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Improving Global Competitiveness of China in Wheat Export by Increasing Wheat Quality

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Abstract:

Technological value of wheat grain and flour, are affected by the a) genotype, b) environment, and c) agronomic management. China, the biggest wheat producer, due to lack of quality germ-plasm still import HRW from the US. The Chinese government considers food self-sufficiency as “a matter of national security”, and its great goal is to stop importing wheat, and even to become one of the leading wheat exporter. To achieve that goal, China has to have overproduction of high quality hard red wheat. In Croatia, as a results of long term breeding effort on high grain protein, a number of new high yieldind and good quality germ-plasm were developed, tested, described and the cultivar ownership offered for sale. Beside the Panonic plato this germ-plasm is well adapted also to some winter wheat growing regions in China. Plato of Panonic region, with rich soil and the semiarid climate is suitable for HRW production. By adequate investment, HRW production in Panonic region can provide wheat for export to the biggest wheat importer Egypt, and at the same time, the status of wheat exporter to the investor.

Keywords:

Winter Wheat for Export, High Yield, High Grain Protein, Wide Adaptability

1. Introduction

Today, beside the main objective and plant breeding goal, the breeder must know for whom the breeding results (a new germplasm or a new cultivar) is intended. Why is accent on 'for whom'?

The World is in process of globalization. Half a century ago cultivars for own region or country were bread. The accent was on specific plant adaptability. Yet, today the point is on wide plant adaptability, and each day more and more foreign cultivars has been grown on our fields. The competition has become stronger and small plant breeding firms hardly survive with much bigger and more powerful

companies. In reality, this is a war in which, instead of conventional arms, more powerful economic armament is used. To avoid this economic war, big international companies merge and become even bigger and more powerful. The recent example was the European Commission approval (March 21. 2018) the acquisition of two mega companies Monsanto and Bayer (proposed US$66 billion). But first deals in the sector were another corporate acquisition between two giants Syngenta and ChemChina for $43 billion finished in 2016 and a proposed merger of Dow Chemical and DuPont (September 01, 2017) for $130 billion.

Those mergers have radically changed and permanently altered the economics of food, farming and the environment. “Big Data” and “Digital Farming”, a form of precision agriculture, are transforming agriculture and boost more profits. The market for digital-based agricultural services is expected to reach US$ 4.55 billion by 2020 [1]. The use of data analytic will give Monsanto and Bayer even more power for their products. The new company with the control of agricultural Big Data and seed market will have an opportunity to exclude competitors. In such an environment, a small breeding company should adapt and choose different approaches to survive.

1.1. The Goal of Particular Breeding Effort

Let's not forget that the worst famine in human history was in China from 1959 to 1961, when about 34 million people starved to death [5]. Today, China is the world's largest wheat producer (124 million tones/year) and consumer. For many years China was also a large wheat importer too. The main import was hard red, high quality wheat from the US (about 1.2 million tones at $390-430 per tone). The US is today the fifth wheat producer in the world, but the biggest wheat exporter! The Chinese great goal is to stop importing wheat, and even to become one of the leading wheat exporters. But for achieving that goal, China has to have overproduction of high quality hard red wheat.

China National Bureau of Statistics reports that the recent Chinese wheat grain production fell sharply (nationwide grain production in summer 2018 was 138.72 million tons), representing a net decrease of 2.2 percent, from 2017. Wheat industry is going to be market-oriented, while the food problems become a big and a very important issue. The wheat price is constantly going up. The Chinese government considers food self-sufficiency as “a matter of national security”, and has been trying to subsidize the wheat production and sale in many ways.

This could be a chance for small breeders with an extraordinary germ-plasm for doing business with some of the largest Chinese seed producing company. The main problems are climate and adaptability of the new wheat.

