

Introduction

Voluminous bread wheat (*Triticum aestivum* L.) collections are conserved in seed genebanks of quite a number of countries around the world. When regenerating and multiplying accessions, they encounter the problem of authenticity determination. Each genebank has its own way of solving this problem. Besides using molecular and protein markers for verifying wheat accessions' identity, the N.I. Vavilov All-Russian Institute of Plant Genetic Resources (VIR, St.-Petersburg) and some European seed genebanks (for example, Germany, Czech Republic, Poland, etc.) traditionally use the data on the botanical variety to which an accession belongs. A botanical variety is a taxonomic category (rank) below that of subspecies (Article 4.1. of the International Code of Botanical Nomenclature [14]). Botanical common (bread) wheat varieties are differentiated by complexes of morphological characters, of spike and kernel mostly.

In the beginning of the previous century, a prominent triticologist from VIR K.A. Flaksberger¹⁷ applied the system of botanical varieties by F. Koernicke [12] for the identification of local wheat cultivated in Russia. In 1908, in his "*Key to true cereal varieties according to Koernicke*"¹⁸ [8], Flaksberger described 22 botanical varieties of bread wheat, namely *albidum* Alef., *lutescens* Alef., *alborubrum* Koern., *milturum* Alef., *leucospermum* Koern., *velutinum* Schubl., *delfi* Koern., *pyrothrix* Alef., *cyanothrix* Koern., *nigrum* Koern., *graecum* Koern., *erythrospermum* Koern., *erythroleucon* Koern., *ferrugineum* Alef., *sardoum* Koern., *caesium* Alef., *meridionale* Koern., *hostianum* Clem., *turcicum* Koern., *barbarossa* Alef., *coeruleovelutinum* Koern., *fuliginosum* Alef. These botanical varieties differ on the grounds of such morphological spike characters as the presence of awns (spikes with or without awns), glume pubescence (glabrous or velvety pubescence spike glumes), spike color (white, red, black or grayish-blue spikes), kernel color (white or red kernels. The black color of awns was taken into consideration for var. *sardoum* Koern.

In the 1920's-1930's, N.I. Vavilov¹⁹ and his associates carried out explorations of vast territories by sending collecting missions all around the globe in search for new valuable plants to introduce them into cultivation and for developing new varieties of cultivated species. The intensive collecting of wild and semi-domesticated wheat, as well as of wheat landraces has significantly broadened the knowledge about botanical diversity of genus *Triticum* L. The results of the study of

¹⁷ Flaksberger Konstantin Andreyevich (1880-1942), an outstanding triticologist, Professor, Dr. (Biol. & Agri. Sci.) From 1907 to 1941, he worked at VIR; since 1940 he has occupied the position of the Head of the Cereal Crops Department.

¹⁸ Sections of this Flyaksberger's work contain the complete translation of "*Die Arten und Varietaten des Getreides*" [12]

¹⁹ Vavilov Nickolai Ivanovich (1887-1943), a prominent scientist who had laid foundations of new trends in plant industry, botany, genetics, breeding and other sciences; Academician, Director of VIR from 1920 to 1940.

collected material laid the basis for a monograph on the wheat taxonomy by K.A. Flaksberger [9, 10]. It was published in 1935 in the first volume of the “*Cultivated Flora of the USSR*” series under the title “*Cereals. Wheat*” [9]. In this monograph, the author described two bread wheat subspecies, namely *ssp. iranoasiaticum* Flaksb. and *ssp. indoeuropaeum* Flaksb., as well as identified 152 botanical varieties of this crop, of which 32 had been for the first time described by the author and 50 more described by N.I. Vavilov. For describing new botanical varieties, K.A. Flaksberger has considerably extended the range of the morphological characters used. For instance, in addition to white and red used for describing the glume color, he also introduced such options as “white with a black border”, “red with a black border”, “white combined with smoked-grayish”, “red combined with smoked-grayish”, “white with black (blue-black)” and “red with black (blue-black)”²⁰. The description of the types of awn formation includes not only awned or awnless forms, but also semi-awned and those with “tailings”, that is, with short awn-like formations at tips of the upper spikelets of a spike. The author has revealed such new characters as black awn color; glume pubescence with coarse, thorn-like hairs, *inflatum*-type spike; the absence of a waxy on the spike; spike branching or the presence of two spikelets per node of spike rachis; solid straw below the spike like in durum wheat, speltoid (spatulate) shape of the glume. Also, the author singled out a number of changes in the spike shape to be used for describing different botanical varieties, that is, the clavate (*capitatum*) shape with a denser location of spikelets at the spike top; the compactoid shape with a short dense spike occupying an intermediate position between bread wheat and *Triticum compactum*; the *rigidum*-type spike with coarse glumes and hard-to-thresh kernels, etc.

Four years later, in 1939, K.A. Flaksberger identified as many as 171 botanical varieties of bread wheat in the “*Key to True Cereals*” [10].

In his treatise on bread wheat taxonomy [13], a German botanist R. Mansfeld²¹ described 404 botanical varieties. This number, however, included botanical varieties of *Triticum compactum* Host and *T. vavilovii* (Thum.) Jakubz., since the author did not recognize them as individual species (sub species). The number of varieties of said species excluded from the total botanical varieties described, the number of those identified by the scientist for bread wheat makes 266. When describing them, R. Mansfeld used mainly the same morphological characters of spike and wheat plant used K.A. Flaksberger [9, 10]. Additionally, he introduced such a character as “spike density (lax, dense, or compact)”.

