SCIENTIFIC REPORT

Development of the New Winter Wheat Variety Skorpion with Blue Grain

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Abstract

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Breeding wheat with blue grain was conducted at the Crop Research Institute in Prague. Initial donor material came from the legacy of Erich von Tschermak-Seysenegg. Long-term crosses with a series of winter wheat varieties were made with the aim of transferring blue grain colour into cultivated varieties. The prospective material was later handed over to Agrotest Fyto, Ltd., Kroměříž, where line no. 6 was selected from the population RU 440. At the end of 2011, the new winter wheat variety Skorpion with blue grain was registered in Austria. It is intended for special use in the food industry. The anthocyanins which it contains are considered to offer health benefits due to their antioxidant effects.

Keywords: agronomic traits; anthocyanins; blue aleurone; grain quality; new variety; *Triticum aestivum* L.

In 2011, after 3 years of testing (2009–2011), the winter wheat variety Skorpion was registered in Austria. In 2012, it was then enrolled in the European Catalogue of Varieties. In contrast to common wheat varieties, it is characterized by blue grain (Figure 1), which, in turn, produces a grey-blue colour in both meal and flour. Due to its unusual grain colour, the variety is intended for special uses in food production. In standard wheat (*T. aestivum* L.) varieties, red grain is usually controlled by one to three dominant alleles: namely *R-A1b* (on chromosome 3AL), *R-B1b* (on 3BL) and *R-D1b* (on 3DL) (Sherman *et al.* 2008). This pigmentation is conditioned by bitter polyphenolic compounds, especially tannins, which positively affect resistance in wheat to sprouting (Himi & Noda 2004). White grain, conversely, is determined by a set of recessive alleles (designated *R-A1a*, *R-B1a* and *R-D1a*). It is naturally "sweeter" and generally more susceptible to sprouting. The variety Skorpion is characterized by the presence of blue aleurone caused by anthocyanins. According to the Catalogue of Gene Symbols for Wheat, blue aleurone in grain is controlled by two genes:

Ba1 is located on the long arm of chromosome 4B (4BS-4el$_2$), which entire arm was transferred from *Thinopyrum ponticum* Podp. (Keppenne & Baenziger 1990). This gene is present in an

important genetic resource UC66049 (Qualset *et al.* 2005).

Ba2 is located on the long arm of chromosome $4A^m$, which was transferred into hexaploid wheat from einkorn wheat (*Triticum monococcum* L.) (Singh *et al.* 2007).

The blue grain colour in the Skorpion comes from donor materials originating from the legacy of Erich von Tschermak-Seysenegg (1871–1962) (Škorpík *et al.* 1983). Older literature, however, raises some uncertainties concerning the origin of the blue colour. The resource TRI 2401 (*Triticum aestivum* var. *tschermakianum* Mansf.) is reported to have come from the gene bank at the IPK Gatersleben in Germany. Blue colour in grain is probably derived from *Elytrigia pontica*, from which the entire chromosomal pair was transferred in place of chromosome 4A as a disomic substitution (Mettin *et al.* 1991; Zeven 1991). It is supposed that the initial donor with blue grain could have originated from an intergeneric cross of wheat with *Aegilops ovata* L. or from rye (Škorpík *et al.* 1983). *Thinopyrum ponticum* (Podp.) Z.-W. Liu & R.-C. Wang, *Agropyron elongatum* (Host) P.B. and *Elytrigia pontica* (Podp.) Holub are among the many synonyms for the identical species (tall wheatgrass), whereas *Aegilops ovata* L. and *T. monococcum* L. are completely different from those species. A blue-grained accession of wheat named Tschermaks Blaukörniger Sommerweizen, clearly coming from the legacy of E. von Tschermak, is maintained in the gene bank at the IPK Gatersleben. This can be assumed to be a similar material that was exploited in the breeding of the variety Skorpion. According to Professor Watanabe, the gene for blue aleurone in Tschermaks Blaukörniger Sommerweizen differs from both *Ba1* and *Ba2* (Watanabe *et al.* 2012; Watanabe 2012 – personal communication). This fact calls for detailed study of the materials coming from the legacy of E. von Tschermak, including the variety Skorpion.