China and ex-Yugoslavia improved their own wheat production in early 1960's by introducing several Italian winter cultivars [10]. We will mention only two of them: Mentana (Chinese name Nanda 2419) was grown in China on 4.7 million hectares in 1958, and Abondanza on 2.1 million ha. Thus, we can conclude that the new Croatian germ-plasm could be well adapted in China. These Italian cultivars have become the core parents of the newly established breeding programs with the following features: lodging resistance, disease resistance, yield increase, early maturity, but without improved industrial quality.

1.2. The Breeding Goals for Chinese Production Areas

The main goal was improving the wheat bread baking quality and its nutritive value [21]. While grain yield has increased over time, the concentrations of all minerals except calcium have decreased. Dietary deficiency of essential micro-nutrients such as zinc and iron in human population are very common and genetic and agronomic bio-fortification to improve zinc (Zn) and iron (Fe) levels in wheat could significantly reduce micro-nutrient malnutrition. It should be possible to improve iron (Fe) and zinc (Zn) levels in wheat grain simultaneously through plant breeding.

1.3. Micronutrients

The soil is the primary source of trace elements Fe, Zn, Mo, Cu and Mn essential for plants, animals and humans. However, the mineral composition of cereal crops, the technological value of grain and flour (protein content), as well as bread quality are affected by the 1) genotype, 2) environment, and 3) agronomic management practices [7, 30] in soils and also because of increasing nutrient demands from increasing cropping practices. There are more than 48.6 million ha of soils deficient in Zn, which are mainly distributed on calcareous soils in the winter wheat region of China. Iron deficiency widespread on the same calcareous soils and alkaline soils affects around 40% of farmland [4]. It is important: grain Zn and Fe content are positively correlated [24] suggesting that these two traits may be combined relatively easily during breeding process. Both minerals are also well correlated with grain protein content, while they are negatively correlated with glutenin in grain [25]. Every year Fe and Zn deficiency cause deaths of about 800 thousand children [28]. The consumption of white flour, made predominantly from endosperm of wheat grain, discarding bran in the milling process, has even worsened the degree of Fe and Zn malnutrition [27]. However, nitrogen fertilization is known, not only to increase wheat grain yield, and grain protein, but also to facilitate the uptake of Fe and Zn in wheat grain [3, 32]. The interactive effect of N, Zn, and Fe on grain yield, protein content and nutrient concentration was investigated in a pot experiment [31]. They concluded that adequate fertilization can be a good agricultural practice to enhance protein content and the Zn and Fe concentration in grain.

2. Materials and Methods

In Croatia, the project of combining the effect for good bread-making characteristics, based on far suited regional breeding programs from USA, Argentina, Romania, and good yield and disease resistance based on New Zealand program has been initiated many years ago. The germplasm of elevated grain protein NE7060 from the International wheat nursery [21], has been used in crossing and further selection of locally adapted high protein, disease resistance improved lines from segregating progenys [8,14].

In the last decade of the past century an extensive examination of 142 wheat cultivars from former Yugoslavia, released in the period 1967 to 1986 was conducted. The pedigrees [13], their coefficients of parentage and cluster analysis [9,11,12], their identification by gliadin electrophoresis and determination of their genetic variability of HMV glutenins [18,22] were examined. The first high protein, but below average yielding wheat Divana was released in 1995.

Finally, eighteen different F8 to F10 wheat selections and two cultivars: Divana (check for quality) and Bologna (check for yield) were tested on yield, grain quality,

grain mineral content, disease resistance, and winter-hardiness in replicated micro-trials during 2016, 2017 and 2018 at Krizevci, Croatia.

The technology applied is listed in Table 1. Novel approach was the treatment with the stone meal/powder [29], and biostimulant BPC-157 [17]. Both technologies are described and published earlier, and will not be described here.