In the “*Cultivated Flora of the USSR. I. Wheat*” [3] and “*Key to Wheat*” [4], V.F. Dorofeev²² *et al.* presented 194 botanical varieties of *T. aestivum* L., among which

²⁰ The smoke-grayish and black coloring is most obvious in the glume central part.

²¹ Rudolf Mansfeld (1901-1960), a German botanist. After World War II, he worked on the systematics of cereals in Gatersleben.

²² Dorofeev Vladimir Filimonovich (1919-1987), Dr. (Agr.Sci.), Academician of VASKhNIL, started working in the VIR network in 1955, first as the Head of a Base Station in Derbent

31 had been for the first time described by R.A. Udachin²³ 21 by A.A. Filatenko²⁴, 120 descriptions taken from the R. Mansfeld's work [13] and the rest borrowed from the works of different authors. In the systematic of bread wheat developed by the above-mentioned authors, the names of subspecies and botanical varieties were brought to conformity with international requirements of botanical nomenclature, therefore many names of intraspecific botanical taxa, initially given by K.A. Flaksberger, have been changed. Besides, the forms with solid straw below the spike and those with green (pale-blue) or purple grain have been identified.

Approximately at the same time, some other books on wheat systematic were published. When studying wheat of Azerbaijan, I.D. Mustafayev [6]²⁵ used the place of collecting for identifying numerous forms within the botanical varieties described mostly according to Flaksberger [9, 10].

In the "*Key to Wheat, Aegilops, Rye and Barley*", P.A. Gandilyan²⁶ described 380 botanical varieties of bread wheat and suggested diagnostic designations for them constructed as a formula in Latin. Each formula was composed according to a certain plan. For instance, for wheat it started with designations characterizing awns and ended with kernel characteristics. For example, var. *erythrospermum* was given the name of «ar-nu-al-ru», in which:

the first syllable "ar" (from "aristatus" – awned) defined the presence of awns;

the second one, "nu" (from "nudus" – glabrous), referred to the absence of glume pubescence;

the third one, "al" (i.e., "albus" – white), described the glume color; and

the fourth syllable "ru" (from "ruber" – reddish) defined the kernel color. The given system of botanical names never gained popularity among triticologists.

(Dagestan), then in 1960 as a senior researcher at the Department of Cereal Crops. In 1965 he was promoted Head of the Department of Wheat, and from 1979 to 1987 he was Director of the VIR.

²³ Udachin Roald Arsenyevich (1932-2010), Dr. (Agr.Sci.), Professor, started working at VIR in 1956; from 1979 to 1988 headed the Laboratory of Bread Wheat, and in 1989-1995 was employed as a chief researcher at the Department of Wheat. Since 2000, he has occupied the position of a leading researcher and VIR historiographer.

²⁴ Filatenko Anna Alexandrovna, Ph.D. (Biol.), senior researcher, has worked at VIR since 1960 through 1995 at the Department of Wheat. In 1965-1995, she headed the Group of Durum and Primitive wheat. Presently retired.

²⁵ Mustafayev Imam Dashdemyr oglu (1910-1998), Dr. (Biol.Sci.), Academician of the Academy of Sciences of Azerbaijan, a geneticist and breeder. In 1954, he started working at the Institute of Genetics and Breeding of the Academy of Sciences of Azerbaijan, and from 1971 to 1998 was Director of said institute.

²⁶ Gandilyan Papin Artashesovich (1929-2001), a botanist, geneticist, breeder, prominent expert in grain crops and their wild relatives in Armenia, Dr. (Biol.Sci.), Professor, Member of the Academy of Agricultural Sciences of Armenia.

In 2009, N.P. Goncharov²⁷ published the “*Key to Bread and Durum Wheat Varieties*” [2] that encompassed the same botanical varieties of bread wheat as were presented in the “*Key to Wheat*” published at VIR in 1980 [4]. However, N.P. Goncharov regarded the species *T. petropavlovskyi* Udacz. et Migusch. as a subspecies of bread wheat and added four botanical varieties of *T. petropavlovskyi* to the list of bread wheat varieties.

To summarise, bread wheat is characterized by a wide range of intraspecific diversity on the grounds of spike and kernel morphological characters, which should be described and systematized within each collection in order to ensure the preservation of authenticity of its accessions and facilitate access to them. Usually, accessions are characterized using individual traits in accordance with lists of descriptors. The data on the characterized traits in verbal or numerical format are entered into descriptive databases. This type and level of description is highly needed during the multiplication and regeneration of accessions.

Identification of bread wheat accessions using complexes of spike and kernel characters

When visiting seed genebanks around the world, or meeting wheat collection curators from foreign countries, VIR experts repeatedly underline that it is possible to considerably simplify the practical work with accessions, their identification included, by using character complexes that are linked with particular botanical varieties. However, this suggestion has not received enthusiastic support, so far. Probably, it is due to the facts that the main publications dealing with description of varieties are either in Russian or German, and that the large number of varieties seems hard to remember.

The present Atlas offers a universal, practically applicable method for describing and prompt memorizing the diversity of bread wheat forms using morphological characters of spike and kernel, and illustrates the method with examples.

The descriptive system is based on the complexes of morphological characters of spike and kernel that occur most frequently in bread wheat and are named after the corresponding botanical varieties. These complexes are listed in Table 1.

It follows from the data presented in the Table 1 that an accession under study should be characterized in terms of presence/absence of awns on the lemma, presence/absence of glume pubescence, as well as glume and kernel color. A complex of characters discovered in the accession is given a relevant name. To

²⁷ Goncharov Nikolay Petrovich, Academician of the Russian Academy of Sciences. Since 1990, he is the Head of the Wheat Genetics Section at the Institute of Cytology and Genetics in Novosibirsk.

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