivars have been favorably accepted by farmers. Since the 1980s there has been a rapid development of triticale in Poland, in respect of the number of registered cultivars and area sown. Its sowing area increased considerably each year and in the late 1990s 600 000 ha of the crop were grown in Poland. Triticale area under commercial production increased to 734 000 ha in 2001 and in 2005 it reached 1.2 mln ha. Because of a frosty winter in 2012 triticale sowing area dropped to 992 000 ha. In recent years triticale again regained its strength by being grown on over 1.3 mln ha.

In general, yield potential and resistance to diseases, lodging and sprouting have been decisive as to whether or not a triticale cultivar can commercially be produced. Polish triticale cultivars have proved widely adapted so could be grown in all geographical regions of the country and most regions of Europe as well. Leaf rust (*Puccinia triticina*), stripe rust and stem rust, *Stagonospora nodorum* blotch, scab, *Rhynchosporium* scald, take-all (*Gaeumannomyces graminis*), foot and root rots caused by *Microdochium nivale* and *Fusarium* sp. and eyespot (*Pseudocercosporella herpotrichoides*) are the main diseases that afflict triticale in Poland. Along with the increasing area planted to triticale, its total grain yield has been increasing almost each year in the past decade. In 2005 Poland produced 3.9 mln tonnes of grain, and in 2015 the tonnage of triticale grain reached 5.2 mln tonnes. Poland is a leading triticale grain exporter, exporting 439 thousand tonnes of triticale totaling 96 million USD in 2014.

Final stage evaluation of triticale cultivars to facilitate commercialization through licensing

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Keywords: commercialization, cultivars, rust resistance, yield increase

The Plant Breeding Laboratory (PBL), Department of Genetics, has been conducting a triticale-breeding programme for several years, which focuses on the release of new high yielding cultivars with excellent disease resistance. Triticale is mainly planted in the western and southern Cape regions of the Western Cape province of South Africa as grain crop for animal feed, for making silage, and for cover crop in vineyards. The project aim was to perform a final stage evaluation of two prospective new triticale cultivars, that outperformed currently available triticale cultivars during the 2013 and 2014 yield trials, in order to be able to apply for plant breeder's rights (PBR) and commercialize it through licensing agreements. The following objectives and activities have been identified in order to achieve this: (1) generate a third year of data that is more expansive (over multiple localities and for inclusion in the South African Agricultural Research Council's national crop production guide as well as to be used as a marketing tool); (2) generate interest among producers and prospective license holders by planting it at producers' field day sites across the potential production area; and (3) perform a large scale breeder's seed multiplication (a prospective licensee needs breeder's seed from which to start commercial seed production). As such the project managed to preliminary register two new cultivars ("US2015" and "US2016") that are currently being evaluated by the Department of Fishery and Forestry (DAFF) of South Africa. In addition, the project also produced breeder's seed of both cultivars and successfully conducted multi-location field trials as well as compile the 2016 annual production guidelines.

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Established in 1924, the Cereal Research Non-Profit Ltd. Szeged, Hungary – the venue of the Symposium – is one of the leading institutions of the Hungarian Agricultural Ministry. The mission and name of the institution were changed several times during the past decades. Two years ago, the Cereal Research Ltd. was successfully integrated as a partner in the governmental institution network of the National Agricultural Research and Innovation Centre (NARIC). Research and innovation work focus on variety development and seed production of small grain cereals, corn, and oil crops and hereby triticale breeding is one of the key research-areas. During the decades, a total of circa 500 plant varieties were registered and 200 patented by this principal Hungarian agricultural place.

EUCARPIA, founded in 1956, aims to promote scientific and technical co-operation in the field of plant breeding in order to foster its further development. To achieve this purpose, the Association arranges and sponsors meetings to discuss general or specific problems from all fields of plant breeding and genetic research. Activities with a predominantly commercial interest are excluded, as EUCARPIA is a non-profit organization.

The Hungarian Plant Breeders' Association is devoted to the support of the art, science, career, work and business of plant breeding as a profession through assistance and communication among professionals in the field of breeding, seed industry, agronomy, and other related areas. It emphasizes the cooperation among the concerned disciplines maintaining the ethical standards, thereby contributing to stable and sustainable agriculture and food supply in our region and elsewhere.

The International Triticale Association (ITA) is an informal association presently proposing to form a formal, word-wide, professional association. It focuses on potential and actual research co-operations, germplasm-exchange and idea flow, organizing meetings and networking in triticale. Its main mission is to coordinate research and communication at an international level on related fields of this crop.