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Rusts Epidemics and their Implications in Wheat Breeding and Research in the Czech Republic

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Rust epidemics

Stem rust of rye. In the early 1950s, a severe stem rust epidemic developed on rye in southern Bohemia. The role of an alternate host, barberry bushes occurring in the hilly area of Šumava, was investigated. Of cerealicolous *Puccinia graminis* subspecies only stem rust that attacks rye was found on barberries. The infection of barberries originated from rust infected couch-grass growing under them. If it grew closer to a field of rye, an infected barberry bush would have a very distinct effect on the spread of stem rust in the field. Barberries were not eradicated after the epidemic, nevertheless, no large-scale outbreak of stem rust on rye has ever appeared since then. Obviously, the incidence of barberry bushes was too low to be the main source of inoculum for severe rust outbreaks. The epidemic in the 1950s probably developed due to a long-distance aerial transfer of inoculum. Of the assortment of rye cultivars and land races tested under severe stem rust infection pressure, landraces from Austria, northern Bohemia and eastern Moravia showed lower disease severity, but insufficient yields (Bartoš & Bareš 1960).

Yellow rust of wheat. In the 1960s yellow rust was the most important rust species. None of the cultivars registered at that time was resistant at the seedling stage to all determined yellow rust races. However, many showed resistance at the adult plant stage. Research on yellow rust supported the decision of the State Board for the Registration of Cultivars that only cultivars possessing yellow rust resistance in field tests should be registered in future. This regulation has initiated a consistent breeding for yellow rust field resistance and thus has avoided possible losses that could be caused by yellow rust at that time. The high yellow rust infection on temporarily introduced cultivars Zlatna Dolina and Sava from the former Yugoslavia showed that the risk of yellow rust was high. The last yellow rust epidemic occurred in 1999 and in subsequent years as a part of the epidemic extending from Western Europe over Central Europe to Hungary. Wheat and triticale suffered considerable losses.

Stem rust of wheat. The year 1972 was a season with a severe stem rust epidemic on wheat. Resistance governed by *Sr5* in cvs. Bezostaya 1, Yubileynaya 50, Aurora and Kavkaz offered good protection against the major part of the stem rust population till 1972. Aurora and Kavkaz possess *Sr31* in addition to *Sr5*. Resistance gene *Sr31* remained effective in the epidemic and has been effective until now, whereas virulence to *Sr5* has prevailed in the stem rust population after the epidemic in 1972 (Bartoš 1975). Mironovskaya 808 with *Sr Tmp* was another important cultivar grown at that time. This gene governed an intermediate level of resistance to the stem rust population. Since 1972 no epidemics of stem rust have occurred, only a local incidence was recorded.

Leaf rust of wheat. Leaf rust occurs regularly, causing higher yield losses mainly in the eastern part of the Czech Republic. The first cultivars with specific genes for leaf rust resistance were introduced already in 1966 from the former USSR. Cultivars Bezostaya 1 and Mironovskaya 808 were grown on large areas in Eastern Europe and for this reason the gene *Lr3*, carried by both cultivars, soon became ineffective. In the early 1960s cv. Salzmünder Bartweizen, the first commercial cultivar with the 1BL.1RS translocation possessing *Lr26*, was tested in the State Variety Trials and was found highly disease resistant. However, it was not registered because of a breakdown of powdery mildew resistance and low baking quality. A similar line with the same translocation from Weihenstephan (Whst. St. 378-57/32b) was often used in crosses and its resistance was transferred into many Czech cultivars. Other important sources of the same resistance were cvs. Aurora and Kavkaz from the former USSR, registered in 1972. The effectiveness of *Lr26* also broke down soon. In the last decades the gene *Lr37* for adult plant resistance derived from *Aegilops ventricosa* has played the most important role among the leaf rust resistance genes in grown cultivars.

After the effectiveness of *Lr3* and *Lr26* was lost, other sources of specific resistance and field resistance were used in breeding. Nevertheless, *Lr3* and *Lr26* continued to appear in newer cultivars probably due to the positive effect of these or closely linked genes on some important agronomical traits.

