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CLASSIFICATION OF GENUS *Triticum*, *SENSU LATO* AND *SENSU STRICTO*, BASED ON SPIKE AND GRAIN MORPHOLOGY

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Abstract

The formulation of the present classifications of species of the genus Triticum associates mainly with several plant morphological factors such as fragility of the spikes spindle, grains threshability, grain sphericity, shape and position of glumes, lemmas and paleas and awns, compactness, etc. Special attention is paid to the factor "cultural/wild" form, the ploidy and the genomic constitution of the species, often supported by molecular data which provides considerable comfort in disclosing phylogenetic features in a particular taxonomic unit. Such taxonomic determination is associated with certain disadvantages. It is not sufficiently focused on the spike morphology related to the reproductive apparatus of the plant, and also the causes of phylogenetic differentiation of certain parameters, such as spike branching, multiple spikelets, as well as the ratios of quantitative properties. The existing classifications do not give a precise answer to the taxonomic position of amphidiploids in the genus Triticum, and also for those obtained from hybrid combinations with genera Aegilops, Secale, Haynaldia, Hordeum, Elymus, Leymus, Elytrigia, Agropyron, as transitional and similar forms. Based on studies of spike and grain morphology of a large number of representatives of the genus Triticum and other interspecific and intergeneric amphidiploid forms, a classification of the genus sensu lato and sensu stricto is composed. Sensu stricto, genus Triticum covers all existing wild and cultivated known wheat forms, together with interspecific artificial synthetic forms. Sensu lato, the genus includes intergeneric hybrids, for which a specific generic epithet was coined - ×Triticum, and also a specific epithet, consistent with the originator of the amphidiploid. Special attention was paid to species and amphidiploids with the genus Aegilops. Classification sensu strictissimo was also formulated where the genus Triticum brings together only diploid species, but natural amphidiploids are separated as genus Aegilotriticum, and artificial as genus ×Aegilotriticum, and the remote intergeneric amphidiploids are not subject to the classification. Drawn up in this way, the classifications cover morphological and ecological, evolutionary and phylogenetic features of the representatives of the genus Triticum.

Key words: *amphidiploids, classification, morphology, taxonomy, Triticum.*

INTRODUCTION

The modern understanding of the systematics of cultivated plants is based on a number of factors, which are mutually complementary. The anatomical and morphological characteristics of the plants both play an important role in this respect, as well as their phylogenetic nature. Essential for the new classification is molecular genetics, which allows following in detail the genetic similarities and differences between individual plant sets (Goncharov et al., 2009). Nevertheless plant species are dynamic, not discrete structures that undergo changes due to the normal processes which involve and are determined by their heredity and variability (Ayala and Kiger, 1984). Therefore the established relationships in a single species are an unsustainable model subjected to the evolutionary factors (Stoyanov, 2014c). Thus the classification of species, regardless of their relative stability, should take into account the dynamic concept of speciation.

In essence, the definition of "species" presents versatile information (de Queiroz, 2005). This is due to the many definitions and interpretations that characterize this concept. On the one hand, the classic definition of ‘species’ given by Ernst Meyer - "a group of actually or potentially crossing populations that are reproductively isolated from other such groups" presents difficulties in identifying and classifying some artificially created synthetic species (de Queiroz, 2005), such as a large number of amfphdiploids in *Poaceae*. This view contradicts the idea of artificial interspecific and intergeneric hybridization because it does not allow the different species to cross but defines them as “reproductively isolated”. The ability to create interspecific and intergeneric hybrids in *Poaceae* (Matsuoka, 2011; Stoyanov et al., 2010; Stoyanov, 2013a; Stoyanov 2014a; Mico et al., 2013), and in particular in tribus *Triticae*, excludes the above hypothesis. Simultaneously, the conventional definition contradicts the basic concept of phylogenetic speciation, since it does not allow for variation in the organisms and they are categorized as constant groups.

Genus *Triticum* represents philogeneticly determined taxon in *Poaceae*, which includes a large number of species. The classification in the genus was initiated by Carl Linnaeus, who grouped seven species - *Triticum aestivum*, *Triticum hybernum*, *Triticum turgidum*, *Triticum monococcum*, *Triticum spelta*, *Triticum repens* and *Triticum caninum* (the last two were subsequently reffered to *Elytrigia repens* and *Elymus caninus*) (Linnaeus, 1753) as in the second edition of Species Plantarum he also adds *Triticum polonicum* (Linnaeus, 1762). Subsequently the family is continuously supplemented, amended and revised by many researcher as Lamarck (1778), Villars (1787), Schrank (1789), Desfontaines (1798), Host (1805), Seringe (1818), Metzger (1824), Seringe (1841), Alefeld (1866), Heuze (1872), Harz (1885), Hackel (1890), Vilmorin (1889), Flaksberger (1915), Percival (1921). Sakamura (1918) indicates the chromosome number of the species identified by Hackel (1890), which allows for significant changes in the current classification and arrangement of species.

The first modern classification of the genus begins with the extensive survey of Flaksberger ending with a classification of the genus *Triticum* (Flaksberger, 1935), which he later revised and supplemented (Flaksberger et al., 1939). Similar additions, modifications and edditions have been made by Shieman (1948), Shieman (1951), von Rosentsiel (1950), Mangelsdorf (1953), Jakubziner (1958). MacKey (1954) grouped the hexaploid species into only one species as subspecies because between the species there are no real specific barrier and they could cross readily with each other and easily exchange hereditary material. Bowden (1959) proposed to unify the tetraploid and hexaploids forms in common species based on the cytogenetic characteristics of the representatives of the genus, as well as including the species of genus *Aegilops* in genus Triticum. This classification was later revised by Morris and Sears (1967) and became fundamental to the later classifications of Kimber and Sears (1987). MacKey (1966) reported such classification (without the species of genus *Aegilops* however), which was later rivized and supplemented (MacKey, 1988).

