



Field Guide for Identification of *Aegilops* species at ICAR-IIWBR

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ICAR-Indian Institute of Wheat and Barley Research

Karnal 132001, (India)



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Foreword

Wheat breeding programme in leading national and international institutes/universities are now focussed on utilization of *Aegilops* species. In the last few decades there has been growing interest in the *Aegilops* species as a gene contributor for the improvement of wheat for the number of traits such as disease resistance, abiotic stresses and quality components. However, the introgression of valuable genes from wild species is not an easy task as it requires sustained and concerted efforts. The breeder first needs to tag the useful traits and feasible accession and then introgress into the cultivar by various techniques, so that these cultivars can be used further. By doing so, the breeders broaden the genetic base of wheat by utilizing the genes from *Aegilops* species. Out of 22 species of *Aegilops* reported by M. van Slageren, the accessions of 15 *Aegilops* species are being maintained under the pre-breeding project of the ICAR-IIWBR. Invariably, *Ae. tauschii* is used for the development of synthetic lines and available literature suggests that other species of *Aegilops* also have the potential and the breeders need to exploit them. In this process, a better understanding of *Aegilops* species may assist the breeders to use them in breeding programme. Since, the genus *Aegilops* is a native of *Transcaucasian* region and identity of different species is some times mistaken by the breeders/researchers. This publication is aimed at identification of *Aegilops* by highlighting the zoom photographs of spike, lateral spikelet, apical spikelet and glume and lemma on lateral and apical spikelet for each species. I am sure the publication will serve as guide for the correct identification of species by the researchers and their utilization in future wheat improvement programmes for various traits.



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01

Introduction

The tribe '*Triticeae*' was first described by Dumortier in 1823, however, the same tribe was described as '*Hordeae*' by German Botanist Spenner in 1825. In India the tribe *Hordeae* was used by Bentham in place of *Triticeae*. The International code of Botanical nomenclature resolved the issue and considered tribe *Triticeae* as the correct name in the family Poaceae (Yen and Yang, 2009). The tribe *Triticeae* provided many agriculturally economically important crop species like wheat, barley, rye and triticale. The tribe *Triticeae* of family Poaceae has around 325 species of which 250 are perennial and 75 are annual (Dewey, 1984). Among the various species of tribe *Triticeae*; bread wheat (*T. aestivum*); durum wheat (*T. durum*); einkorn (*T. monococcum*); barley (*H. vulgare*) and rye (*Secale cereale*) are cultivated ones (Rasheed *et al.*, 2018). Linnaeus recognized five genera namely *Elymus*, *Hordeum*, *Secale*, *Triticum* and *Aegilops* in the tribe *Triticeae*. Dumortier added two more genera *Hystrix* and *Agropyron* in tribe *Triticeae*. These all are based on clear cut identification at field level.

Harlan and DeWet (1971) enumerated the concept of gene pool based on crossability between crops and other taxa. The primary, secondary and tertiary gene pool in wheat was provided by Mujeeb-kazi and Rajaram (2002). The wheat landraces, obsolete cultivars, breeding lines, cultivated tetraploid of wheat and diploid donors of A and D genomes to durum and bread wheat were considered as primary gene pool. Those *Aegilops* species which are directly crossable with wheat are considered as the primary gene pool. However, the other *Aegilop* species with some degree of crossability with *Triticum sp.* were considered as secondary gene pool (Mackey 1966). Stebbin in 1956 amalgamated the *Triticum* and *Aegilops* genera into one. Similarly Kimber and Fieldman (1987) also considered both *Triticum* and *Aegilops* as one genera, while, Slageren (1994) provided separate status to *Aegilops* and *Triticum* genera.

With the advent of molecular tools, researchers are now interested in exploitation of *Aegilops* gene pool for the future improvement in yield, disease resistance and quality in wheat. The *Aegilops* species can provide genes for the improvement of wheat crop in traits like various biotic and abiotic stress tolerance. In fact through introgression of genes from *Aegilops* species many elite cultivars/genotypes have been developed. The important genes from *Aegilops* can be introgressed in the cultivable wheat via the development of synthetic hexaploid and their subsequent crossing with modern cultivars.

Investigation of species diversity using morphological traits is very important for the systematic study and also for determining the taxonomic position. The taxonomy of *Aegilops* has been confusing and attracted many taxonomist, breeders, cytogeneticist and biotechnologist because of its close affinity with genus *Triticum*. In recent years, there is many fold increase in the demand of wild wheat germplasm. But, if breeders are to use *Aegilops* species effectively in the breeding programme, they have to identify and well verse with the floral structure of *Aegilops* species. Therefore in this bulletin, the authors provide the key for identification of *Aegilops* species along with photographs of spike, spikelet, outer glume and lemma. HP Scanjet G4010 scanner was used for imaging the spike, spikelet, glume and lemma. To give the large view to the images, we scan the spike images by enlarging it two times in majority of cases, while spikelet, glumes and lemma images were captured by enlarging it four times. This helps in increase the visibility of plant part, and considered as promising approach for guiding research worker in species identification. The distribution map of *Aegilops* species has been reproduced from the IUCN website www.iucn.org.

The basic purpose of this bulletin is to provide the key identification characters of *Aegilops* species maintained under pre breeding project at ICAR-IIWBR, Karnal and encourage the researchers to exploit non-conventional germplasm for traits of interest.

02

Aegilops

Aegilops is the most closely related genus to *Triticum* and both share annual growth habits. Of the 22 species of *Aegilops* reported from world-wide by Van Salgreen (1994), 10 are diploid, 10 are tetraploid and two are hexaploid. Seven different genomes (D, S, U, C, N, M and T) were identified in the diploid species indicating the extreme genetic diversity in the genus (Zhang and Dvorak, 1992).

The *Aegilops* species is originated in Transcaucasian area from where diploid species then moved to western and south western direction. Of the various *Aegilops* species, only *Ae. tauschii* is reported from India. The rest of the species were introduced in India by research institutes including ICAR- NBPGR, Delhi. Similarly, these *Aegilops* species are also maintained by some of the research institutes/universities for research purposes. The *Aegilops* genus was extensively studied by the Slageren and thus the nomenclature as name proposed by Slageren and their synonyms is given in the table 1

Table 1. Overview of *Aegilops* Species

Species of <i>Aegilops</i>	Genome	Species of <i>Triticum</i>
<i>Aegilops bicornis</i> (Forssk.) Jaub. & Spach	Sb	<i>Triticum bicornis</i> Forssk.
<i>Aegilops biuncialis</i> Vis.	UM	<i>Triticum macrochaetum</i> (Shuttlew. & A. Huet ex Duval-Jouve) K. Richt.
<i>Aegilops caudata</i> L.	C	<i>Triticum dichasians</i> Bowden
<i>Aegilops columnaris</i> Zhuk.	UM	<i>Triticum</i> - none
<i>Aegilops comosa</i> Sm. in Sibth. & Sm.	M	<i>Triticum comosum</i> (Sm. in Sibth. & Sm.) K. Richt.
<i>Aegilops crassa</i> Boiss.	DM/ DDM	<i>Triticum crassum</i> (Boiss.) Aitch. & Hemsl.
<i>Aegilops cylindrica</i> Host	DC	<i>Triticum cylindricum</i> (Host) Ces., Pass. & Gibelli
<i>Aegilops geniculata</i> Roth (<i>Ae. ovata</i>)	MU	<i>Triticum</i> - none
<i>Aegilops juvenalis</i> (Thell.) Eig	DMU	<i>Triticum juvenale</i> Thell.
<i>Aegilops kotschy</i> Boiss.	SU	<i>Triticum kotschy</i> (Boiss.) Bowden
<i>Aegilops longissima</i> Schweinf. & Muschl.	S1	<i>Triticum longissimum</i> (Schweinf. & Muschl.) Bowden
<i>Aegilops neglecta</i> Req. ex Bertol.	UM	<i>Triticum neglectum</i> (Req. ex Bertol.) Greuter
	UMN	<i>Triticum recta</i> (Zhuk.) Chennav.
<i>Aegilops peregrina</i> (Hack, in J. Fraser) Maire & Weiller	SU	<i>Triticum peregrinum</i> Hack, in J. Fraser

<i>Aegilops searsii</i> Feldman & Kislev ex Hammer	Ss	<i>Triticum</i> - none
<i>Aegilops sharonensis</i> Eig	S1	<i>Triticum longissimum</i> (Schweinf. & Muschl.) Bowden ssp. <i>sharonense</i> (Eig) Chennav.
<i>Aegilops speltoides</i> Tausch	S	<i>Triticum speltoides</i> (Tausch) Gren. ex K. Richt.
<i>Aegilops tauschii</i> Coss.	D	<i>Triticum aegilops</i> P. Beauv. ex Roem. ex Schult.
<i>Aegilops triuncialis</i> L.	UC	<i>Triticum triunciale</i> (L.) Rasp. (var. <i>triunciale</i>)
	CU	(<i>T. triunciale</i> ssp. <i>persicum</i>)
<i>Aegilops umbellulata</i> Zhuk.	U	<i>Triticum umbellulatum</i> (Zhuk.) Bowden
<i>Aegilops uniaristata</i> Vis.	N	<i>Triticum uniaristatum</i> (Vis.) K. Richt.
<i>Aegilops vavilovii</i> (Zhuk.) Chennav.	DMS	<i>Triticum syriacum</i> Bowden
<i>Aegilops ventricosa</i> Tausch	DN	<i>Triticum ventricosum</i> (Tausch) Ces. Pass. & Gibelli
Species of Amblyopyrum		
<i>Amblyopyrum muticum</i> (Boiss.) Eig	T	<i>Triticum tripsacoides</i> (Jaub. & Spach) Bowden

Following three broad types of spikes disarticulation have been reported in *Aegilops*:

- i) Barrel type: Spikelet breaking into unit with rachis segment of next higher spikelet.
- ii) Wedge type: Spikelet breaking into unit with own rachis segment.
- iii) Entire type: Whole spike break.

