

Significance of *Aegilops triuncialis* L. for the development of new breeding lines of wheat *Triticum* spp.

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Summary

Bulgaria is one of the countries on the Balkan Peninsula with a diversity of species from the genus *Aegilops*. They are a source of genes for resistance to biotic and abiotic environmental stress factors which, when introduced into the genome of durum and common wheat through hybridization, can improve their resistance. The interest in these species is also justified by the possibility of using them in breeding for broadening the

genetic base of durum and common wheat. The wild relative of wheat, *Aegilops triuncialis* L., is an annual herbaceous plant known as barbed goatgrass. It is a tetraploid species ($2n = 4x = 28$) with a genomic constitution UUCC. The species is widely distributed in Bulgaria, where it also exhibits pronounced genetic variation in its plant forms. This provides grounds for an in-depth study of the genetic potential of *Aegilops triuncialis* L., distributed in the country, and its qualities for breeding purposes in wheat.

Countries of distribution: Afghanistan, Albania, Algeria, Bulgaria, Greece, Iran, Iraq, Spain, Italy, Kazakhstan, Cyprus, Kyrgyzstan, Crimea, Kuwait, Lebanon-Syria, Libya, Morocco, Pakistan, Palestine, Portugal, Italy (Sardinia, Sicily), Tajikistan, Tunisia, Turkey, Turkmenistan, Uzbekistan, the countries of the former Yugoslavia (Slovenia, North Macedonia, Croatia, Serbia, Montenegro, Kosovo and Bosnia).

The species has been introduced into: Germany, California, Maryland, New York, Pennsylvania.



Botanical description and morphology

Winter annual tufted herbaceous plant, forming from several to many productive tillers. At the base the culms are semi-prostrate, and later become erect. The culm length is usually 15–45 cm. The leaves are linear-lanceolate, glabrous or pubescent, 2–3 mm wide and 5–10 cm long. The lowest and uppermost leaves are shorter than the remaining ones on the culm. Between the leaf sheath and the blade there is a short membranous ligule and pubescent auricles. The inflorescence is a compound spike, slightly tapering towards

the apex, 3–6 cm long (without the awns) and 3–5 mm thick, consisting of 3–6 fertile spikelets arranged loosely and alternately along the main axis of the spike. The spikelets are sessile, 7–10 mm long and about 3–4 mm wide. The terminal spikelet is reduced, shorter and thinner, about 7 mm long and about 3 mm wide. In a spikelet there are 3–5 florets, of which the lower 3–4 are usually fertile, but there may be up to five fertile florets, which produce 5 grains per spikelet. The glumes of the lateral spikelets are ovate-elongate, 7–10 mm long, green to purple-green at heading and flowering, with a striated surface and unevenly wide veins (7–9), sunken into the surface, more or less parallel, with 2–3 awns, one of which is 10–60 mm long. The lemmas of the fertile florets are 7–10 mm long, elongate, five-veined, boat-shaped and folded lengthwise in the upper part. The outer lemma is longer than the glume. Awns on the outer lemmas occur only on the lateral spikelets and are three in number, 5–6 mm long. The palea is 2-veined with crowded keels. The inner lemma is narrowly ovate-elliptic, with 1 awn 5–6 mm long. The pistil is enclosed between the appressed outer and inner lemmas. Usually the uppermost spikelet of the spike is poorly developed, with awns equal to or longer than the spike. At fruiting, the spike usually breaks off at the base and falls as a whole, leaving sometimes only the rudimentary 1–2 sterile spikelets attached to the culm. When the spike disarticulates into separate spikelets, the spikelet detaches together with the adjacent rachis segment.

The fruit is a dorsiventral flattened caryopsis with a groove along the entire ventral side, pubescent at the apex. The grain colour is red. It reproduces by seeds.

Phenology: Flowering (April–August), fruiting (May–August)

Habitats: Uncultivated and heavily disturbed sites – fallow lands, roadsides, dry, sandy, grassy slopes, pastures. Distributed throughout Bulgaria at altitudes of 500–1200 m.

Ecology: Least affected or threatened species.