Although it is the most recent classification of the genus *Triticum*, classification Dorofeev et al. (1979) remains unknown outside Russia. It is considered to be controversial as it gives the ‘species’ status to almost all cultivated and wild forms. Highly significant is the contribution of Gandilyan (1980) in the taxonomy of the genus; his classification and identification key give an extremely simple but effective scheme for grouping the wheat forms on the basis of their spike qualitative morphology. Love (1984) revised the classification of the genus, splitting it into three genera (*Chritodium* (diploid), *Gigachilon* (tetraploid), *Triticum* (hexaploid)). Flora of Turkey (1985) complemented the genus with the extinct species *Triticum parvicoccum* reported by Kislev (1979), but it gives an overly simplified classification. The classification of Kimber and Sears (1987) gives an idea of the genus *Triticum sensu lato*, unifying it with the species of the genus *Aegilops* as a correction to the classification of Kimber and Feldman (1987). Van Slageren (1994) follows the primary classification of MacKey (1988), with slight modifications. Goncharov et al. (2009), based on genetic markers, summarize their classification of the genus *Triticum*, and include hybrid and amfidiploid forms in a new section, basically following the classification of Dorofeev et al. (1979).

All classification of genus *Triticum* are based on qualittative indices of the current wheat forms with adjustments based on cytogenetic and molecular genetic studies. In any of the wheat classifications, the morphological quantitative characteristics are not considered. Certain indices for species separation, which are confered only of one or several genes become reason for species formation (fragility, shape of grains, compactness of spikes) (Goncharov et al., 2009). Other indices such as branching, vernalization, multiple spikelets, multiple embryos are excluded as too variable and controversial with regard to heritability (MacKey, 1954). Despite these facts, none of the classifications address the essence of the concept of ‘species’ - the ability to reproduce. The phylogenetic differentiation of the spike morphology is associated with two main factors - the reproduction and survival of the species (Stoyanov, 2014f). While the possibility of survival of a species is not related to the plant taxonomy, since the presence of specific morphology means that the species is able to survive under specific environmental conditions, the reproduction should have a key role because its mechanisms are fundamental for both the concept of ‘species’ and for the realization of the heredity and variability of every single species (Ayala and Kiger, 1987).

The main purpose of this report was to compose a classification of genus *Triticum* based on the spike morphology and on data and research on quantitative and qualitative indices pertaining to the ability of plants to reproduce by presenting it in different versions (*sensu lato*, *sensu stricto*, *sensu strictissimo*) on the basis of the phylogeny of the genus.

MATERIALS AND METHODS

For the compilation of this classification data and graphics from our previous research related to the spike morphology of different species of the genus *Triticum*, *Aegilops* and amphdiploids and hybrids were used (Stoyanov et al., 2010; Stoyanov et al., 2012; Stoyanov, 2013b; Stoyanov, 2013c, Stoyanov, 2013d; Stoyanov, 2014a; Stoaynov, 2014b; Stoyanov, 2014c; Stoaynov 2014d; Stoyanov 2014e; Stoyanov and Plamenov, 2014). The morphology of each species was evaluated on the basis of definitive botanical keys based on existing classifications (Gandilyan, 1980; Dorofeev et al., 1979). The correction of these classifications was based on the quantitative parameters of the cited studies. The affiliation to a certain species was determined by combining the data of the identification keys and the summarized information of the quantitative parameters. The different types of classifications (*sensu lato*, *sensu stricto*, *sensu strictissimo*) are generated according to the phylogenetic distance of the certain species, hybrids and amphidiploids. Taxonomic novelties are described accordind to International Code of Nomenclature for algae, fungi, and plants (ICNAFP) (2012) in English.

RESULTS AND DISCUSSIONS

The current classification of the genus *Triticum sensu lato*, *sensu stricto*, *sensu strictissimo* is presented in Appendix 1, Table 1. In this Table, the affiliation of a particular species to its genomic constitution can be followed by sections. Thus composed, this classification implies the need for clarification of the taxonomic status of certain plant forms and the reasons for changing it.

The necessity, the representatives of genus *Triticum*, to be classified and reclassified in three different ways is imposed by the presence of many diverse criteria regarding the concept of ‘species’ (de Queiroz, 2005; de Queiroz, 2007). On the one hand there is the conventional definition that puts the species in narrow frames as a discrete unit (*sensu stricto*) (de Queiroz, 2005). On the other hand, the notion of particular form as a dynamic and evolving system (Stoyanov, 2014c) requires integration of such plant forms within a species that represent a similar mechanisms of reproduction, distribution and ontogenesis (*sensu lato*). Last but not least is the issue of common phylogenetic origin (Matsuoka, 2011; Stoyanov et al., 2010), which implies the effective and strict separation between the forms of origin of each of the species (*sensu strictissimo*). Since genus *Triticum* and its representatives follow these three criteria (because of the presence of different classification systems), it is necessary to effectively refer each distinct plant form, on the basis of its morphological parameters of heredity and variability, to a particular taxonomic unit in parallel in all three types of classification.

A major milestone in the classification of the different wheat species is associated with species *Triticum turgidum* and *Triticum aestivum*, according to the classification of MacKey (1988) and Van Slageren (1994). Both are presented as aggregate species which, on subspecies level, unify all known cultivated and wild forms with 'species' status under other classifications. The main reason for such clustering is the cytogenetic similarity that exists between the different forms inside the species and allows for easy crossability and exchange of genetic material. Particular studies, however (Naskidashvili, 1974, Tsitsin, 1978), conclude that in progressive hybrid generation, often a large number of plants assimilated largely their initial parental components. A small number of hybrid plants develop intermediate morphology, and quite a few of them - a new type of morphological features. Therefore, regardless of the high degree of similarity, the distinction between these forms is necessary to follow the processes of reproduction of the species and not their cytogenetic affiliation. In this respect, such parameters as spindle fragility, density, shape and structure of the glumes, form of grains are directly related to the plant reproductive system, giving it higly specific features (Stoyanov, 2014c). These features are related to adaptability to specific levels of stress realized through the development of particular parameters in relation to spike and grain morphology (Stoyanov, 2014c). The data from the cluster analysis on quantitative morphology of various tetraploid species (Stoyanov, 2014b; Stoyanov, 2014c), exhibits significant differences in the overall spike morphology of the pooled species *Triticum turgidum*, which in 80% of the cases represent species affiliation according to the definitive key tables. Since the division of the pooled species *Triticum aestivum* follows the same principles (Stoyanov, 2004e), the presence of two more recent subspecies, according to the classification of the Flora of China (2006) should alter their status from subspecies to species level according to the characteristics described:

Triticum tibeticum (King ex S.L.Chen) H.P.Stoyanov stat. nov. of *Triticum aestivum* ssp. *tibeticum* King ex S.L.Chen (Acta Genet. Sin. 7(2):155. 1980) - Spike rachis disarticulating. Glumes laxly appressed to floret, distinctly keeled. 2n=42. (Flora of China, 2006)

Triticum yunnanense (J.Z. Shao) H.P. Stoyanov stat. nov. of *Triticum aestivum* ssp. *yunnanense* J.Z. Shao (Novon 7:230. 1997) - Spike rachis easily disarticulating. Glumes adnate to floret, very hard, distinctly keeled. Fl. and fr. Apr–Aug. 2n = 42. (Flora of China, 2006).