03 Species descriptions and plate

Out of the twenty-two species reported by Slageren (1994), fifteen species are being maintained at ICAR-IIWBR, Karnal under pre-breeding project. The identification key of *Aegilops* species based on Slageren(1994) are given below:

No.	Couplet	Go to number/Species
1	Spike disarticulation: Barrel type.	2
	Spike disarticulation: Wedge or Entire type.	6
2	Spike shape moniliform.	3
	Spike cylindrical to slightly moniliform.	4
3	Glume pubescent, lemma of apical spikelet with flat awn upto 7-9 cm; spikelet ventricose or inflated.	<i>Ae. crassa</i>
	Glume glabrous with two marginal teeth.	<i>Ae. ventricosa</i>
4	Glumes on lateral spikelet with 2-3 teeth, one of which may develop into a short awn; spike narrowly cylindrical with 6-12 spikelets.	5
	Lateral spikelet with two awns, one of which reduced to sharp tooth, spike cylindrical to moniliform with 3-6 spikelets.	<i>Ae. juvenalis</i>
	Glume scabrid (rough), glumes truncate with thickened rim, lemma awned.	<i>Ae. tauschii</i>
5	Glume adpressed-velutinous, glume of lateral spikelet with 2-3 teeth, the adaxial one sharply acute, apical glume with a central awn, lateral spikelet lemma with sharp tooth; apical spikelet lemma with long flat awn and two basal teeth.	<i>Ae. vavilovii</i>
6	Spike disarticulate 'Wedge type': spike cylindrical two rowed.	7
	Spike disarticulate entire; spike moniliform, narrowly cylindrical, sub cylindrical, narrowly ovoid, but not flattened.	10
7	Apex of lateral glume with two triangular teeth.	8
	Apex of lateral glume truncate with a thickened edge, awn on lateral spikelets.	<i>Ae. speltoides var ligustica</i>
8	Lemma awn without teeth at 'base'; apical glume with 1 central tooth and sometimes two lateral teeth.	9
	Lemma awn with two lateral teeth at the base; 1 apical glume apex with 2 triangular teeth, 1 apical glume with a short, central tooth and 2 lateral teeth.	<i>Ae. sharonensis</i>

9	All lemmas awned. Lemmas of upper 5-7 spikelet awned.	<i>Ae. bicornis</i> var. <i>bicornis</i> <i>Ae. bicornis</i> var. <i>anathera</i>
10	Spike moniliform. Spike sub cylindrical or narrowly ovoid.	11 12
11	Rudimentary spikelet 1 or 2, fertile spikelet 2-3 lateral glume apex with broad, triangular tooth and short 2-4 mm long awn, apical spikelet glume with one broad triangular tooth and a short 2-4 mm long awn, apical spikelet glumes with one broad long awn and two lateral teeth. Rudimentary spikelet (2 or 3), fertile spikelets 3-5; lateral glume apex with broad, triangular tooth and long awn; apical spikelet with a flat awn without lateral teeth or awn.	<i>Ae. comosa</i> var. <i>sub ventricosa</i> <i>Ae. uniaristata</i>
12	Spike narrowly cylindrical; more than 20 times as long as wide. Spike narrowly ovoid, widest in the basal part, then gradually or abruptly narrowing into more slender usually 10 times as long as wide.	13 18
13	Apex of terminal glumes either obtuse and without teeth or 1 shorter or longer awn or variable; with 1 cm long awn flanked by lateral teeth or with 2 teeth. Apex of apical glumes with 3 awns; central awn is 11 cm long with comparatively two lateral small awns.	14 <i>Ae. comosa</i> var. <i>comosa</i>
14	Apex of apical glume with awn, apex glumes of lateral spikelet not thickened with teeth and or awn. Apex of apical spikelet glumes obtuse, thickened without teeth; apex of lateral glumes truncate with a thickened rim.	15 <i>Ae. speltoides</i> var. <i>speltoides</i>
15	Apex of glumes of apical spikelet with one awn of atleast 3 cm long. Apex of apical spikelet variable with 1 cm long awn flattened by two lateral teeth.	16 17
16	Apex of glumes of apical spikelet with long awn, longer than the entire spike, lateral teeth at the base absent; lemmas of apical spikelet mucronate to subulate. Awns of the apical spikelet shorter than the entire length of the spike. Glumes with a 3-6 cm long awn with 1-2 lateral teeth at base; lemmas awn longer than those glume.	<i>Ae. caudata</i> <i>Ae. cylindrica</i>
17	Apical spikelet with 2 fertile glumes, lemmas of both sterile and fertile extending to long awn of 7-8 cm. with 2 small (6 mm long) lateral teeth at base; one of the glume of the apical spikelet with apex acute to apiculate. Apical spikelet with 1 fertile florets, lemma extending into > 8 cm long awns with 1-2 long (3 cm. long) lateral teeth in the basal part; lemma of apical sterile floret usually shorter awn than fertile floret; one of the apical glumes with apex bidental.	<i>Ae. longissima</i> <i>Ae. searsii</i>

18	Glumes with veins equal in width. \pm parallel equally spaced.	19
	Glumes with veins unequal in width unequally spaced.	21
19	Spike stout with an irregular appearance due to wide variation in glume and awn development.	20
	Spike with a slender, regular appearance, awns of all glumes and lemma being equally long, both glumes of the lowest fertile spikelet always with 3 awns equally wide at the base.	<i>Ae. kotschyi</i>
20	Glume of lateral spikelet with 2-3 awns, glume of apical spikelet with 3 awns; lemmas of all spikelet with 1-2 awn of widely uneven length, flanked by 1-2 teeth.	<i>Ae. peregrina</i> var. <i>peregrina</i>
	Glume of lateral spikelets with 2-3 sharp teeth, glume of apical spikelet with 1-3 awns, lemma apex of all spikelets with 2-3 teething.	<i>Ae. peregrina</i> var. <i>brachyathera</i>
21	Rudimentary spikelet 1.	22
	Rudimentary spikelet 3.	23
22	Spike with 2-3 spikelets, spikelets narrowly ovoid, glume apex with 2-3 awns, longer towards apex of the spike.	<i>Ae. biuncialis</i>
	Spike with 3-4 spikelets; spikelet sub ventricosa, glume apex with 4-5 awns, shorter towards apex of spike.	<i>Ae. geniculata</i>
23	Glumes of apical spikelets with 3 awns, central one the longest awn of the spike, the 2 lateral awns shorter; spike sub cylindrical.	24
	Glume of apical spikelet with 3-4 awns of similar size and position; spike ovoid to oblong.	25
24	Glumes of lateral spikelets with 2-3 well developed awn widely varying in length; apical glume with well developed long central awn and shorter lateral awn.	<i>Ae. triuncialis</i> var. <i>triuncialis</i>
	Glumes of lateral spikelet with 2 teeth or 1 tooth and 1 shorter awn. Glumes of apical spikelet with long central awn and lateral awn reduced to teeth.	<i>Ae. triuncialis</i> var. <i>persica</i>
25	Glumes of lowest 2 or 3 spikelets oblong, widest at the middle, the apex with 2-3 awns.	26
	Glumes of lowest 2-3 spikelets obovate, widest above the middle then abruptly constricted the apex with >3 awns.	<i>Ae. umbellulata</i>
26	Glumes of lower 2-3 spikelet with 2 awns, one large and wide, one small and linear, spike ovoid in the lower part linear in upper part.	<i>Ae. columnaris</i>
	Glumes of lower spikelet usually with 3 awns of equal length, spike ovoid ellipsoid in the lower part narrowly cylindrical in the upper part.	<i>Ae. neglecta</i>

3.1. *Aegilops biuncialis* Vis.

Synonymous: *Triticum macrochaetum* (Shuttlew. & A. Huet ex Duval-Jouve) K. Richt.; *Aegilops lorenti*

Ploidy level: $2n=4x=28$ (tetraploid); **Genomic constitution:** $U^bU^bM^bM^b$

Habit: Spreading. Ciliate margin on upper part of leaf-sheath.

Inflorescence: Spike narrowly ovoid; Inflorescence bearing 4-5 fertile spikelets.

Rachis brittleness: Entire spikelet disarticulate.

Spikelet: Lower fertile spikelet ovate or oblong.

Glumes: Apex of lateral spikelet extending to 2-3 awns more or less equally wide at the base; apical spikelet glume always with three awns. Awn length increasing towards apex of spike.

Lemma: Boat shaped; lemma with 1-2 lateral teeth/awns.

Caryopsis: Caryopsis free.

Distribution: Native to mediterranean and western Asiatic regions, Algeria, Turkey, Bulgaria, Cyprus, in the western part of the fertile crescent, in Cis- and Transcaucasia, and in the southern parts of Russia and Ukraine.

Distinctive characters: Glume with 2-3 awns of equally wide at the base. Awn length increasing towards apex of spike.

Promising traits for utilization: Potential donor to improve the wheat end product quality traits like protein content, sedimentation value, wet gluten content, and grain hardness (Zhou *et al.*, 2014).



