Review

Historic Role of the Wheat Variety Akakomugi in Southern and Central European Wheat Breeding Programs

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The old semidwarf, not very attractive, Japanese wheat variety Akakomugi was the source of the dwarfing gene *Rht8* and photoperiodic insensitive gene *PpD1* to many semidwarf wheat varieties in South and Central Europe in the 20th century. Integrating the *Rht8* and *PpD1* genes in wheat varieties offered the best opportunities for reducing plant height, accelerating time of flowering, improving grain fill before the onset of dry summer conditions, enhancing spikelet fertility, and consequently increasing yields. Many breeders from South and Central Europe and from the former Soviet Union were creating winter short high yielding wheat varieties without knowing at the time that Akakomugi was the donor of such important genes. At the end of the 20th century, it was discovered that dwarfing gene *Rht8* and photoperiodic insensitive gene *PpD1* are located on the short arm of chromosome 2D in wheat. Microsatellite analyses proved that Akakomugi is the source for the *Rht8* and *PpD1* genes in many short wheat varieties in South and Central Europe.

Key Words: Wheat, Akakomugi, *Rht8*, *PpD1*, wheat history.

Introduction

In the beginning of the 20th century, the Italian breeder Nazareno Strampelli was in charge of wheat breeding in Rieti when the project “Bataglia del Grano” (Wheat Battle) was launched by the Italian government in hopes of making the country self-sufficient in wheat production. Strampelli was aware of the fact that selection within the variety, or by crossing Italian wheat varieties with each other, would not lead to much progress. He also realized that western European wheat varieties are more productive than Italian, but were late ripening for Italian climate, so he crossed the Dutch variety Wilhelmina Tarwe with the Italian variety Rieti. In the lines selected from this cross, the productivity was somewhat increased, but because of the high stem, there was much lodging, which could not justify higher investments. Then, he came up with the ingenious idea for that time, to use Japanese short straw varieties and cross them with European varieties. In 1913, Strampelli crossed the Japanese wheat variety Akakomugi with the (Wilhelmina Tare × Riete) in order to shorten the straw and to obtain resistance to lodging and earliness. From the literature survey, we were not able to find when and how exactly Akakomugi reached Europe. At a meeting in Rieti in Italy, at the occasion of the

Centenario of Nazareno Strampelli 2000, most of the scientists present supposed that the seeds of Akakomugi were brought by a visitor to Strampelli at the beginning of the 20th century (according to the personal communication of the senior author). From the progeny of this cross, the new wheat varieties Villa Gloria, Ardito, Mentana and Damiano were obtained in 1918. These varieties were very well known and widely grown in Italy, in South America, and especially in Argentina (Lorenzetti 2000). Ardito was crossed with the Argentinean variety Vencedor, and the new short straw Argentinean wheat variety Klein 33 was created (Worland *et al.* 1998). Later, around 1925, Strampelli crossed Villa Gloria with the variety Balilla (obtained from the cross Duro di Puglia × Akakomugi). From such a complex cross, Strampelli created the variety San Pastore in 1931 (Strampelli 1932). San Pastore was grown for more than 35 years with extraordinary success in Italy and many other countries (Borojevic 2000, Boggini 2003). Because of the genes inherited from Akakomugi, all Strampelli’s varieties were much shorter than Rieti or Wilhelmina Tarwe, more resistant to lodging, and were earlier. So, Nazareno Strampelli was a creator of a new type of semidwarf wheat varieties that was not known in Europe before. This type of varieties contributed significantly not only to the increase of the Italian wheat production, but also to the increase of wheat production in several South and Central European countries after World War II (Borojevic 2000, 2003).