A very important aspect of the classification is the inclusion of genus *Aegilops* to genus *Triticum*, which meets many contradictions based on genetic and cytological studies (MacKey, 1988; Van Slageren, 1994). The ontogenetic development of the representatives of the genus allows species of the genus *Aegilops* to be classified in a larger group – *Triticum sensu lato*, together with the wheat species due to their similar morphoecological characteristics related to both reproduction and distribution. Similar classification is presented by Kimber and Sears (1987). A new section in the genus *Triticum* is created - *Aegilopsiformis* H.P.Stoyanov sect. nov. *sensu lato*: Inflorescence composed of racemes; deciduous or not as a whole. Typus - *Triticum cylindricum* Ces.

However, due to the phylogenetic origin of the natural polyploid series of genus *Triticum* based on natural hybridization with representatives of genus *Aegilops* (Stoyanov et al., 2010; Spetsov et al., 2008; Spetsov et al., 2009; Matsuoka, 2011), it is necessary to generate a stricter idea of genus *Triticum* - *sensu strictissimo*. Since *Aegilops* vary considerably in morphological terms (van Slageren, 1994) (excluding environmental factors) and although they are similar in genetic aspect to *Triticum*, *sensu stricto* and *sensu strictissimo* these species do not represent the basic notion of genus *Triticum*. Nevertheless, since they participate as a genomic component of the polyploid wheat species (according to Stoyanov et al., 2010), the 4x and the 6x species of *Triticum* are a specific taxonomic paradox and their referrence to this genus in the strict sense contradicts the phylogenetic definition of 'species'. For a proper and legitimate compilation of the classification of genus *Triticum sensu strictissimo,* a proposal is made on the basis of Div. III of ICNAFP (2012) to add a synonymous taxa (cognomen) regarding the phylogenetic species for which it is known that they represent intergeneric natural polyploid series based on taxonomically various generic names, and to compose categories - coggenus (coggen., synonymous genus), cogspecies (cogsp., synonymous species), with strict indication of the scope of the classification - *sla* (*sensu lato*), *sst* (*sensu stricto*) , *sss* (*sensu strictissimo*), after the name of the species (eg: *Aegilotriticum durum sss* (Desf.) H.P. Stoyanov - *Triticum durum sla* (*sst*) Desf.). A new synonymous genus is created: *Aegilotriticum* H.P. Stoyanov coggen.nov. - Synonym of *Triticum* L. (Sp. Pl. 1:85. 1753) - Represent polyploid species in the genus *Triticum sensu strictissimo*. To this genus are refferred all polyploid wheats, excluding species of sections *Urartu* and *Monococcon* and possible their hybrids which are classified to the genus *Triticum*.

In this respect, genus×*Aegilotriticum* is a legitimate genus from a taxonomical point of view, different from *Aegilotriticum,* and it does not represent the phylogenetic origin of the families, but the actual hybridization (natural and artificial) between the two genera *Triticum* and *Aegilops*.

Sensu lato, such kind of artificial and natural hybrids as the different species of *Aegilops*, represent identical morphology related to their reproduction and distribution (Stoyanov, 2012; Stoyanov, 2014f), and are also assigned *sensu lato* to the genus *Triticum*. The natural hybrids represent a specific taxonomic unit, as they exist in this genetic condition and perform its own morphology only in the first hybrid generation (Stoyanov et al., 2012; Stoyanov, 2013b; Stoyanov, 2013c; Stoyanov and Plamenov, 2014). Since genomically they are specific polyhaploids they are assigned to a new section of the genus *Triticum* - *Hybrida* HPStoyanov sect. nov. - Inflorescence deciduous as a whole. Glumes rigid. Seeds higly shriveled. Typus - *Triticum×sancti-andreae* Degen.

Other intergeneric amphidiploids with participation of wheat species are also a subject of controversy in their classification. The proximity of the genera *Elymus*, *Leymus*, *Agropyron*, *Elytrigia* to genus *Triticum* and their early classification as its representatives (Linnaeus, 1753) (as for the genus *Aegilops*), often are reasons the amphidiploids between these two genera to be assigned to the genus *Triticum* (Stoyanov, 2012). However, since the definition of the genus *Triticum* (Flora of China, 2006) and its taxonomic description exclude perennial forms, even *sensu lato*, such kind of amphidiploids do not meet the morphoecological criteria of the genus. Therefore in order to maintain the taxonomic affiliation given by the creators of the amphidiploids it is made a proposal for the formation of complementary hybrid genus (nothogenus novum) within the genus *Triticum* - ×*Triticum* (L.) H.P. Stoyanov, nothogen.nov. - unite the morphology of genus *Triticum* (Flora of China 22: 442. 2006) with perennial habitus. A new section in the genus *Triticum* is created: *Amphidiploida* H.P. Stoyanov sect. nov. – Perennial; culms solitary, or caespitose. Typus - ×*Triticum tsitsini* H.P. Stoyanov sp. nov.

×*Triticum tsitsinii* H.P. Stoyanov sp.nov. Perennial, tufted grass up to 100 cm tall, with 2-5(-8) tillers; stem (culm) cylindrical, smooth, hollow except at nodes. Leaves distichously alternate, simple and entire; leaf sheath rounded, auricled; ligule membranous; blade linear, 20-30 cm × 1-1.5 cm, parallel-veined, flat, glabrous. Inflorescence a terminal, distichous spike 7-8 cm long, with non-sessile spikelets borne solitary on zigzag rachis. Spikelet 10-15 mm long, laterally compressed, 3-5-flowered with bisexual florets, but 1-3 uppermost ones usually rudimentary, sometimes only 2 of the florets bisexual; glumes almost equal, oblong, shorter than spikelet apex, thinly leathery, veined; lemma rounded on back but keeled towards the tip, leathery, without awns; palea 2-keeled, not hairy on the keels; lodicules 2, ciliate; stamens 3; ovary superior, tipped by a small fleshy hairy appendage and with 2 plumose stigmas. Fruit an ellipsoid caryopsis (grain) at one side with a central groove, reddish brown to red or greyish blue. (2x=8n=56, AABBDDEE).