Plate. 3.1.1. Distribution map of *Ae. biuncialis* (downloaded from iucn.org)



Plate. 3.1.2. Spike of *Ae. biuncialis* (x 2)

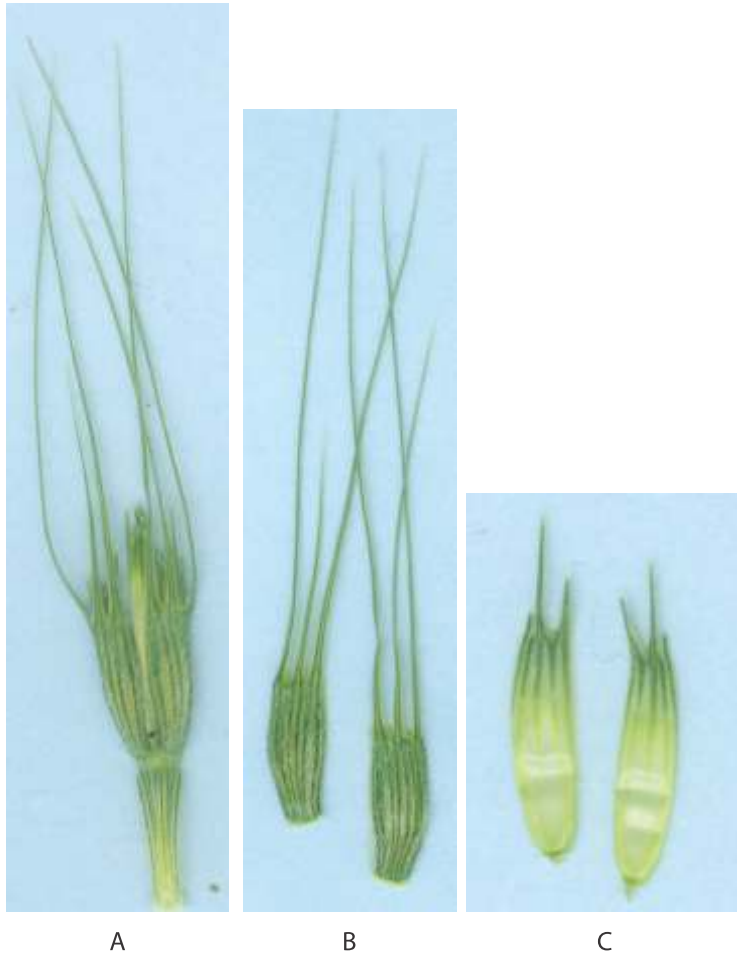


Plate. 3.1.3. *Ae. biuncialis* : A. Lower spikelet (x4); B. Glume of lower spikelet (x4); C. Lemma of lower spikelet (x4)

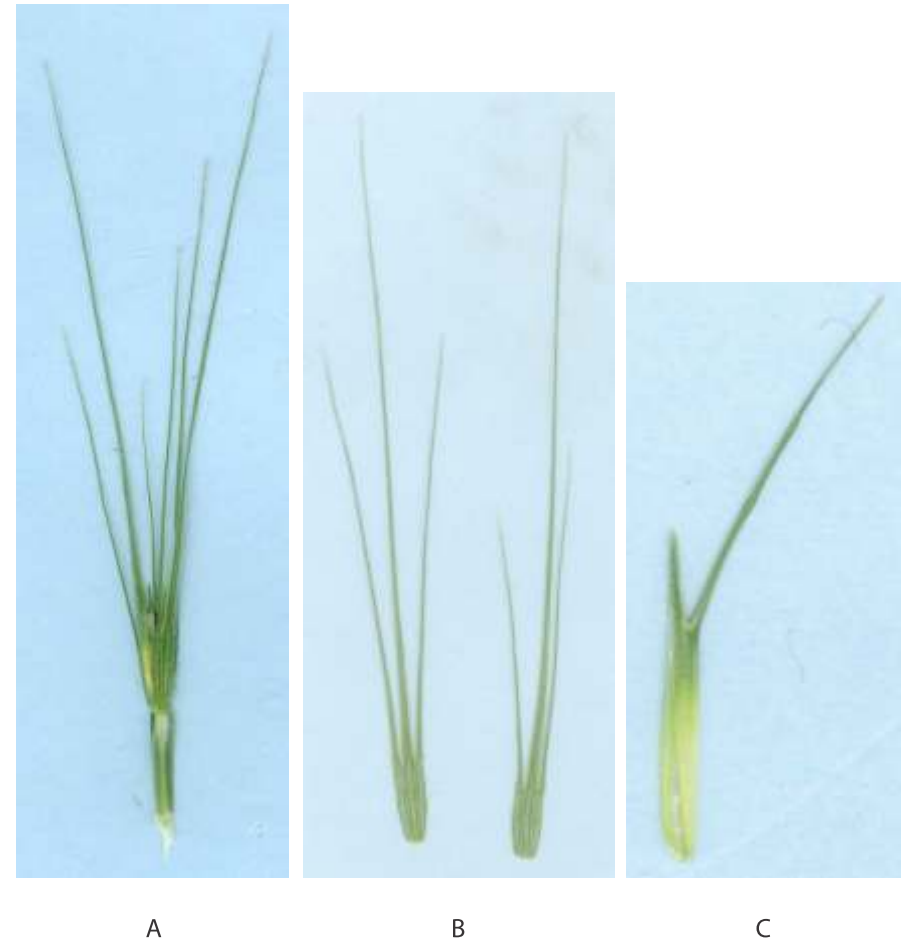


Plate. 3.1.4. *Ae. biuncialis* : A. Apical spikelet (x4); B. Glume of apical spikelet (x4); C. Lemma of apical spikelet (x4)

3.2. *Aegilops caudata* L.

Synonymous: *Triticum dichasians* Bowden

Ploidy level : $2n=2x=14$ (Diploid); **Genomic constitution:** CC

Habit: Semi-spreading. Margin of leaf-sheath hyaline

Inflorescence: Spike cylindrical slight tapering towards end; spike with 5-6 fertile spikelets

Rachis brittleness: Spikelet disarticulate as a entire spike.

Glumes: Glumes elliptic oblong, veins unequally wide, apex of lateral glumes ending in two awns (one tooth and one short to long awn) ; glumes of apical spikelet protruding into long awn (8-10cm long) with or with out lateral teeth.

Lemma: Boat shaped, apex with central tooth or small awn with two sharp lateral teeth

Caryopsis: Caryopsis adherent to lemma and palea..

Distribution: Turkey, Iran, Iraq, Syria and adjoining area.

Distinctive characters: Glume with one tooth and one short awn; terminal glume protruding into long awn (8-10 cm) with or without lateral teeth.

Promising traits for utilization: Possess genes for leaf and stem rust and powdery mildew resistance (Gong *et al.*, 2017).



Plate. 3.2.1. Field photograph of *Ae. caudata*



Plate. 3.2.2. Distribution map of *Ae. caudata* (downloaded from iucn.org)



Plate. 3.2.3. Spike of *Ae. caudata* (x2)



A

B

C

Plate. 3.2.4. *Ae. caudata* : A. Lower Spikelet (x4) B. Glume of lower spikelet (x4); C. Lemma of lower spikelet (x4)



A

B

C

Plate. 3.2.5. *Ae. caudata* : A. Apical spikelet (x 4); B. Glume of apical spikelet (x4); C. Lemma of apical spikelet (x4)

3.3. *Aegilops columnaris* Zhuk.

Synonymous : *T. columnare* (Zhuk) Morris and Sears

Ploidy level : $2n=4x=28$ (tetraploid); **Genomic constitution:** UUMM

Habit: Spreading. Leaf-sheath ciliate on margin. Leaf-blades 6-9 cm long; 5-6 mm wide. Leaf-blade surface sparsely hairy on both sides.

Inflorescence: Inflorescence 4-5 cm long bearing 4-5 fertile spikelets. Basal rudimentary sterile spikelet 2-3.

Rachis brittleness: Spikelet disarticulate with own rachis

Spikelet: Lower fertile spikelet are longer than adjacent rachis segment, upper spikelet shorter than the adjacent rachis.

Glumes: Glumes of unequal length with two awns, one of the glumes awn is much broader than other. Apical spikelet glume with three awn.

Lemma: Lemma awned shorter or equal to glume's awn. Lemma awn decreases in length.

Caryopsis: Caryopsis free.

Distribution: Asia-temperate: Caucasus and western Asia (Iran Iraq, Lebanon, Syria, Turkey, Armenia, Azerbaijan, Egypt).

Distinctive characters: One of the base of glume's awn is much broader and have deep cleft than others.

Promising traits for utilization: Possesses valuable traits, such as heat and drought tolerance and resistance to pests (Badaeva *et al.*, 2018).