The blue colour of aleurone is produced by anthocyanins. The anthocyanins, among many other compounds, are antioxidants with potential to reduce free radicals (Abdel-Aal *et al.* 2008; Knievel *et al.* 2009). Thus, they could exhibit beneficial health effects with potential for their use in the food industry. Wheat varieties with non-traditional grain colour, such as blue aleurone, purple pericarp (Zeven 1991) and yellow endosperm (He *et al.* 2008; Crawford *et al.* 2011), can be important for enriching the assortment of food products. It can be assumed that long-term and regular consumption of these wheat varieties by their inclusion into the human diet could be beneficial to consumers' health (Knievel *et al.* 2009) and that the grains could be defined as functional foodstuffs. Blue grain of wheat contains a high percentage of delphinidin 3-glucoside plus smaller quantities of delphinidin 3-rutinoside, cyanidin 3-glucoside and 3-cyanidin rutinoside (Knievel *et al.* 2009). The content of anthocyanins differs in particular grain fractions, and thus in flour and bran (Abdel-Aal & Hucl 2003). Their level is also highly variable in the post-anthesis period, and it is affected by conditions of the growing season. Positive effects of blue-grained wheat consumption on human health have not yet been confirmed by clinical testing. Antioxidants (main sources being vegetables and fruits) are generally considered essential for humans to prevent inflammation, diabetes, cancer, oxidative stress and ocular diseases (Lamy *et al.* 2006).

Figure 1. Differences in grain colour: left – Samanta with red grain, right – Skorpion with blue grain (photo: O. Jirsa)

Development and origin of the variety

In the Czech Republic, breeding of wheat with blue grain was conducted at the Research Institute of Crop Production in Prague (Škorpík *et al.* 1983). Initial donor material came from the legacy of Erich von Tschermak-Seysenegg and was obtained from Konstantin Ivanovich Mostovoiy (director of the Research Institute in Prague during 1951–1953). Systematic long-term crosses with a series of winter wheat varieties were made, aiming to transfer the blue grain colour into cultivated varieties. Also studied were segregation ratios of grain colour in plant offspring, the presence of

colour spots on grains and protein composition (Škorpík & Šašek 1980). The following new blue-grained varieties were described: *T. spelta* L. var. *mostovoiy* Škorpík, *T. spelta* L. var. *cyanospermum* Škorpík, *T. aestivum* L. var. *rodianum* Škorpík and *T. aestivum* L. var. *kovacikianum* Škorpík (Škorpík *et al.* 1983). Some of these original materials are housed in the Gene Bank of the Crop Research Institute in Prague. The variety *T. aestivum* L. var. *rodianum* was used in developing Scorpion.

Later, the lines and hybrid populations were handed over to Agrotest Fyto, Ltd., Kroměříž, where line no. 6 was selected from the population RU 440. It was designated RU 440-6 and sent to the official trials for the organic agriculture testing system in Austria. The pedigree of the variety Skorpion is shown in Figure 2.

Skorpion is a Czech variety, registered in Austria. It is represented by Saatbau Linz OÖ. Landes-Saatbaugenossenschaft reg. Gen.m.b.H., Leonding. Maintenance breeding is performed by Saatzucht Donau GmbH&CoKG, Reichersberg.

Agronomic traits and quality characteristics

Parameters of bread-making quality in the variety Skorpion are on the B class level (complementary bread wheat), and grain yield is lower than in current European varieties. In the three-year tests in Austria, the average yield, 4.53 t/ha, was some 25% lower than in the check varieties Pirneo, Capo and Stefanus, and approximately the same as in the British winter wheat variety Indigo having purple grain. Similar yield results in relation to check varieties were also obtained at the Kroměříž location, where the yield of Skorpion in 2010 was 7.93 t/ha, which was 82% of the average for the check varieties Bohemia, Cubus, Elly, Iridium and Samanta. In the more favourable year 2011, its yield was 9.89 t/ha, which was 92% of the average of the aforementioned check varieties. The higher yield in Kroměříž could be explained by intensive growing conditions with fungicide and plant growth regulator treatment, which decreased the occurrence of fungal pathogens and lodging.