So composed the current classification meets the morphological description of the "unbranched spike with individually arranged spikelets" (Flora of China, 2006). Therefore spikes which do not fullfil this description should not be included in this arrangement of the genus *Triticum*. However, many forms with branched spikes and/or with multiple spikelets, even with multiple embryos were reported as forms of *Triticum aestivum* and *Triticum turgidum* (Stoyanov, 2014c). They differ greatly in relation to their quantitative morphology according to various studies (Stoyanov, 2013d; Stoyanov, 2014b; Stoyanov 2014c; Stoyanov, 2014d; Stoyanov, 2014e). Therefore additional studies in this direction are required to clarify their status and to determine precisely their taxonomic affiliation.

CONCLUSIONS

Based on the above classification the following conclusions could be made:

1. Genus *Triticum* is a complex systematic unit, covering morphologically various, ecologically similar and phylogenetically close related species, suggesting a wide (*sensu lato*), narrow (*sensu stricto*) and very narrow (*senso strictissimo*) classification.
2. The species separation of the pooled species *Triticum turgidum* and *Triticum aestivum* is based on the different spike morphology of particular forms, which is related to their reproductive apparatus.
3. New sections in the classification sensu lato are composed (*Aegilopsiformis*, *Hybrida*, *Amphidiploida*) for grouping the species, hybrids and amphidiploids added to the genus.
4. A synonymous genus *Aegilotriticum* and a complementary genus ×*Triticum* are proposed aiming at accurate classification of the species in genus *Triticum*.
5. Additional studies are necessary to establish the taxonomic affiliation of forms with branched spikes, multiple spikelets and multiple embryos.

PROVISIONS

This classification does not claim to be completely comprehensive regarding various forms and accessions in the genus *Triticum*, but only aims the organizing it in the form and vision allowing the parallel consideration of species to different interpretations of the term "species".

REFERENCES

Ayala F.J., Kiger J.A., 1987. Modern genetics. Zemizdat. Sofia (Bg).

Alefeld F., 1866. Landwirtschaftliche flora oder die nutzbaren kultivierten garten- und feldgewaechse mittelewiopa’s. Berlin, 363 p. (Ge)

Bowden W.M., 1959. The taxonomy and nomenclature of the wheats, barleys and ryes and their wild relatives. Can. Jour. Bot, 37: p. 657-684.

Caldwell R.M., Cartwright W.B., Compton L.E., 1959. Dual - a Hessian fly resistant soft red winter wheat. Purdue Univ. Agr. Expt. Sta. Res. Bul. 681, 20 p.

Davis P.H., 1985. Flora of Turkey and the East Aegean Islands, Vol. 9 (Davis PH Ed.). Edinburgh at the University Press, Scotland.

Desfontaines R., 1798. Flora Atlantica, t.1. Parisiis.

Dorofeev V.F., Filatenko A.A., Migushova E.F., Udaczin R.A., Jakubziner M.M., 1979. Wheat. vol. 1. In: Flora of Cultivated Plants (Dorofeev VF and Korovina ON, Eds.) Leningrad (St. Petersburg), Russia. Kolos, 346 p. (Ru)

Flaksberger C., 1915. Determination of wheats. Trudy Prikl. Bot. i Selek. (Bul. Appl. Bot.), 8: p. 9-210 (Ru).

Flaksberger C., 1935. Cereals. Wheat. In Flora of Cultivated Plants. Lenin Acad. Agr. Sci. U.S.S.R., Inst. Plant Indus. Moscow and Leningrad. 434 p. (Ru)

Flaksberger, C., Antropov V.I., Antropov V.F., 1939. Key to true cereals, wheat, rye, barley, oats. People’s Commis. Agr. U.S.S.R. Lenin Mem. All-Union Acad. Agr. Sci. Inst. Plant Cult., 416 p. (Ru).

Flora of China, 2006. 109. Triticum. 22: p. 442-444.

Gandilyan P.A., 1980. Key to wheat, Aegilops, rye and barley. Academy of Science. Armenian SSR, Erevan 190p. (Ru)

Goncharov N.P., Golovnina K.A., Kondratenko E., 2009. Taxonomy and molecular phylogeny of natural and artificial wheat species. Breeding Science, 59(5): p. 492-498.

Hackel E., 1890. The true grasses. Transl. from Die Natuerlichen Pflanzenfamilien by F.Lamson-Scribner and Effie A. Southworth, New York, 228 p.

Harz C.D., 1885. Landwirtschaftliche semenkunde - Bd.1. Berlin. (Ge)

Heuze G., 1872. Les Plantes Alimentaires, t.1. Paris, 576 p. (Fr)

Host N.T., 1809. Icones et descriptions graminum austriacorum. V.3., V.4. Vindobonae. (L)

International Code of Nomenclature for algae, fungi, and plants (Melbourne Code), 2012. Regnum Vegetabile 154. Koeltz Scientific Books.

Jakubziner M.M., 1958. New Wheat Specie. First International Wheat Genetic Symposium Proc: p. 207-217.

Kimber G., Feldman M., 1987. Wild Wheat, an introduction. Special Report 353, College of Agriculture, Univ. of Missouri, Columbia. 146 p.

Kimber G., Sears E.R., 1987. Evolution in the genus *Triticum* and the origin of cultivated wheat. In: Wheat and Wheat Improvement, 2nd Ed (Heyne EG, Ed.). Ameican Society of Agronomy, Madison, WI. p. 154-164.

Kislev M.E., 1979. *Triticum parvicoccum* sp. nov., the oldest naked wheat. Israel Journal of Botany, 28(2): 95-107.

Koernicke F., Werner H., 1885. Handbuch des getreidebanes, 2v, Berlin (Ge).