3.3.1. Distribution map of *Ae. columnaris* (downloaded from iucn.org)



3.3.2. Spike of *Ae. columnaris* (x 2)

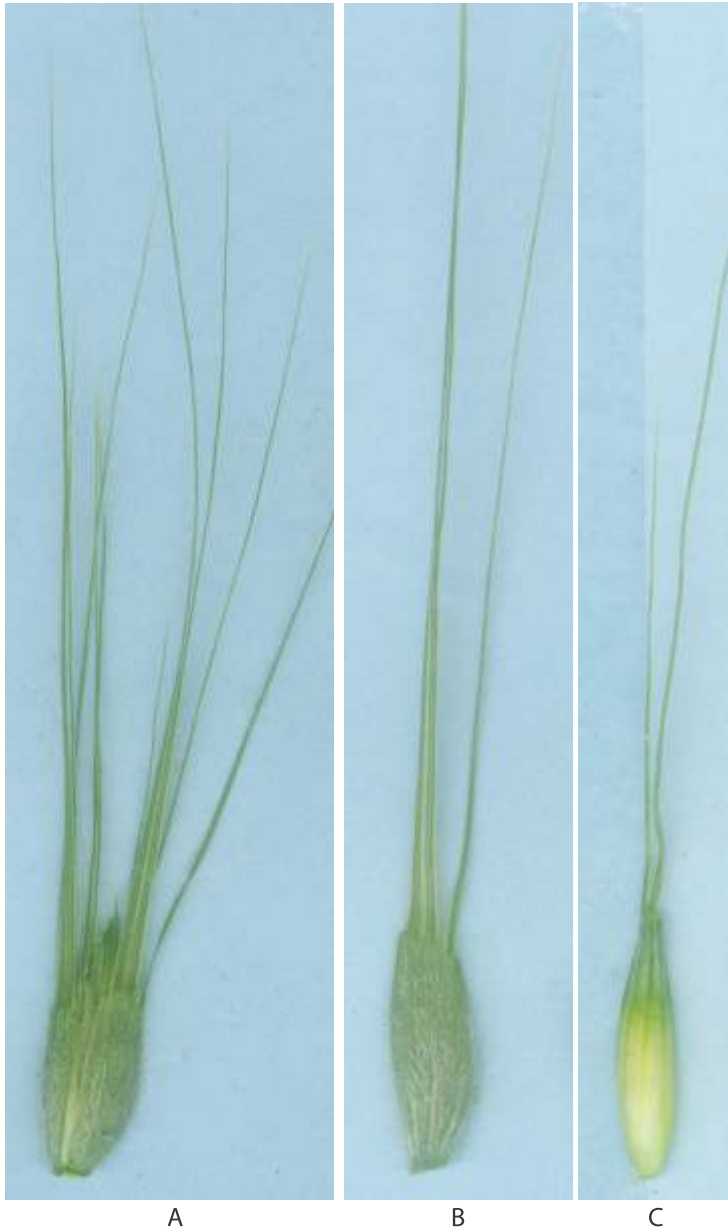


Plate. 3.3.3. *Ae. columnaris* : A. Lower spikelet (x4);
 B. Glume of lower spikelet (x4); C. Lemma of lower spikelet (x4)

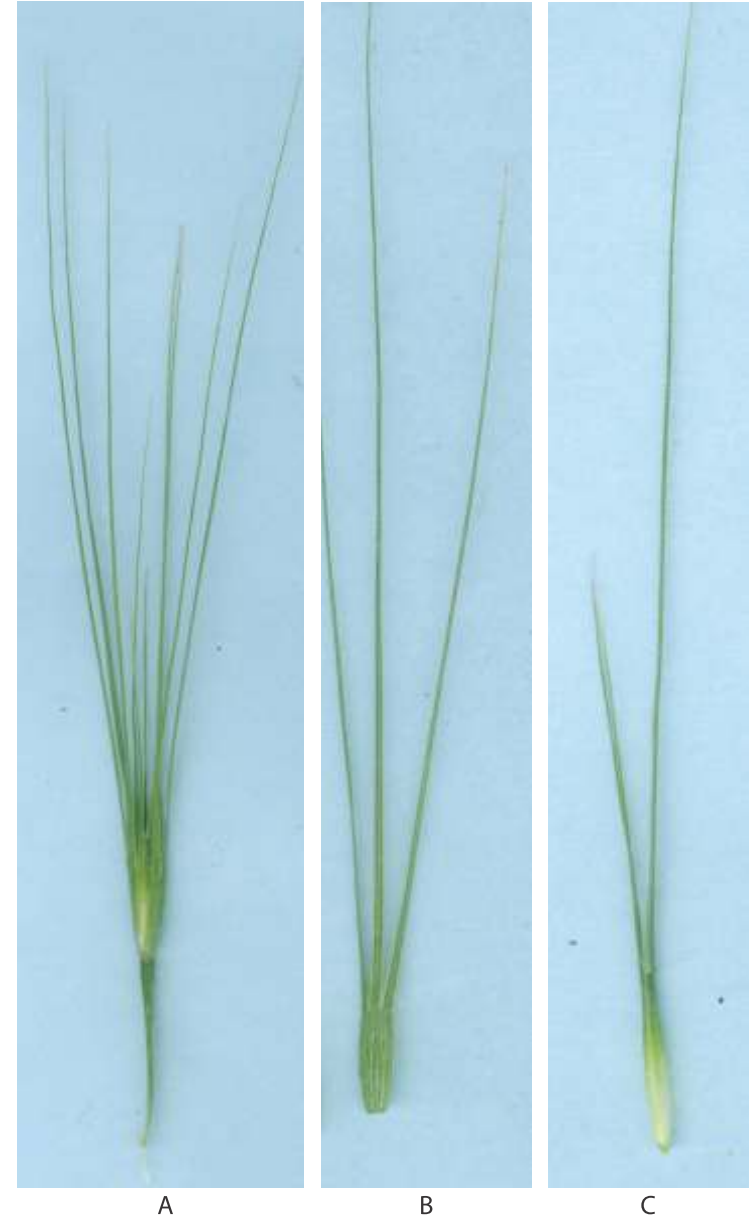


Plate. 3.3.4. *Ae. columnaris* : A. Apical spikelet (x4);
 B. Glume of apical spikelet (x4); C. Lemma of apical spikelet (x4)

3.4. *Aegilops crassa* Boiss.

Synonymous : *Triticum crassum* (Boiss.) Aitch. & Hemsl.

Ploidy level : $2n=4x=28$ (tetraploid); $2n=6x=42$; (Hexaploid) **Genomic constitution:** D^cM (tetraploid); D^cDM (Hexaploid)(Zhang and Dvorak, 1992)

Habit: Spreading. Margin of leaf-sheath: ciliate; leaf blade: 15-20 cm long.

Inflorescence: Spike moniliform; rudimentary spikelet absent; Spike 9-10 cm long with 9-10 cm long.

Rachis brittleness: Spikelet disarticulate with adjacent rachis segment.

Spikelet: Lower fertile spikelet broadly ovate truncate .

Glumes: Apex of lateral spikelet glume with truncate apex ending with sharp tooth; apical spikelet glume with central awn flanked with two lateral teeth.

Lemma: In lower and lateral spikelet lemma with one sharp tooth developing of spike.

Caryopsis: Caryopsis free.

Distribution: Northern Iraq, northern Afghanistan, southern Kazakhstan, western Kyrgyzstan, southern Turkmenistan, Uzbekistan, northern Tajikistan, north and north eastern Syria and Southern Turkey.

Distinctive characters: Spike moniliform; disarticulate with adjacent rachis segment; the lemma awn increasing in length towards the apex of spike.

Promising traits for utilization: Potential agronomic traits, such as seed quality and salinity tolerance were recognized in *Ae. crassa* (Liu *et al.*, 2002; Naghavi *et al.*, 2002).



Plate. 3.4.1. Distribution map of *Ae. crassa* (downloaded from iucn.org)



Plate. 3.4.2. Spike of *Ae. crassa* (x2)

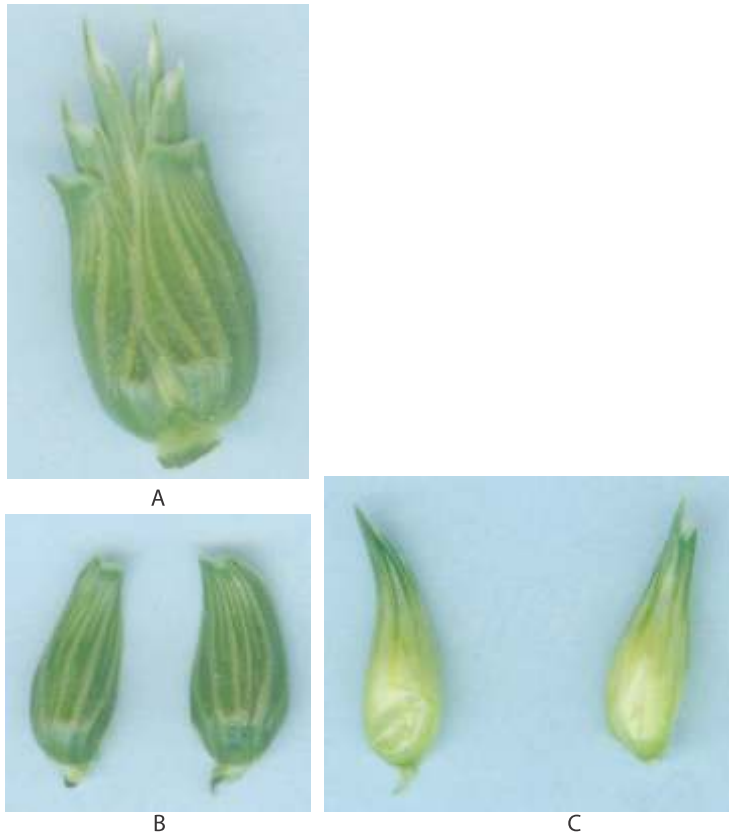


Plate. 3.4.3. *Ae. crassa* : A. Lower spikelet(X4);
B. Glume of lower spikelet (x4); C. Lemma of lower spikelet (x4)