Rust research

Physiologic races

Leaf rust. Physiologic specialization of rusts has been studied since the 1960s (Šebesta & Bartoš 1968). In wheat leaf rust the first determined races in 1962–1963 were 14, 20/31, 84, 77, 143 and 102 (after Johnston & Browder 1966). Besides the races avirulent to *Lr3* possessed by many cultivars grown at that time, several above-mentioned races were virulent to this gene. Also virulence to the gene *Lr26* located on the 1BL.1RS translocation was already found at that time though this gene was not yet possessed by commonly grown wheat cultivars. In 1964-1965 races 14, 20/31, 84, 77, 143 and 102 were determined like in previous years and in addition races 15 and 122 (Šebesta & Bartoš 1969a). In the years 1966–1969 races 14, 77, 15, 84, 102, 20/31, 143, 122 and 17 were identified. Races 14 and 77 prevailed (Bartoš & Šebesta 1971). In the 1980s race 61 later followed by race 53 were the most important races (Bartoš *et al.* 1996). In the prevailing races virulence to *Lr26* appeared and was designated by the suffix SaBa (after the cv. Salzmünder Bartweizen). Physiologic races were determined on standard 8 differentials by the mid-nineties, when a set of *Lr* Thatcher near isogenic lines was added to them and later replaced the original differential varieties. In 1996–1999 the virulence and pathotype survey in the Czech Republic were a part of the COST 217 Project. Fifteen *Lr* Thatcher near isogenic lines were selected in the framework of that project for the determination of virulence in the rust population. Only the genes *Lr9* and *Lr19* were completely effective to all leaf rust isolates. The same was true of France, Germany, Italy, Slovakia, Spain, Hungary, Poland, Bulgaria and Romania (where only *Lr19* was tested) (Mesterházy *et al.* 2000). Virulence to *Lr19* was found in the Czech Republic for the first time in 2008 (Hanzalová 2010). Many cultivars released in the 1970s have specific genes for resistance that have not been identified.

Stem rust. In 1962–1963 in wheat stem rust physiologic races 14, 21, 24, 34, 111 (according to Stakman *et al.* 1962) and other four provisionally designated races (CS1-CS4) were determined (Šebesta & Bartoš 1967). Though most races were avirulent to *Sr5* possessed by many cultivars grown at that time, some races were virulent. Like in the two previous years races 14 and 21 predominated; resistance governed by the gene *Sr5* was effective against them (Šebesta & Bartoš 1969b). In 1965 to 1966 the succession of physiologic races during the vegetation period was also investigated. Succession was influenced by the onset of teliospore formation. Races that formed teliospores earlier than other races were replaced later in the vegetation period by races with delayed or no teliospore formation, e.g. 14 or 21 (Šebesta & Bartoš 1969c). In the years 1966–1971 races 21, 14, 111, 20, 196, 214, CS7K, CS8, and CS9 were determined. Races 21 and 14 prevailed again. An intermediate reaction of some races was observed on *Sr11*. Several races were virulent to *Sr5* (Bartoš 1972). In 1972 and 1973 the frequency of virulence to *Sr5* increased considerably and in 1974–1976 about a half of the isolates were virulent to Sr5, mainly races 34, 11, 35 and 211. Other determined races, namely 14, 21 and 111, were avirulent (Bartoš 1975; Bartoš & Hladká 1978). In the years 1977–1980 races 34 and 11 continued to prevail (Bartoš *et al.* 1982). Stem rust surveys continued in the eighties till the early nineties. The last information on stem rust races was published in 1994 (Bartoš *et al.* 1994). Because of only sporadic or very low incidence of stem rust, physiologic races have not been tested since then.