Lamarch C. de, 1778. Flore Francaise, v.3. Paris. (Fr)

Löve Á. 1984. Conspectus of the Triticeae. Feddes Repert 95(7-8): p. 425-521.

Harz C.D., 1885. Landwirtschaftliche semenkunde - Bd.1, Berlin. (Ge)

Linnaeus C., 1753. Species Plantarum. T.1. Holmiae (L).

Linnaeus C., 1762. Species Plantarum. Ed. 2, T.1. Holmiae (L).

MacKey J., 1954. The taxonomy of hexaploid wheat. Svensk. Bot. Tidskr. 48: p. 579-590.
MacKey J., 1988. A plant breeder's perspective on taxonomy of cultivated plants. Biologisches Zentralblatt 107: p. 369-379.
Mangelsdorf P.C., 1953. Wheat. Sci. Amer. 189: p. 50-59.
Matsuoka Y., 2011. Evolution of Polyploid Triticum Wheats under Cultivation: The Role of Domestication, Natural Hybridisation and Allopolyploid Speciation in their Diversification. Plant and Cell Physiology, 52(5), p. 750-764.
Metzger J., 1824. Europaesche cerealien. Mannheum, 7 p. (Ge)
Mico P., Megyeri M., Molinar-Lang M., Kovacs G., 2013. Characterization of Triticum timopheevii Zhuk. Gene Bank accessions for the development of synthetic amphidiploid wheat lines. Acta Agronomica Hungarica, 61(2): p. 113-121.
Morris R., Sears E.R., 1967. The cytogenetics of wheat and its relatives. In: Wheat and Wheat Improvement (Quisenberry KS and Reitz LP, Eds.). American Society of Agronomy, Madison WI. P. 19-87.
Naskidashvili P.P., 1984. Wheat wide hybridization. Kolos. Moscow (Ru).
Percival J., 1921. The wheat plant. A monograph. London, 463 p.
Queiroz K. de, 2005. Ernst Mayr and the modern concept of species. Proc. Natl. Acad. Sci. U.S.A. 102 (Suppl. 1): 6600-7.
Queiroz K. de, 2007. Species Concepts and Species Delimitation. Syst. Biol. 56(6): p. 879-886.
Rosentsiel K. von, 1950. Weizen, Triticum. Handb.d.Pflanzenzuchtg. Berlin (Ge).
Sakamura T., 1918. Kurze mittelung ueber die chromosomenzahlen und die verwandtschaftsverhaeltnisse der Triticum-arten. Bot. Mag. [Tokyo] 32: 150-153 (Ge).
Schiemann E., 1948. Weizen, rogen, gerste systematic, geschichte und verwendung. Jena, Germany, 102 p. (Ge).
Schiemann E., 1951. New results on the history of cultivated cereals. Heredity, 5: p. 305-320.
Schrank F. von P., 1789. Baierische Flora. v.1., Muenchen, 753 p. (Ge)
Seringe N.C., 1818. Monographie des cereals de la Suisse. In his Melanges Botaniques, ou Recueil d'Observations, Memoires, et Notices sur la Botanique. v. 1, No 2.: [65]-244. Berne (Fr).
Seringe N.C., 1842. Descriptions et figures des cereals europeennes. Ann. Sci. Phys. Et Natl. Soc. Roy. Agr. Lyon 4: 321-384, 1841; 5(2): 103-196, 1842. (Fr).
Slageren M.W. van, 1994. Wild wheats: a monograph of *Aegilops* L. and Amblyopyrum (Jaub. & Spach) Eig (Poaceae). Wageningen Agriculture University Papers 1994(7). 513 p.
Spetsov P., Belchev I., Plamenov D., 2008. Breeding of synthetic wheats: Crossability and production of hybrids with participation of Aegilops tauschii. Proceedings of Technical university-Varna, I, p. 71-76 (Bg).
Spetsov P., Plamenov D., Belchev I., 2009. Breeding of synthetic wheats: analysis of amphidiploid plants obtained with Aegilops tauschii Coss. Field crops studies, V-2, p. 207-216 (Bg).
Stoyanov H., Spetsov P., Plamenov D., 2010. Origin of common wheat (*Triticum aestivum* L.) and analysis of synthetic wheat forms as sources of genetic diversity. Proceedings of University of Ruse, 49(1.1), p. 55-60 (Bg).
Stoyanov H., Koleva M., Plamenov D., Spetsov P., 2012. Influence of wheat genome in hybrids with participation of Aegilops cylindrica Host. Field Crops Studies VIII-1, p. 41-52 (Bg).
Stoyanov H., 2012. Characteristics of amphidiploids in the Triticum-Aegilops-Haynaldia-Agropyron group. Scientific Papers. Series A. Agronomy, LV: p. 249-255.
Stoyanov H., 2013a. Status of remote hybrids in the Poaceae: problems and prospects. Agricultural science and technology, 5(1): p. 3-12.
Stoyanov H., 2013b. Characteristics of natural hybrids between *Aegilops cylindrica* Host. and common winter wheat (*Triticum aesticum* L.). AgroLife Scientific Journal, 2(1): p. 66-71.
Stoyanov H., 2013c. Characteristics of second generation hybrids between wheat species (Triticum sp.) and Aegilops cylindrica Host. Scientific Papers. Series A. Agronomy, LVI: p. 357-362.
Stoyanov H., 2013d. Correlation between the spike characteristics in common winter wheat varieties (Triticum aestivum L.). Scientific works of the Institute of Agric.-Karnobat, 2(1): p. 95-104. (Bg).
Stoyanov H., Plamenov D., 2014. Mechanism of emerging and morphology of natural hybrids between Aegilops cylindrica Host. and *Triticum aestivum* L. near Black sea climatic region. Proc. of Union of scientists-Varna 2014. Series Marine sci.: p. 18-24.
Stoyanov H., 2014a. New amphidiploid wheat species (nothosp. nov.) as a result of artificial hybridisation. Sci. Papers. Series A. Agronomy, LVII: p. 331-338.
Stoyanov H., 2014b. Morphological analysis of spikes and grouping of accessions of *Triticum turgidum* ssp. dicoccon. Agric. science and techn., 6(2): p. 124-133.
Stoyanov H., 2014c. Similarity of spike properties of tetraploid wheat species of section Dicoccoides (2n=4x=28, AABB). Field Crop Studies (in press).
Stoyanov H., 2014d. Determining and characteristics of grain volume in common winter wheat (*Triticum aestivum* L.). Field Crop Studies (in press).
Stoyanov H., 2014e. Dependence of the spike properties of factor "accession" in common winter wheat (*Triticum aestivum* L.). Proc. of Univ. of Ruse.
Stoyanov H., 2014f. Analysis and assessment of amphidiploids of *Triticum-Aegilops* group as a source of genetic diversity. Bulgarian Journal of Agricultural Science, 20 (Supplement 1), p. 173-178.
Tsitsin N.V., 1978. Perrenial wheat. Nauka. Moscow (Ru).
Vasconcelos J. de C.E., 1933. Portuguese wheats. Bol. de Agr. [Portugal] 1 (1 and 2): [151].
Villars D., 1787. Histoire des plantes de dauphine. t.2., Grenoble, Lyon, and Paris, 690 p. (Fr)
Vilmorin H.L. de, 1889. Catalogue methodique et synonymique des froments. Paris, 76p. (Fr).
Zhukovsky P.M., 1928. A new species of wheat. Trudy Prikl. Bot. Genet., i Selek. (Bul. Appl. Bot., Genet., and Plant Breeding) 19(2): [59]-66, (Ru).