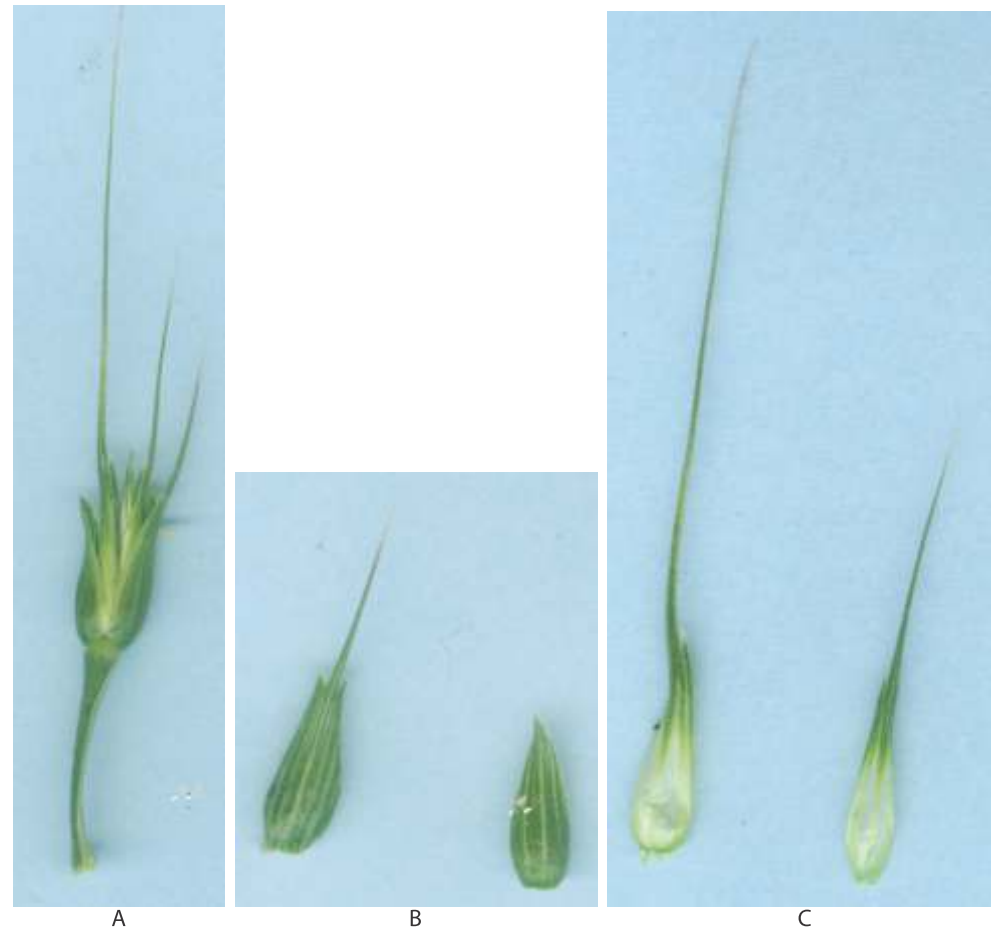


Plate. 3.4.4. *Ae. crassa* : A. Apical spikelet (x4); B. Glume of apical spikelet (x4);
C. Lemma of apical spikelet (x4)

3.5. *Aegilops geniculata* Roth.

Synonymous : *Ae. ovata* Linn.

Ploidy level : $2n=4x=28$ (tetraploid); **Genomic constitution:** MMUU where genome MM is from *Ae. comosa* and UU is from *Ae. umbellulata*

Habit: Initial growth habit spreading and upright at lateral stage. Culms length range 70-80cm. Leaf-sheath hairs on margin. Leaf-blades 8-10 cm long; 8-10 mm wide; surface sparsely hairy on both sides.

Inflorescence: Inflorescence 3.5-4.5 cm long bearing normally 3 fertile spikelet but rarely 4. Basal rudimentary sterile spikelet 1.

Rachis brittleness: Spikelet disarticulate with own rachis. Lower most fertile spikelet rachis length 4-6mm

Spikelet : Lower fertile spikelet comprising 3 fertile florets and 1-2 sterile upper floret. Rachis segment shorter than adjacent spikelet.

Glumes: Glumes with 4 or more awns. Glume highly inflated just below the middle. Upper spikelet glume's awn and lower fertile spikelet glume's awn are of equal length.

Lemma: Number and length of lemma awn equal/similar to glume's awn. Lemma awn decreases in length. Lemma of lower spike have 5-6 veins at upper margin.

Caryopsis : Caryopsis free.

Distribution: Europe: south western, south eastern and eastern. Africa: north and Macaronesia. Asia-temperate: Caucasus and western Asia.

Distinctive characters: 3-4 spikelets, glume inflated just below the middle, glume with 4 or more awns.

Promising traits for utilization: Tolerant to high temperature stress (Pradhan *et al.*, 2012).



Plate. 3.5.1. Field photograph of *Ae. geniculata*



Plate. 3.5.2. Distribution map of *Ae. geniculata* (downloaded from iucn.org)



Plate. 3.5.3. Spike of *Ae. geniculata* (x2)



A



B



C

Plate. 3.5.4. *Ae. geniculata* : A. Lower spikelet (x4);
B. Glume of lower spikelet (x4) C. Lemma of lower spikelet (x4)



A



B



C

Plate. 3.5.5. *Ae. geniculata* : A. Apical spikelet (x4); B. Glume of apical spikelet (x4);
C. Lemma of apical spikelet (x4)

3.6. *Aegilops juvenalis* (Thell.) Eig.

Synonymous : *Ae. turcomanica* Roshev; *Triticum juvenile* Thell.

Ploidy level : $2n=6x=42$ (hexaploid); **Genomic constitution:** DDMMUU where genome DDMM is from *Ae. crassa* and UU genome is from *Ae. triuncialis* or *Ae. umbellulata*.

Habit: Spreading. Leaf-blade glabrous, Leaf-blades 7-8 cm cm long; 5-6 mm wide.

Inflorescence: Spike cylindrical, tapering towards apex, inflorescence 4-5 cm long bearing 4-5 spikelets. Basal rudimentary sterile spikelet 1-2.

Rachis brittleness: Spikelet disarticulate with adjacent rachis segment.

Spikelet: Weekly inflated somewhat elliptical, spikelet arranged in somewhat moniliform manner.

Glumes: Upper parts of the glume is overlapped, glume covered with silky small hairs, lateral glume with 2-3 flat awns, glume ovate in shape slightly inflated below middle.

Lemma: Lemma awn well developed and exceeding the glume's, terminal spikelet has well developed central awn flanked by 2 teeth or shorter awns.

Caryopsis: Adhere to lemma palea

Distribution: Asia-temperate: Iran, Iraq, Syria, Turkmenistan, Uzbekistan, Azerbaijan.

Distinctive characters: Spike cylindrical glume covered with silver hairs, well developed awns in glume and lemma. Apex of lateral glumes truncate.

Promising traits for utilization: Potential source for low-molecular-weight glutenin subunit gene (Li *et al.*, 2008).



Plate. 3.6.1. Distribution map of *Ae. juvenalis* (downloaded from iucn.org)



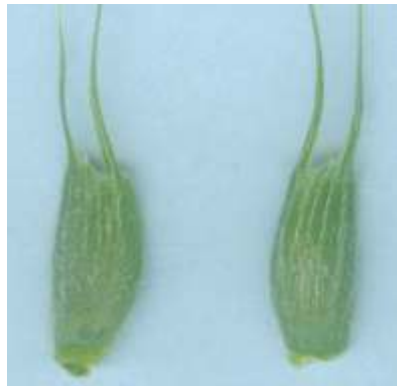
Plate. 3.6.2. Spike of *Ae. juvenalis* (x2)



A



B



C

Plate. 3.6.3. *Ae. juvenalis* : A. Lower spikelet (x4);
B. Glume of lower spikelet (x4); C. Lemma of lower spikelet (x4)



A



B



C

Plate. 3.6.4. *Ae. juvenalis* : A. Apical spikelet (x4); B. Glume of apical spikelet (x4);
C. Lemma of apical spikelet (x4)

3.7. *Aegilops kotschy* Boiss.

Ploidy level : $2n=4x=28$ (tetraploid); **Genomic constitution:** UUSS where genome UU genome is from *Ae. umbellulata* and SS genome is from *Ae. longissima* or *Ae. sharonensis*.

Habit: Semi-Spreading growth habit. Leaf-blade glabrous, leaf-blades 8-9 cm long; 5-6 mm wide. Leaves ciliated on the margin

Inflorescence: Spike 5-7 cm long, tapering, lanceolate, bearing 4-6 spikelets. Basal rudimentary sterile spikelet 1-2 in number.

Rachis brittleness: Entire spikelet disarticulate with own rachis segment.

Spikelet: Lower spikelets appressed tightly each other.

Glumes: Glumes similar; shorter than spikelet. Lower glume oblong, or ovate; lower glume apex dentate; 3 -awned or 2 awns and central awn replace with tooth. Awn of upper and lateral glume of same length.

Lemma: Lemma awn well developed slightly shorter than glume awn.

Caryopsis: Adhere to lemma palea.

Distribution: Ukraine, Uzbekistan, Turkmanistan, Afghanistan, Iran, Iraq, Kuwait, Saudi Arabia, Turkey, Syria, Lebanon, Cyprus, Israel, Jordan, Egypt, Libiya, Tunisia.

Distinctive characters: Glumes usually three equal sized awns which are equal to length to lemma awns.

Promising traits for utilization: Donor for nutritional quality especially protein, zinc and iron and abiotic stresses like drought, heat and salt tolerance (Chhuneja *et al.*, 2006; Prazak and Paczos-Grzeda, 2013).



Plate. 3.7.1. Field photograph of *Ae. kotschy*



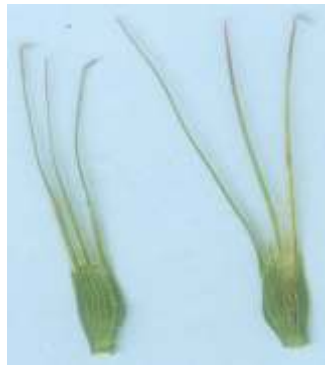
Plate. 3.7.2. Distribution map of *Ae. kotschyi* (downloaded from iucn.org)



Plate. 3.7.3. Spike of *Ae. kotschyi* (x2)



A



B



C

Plate. 3.7.4. *Ae. kotschyi* : A. Lower spikelet (x4);
B. Glume of lower spikelet (x4);
C. Lemma of lower spikelet (x4)



A



B



C

Plate. 3.7.5. *Ae. kotschyi* : A. Apical spikelet (x4); B. Glume of apical spikelet (x4);
C. Lemma of apical spikelet (x4)

3.8. *Aegilops longissima* Schweing & Muschl.