Skorpion is a mid-late to late variety (heading 4 days later than Samanta), with medium plant height (10 cm taller than Samanta) and medium to lower tillering capacity. It is suitable for areas with good water supply. Under dry conditions, it suffers from late dry spells. According to official results in Austria converted to a 1–9 scoring scale (1 = poorest value, 9 = best value), it is resistant to whiteheads disease (8), less resistant to susceptible to frost damage (4), moderately resistant to lodging (5), moderately resistant to sprouting (4), moderately susceptible to susceptible to powdery mildew (3), susceptible to leaf rust of wheat (2), moderately resistant to yellow rust (5), moderately resistant to stem rust (6), moderately resistant to Septoria tritici leaf blotch (5), moderately resistant to glume blotch (4), susceptible to tan spot (3), susceptible to Fusarium head blight (3), and moderately resistant to snow mould (4). The variety was found suitable for conventional growing in the east of Austria. It has not been tested in the Czech Republic in any trial network. It is

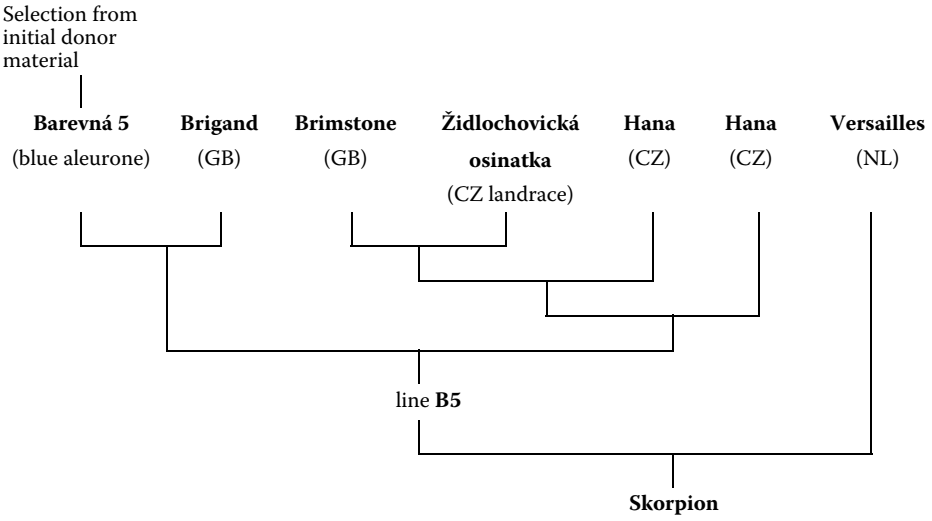

Figure 2. Pedigree of the variety Skorpion; GB – Great Britain; CZ – Czech Republic; NL – Netherlands

presumed, however, to perform well in better soils of cereal-, sugar beet- and potato-growing regions. Because of its susceptibility to Fusarium head blight, moderate resistance to snow mould and low frost resistance, sowing is recommended in the first half of the autumn sowing period, after a good preceding crop, and at sites that are not highly prone to frost damage. It is not recommended for late sowing and following another cereal crop.

Skorpion has very high 1000-grain weight (8) (46.3 g, Samanta 41.0 g) but very low test weight (1) due to the grain's drying up and shrivelling. Flour yield is medium (6), as is grain hardness (5). Content of crude protein and gluten is high (7), while gluten swelling is medium to low (3), and falling number value is usually very low (1). Water absorption is very high (8), dough stability low to very low (2), score of dough quality low (3), and dough extensibility (after 135 min) very high (9). Dough resistance and deformation energy are very low (1), while loaf volume is medium (5) (on average for 3 years, 536 ml/100 g flour).

In the Skorpion seeds there were found two different high-molecular-weight sublines: (a) *Glu-A1a* (subunit 1), *Glu-B1e* (subunit 20), *Glu-D1d* (subunits 5+10) and (b) *Glu-A1a* (subunit 1), *Glu-B1d* (subunits 6+8), *Glu-D1d* (subunits 5+10). Both sublines have the same glu-score of 8 (Gregová 2013 – personal communication). Dough workability is normal to poorer. Low dough stability and low falling number result in increased dough stickiness. The imbalance of technological parameters constitutes a disadvantage, as this can hinder its use in larger bread-making plants. Flour from the variety Skorpion is slightly grey-blue; brans have stronger coloration. Skorpion can be recommended for making wholegrain rolls. Finely ground brans can be added to flour for stronger coloration. The content of anthocyanins in the grain of Skorpion harvested in 2008 was 31.6 µg/g, whereas check varieties with red (Complet) and white (Novosibirskaya 67, Heroldo) grain had negligible content of anthocyanins not exceeding 8.7 µg/g (Martinek *et al.* 2010). According to data from other countries (Abdel-Aal 2011), the content of anthocyanins may be as high as 212 µg/g and is influenced by growing conditions, storage conditions and length of storage period.

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