APPENDIX 1.

Table 1. Classification of genus *Triticum* sensu lato, sensu stricto and sensu strictissimo.

No	Name of the species			Ploidy	Genome formula
	Sensu lato	*Sensu stricto*	*Sensu strictissimo*		
Section *Urartu* Dorof. & A.A.Filatenko					
1	*Triticum urartu* Tumanian *ex* Gandilyan	*Triticum urartu* Tumanian *ex* Gandilyan	*Triticum urartu* Tumanian *ex* Gandilyan	2x	A^uA^u
Section *Monococcon* Dum.					
2	*Triticum boeoticum* Boiss.	*Triticum boeoticum* Boiss.	*Triticum boeoticum* Boiss.	2x	A^bA^b
3	*Triticum monococcum* L.	*Triticum monococcum* L.	*Triticum monococcum* L.	2x	A^mA^m
4	*Triticum sinskajae* A.A.Filatenko & U.K.Kurkiev	*Triticum sinskajae* A.A.Filatenko & U.K.Kurkiev	*Triticum sinskajae* A.A.Filatenko & U.K.Kurkiev	2x	A^mA^m
Section *Dicoccoides* Flaksb.					
5	*Triticum dicoccoides* (Körn. *ex* Asch. & Graebner) Schweinf.	*Triticum dicoccoides* (Körn. *ex* Asch. & Graebner) Schweinf.	*Aegilotriticum dicoccoides* [(Körn. *ex* Asch. & Graebner) Schweinf.] H.P.Stoyanov comb.nov.	4x	A^uA^uBB
6	*Triticum dicoccum* Schrank *ex* Schübler	*Triticum dicoccum* Schrank *ex* Schübler	*Aegilotriticum dicoccum* (Schrank *ex* Schübler) H.P.Stoyanov comb.nov.	4x	A^uA^uBB
7	*Triticum durum* Desf.	*Triticum durum* Desf.	*Aegilotriticum durum* (Desf.) H.P.Stoyanov comb.nov.	4x	A^uA^uBB
8	*Triticum polonicum* L.	*Triticum polonicum* L.	*Aegilotriticum polonicum* (L.) H.P.Stoyanov comb.nov.	4x	A^uA^uBB
9	*Triticum turgidum* L.	*Triticum turgidum* L.	*Aegilotriticum turgidum* (L.) H.P.Stoyanov comb.nov.	4x	A^uA^uBB
10	*Triticum turanicum* Jakubz.	*Triticum turanicum* Jakubz.	*Aegilotriticum turanicum* (Jakubz.) H.P.Stoyanov comb.nov.	4x	A^uA^uBB
11	*Triticum aethiopicum* Jakubz.	*Triticum aethiopicum* Jakubz.	*Aegilotriticum aethiopicum* (Jakubz.) H.P.Stoyanov comb.nov.	4x	A^uA^uBB
12	*Triticum karamyschevii* Nevski	*Triticum karamyschevii* Nevski	*Aegilotriticum karamyschevii* (Nevski) H.P.Stoyanov comb.nov.	4x	A^uA^uBB
13	*Triticum ispahanicum* Heslot	*Triticum ispahanicum* Heslot	*Aegilotriticum ispahanicum* (Heslot) H.P.Stoyanov comb.nov.	4x	A^uA^uBB
14	*Triticum jakubzineri* Udaczin & Schachm.	*Triticum jakubzineri* Udaczin & Schachm.	*Aegilotriticum jakubzineri* (Udaczin & Schachm.) H.P.Stoyanov comb.nov.	4x	A^uA^uBB
15	*Triticum carthlicum* Nevski *in* Kom.	*Triticum carthlicum* Nevski *in* Kom.	*Aegilotriticum carthlicum* (Nevski *in* Kom.) H.P.Stoyanov comb.nov.	4x	A^uA^uBB
16	*Triticum parvicoccum* Kislev (extinct)	*Triticum parvicoccum* Kislev (extinct)	*Aegilotriticum parvicoccum* (Kislev) H.P.Stoyanov comb.nov. (extinct)	4x	A^uA^uBB
Section *Timopheevii* A.A.Filatenko & Dorof.					
17	*Triticum timopheevii* (Zhuk.) Zhuk.	*Triticum timopheevii* (Zhuk.) Zhuk.	*Aegilotriticum timopheevii* [(Zhuk.) Zhuk.] H.P.Stoyanov comb.nov.	4x	A^uA^uGG
18	*Triticum araraticum* Jakubz.	*Triticum araraticum* Jakubz.	*Aegilotriticum araraticum* (Jakubz.) H.P.Stoyanov comb.nov.	4x	A^uA^uGG
19	*Triticum militinae* Zhuk. & Migush.	*Triticum militinae* Zhuk. & Migush.	*Aegilotriticum militinae* (Zhuk. & Migush.) H.P.Stoyanov comb.nov.	4x	A^uA^uGG
20	*Triticum zhukovskyi* Menabde & Ericzjan	*Triticum zhukovskyi* Menabde & Ericzjan	*Aegilotriticum zhukovskyi* (Menabde & Ericzjan) H.P.Stoyanov comb.nov.	6x	$A^uA^uGGA^mA^m$
Section *Triticum* L.					
21	*Triticum macha* Dekapr. & Menabde	*Triticum macha* Dekapr. & Menabde	*Aegilotriticum macha* (Dekapr. & Menabde) H.P.Stoyanov comb.nov.	6x	A^uA^uBBDD