Ploidy level : $2n=2x=14$ (Diploid); **Genomic constitution:** SS closely related to B genome of wheat.

Habit: Intermediate growth habit turning upright at later stage. Plant length 120-130cm. Peduncle well exerted; leaf-blade 10-15-cm long, 5-6 mm wide.

Inflorescence: Spike narrow linear, 10-15 cm long , bearing 5-17 spikelets. Rachis is longer than glume.

Rachis brittleness: Spikelet at upper part of spike disarticulate along with adjacent rachis segment.

Spikelet: Length of spikelet equal to adjacent rachis. Lower spikelet awnless, upper spikelet extending in to 10-13 cm long awns. Spikelet appressed to rachis segment.

Glumes: Glumes 2/3 of spikelet similar; glume two teeth, shorter than spikelet. Lower glume oblong, or ovate; lower glume apex dentate; 3 –awned or 2 awns and central awn replace with tooth. Awn of upper and lateral glume of same length.

Lemma: Lemma of lateral spikelets not awned, while terminal spikelet with a long broad awn..

Caryopsis: Adhere to lemma palea.

Distribution: Egypt, Israel, Jordan, Lebanon, Syria, Iran

Distinctive characters: Spike narrow linear, glume two teeth, terminal spikelet with long awn.

Promising traits for utilization: Source for resistance to yellow, brown and black rust (Huang *et al.*, 2018); and dominant powdery mildew gene *Pm13* is has been successfully transferred in wheat (Cenci *et al.*, 1999).



Plate. 3.8.1. Field photograph of *Ae. longissima*



Plate. 3.8.2. Distribution map of *Ae. longissima* (downloaded from iucn.org)



Plate. 3.8.3. Spike of *Ae. longissima*



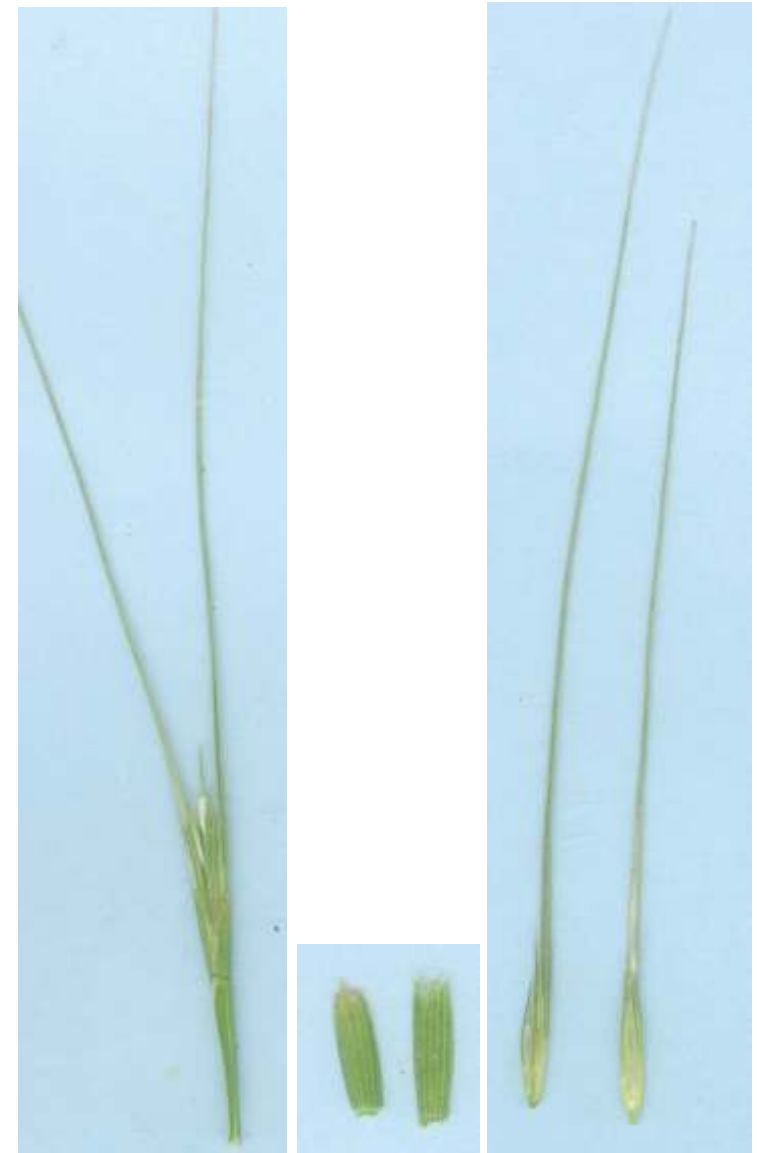
A

B



C

Plate. 3.8.4. *Ae. longissima* : A. Lower spikelet (x4);
B. Glume of lower spikelet (x4); C. Lemma of lower spikelet (x4)



A

B

C

Plate. 3.8.5. *Ae. longissima* : A. Apical spikelet (x4);
B. Glume of apical spikelet (x4); C. Lemma of apical spikelet (x4)

3.9. *Aegilops neglecta* Req. ex Bertol.

Synonymous: *Ae. triaristata* Willd.; *T. neglectum* (Req. ex Bertol.) Greuter

Ploidy level: $2n=4x=28$ (tetraploid); **Genomic constitution:** UUMM

Habit: Intermediate growth habit, decumbent, peduncle well exerted. Leaf-blades 7-8 cm long, 4-5 mm wide, leaves pubescent with ciliated margin.

Inflorescence: Spike lanceolate, 4-5 cm long, bearing 5-6 spikelets. Spike abruptly narrow in the upper part.

Rachis brittleness: Entire spikelet disarticulate at maturity.

Spikelet: Lower two spikelets are large and big and lying appressed to each other. Upper two spikelets are sterile.

Glumes: Glumes curved not inflated, glume pubescent with small hairs in lower spikelet glume awns usually 3 or 3-2. Upper spikelet have 3 awns in a glume.

Lemma: Usually 2 awns in lower spikelets and weakly developed or without awns in upper spike. Lemma equal in length to glume in lateral spikelet.

Caryopsis: Free threshability.

Distribution: France, Italy, Spain, Portugal, Bulgaria, Albania, Turkey, Irak, Iran, Syria, Lebanon, Libya.

Distinctive characters: Glume with 3 awns of equal width or one glume with 3 awns or other with 2 awns unequally broad.

Promising traits for utilization: Source of rust resistance gene *Lr62* (leaf rust) and *Yr42* (stripe rust) as reported by Marais *et al.*, 2009.



Plate. 3.9.1. Field photograph of *Ae. neglecta*



Plate. 3.9.2. Distribution map of *Ae. neglecta* (downloaded from iucn.org)

Plate. 3.9.3. Spike of *Ae. neglecta* (x2)

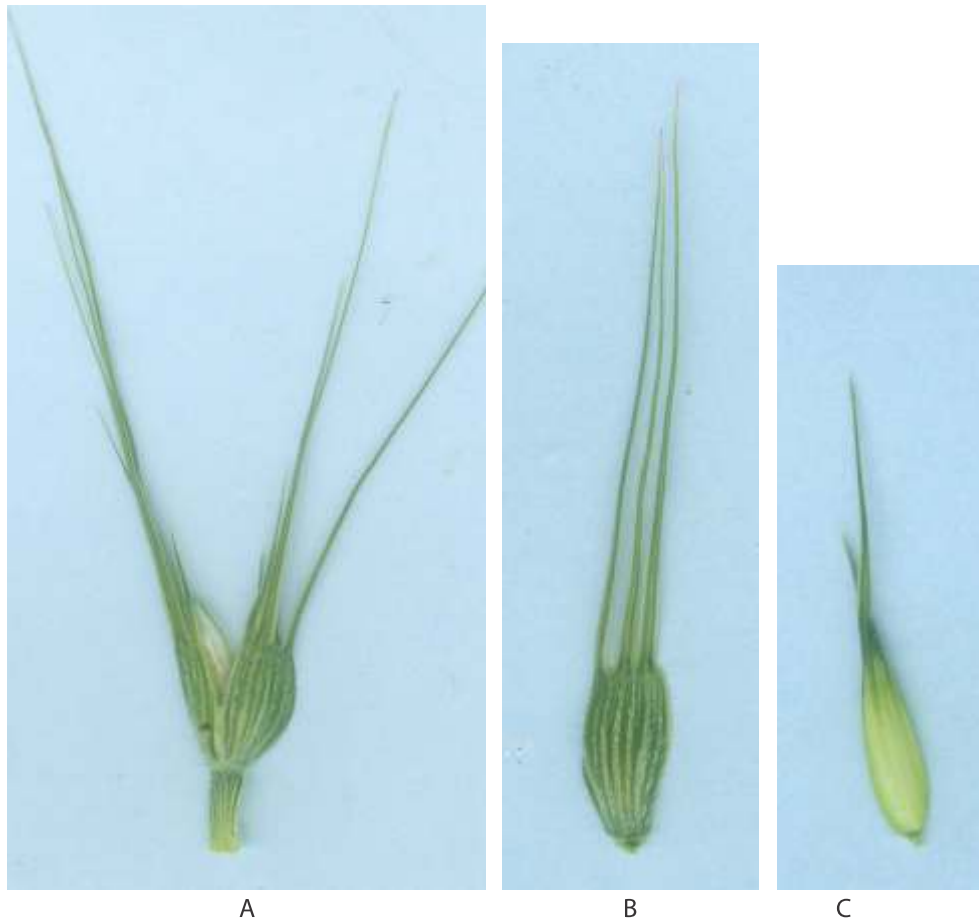


Plate. 3.9.4. *Ae. neglecta* : A. Lower spikelet (x4);
 B. Glume of lower spikelet (x4); C. Lemma of lower spikelet (x4)



Plate. 3.9.5. *Ae. neglecta* : A. Apical spikelet (x4);
 B. Glume of apical spikelet (x4); C. Lemma of apical spikelet (x4)

3.10. *Aegilops peregrina* (Hack.) Maire & Weiller

Synonymous: *Aegilops variabilis* Eig; *Triticum peregrinum* Hack. in J. Fraser

Ploidy level: $2n=4x=28$ (tetraploid); **Genomic constitution:** SSUU

Habit: Intermediate growth habit, leaves sparsely ciliated at margin.