Taxonomy: Royal Botanic Gardens, Kew

Synonyms: *Aegilopodes triuncialis* (L.) Á.Löve, *Aegilops elongata* Lam., *Aegilops triuncialis* subsp. *eutriuncialis* Eig, *Aegilops triuncialis* subsp. *typica* Zhuk., *Aegilops triuncialis* var. *typica* Eig, *Triticum triunciale* (L.) Raspail, *Aegilopodes triuncialis* subsp. *persica* (Boiss. ex Hohen.) Á.Löve, *Aegilops aristata* Req. ex Bertol., *Aegilops buschirica* Roshev., *Aegilops echinata* C. Presl, *Aegilops persica* Boiss. ex Hohen., *Aegilops squarrosa* L., *Aegilops squarrosa* subsp. *eusquarrosa* Eig, *Aegilops squarrosa* subsp. *typica* Zhuk., *Aegilops squarrosa* var. *typica* Eig, *Aegilops triaristata* Req. ex Bertol., *Aegilops triuncialis* var. *albescens* Popova, *Aegilops triuncialis* var. *assyriaca* Eig, *Aegilops triuncialis* subsp. *bozdagensis* Cabi & Dogan, *Aegilops triuncialis* var. *breviaristata* Hack., *Aegilops triuncialis* f. *brunnea* (Popova) K. Hammer, *Aegilops triuncialis* var. *brunnea* Popova, *Aegilops*

triuncialis subsp. *caput-medusae* Zhuk., *Aegilops triuncialis* var. *constantinopolitana* Eig, *Aegilops triuncialis* subsp. *fascicularis* Zhuk., *Aegilops triuncialis* var. *ferruginea* Popova, *Aegilops triuncialis* f. *ferruginea* (Popova) K. Hammer, *Aegilops triuncialis* var. *flavescens* Popova, *Aegilops triuncialis* f. *flavescens* (Popova) K. Hammer, *Aegilops triuncialis* var. *glabripica* Eig, *Aegilops triuncialis* subvar. *glauca* Miczyn, *Aegilops triuncialis* subvar. *hirsuta* (H. Lindb.) Jahand. & Maire, *Aegilops triuncialis* f. *hirsuta* H. Lindb., *Aegilops triuncialis* var. *hirta* Zhuk., *Aegilops triuncialis* subvar. *hispida* Miczyn., *Aegilops triuncialis* var. *leptostachys* Bornm., *Aegilops triuncialis* var. *muricata* Zhuk., *Aegilops triuncialis* var. *nigriaristata* Flaksb., *Aegilops triuncialis* var. *nigroalbescens* Popova., *Aegilops triuncialis* f. *nigroalbescens* (Popova) K.Hammer., *Aegilops triuncialis* var. *nigroaristata* Flaksb., *Aegilops triuncialis* var. *nigroferruginea* Popova., *Aegilops triuncialis* f. *nigroferruginea* (Popova) K.Hammer., *Aegilops triuncialis* var. *nigroflavescens* Popova., *Aegilops triuncialis* f. *nigroflavescens* (Popova) K.Hammer., *Aegilops triuncialis* var. *nigrorubiginosa* Popova., *Aegilops triuncialis* f. *nigrorubiginosa* (Popova) K.Hammer., *Aegilops triuncialis* subsp. *orientalis* Eig., *Aegilops triuncialis* subsp. *persica* (Boiss. ex Hohen.) Zhuk., *Aegilops triuncialis* var. *persica* (Boiss. ex Hohen.) Eig., *Aegilops triuncialis* var. *pubispica* Eig., *Aegilops triuncialis* var. *rubiginosa* Popova., *Aegilops triuncialis* f. *rubiginosa* (Popova) K.Hammer., *Aegilops triuncialis* subvar. *subglabra* (H.Lindb.) Jahand. & Maire., *Aegilops triuncialis* f. *subglabra* H. Lindb., *Triticum persicum* (Boiss. ex Hohen.) Aitch. & Hemsl., *Triticum squarrosum* (L.) Raspail.