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History of developing semidwarf high-yielding winter wheat varieties

After the World War II, Yugoslavia (former) was not self-sufficient in wheat production. Therefore, in the 1950s, the Yugoslav government decided to have the grain yields increased in order to relieve the country from importing wheat. Agricultural practices were first being improved by using better soil cultivation and using more mineral fertilizers. It was realized that the existing domestic varieties were not suitable for such conditions; they were not resistant to lodging and they could not compensate for the costs invested. The Agricultural Chamber of Yugoslavia, which deserves the credit for the intensification of the agriculture, came to the conclusion that higher yielding wheat varieties should be sought. Several agronomists went to the neighboring countries, first to Italy, to find out whether there were more productive varieties that could be successfully grown in Yugoslavia. The most impressive were the varieties grown in Italy and some of them (e.g., San Pastore, Autonomia, Fortunato, Libellula, Mara) were imported to Yugoslavia in large quantities and distributed to state farms in 1956–1957. However, Italian varieties did not completely satisfy the demands of wheat production, so wheat breeders in the former Yugoslavia started developing high-yielding varieties that would be more suitable for the local climatic conditions (especially winter hardiness) and the requirements of milling and baking industry (Borojevic 1960). The new varieties had to be semidwarf, resistant to winter cold and lodging, and had to have early flowering in order to improve grain fill before the onset of desiccating summer conditions. They had to have increased spikelet fertility, which, consequently, would produce higher yields than the Italian varieties (Borojević and Potočanac 1966). Thanks to very good adaptive possibility of the linkage group of the *Rht8*, *Ppd1* genes from Akakomugi in Italian varieties (not known at that time) to the phenotypic expression traits, semidwarf, daylight-insensitive and high-yielding, winter wheat varieties were developed in the countries of the former Yugoslavia. In Table 1, the varieties carriers of *Rht8* and *Ppd1* genes are compared with old variety Bankuty 1205. (Bankuty 1205 was grown in Pannonian Plain before semidwarf varieties were introduced.) From Table 1, it may be seen that increased yields of the new varieties were the result of an increased harvest index. The new variety Sava, developed in Novi Sad, was the highest yielding wheat in comparison

with the Italian variety San Pastore, the Russian variety Bezostaja, and the old Hungarian variety Bankuty 1205. Sava had higher yields than Bankuty 1205 by 56%. Sava is the carrier of *Rht8* and *Ppd1* genes; it came from the cross Fortunato2 (Italy) × Redcoat (USA). Fortunato2 came from a complex cross, which included an Italian variety, Damiano, of which one parent was the Japanese variety Akakomugi (Fig. 1). In the 1970s, the variety Sava was the highest yielding variety in the International Wheat Experiments conducted in 33 locations worldwide (Wilhelmi *et al.* 1979). The world record of 10.90 t/ha was obtained from growing Sava on 30 hectares in Sale, Galanta in Slovakia in 1976 (Spaldon 1986). The Italian variety San Pastore over-yielded Bankuty 1205 by 34%. The Russian variety Bezostaja 1 over yielded variety Bankuty 1205 by 32%. Bezostaja 1 is a winter-hardy variety created by Lukyanenko in 1959 in Krasnodar in the former USSR (Lukyanenko 1973, Rabinovich 1972). Bezostaja 1 was widely spread in East and Central Europe, including the countries of the former Yugoslavia. Bezostaja 1 is also carrier of the *Rht8* and *Ppd1* genes; it came from very complex crosses in which one parent was Klein 33 from Argentina. Klein 33 came from a cross in which one parent was Ardito, of which one parent was Akakomugi (Fig. 1).

The impact of semidwarf winter wheat varieties on the neighboring countries of the former Yugoslavia

The new semidwarf winter wheat varieties having *Rht8* and *Ppd1* genes, which at the time were unknown, had a significant impact on wheat production and breeding in neighboring countries of the former Yugoslavia (Table 2). In Hungary, the first Italian varieties, San Pastore and Autonomia (carriers of *Rht8* and *Ppd1*) were registered in 1960 (Anonimus 2000). Later, many Yugoslavian varieties (carriers of *Rht8* and *Ppd1*) were imported and used in agriculture practices and in wheat breeding programs. For example, of 45 wheat varieties released by the Cereal Research Institute in Szeged, 40 have in their genetic background Italian or Yugoslavian wheat parents with *Rht8* and *Ppd1* (Borojevic 2003). Several of Strampelli's cultivars were introduced in Romania in the 1920s. They were used as parents in crosses with old local varieties and, later on, were replaced by Bezostaja 1 and Mexican cultivars (Borojevic 2003). In Bulgaria, in General Toshevo and Plovdiv, the Italian wheat varieties Ardito, Mentana, San Pastore, Mara and Produttore were

Table 1. Advancement in increasing biomass and grain yield in wheat by breeding (8-year average data, 1970–1977)