Inflorescence: Spike ovate, 4-7 cm long, bearing 5-6 spikelets. Lower spikelets are not appressed to each other. Each spikelet contains 3-5 florets. Upper floret sterile.

Rachis brittleness: Spikelets disarticulate at maturity with own rachis.

Spikelet: Each spikelet contains 3-5 florets. Upper floret sterile.

Glumes: Glumes with 3 awns, or 2 awns centre on each replaced by tooth. Central awn variable.

Lemma: Lemma awn poorly developed.

Caryopsis: Adhere to lemma palea.

Distribution: Italy, Greece, Cyprus, Turkey, Israel, Jordan, Lebanon, Syria, Iran, Iraq, Afghanistan, Saudi Arabia, Egypt, Libya, Morocco.

Distinctive characters: Glume awns are unequal in length and width. Lemma awn poorly developed.

Promising traits for utilization: Source of resistance to leaf and stripe rust (Narang *et al.*, 2018) and root rot nematode (Yu *et al.*, 1990).



Plate. 3.10.1. Field photograph of *Ae. peregrina*



Plate. 3.10.2. Distribution map of *Ae. peregrina* (downloaded from iucn.org)



Plate. 3.10.3. Spike of *Ae. peregrina* (x2)

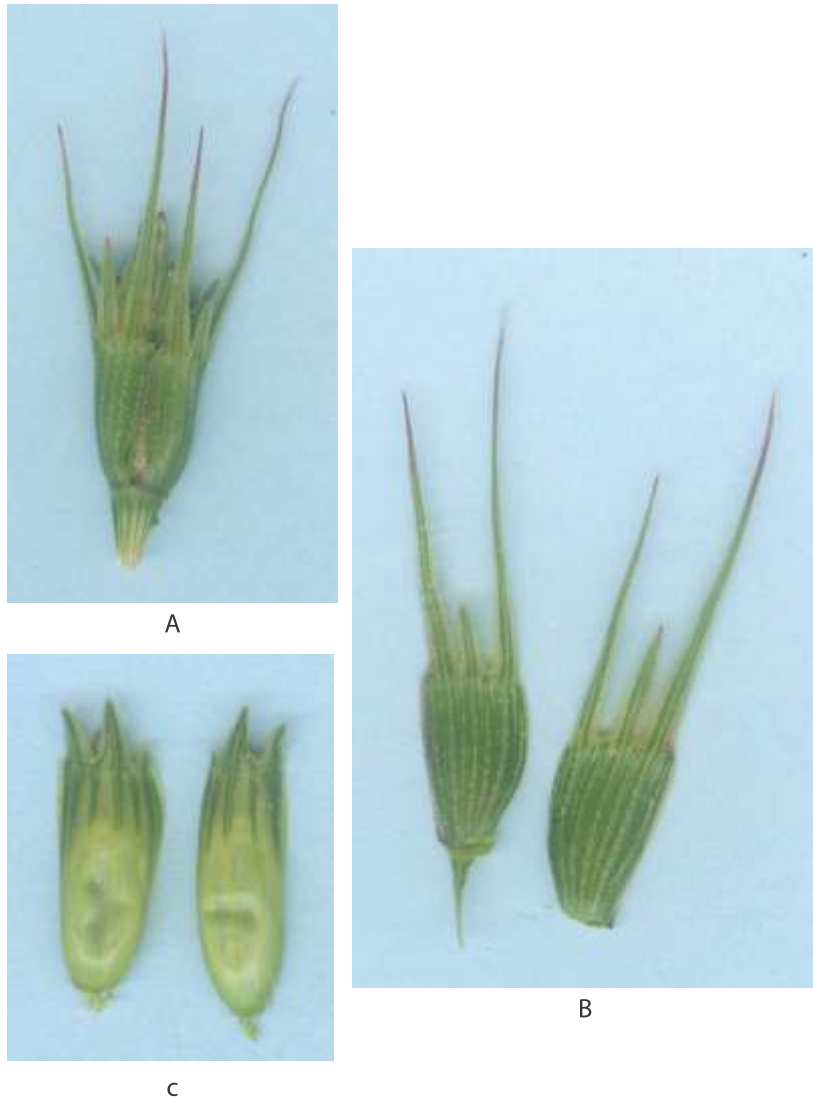


Plate. 3.10.4. *Ae. peregrina* : A. Lower spikelet (x4);
B. Glume of lower spikelet (x4); C. Lemma of lower spikelet (x4)

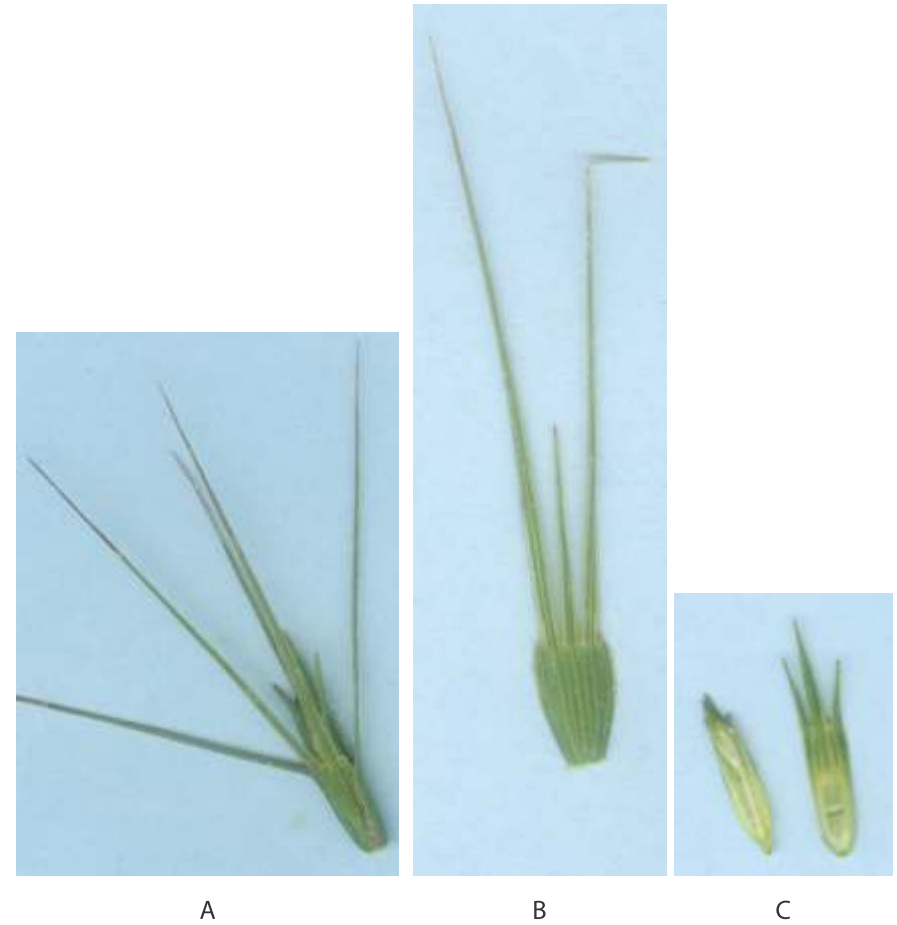


Plate. 3.10.5. *Ae. peregrina* : A. Apical spikelet (x4);
B. Glume of apical spikelet (x4); C. Lemma of apical spikelet (x4)

3.11. *Aegilops speltoides* Tausch .

Synonymous: *Triticum speltoides* (Tausch) Gren. ex K. Richt.

Ploidy level : $2n=2x=14$ (Diploid); **Genomic constitution:** SS

Habit: Initial growth habit intermediate, thin culm, leaf length 10-15 cm, leaf width 4-6 mm.

Inflorescence: Spike linear, tapering to the tip, 12-18 cm long, bearing 14-16 spikelets.

Rachis brittleness: Entire spikelet disarticulate at maturity alongwith with own rachis.

Spikelet: Lanceolate, spikelet usually longer in length to the adjacent rachis segment.

Glumes: Glumes truncate, about 2/3 as long as the lemma, glumes unawned truncate with short tooth awn on upper margin.

Lemma: Lemma not awned in lower spikelet but long awn in the uppermost spikelet.

Caryopsis: Adhere to lemma palea.

Distribution: Turkey, Syria, Iraq, Iran, Israel, Jordan, Lebanon.

Distinctive characters: Spike linear, glume truncate. Lemma awned only on apical spikelet.

Promising traits for utilization: Good resistance against leaf rust (*Niranjana et al.*, 2017) and drought (*Djanaguiraman et al.*, 2019).