Table 1. *Technology applied in the three micro-trials (5 sqm plot in five replications).*

Growing season	**a) 2015/16, b) 2016/17** and **c) 2017/18**
Previous crop	a) Lupinus albus, b) Rapeseed and c) Zucchini
Fertilizer N:P:K	a, b, c) NPK 7:20:30 300 kg/ha + 130 kg Urea
Seed treatment*	a, b, c) Stone meal* + 3% cuprablau
Seeding a) and b) 220; c) 230 kg/ha	a) November 5, -b) October 10, -c) November 3
Top dressing	150 kg/ha KAN+S (ASN), a) Mart 03 - b) Mart 24 - c) Apr. 23
Herbicide	Hussar 0.1 l/ha, a) Mart 31 -b) Apr. 09 -c) Apr. 14
Biostimulant**	BPC157 ** 125 x 10^{-7} ppm , a) May 12 -b) May 06 -c) May 17
Foliar dressing II	5% stone meal, a) Apr. 10, -b) Apr. 17, - c) Apr. 26
Fungicide-Insectiside	Stil+Agrostemin 2 l/ha, Apr. 17 Elatius Era 0.8 l/ha+Karate Zeon 0.2 l/ha, May 05 Amistar-extra 1 l/ha, May 10 Mangelo 0.8 l/ha, + Decis 0.3 l/ha, May 15 Amistar-extra 1 l/ha + Direct 0.1 l, May 27
Foliar treatment	15% Urea, a) -b) May 12, - c) May 19
Harvest	a) June 30, - b) July 02, - c) July 03

*** The two novel - not common technology approach applied.*

2.1. Stone Meal Seed Treatment

Stone meal seed treatment before sowing – To avoid possible negative effect of seed treatment with chemical fungicide, we are using seed protection with natural stone meal just before sowing, mixed with 3% cuprablau solution, for better adhesion of stone meal to seed. Beside the positive effects of the other micro-nutrients, this stone meal contains around 57% SiO_2 which has a very good effect on seed protection, as well as plant protection from plant diseases and insects if used for foliar treatment during vegetation [29].

2.2. Biostimulant BPC-157

Biostimulant BPC-157 is pentadecapeptide, produced in human gastric juice, molecular formula C^{62}-H^{89}-N^{16}-O^{22}. Till now its effect on plants have not been tested enough. But from recent experience [17*]* this biostimulant in very small concentrations (125 to 1.25x10^{-7} ppm) could be useful when applied during dry period, with final effects in grain yield increase.

2.3. Quality Testing

Beside grain protein (Kjeldahl method ISO 20483-2013), sedimentation SDS testing techniques (ZELENI PN-ISO-%) are used as a means of measuring gluten strength [24]. While the final value of wheat quality was tested by experimental bread baking, and mineral content by using inductively coupled plasma mass spectrometry (ICP-MS).

3. Results and Discussion

3.1. Grain Yield

Good grain yield and grain characteristics were obtained throughout the testing years, the best results was in the third year. (Table 2, Figure 1.) Twenty years average yield for cultivar DIVANA is 5.87 t/ha, and hire we have three years average 6.67 t/ha (Table 2), and even 7.99 t/ha in one year (2018) Figure 1. It seems, when grain yield is in question, we succeed to improve it. Between check for yield cv. BOLOGNA (8.44 t/ha) and the lines J-77 (8.24 t/ha) and J-85 (8.00 t/ha) there were no significant difference in yield. (Table 2)

Table 2. *Cultivar-line yield, yield components, and some grain quality properties - average for three growing seasons 2016, 2017 and 2018.*

No.	CULTIVAR -LINE (generation)	Heads per sqm	Grain yield t/ha*	TKW g	Test weight kg/hl	Grain protein %	Wet gluten %	Sediment. value - ml
1	DIVANA (Check)	745.3 b	6 67 a	47.70 b	80.41 a	17.52 a	38.15 c	71.0 b
2	J-77 (F_8, F_9 and F_{10})	646.3 a	8 24 b	45.51 b	81.65 a	16.00 b	35.13 b	70.0 b
3	J-85 (F_8, F_9 and F_{10})	660.0 a	8.00 b	52.21 c	81.08 a	16.45 b	37.75 c	70.0 b
4	BOLOGNA (Check)	808.3 c	8 44 b	34.57 a	84.20 b	13.49 c	28.68 a	55.5