Significance of the species:

Aegilops triuncialis L., also known as barbed goatgrass, is a tetraploid species with the genomic formula UUCC ($2n = 4x = 28$) and chromosome number ($x = n = 7$). It has been established that the U genome in this species

contributed to the formation of cultivated wheats (Peng et al. 2011). *Aegilops triuncialis* L. is resistant to various stress factors, such as drought and salinity. The species may be a suitable candidate for crossing with bread wheat, as well as for the development of new breeding lines possessing high levels of drought tolerance (Colmer et al. 2006). This is one of the main reasons for studying the genetic diversity in accessions of *Aegilops triuncialis* L., which provides useful information for improving various traits in common bread wheat. Crosses between wheat and a closely related wild relative such as *Aegilops triuncialis* L. are being investigated by breeders and biologists to identify suitable combinations.

In a study on the sensitivity of different species to the application of ozone (O₃) during plant vegetation, it was found that plants of *Aegilops triuncialis* L. are among the least affected and only slightly sensitive to high doses of ozone (O₃), which are toxic to plant cells (Bermejo et al., 2003).

The species *Aegilops triuncialis* L. is widely distributed from Asia to Europe and is generally well known and studied, but recently researchers of this species have discovered and described a new subspecies called *Aegilops triuncialis* L. subsp. *bozdagensis* Cabi and Dogan. A distinguishing feature of this newly discovered subspecies is that the outer and inner glumes of the lateral spikelets lack awns, which differentiates it from the other two long-known subspecies *Aegilops triuncialis* subsp. *persica* and *Aegilops triuncialis* subsp. *triuncialis*. The distribution of the new subspecies is restricted to the southwestern region of Anatolia (Evren et al., 2018; Karatassiou et al., 2021).

Genotypes of the species may provide potential sources of physico-chemical traits for use in future breeding studies. It has been established that the species could be involved in breeding for increasing grain nutrients, grain number and grain mass, as well as in breeding for earlier flowering (Meimberg et al., 2010). Breeding for rust resistance includes conventional and molecular tools, such as mapping of loci for specific traits. *Aegilops triuncialis* L. is also used for developing new genetic resources and for understanding genetic diversity in order to diversify rust resistance (Tomar et al. 2014). A major gene, Lr58, responsible for conferring leaf rust resistance in wheat, is known; this gene was transferred from its donor *Aegilops triuncialis* L. into common bread wheat and was mapped on chromosome 2BL (Kuraparthi et al. 2007).

The C genome of *Aegilops triuncialis* L., its structure and significance, is also of interest. This genome is considered an important source for improving bread wheat (Molnár et al., 2015). Hybrids are also created by flow-sorted chromosomes with the diploid *Ae. markgrafii* (2n = 2x = 14; CC) and the allotetraploid species *Ae. triuncialis* (2n = 4x = 28; UtUtCtCt) and *Ae. cylindrica* (2n = 4x = 28; DCDC(C)CC). The genome of *Aegilops triuncialis* L. has been used to generate more than 400 DNA elements, which are now routinely used for physical

mapping of DNA-based markers. Line BTC17 is an interspecific derivative obtained from a 5U-5A substitution of chromosome 5U from *Aegilops triuncialis* L. into the bread wheat line WL711 (Singh et al., 2000). Line BTC17 is characterized by specific high-molecular-weight glutenins for improving starch quality in wheat (Giroux and Morris, 1997). A study conducted in 2020 identifies *Aegilops triuncialis* L. as one of the most tolerant species in the genera *Triticum* and *Aegilops* as a result of the activity of the gene TaHKT1;5 (Ahmadi et al. 2020). Various studies show that *Aegilops triuncialis* L. also possesses resistance traits to Hessian fly, which could be transferred to common wheat through transfer of H30, the gene responsible for this trait (Martin-Sanchez et al., 2003). It has been established that chromosome 3C of *Aegilops triuncialis* L. has a gametocidal function and induces structural changes in chromosome 4V of *Haynaldia villosa* L. (Chen et al., 2002). Chromosome 3C from *Aegilops triuncialis* L. in common bread wheat of the variety Norin-26 can induce variation in chromosome structure, in the search for useful traits within these variations (Tsujiimoto et al., 1985; Endo et al., 1998; Endo et al., 1994; Endo et al., 1988; Endo and Gill, 1990).

Line TR-3531, which is the result of another cross between common bread wheat and *Aegilops triuncialis* L., carries the gene Cre7, which induces the production of protective enzymes in the root cells that act against the cereal cyst nematode, and is used for research as well as for breeding purposes (Maria et al. 2004).

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