Yellow rust. The first epidemic developed in 1961 and was mainly due to race 8. This race was characterized by virulence on cv. Heines VII, and had already caused earlier epidemics in Western Europe. Of the Czech cultivars Diana was highly susceptible. Other races important in Western Europe (e.g. 3/55, 54) were found also in the former Czechoslovakia with a delay of several years (Slovenčíková 1968, 1969, 1971). In 1977–1978 eleven races were identified. Yellow rust occurred mainly on cultivars Sava and Zlatna Dolina from the former Yugoslavia (Slovenčíková 1980). In 1981–1982 eight yellow rust races were determined on the differentials suggested by Johnson *et al.* (1972), namely 0E0, 32E128, 32E1292, 40E136, 36E141, 104E8, 104E137 and 64E41 (Bartoš *et al.* 1984). Virulence to *Yr9* prevailed in 1988. All important winter wheat cultivars grown at that time were resistant or medium resistant in the field. At the seedling stage some of them displayed susceptible reactions. Cv. Baranyka from the former Yugoslavia, which was resistant in previous tests, was susceptible to race 40E136 both at the seedling and adult plant stage. In 2001 the virulence in the yellow rust population was studied. Only resistance genes *Yr5, Yr10* and *Yr15* were effective against all tested yellow rust isolates (Bartoš unpublished)

Genetic variability of rusts

An attempt to study the effect of the sexual stage on the variability of virulence was carried out both in leaf and stem rust. The sexual stage of leaf rust and stem rust was induced by exposing wetted straw with telia over plants of *Thalictrum speciosissimum* Loefl. and *Berberis vulgaris* L., respectively. Straw with telia of leaf rust was collected in the field whereas straw of stem rust carrying telia was collected from a plant inoculated with stem rust race 21. Straw with telia was kept outdoors over winter and exposed over alternate hosts in the greenhouse in February–March. The transfer of nectar with pyknospores was carried out with an inoculation needle. The susceptible cultivar Little Club was inoculated with developed aeciospores from single aecia. Increased single pustule isolates were tested on standard differentials. Several new recombinants of virulence genes not found in race surveys were revealed (Bartoš *et al.* 1996)

Resistance genes and sources of resistance

Genes for resistance in the registered cultivars were postulated according to their reactions to a set of rust isolates with different virulence genes. In many cases results were verified by the genetic analysis of hybrids. Recently molecular markers have also been applied. After World War II many cultivars were introduced from the former USSR and used in breeding in the former Czechoslovakia. Domestic cultivars gradually prevailed. Since the nineties many foreign cultivars mainly from Western Europe have been introduced. Of the genes for leaf rust resistance the gene *Lr3* was the most common one in the registered cultivars. This gene was introduced with wheat cultivars from the former USSR and later appeared also in domestic cultivars. Cvs. Mironovskaya 808, Mironovskaya ulutchshennaya, Bezostaya 1, Belocerkovskaya 198, Yubileynaya 50 or Ilyichovka, possessing *Lr3* were introduced, whereas in domestic cultivars Istra, Amika, Odra, Mara, Viginta, Agra, Hana, Branka, Sparta, Sofia, Vega, Senta, Samanta, Asta, Mona, Brea, Bruneta, Saskia, Niagara, Banquet *Lr3* was mostly derived from the older cultivars from the former USSR or their derivatives. Another gene that was common particularly in the above-mentioned time period was the resistance gene *Lr26* located on the 1BL.1RS translocation. Several papers dealing with this topic originated in the Research Institute of Crop Production, Praha-Ruzyně (Bartoš & Bareš 1971; Bartoš *et al.* 1973; Bartoš 1993). In the progenies of crosses with cv. Salzmünder Bartweizen chimerical plants in which the longitudinal half of the leaf showed a resistant reaction and the other half a susceptible reaction to leaf rust were observed. Leaves with alternating stripes of resistant and susceptible tissue also occurred. Of the registered cultivars the 1BL.1RS translocation was possessed by cvs. Kavkaz, Aurora and Mironovskaya nizkoroslaya as well as by domestic cultivars Solaris, Istra, Amika, Iris, Sabina, Danubia, Agra, Roxana, Selekta, Branka, Vlada, Sparta, Sofia, Lívia, Senta, Sida, Mona, Rialto, Rapsodia, Clarus, Etela, Orlando and Karolinum. Cultivars possessing *Lr26* also carry genes linked in the 1BL.1RS translocation, *Sr31* for stem rust resistance, *Yr9* for yellow rust resistance and *Pm8* for powdery mildew resistance. A suppressor of the gene *Pm8* was first recorded by Hanušová *et al.* (1996). Of less frequent *Lr* genes, e.g. *Lr1* and *Lr13* were postulated in cv. Vlada in addition to *Lr3,* in cv. Samanta *Lr13* in addition to *Lr3,* in cvs. Siria and Alka *Lr10* and *Lr13.* The genes *Lr13* and *Lr14a* were postulated in cvs. Estica and Ilias. In the last two decades the translocation from *Aegilops ventricosa* carrying *Lr37, Sr38* and *Yr17* has been revealed in many cultivars registered in the Czech Republic, namely Apache, Bill, Clever, Corsaire, Rheia, Bakfis, Barryton, Biscay, Nikol, Kodex, Mulan, Orlando, Sultan. Some of these cultivars possess other resistance genes in addition to *Lr37* (Hanzalová 2010). Several resistant cultivars grown in the former Czechoslovakia possessed *Sr29* (cvs. Slavia, Hela, Mara, Vala and Torysa) or *Sr11* (cvs. Ilona and Lívia), which provided sufficient protection from stem rust (Bartoš *et al.* 1996). For the postulation of resistance genes the international project COST 817 was of considerable importance (Winzeler *et al.* 2000). The cooperation with the Plant Breeding Institute, University of Sydney, also contributed to the knowledge of resistance genes (Pathan & Park 2006).