** Values followed by the same letter are not significantly different according to Duncan multiple range test (p=0,05)*

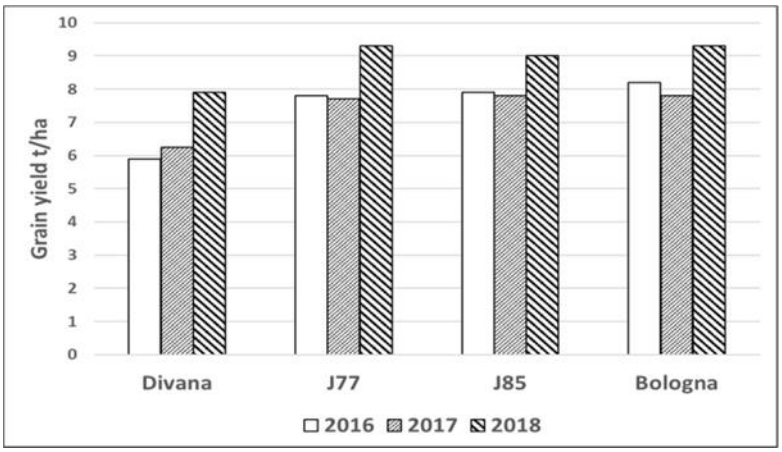

Figure 1. *Grain yield of the two cultivar: Divana check for quality, Bologna check for yield, and the two breeding lines: J-77 and J-85, in which yield and grain quality are combined.*

The grain belongs to hard red winter (HRW) wheat (Figure 2 and Figure 4)

Figure 2. *The grain of high quality line J-77 in comparison with check for quality - cv. DIVANA.*

The bread slices and the bread properties of the lines L-77 and L-85, compared with the bread slices and and the bread properties of the check cultivars DIVANA and BOLOGNA are shown in Figure 3, Figure 5, and Table 3.

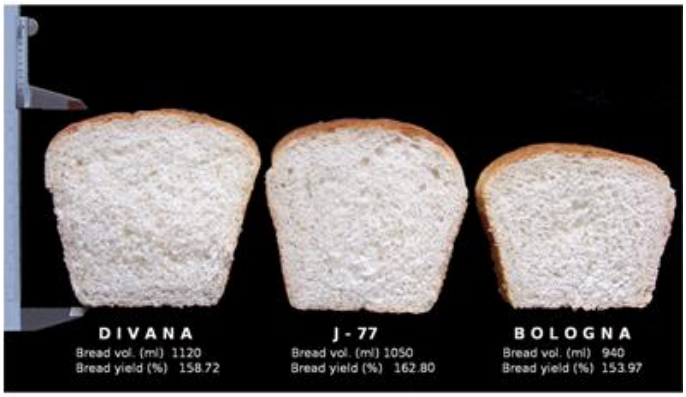

Figure 3. *Bread slices of cv. DIVANA (check for quality), line J-77, and cv. BOLOGNA (check for yield).*

Figure 4. *The grain of high quality line J-85 in comparison with check for quality - cv. DIVANA.*

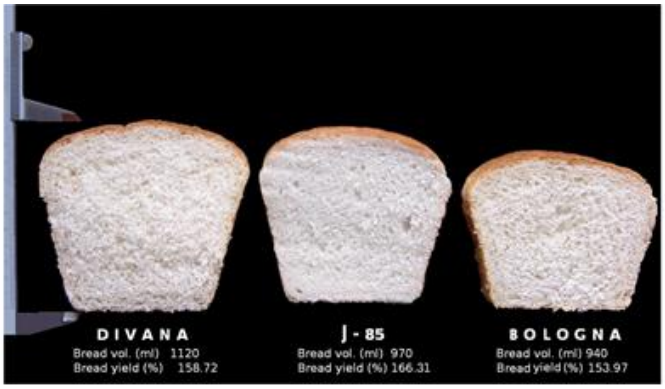

Figure 5. *Bread slices of cv. DIVANA (check for quality), line J-85, and cv. BOLOGNA (check for yield).*