22	*Triticum spelta* L.	*Triticum spelta* L.	*Aegilotriticum spelta* (L.) H.P.Stoyanov comb.nov.	6x	A^uA^uBBDD
23	*Triticum aestivum* L.	*Triticum aestivum* L.	*Aegilotriticum aestivum* (L.) H.P.Stoyanov comb.nov.	6x	A^uA^uBBDD
24	*Triticum petropavlovskyi* Udaczin & Migush.	*Triticum petropavlovskyi* Udaczin & Migush.	*Aegilotriticum petropavlovskyi* (Udaczin & Migush.) H.P.Stoyanov comb.nov.	6x	A^uA^uBBDD
25	*Triticum vavilovii* (Tumanian) Jakubz.	*Triticum vavilovii* (Tumanian) Jakubz.	*Aegilotriticum vavilovii* [(Tumanian) Jakubz.] H.P.Stoyanov comb.nov.	6x	A^uA^uBBDD
26	*Triticum compactum* Host	*Triticum compactum* Host	*Aegilotriticum compactum* (Host) H.P.Stoyanov comb.nov.	6x	A^uA^uBBDD
27	*Triticum sphaerococcum* Percival	*Triticum sphaerococcum* Percival	*Aegilotriticum sphaerococcum* (Percival) H.P.Stoyanov comb.nov.	6x	A^uA^uBBDD
28	*Triticum tibeticum* (J.Z.Shao) H.P.Stoyanov comb.nov.	*Triticum tibeticum* (J.Z.Shao) H.P.Stoyanov comb.nov.	*Aegilotriticum tibeticum* (J.Z.Shao) H.P.Stoyanov comb.nov.	6x	A^uA^uBBDD
29	*Triticum yunnanense* (King ex S.L.Chen) H.P.Stoyanov comb.nov.	*Triticum yunnanense* (King ex S.L.Chen) H.P.Stoyanov comb.nov.	*Aegilotriticum yunnanense* (King ex S.L.Chen) H.P.Stoyanov comb.nov.	6x	A^uA^uBBDD
Section *Compositae* N.Gonch.					
30	*Triticum ×palmovae* G.Ivanov	*Triticum ×palmovae* G.Ivanov	*×Aegilotriticum erebunii* (Gandilyan) Van Slageren	4x	DDA^bA^b
31	*Triticum ×kiharae* Dorof. Et Migusch.	*Triticum ×kiharae* Dorof. Et Migusch.	*×Aegilotriticum kiharae* (Dorof. et Migusch.) H.P.Stoyanov comb.nov.	6x	A^uA^uGGDD
32	*Triticum ×soveticum* Zhebrak	*Triticum ×soveticum* Zhebrak	*Aegilotriticum ×soveticum* (Zhebrak) H.P.Stoyanov comb.nov.	8x	$A^uA^uBBA^uA^uGG$
33	*Triticum ×fungicidum* Zhuk	*Triticum ×fungicidum* Zhuk	*Aegilotriticum ×fungicidum* (Zhuk) H.P.Stoyanov comb.nov.	8x	$A^uA^uBBA^uA^uGG$
34	*Triticum ×borisovii* Zhebrak	*Triticum ×borisovii* Zhebrak	*Aegilotriticum ×borisovii* (Zhebrak) H.P.Stoyanov comb.nov.	10x	$A^uA^uBBDDA^uA^uGG$
35	*Triticum ×flaksbergerii* Navr.	*Triticum ×flaksbergerii* Navr.	*Aegilotriticum ×flaksbergerii* (Navr.) H.P.Stoyanov comb.nov.	8x	$A^uA^uBBA^uA^uGG$
36	*Triticum ×dimococcum* Schieman et Staudt	*Triticum ×dimococcum* Schieman et Staudt	*Aegilotriticum ×dimococcum* (Schieman et Staudt) H.P.Stoyanov comb.nov.	6x	$A^uA^uBBA^mA^m$
37	*Triticum ×miguschovae* Zhirov	*Triticum ×miguschovae* Zhirov	*×Aegilotriticum miguschovae* (Zhirov) H.P.Stoyanov comb.nov.	6x	A^uA^uGGDD
38	*Triticum ×timonovum* Heslot et Ferrary	*Triticum ×timonovum* Heslot et Ferrary	*Aegilotriticum ×timonovum* (Heslot et Ferrary) H.P.Stoyanov comb.nov.	8x	$A^uA^uA^uA^uGGGG$
39	*Triticum ×timococcum* Kostov	*Triticum ×timococcum* Kostov	*Aegilotriticum ×timococcum* (Kostov) H.P.Stoyanov comb.nov.	6x	$A^uA^uGGA^mA^m$
40	*Triticum ×teres* H.R.Jiang & X.X.Kong	*Triticum ×teres* H.R.Jiang & X.X.Kong	*×Aegilotriticum teres* (H.R.Jiang & X.X.Kong) H.P.Stoyanov comb.nov.	4x	DDA^uA^u
41	*Triticum ×edwardii* Zhebrak	*Triticum ×edwardii* Zhebrak	*Aegilotriticum ×edwardii* (Zhebrak) H.P.Stoyanov comb.nov.	6x	$A^uA^uBBA^mA^m$
42	*Triticum ×savovii* H.P.Stoyanov	*Triticum ×savovii* H.P.Stoyanov	*Aegilotriticum ×savovii* H.P.Stoyanov comb.nov.	6x	$A^uA^uBBA^bA^b$
43	*Triticum ×spetsovii* H.P.Stoyanov	*Triticum ×spetsovii* H.P.Stoyanov	*Aegilotriticum ×spetsovii* H.P.Stoyanov comb.nov.	6x	$A^uA^uBBA^bA^b$
44	*Triticum ×toschevii* H.P.Stoyanov	*Triticum ×toschevii* H.P.Stoyanov	*Aegilotriticum ×toschevii* H.P.Stoyanov comb.nov.	6x	-
Section *Aegilopsiformis* H.P.Stoyanov sect.nov.					
45	*Triticum macrochaetum* (Shuttl. & Huet) Richter	*Aegilops biuncialis* Vis.	*Aegilops biuncialis* Vis.	4x	UUMM
46	*Triticum ovatum* (L.) Raspail	*Aegilops geniculata* Roth	*Aegilops geniculata* Roth	4x	UUMM
47	*Triticum triaristatum* (Willd.) Godr. & Gren.	*Aegilops neglecta* Req. ex Bertol.	*Aegilops neglecta* Req. ex Bertol.	4x, 6x	UUMM, UUMMNN
48	*Triticum peregrinum Hack.*	*Aegilops peregrina* (Hack. in J.Fraser) Marie & Weiller	*Aegilops peregrina* (Hack. in J.Fraser) Marie & Weiller	4x	UUSS