Cultivar	Stem height (cm)	Yield in t/ha		Total biomass		Grain yield %	Harvest index
		straw	grain	t/ha	%		
Bankuty-1205 (Hun.)	112	10.08	4.42	14.50	100	100	0.30
San Pastore (Ital.)	91	9.00	5.91	14.91	103	134	0.40
Bezostaja-1 (USSR)	90	9.31	5.82	15.13	104	132	0.38
Sava (Yug.)	81	8.93	6.90	15.83	109	156	0.44

Source: Borojević (1978, modified)

Fig. 1. The Pedigree of semidwarf wheat varieties derived at early stage in the Yugoslavian breeding program (Worland *et al.* 1998).

Table 2. Changes in cereal mean yields per crop season in different countries from 1948/52 to 1981/85

Country	Mean yields 1948/52 (t/ha) ¹⁾	Mean yield; % of yields for 1948–1952				
		1961/65 ²⁾	1966/70	1971/75	1976/80	1981/85
Bulgaria	1.24	146	218	274	306	290
Hungary	1.38	135	174	233	253	326
Romania	1.02	143	166	225	265	265
USSR	0.84	114	155	166	190	178
Yugoslavia	1.14	158	210	254	289	298

¹⁾²⁾ Data from Sehgal (1977) in Sneep, J. and A.J.T. Hendricksen (eds.), (1979) Plant Breeding Perspectives. Pudoc, Wageningen. p.432. Other data are calculated on the basis of mean yields supplied from the FAO year-books. The table according to S. Borojević (1990, modified).

imported in 1955. The Yugoslav high-yielding variety Sava and others were imported later and were used extensively in crossing programs. They were crossed with the Russian variety Bezostaja and later with Aurora and Kavkaz, also carriers of the *Rht8* and *Ppd1* genes. Between 1969 and 1988, more than 70 cultivars were created and officially approved. The average yield increased more than three times in that period (Panayotov 1998, 2000).

Discussion

The small sample of grains of the wheat Akakomugi, which an unknown visitor brought to Strampelli in Italy in the beginning of the 20th century, contributed to the three-fold increase of wheat production in Italy and many countries of South and Central Europe (Table 2). Nazareno

Strampelli was the first person in Europe who used the Japanese variety Akakomugi, to shorten the straw and to increase the productivity per unit of area (Strampelli 1932). The Yugoslav wheat breeders, by crossing Italian short straw varieties with winter wheat varieties, were successful in creating semidwarf high-yielding winter wheat varieties (Borojevic and Potocanac 1966). The new Yugoslavian varieties had a significant impact on wheat breeding and production elsewhere (Kronstand 1997, Borojevic 2000). In the former USSR, Lukyanenko (1973), independently of the groups mentioned above, selected Bezostaja 1, a semidwarf winter wheat variety with very good grain quality after many complicated crosses. However, the source of the *Rht8* and *Ppd1* in all those varieties was not known until the end of the 20th century, when it was discovered that dwarfing gene *Rht8* and photoperiodic insensitive gene *Ppd1* gene were

both located on the short arm of chromosome 2D in wheat (Gale and Youssefian 1985). Microsatellite analyses proved that, in Akakomugi, the gene *Rht8* is closely linked with Wheat Microsatellite Locus (WMS) 261, alel 192 bp. The microsatellite screening showed that Akakomugi was the source of the *Rht8* and *PpD1* genes for many varieties in South and Central Europe, including the varieties Kavkaz and Aurora in the former USSR (Worland *et al.* 1998, 1998, Korzun *et al.* 1998).

Conclusion

Various carriers of *Rht8* and *PpD1* genes contributed to the significant increase of total wheat production in South and Central Europe, thanks to the old Japanese variety Akakomugi. This was not the Green Revolution, but an "Evolution of Wheat Breeding," which took place in the last century in countries from Italy, across the south and central European countries, to the former USSR.

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We would like to dedicate this paper to the memory of the late wheat breeders Nazareno Strampelli, Slavko Borojevic, and Pavel Panteleymonovich Lukyanenko for their vision to create short wheat varieties by using varieties that inherited *Rht8* and *PpD1* genes from the Japanese variety Akakomugi.

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