Table 3. *The bread properties of the lines L-77 and L-85, compared with the breads of the check cultivars DIVANA and BOLOGNA.*

No.	**BAKING TEST**		Cultivar - line			
			DIVANA (check)	Line **J-77**	Line **J-85**	**BOLOGNA** (check)
1	Dough yield (%)	no additive	174.3	178.8	181.8	167.8
		with additive	174.8	177.3	180.3	169.3
2	Bread yield (%)	no additive	158.72	162.80	166.31	153.97
		with additive	156.45	162.37	165.41	155.54
3	Volume yield /(%)	no additive	488.04	469.35	440.87	394.33
		with additive	511.29	478.71	446.24	434.37
4	Loaf widt/height (cm)	no additive	12.0 / 11.5	11.7 / 9.9	11.6 / 10.3	11.7 / 9.0
		with additive	12.0 / 11.2	11.0 / 11.2	11.7 / 10.0	12.0 / 1 0.1
5	Loaf volume (ml)	no additive	1120	1050	970	940
		with additive	1170	1080	990	1030
6	Loaf yield (ml/g)	no additve	3.07	2.88	2.65	2.56
		with additive	3.21	2.97	2.71	2.81

3.2. Cultivars Blend

Using a cultivars blend could be good practice for combining two or more good properties of different cultivars grown as one crop. Grain yield and grain quality are main target characters combined in needed proportions, but dwarfism-lodging resistance, disease resistance, low temperatures or drought resistance could be also combined as an additional property. By this method a higher value of desired characters could be obtained during harvest of one crop [16].

3.3. Micronutrients

The soil is the primary source of trace elements Fe, Zn, Mo, Cu and Mn essential for plants, animals and humans. However, the mineral composition of cereal crops, the technological value of grain and flour, as well as bread quality are affected by the 1) genotype, 2) environment, and 3) agronomic management practices. Nearly half of the world cereal production comes from soils low, or marginal in plant available zinc, leading to unsustainable and poor-quality grain production [27].

Micro-nutrient deficiency, widespread in China, is one of many factors limiting crop yields, and crop product quality, because of the generally low micro-nutrient availability in soils and also because of increasing nutrient demands from increasing cropping practices [6]. There are more than 48.6 million ha of soils deficient in Zn,

which are mainly distributed on calcareous soils in the winter wheat region of China. Iron deficiency widespread on the same calcareous soils and alkaline soils affects around 40% of farmland [34]. Both minerals are also well correlated with grain protein content, while they are negatively correlated with glutenin in grain [26]. In China, on average, people consume 140 g wheat and its products per day [35]. The consumption of white flour, made predominantly from endosperm of wheat grain, discarding bran in the milling process, has even worsened the degree of Fe and Zn malnutrition [30, 31]. Supplementation and fortification can be applied as short-term intervention, while dietary diversification and biofortification are the long-term and cost-effective strategies [6]. Foliar Zn and Fe spraying increases their concentration in wheat grain. This can be a good agricultural practice to enhance protein content and the Zn and Fe concentration in grain.

Table 4. *Average mineral content in wheat flour samples of lines J-77 and J-85, and check cvs. DIVANA and BOLOGNA, CHANGED rows/columns.*

No.	Cultivar or line	Mineral		
		Zn (mg/kg^{-1})	**Mn** (mg/kg^{-1})	**Fe** (mg/kg^{-1})
1	**DIVANA**	22.4 b	56.0 bc	96.4 c
2	Line **J-77**	23.2 b	50.8 b	98.2 c
3	Line **J-85**	43.6 c	60.0 c	60.0 b
4	**BOLOGNA**	9.6 a	22.8 a	33.6 a

** Values followed by the same letter are not significantly different according to Duncan multiple range test (p=0,05)*

Iron availability to plant depends to a large extent on soil pH and redox potential, while phytic acid from cereal grains reduces bioavailability of iron and zinc to humans [6]. Genotype effects largely controlled Fe concentration, whereas Zn concentration was almost totally dependent on location effects [25].