Links between rust research and wheat breeding

Generally the main links between the rust research and breeding programs were tests for rust resistance carried out for the breeders. They comprised advanced breeding lines and sources of resistance. Race surveys offered information on the virulence present in this country. A further link with breeding was our effort to develop sources of resistance suitable for commercial breeding by crossing donors of resistance with the most productive domestic cultivars. We transferred in this way for example *Lr9, Lr19* and *Lr24* (Stuchlíková 1993), *Lr38* (Bartoš *et al.* 1998) or already earlier resistance from *Triticum timopheevii* (Zadražil & Bartoš 1964). Through these transfers *Lr19* was present in the advanced line SO-997, tested in the Slovak State Variety Trials. Resistant lines developed in the course of the transfer of stem and leaf rust resistance from *T. monococcum* were of particular importance for further breeding (Valkoun *et al.* 1989a, b). Contacts with foreign specialists were supported by the participation in international research projects and organization of international conferences and workshops, e.g. The Third European and Mediterranean Cereal Rusts Conference in 1972 or the COST 817 Conference "Approaches to improving disease resistance to meet future needs: airborne pathogens of wheat and barley" in 1997 both held in Prague. Another contribution to the breeding was reviews comprising recent pieces of knowledge useful for resistance breeding (Bartoš *et al.* 2002; Šíp *et al.* 2005). The cooperation with plant breeders was recognized by the co-authorship of a number of registered cultivars.

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Short review to the 80th birthday of Ing. Pavel Bartoš DrSc.

Dr. Pavel Bartoš started his studies of cereal diseases in the Research Institute of Crop Production in Praha-Ruzyně immediately after graduation from university in 1953.

He did not concentrate only on basic research of diseases but also he closely cooperated with breeders, with Central Institute for Supervising and Testing in Agriculture and farmers.

Around 1960 wheat varieties susceptible to yellow rust were planted and an epidemic damaged the wheat crop on a large acreage.

Between 1965 and 1972 the Czechoslovak wheat breeding programmes started a broad testing of resistance to diseases in disease nurseries with artificial infections. Dr. P. Bartoš helped in the testing of rusts not only by methodology but also with the preparation of samples of mixed inoculum of yellow, brown and stem rust for artificial infections.

One of the goals of his work was to determine the race spectrum of three rusts in Czechoslovakia. His cooperation with foreign research institutes enabled him also to predict race changes.

In Official Tests for the registration of new varieties new materials were evaluated only under natural infection of diseases. Dr. P. Bartoš introduced the evaluation of disease resistance under artificial infections into these tests. These tests were done in his department. He determined the level of rust resistance acceptable for registration. This system was helpful and only varieties with a good level of rust resistance were planted in the fields.

The broad international cooperation enabled him to collect sources of cereal disease resistance from the world, test them in our conditions and then to recommend to breeders.

On behalf of wheat breeders I would like to thank Dr. Pavel Bartoš for his important help in wheat breeding.

Alena Hanišová