49	*Triticum umbellulatum* (Zhuk.) Bowden	*Aegilops umbellulata* Zhuk.	*Aegilops umbellulata* Zhuk.	2x	UU
50	*Triticum columnare* (Zhuk.) Morris & Sears	*Aegilops columnaris* Zhuk.	*Aegilops columnaris* Zhuk.	4x	UUMM
51	*Triticum triunciale* (L.) Raspail	*Aegilops triuncialis* L.	*Aegilops triuncialis* L.	4x	UUCC
52	*Triticum kotschyi* (Boiss.) Bowden	*Aegilops kotschyi* Boiss	*Aegilops kotschyi* Boiss	4x	UUSS
53	*Triticum comosum* (Sibth. & Sm.) Richter	*Aegilops comosa* Sm. in Sibth. & Sm.	*Aegilops comosa* Sm. in Sibth. & Sm.	2x	MM
54	*Triticum uniaristatum* (Vis.) Richter	*Aegilops uniaristata* Vis.	*Aegilops uniaristata* Vis.	2x	NN
55	*Triticum dichasians* (Zhuk.) Bowden	*Aegilops caudata* L.	*Aegilops caudata* L.	2x	CC
56	*Triticum cylindricum* Ces.	*Aegilops cylindrica* Host	*Aegilops cylindrica* Host	4x	CCDD
57	*Triticum bicorne* Forssk	*Aegilops bicornis* (Forssk.) Jaub. & Spach	*Aegilops bicornis* (Forssk.) Jaub. & Spach	2x	S^bS^b
58	*Triticum longissimum* (Schweinf. & Muschl.) Bowden	*Aegilops longissima* Schweinf. & Muschl.	*Aegilops longissima* Schweinf. & Muschl.	2x	S^lS^l
59	*Triticum searsii* (Feldman & Kislev) Feldman	*Aegilops searsii* Feldman & Kislev *ex* Hammer	*Aegilops searsii* Feldman & Kislev ex Hammer	2x	S^sS^s
60	*Triticum sharonense* L.	*Aegilops sharonensis* Eig	*Aegilops sharonensis* Eig	2x	S^hS^h
61	*Triticum speltoides* (Tausch) Gren. ex Richter	*Aegilops speltoides* Tausch	*Aegilops speltoides* Tausch	2x	SS
62	*Triticum juvenale* Thell.	*Aegilops juvenalis* (Thell). Eig	*Aegilops juvenalis* (Thell). Eig	6x	DDMMUU
63	*Triticum tauschii* (Coss.) Schmalh.	*Aegilops tauschii* Coss.	*Aegilops tauschii* Coss.	2x	DD
64	*Triticum syriacum* Bowden	*Aegilops vavilovii* (Zhuk.) Chennav.	*Aegilops vavilovii* (Zhuk.) Chennav.	6x	DDMMSS
65	*Triticum crassum* (Boiss.) Aitch. & Hensl.	*Aegilops crassa* Boiss.	*Aegilops crassa* Boiss.	4x, 6x	DDMM, DDDDMM
66	*Triticum ventricosum* Ces.	*Aegilops ventricosa* Tausch	*Aegilops ventricosa* Tausch	4x	DDNN
67	*Triticum tripsacoides* (Jaub. & Spach) Bowden	*Ambylopyrum muticum* (Boiss.) Eig	*Ambylopyrum muticum* (Boiss.) Eig	2x	TT
Section *Amphidiploida* H.P.Stoyanov sect.nov.					
68	×*Triticum tsitsinii* H.P.Stoyanov sp.nov.	×*Elymotriticum* sp. P.Fourn.	-	8x	A^uA^uBBDDEE
69	×*Triticum duelongatum* (Poleva) H.P.Stoyanov comb.nov.	×*Elymotriticum* sp. P.Fourn.	-	6x	EEA^uA^uBB
70	×*Triticum duromedium* (Lubimova) H.P.Stoyanov comb.nov.	×*Elymotriticum* sp. P.Fourn.	-	10x	JJJ^sJ^sSSA^uA^uBB
Section *Hybrida* H.P.Stoyanov sect.nov.					
71	*Triticum* ×*grenieri* K.Richter	×*Aegilotriticum grenieri* (K.Richter) A.Camus	×*Aegilotriticum grenieri* (K.Richter) A.Camus	5x	UMA^uBD
72	*Triticum* ×*loreti* K.Richter	×*Aegilotriticum loreti* (K.Richter) A.Camus	×*Aegilotriticum loreti* (K.Richter) A.Camus	5x	UCA^uBD
73	*Triticum* ×*requieni* Cesati, Passerini & Gibelli	×*Aegilotriticum requieni* (Cesati, Passerini & Gibelli) P.Fourn.	×*Aegilotriticum requieni* (Cesati, Passerini & Gibelli) P.Fourn.	5x	UMA^uBD
74	*Triticum* ×*rodetii* Trabut	×*Aegilotriticum rodetii* (Trabut) A.Camus	×*Aegilotriticum rodetii* (Trabut) A.Camus	4x	DNA^uB
75	*Triticum* ×*sancti-andreae* Degen	×*Aegilotriticum sancti-andreae* (Degen) Van Slageren	×*Aegilotriticum sancti-andreae* (Degen) Van Slageren	5x	CDA^uBD