According to the report of the 2002 China National Nutrition and Health Survey the diets of Chinese people are still plant-food-based. Cereals are the important source of iron and zinc, but also contain phytate, which has an inhibitory effect on their human absorption. The World Bank indicated that interventions to end micronutrient deficiency were among the most cost-effective investments in the health sector and biofortification is the most promising sustainable solution [24].

3.4. Celiac Disease and Gluten Intolerance

The prevalence of undiagnosed celiac disease has increased dramatically in the United States during the past 50 years. Celiac disease, and, more generally, gluten intolerance, is a growing problem worldwide, but especially in North America and Europe, where an estimated 5% of the population now suffers from it. [31].

In celiac disease, T cells develop antibody responses against dietary gluten, a protein present in wheat. It is proposed that other exogenous factors might be identified as drivers of autoimmune processes, (Jabri & Sollid, 2009).

Symptoms include nausea, diarrhea, skin rashes, macrocytic anemia, depression, and cancer. A recent estimate suggests that one in twenty people in North America and Western Europe suffer from celiac disease [20].

Despite the fact that China is the world's largest wheat producer and has a high and rapidly increasing consumption of wheat and gluten-containing products, celiac

disease was considered to be rare in China for now, and had not been studied thoroughly. At present, the number of reported celiac disease cases is extremely low.

However, glyphosate residues in wheat are likely increasing recently due to the growing practice of crop desiccation just prior to the harvest, and it seems glyphosate, the active ingredient in the herbicide Roundup®, is the most important causal factor in this epidemic. [31]

The U.S. currently represents 25% of the total world market on herbicide usage. Glyphosate has been the most popular herbicide in the U.S. since 2001. Using Roundup on wheat crops as a desiccant just prior to harvest save the farmer money and increase profits. The usage of glyphosate on wheat in the U.S. has risen sharply in the last decade, in step with the sharp rise in the incidence of Celiac disease.

At the moment, for China is important to produce own high protein wheat, and stop with import of wheat from the USA.

4. Conclusions

As the grain yields, as well as technological value of grain and flour, are affected by the genotype, environment, and agronomic management practices, our efforts should be oriented to select the best cultivar, and apply suitable agronomic management to minimize environmental stress.

Low precipitation and shortage of water is common during vegetation, so a new technology of spraying biostimulant BPC-157 by drones, during draft period, could be useful approach, especially because of low costs of these treatments. As this is a new technology, more experience is needed, and additional testing should be done.

Introducing cultivar blends of high yielding and high-quality cultivar in commercial wheat production as a step forward to sustainable agriculture (less pesticides, higher yield and better quality) should be adopted.

A deficiency of one or more of the eight plant micronutrients (boron, chlorine, copper, iron, manganese, molybdenum, nickel and zinc) will adversely affect both the yield and quality of crops. So, mineral fertilizer should be applied, especially in regions which are known for micro-nutrient deficiency, like the wheat growing North China Plain. For biofortification we used, from river stones grinded Holocene minerals of known chemical composition.

Egypt is today the biggest hard red wheat importer and the Pannonian Basin (relatively close to Egypt), with sub-arid climate and reach soil, is suitable for HRW production. Those facts could give China big chances to invest in these regions and quickly become the bigest exporter of wheat produced out of China (in Croatia-Slavonia, Serbia-Vojvodina and Hungary) with the help of the special high-quality germplasm. It is only a subject of judgement of competent institutions in China.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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