Plate. 3.11.1. Field photograph of *Ae. speltoides*



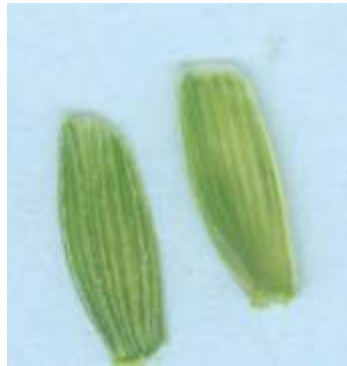
Plate. 3.11.2. Distribution map of *Ae. speltoides* (downloaded from iucn.org)



Plate. 3.11.3. Spike of *Ae. speltoides*



A



B

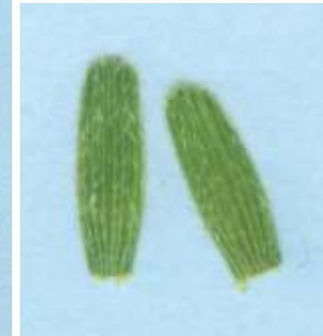


C

Plate. 3.11.4. *Ae. speltoides* : A. Lower spikelet (x4);
B. Glume of lower spikelet (x4); C. Lemma of lower spikelet (x4)



A



B



C

Plate. 3.11.5. *Ae. speltoides* : A. Apical spikelet (x4);
B. Glume of apical spikelet (x4); C. Lemma of apical spikelet (x4)

3.12. *Aegilops tauschii* Coss.

Synonymous: *Ae. squarrosa* L.; *T. tauschii* (Coss.) Schmalh

Ploidy level: $2n=2x=14$ (Diploid); **Genomic constitution:** DD

Habit: Initial growth habit spreading, thin culm, leaf length 9-12 cm, leaf width 6-9 mm.

Inflorescence: Spike cylindrical, tapering to the tip, 8-11 cm long, bearing 8-15 spikelets.

Rachis brittleness: Entire spikelet disarticulate at maturity along with adjacent rachis.

Spikelet: Barrel shaped arranged in one row, spikelets usually equal in length to the adjacent rachis segment.

Glumes: Glumes rectangular with equally spaced nerves, glumes unawned truncate with short tooth awn on upper margin.

Lemma: Lower lemma with small awns 1-2 cm, lemma of apical spikelet with long awn (3-6 cm).

Caryopsis: Adhere to lemma palea.

Distribution: Turkey, Syria, France, Iran, USSR, Afghanistan, India (Kashmir), China (western slopes of Himalayas).

Distinctive characters: Spikelet cylindrical, glume truncate. Lemma awn on apical spikelet is longer than lateral awns.

Promising traits for utilization: Synthetic lines derived from *tauschii* showed resistance against abiotic stresses (Dreccer et al., 2007) and also promising source for high Fe and Zn (Chhuneja et al., 2006).



Plate. 3.12.1. Field photograph of *Ae. tauschii*



A



B



C

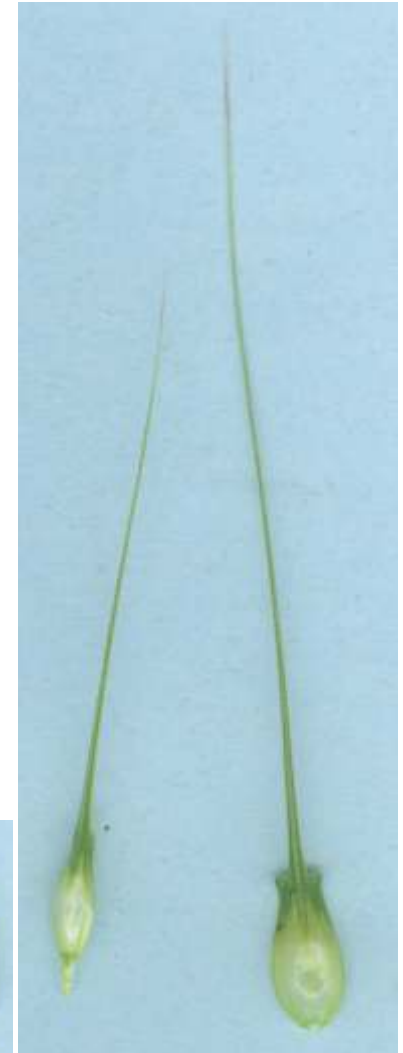
Plate. 3.12.4. *Ae. tauschii* : A. Lower spikelet (x4); B. Glume of lower spikelet (x4); C. Lemma of lower spikelet (x4)



A



B



C

Plate. 3.12.5. *Ae. tauschii* : A. Apical spikelet (x4); B. Glume of apical spikelet (x4); C. Lemma of apical spikelet (x4)

3.13. *Aegilops triuncialis* L.

Synonymous : *Triticum triunciale* (L.) Rasp. (var. *triunciale*) (*T. triunciale* ssp. *persicum*)

Ploidy level : $2n=4x=28$ (Diploid); **Genomic constitution:** CCUU

Habit: Intermediate growth habit, plant height 100-105 cm, leaf length 8-11 cm, leaf width 6-7 mm, well exerted peduncle.

Inflorescence: Spike narrow lanceolate 6-7 cm long bearing 4-6 spikelets.

Rachis brittleness: Spikelets disarticulate at maturity along with own rachis.

Spikelet: Spikelet decreasing in size upwards.

Glumes: 5-8 nerves of unequal size covered with short silver hairs, the apical spikelet with 3 flat awns, central awn is usually the longest and widest.

Lemma: Lemma usually 5 veined, lemma apex dentate, 2 fid. lemma awn weak or not developed.

Caryopsis: Free threshability.

Distribution: Portugal, Spain, France, Italy, Yugoslavia, Greece, Bulgaria, Cyprus, Turkey, Israel, Lebanon, Syria, Iraq, Kuwait, Saudi Arabia, Iran, USSR, Afganistan.

Distinctive characters: Apical spikelet with 3 flat awns, central awn is usually the longest and widest.

Promising traits for utilization: Resistant to leaf rust (Aghaee-Sarbarzeh *et al.*, 2002) and tolerance to drought (Baalbaki *et al.*, 2006).



Plate. 3.13.1. Distribution map of *Ae. triuncialis* (downloaded from iucn.org)



Plate. 3.13.2. Spike of *Ae. triuncialis* (x2)

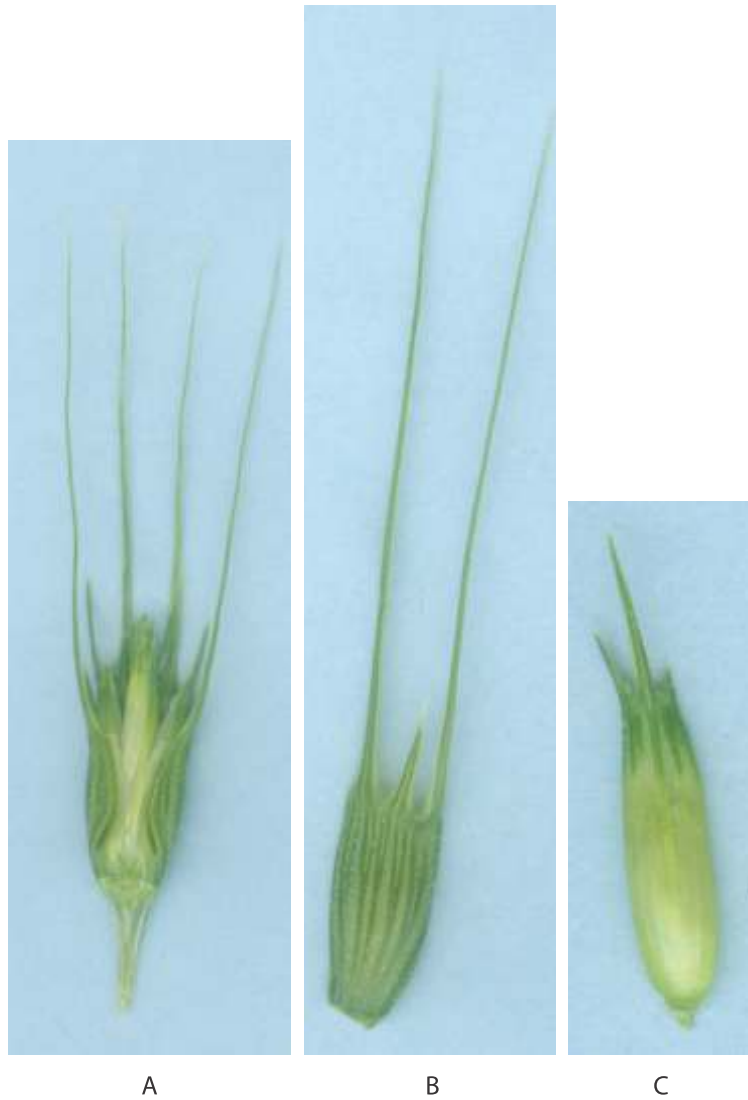


Plate. 3.13.3. *Ae. triuncialis* : A. Lower spikelet (x4);
B. Glume of lower spikelet (x4); C. Lemma of lower spikelet (x4)



Plate. 3.13.4. *Ae. triuncialis* : A. Apical spikelet (x4);
B. Glume of apical spikelet (x4); C. Lemma of apical spikelet (x4)

3.14. *Aegilops umbellulata* Zhuk.

Synonyms: *Triticum umbellulatum* (Zhuk.) Bowden

Ploidy level: $2n=2x=14$ (Diploid); **Genomic constitution:** UU

Habit: Growth habit spreading, plant bushy in appearance, leaf length 7-10 cm, leaf width 6-8 mm, leaf margin ciliated.

Inflorescence: Spike 4-5 cm long, lanceolate or ovate in shape bearing 3-4 spikelets.

Rachis brittleness: Spikelets disarticulate at maturity along with own rachis.

Spikelet: Rachis of fertile spikelet is 1-3 mm long, rachis segment of upper spikelet is longer than adjacent spikelet.

Glumes: Lateral veins of lower glume is unequally thick while, veins on upper glume are parallel. Glume with 4-5 awns, upper glume awns are longer than lateral glume. Lateral glume inflated from the mid of glume.

Lemma: Lemma awn well developed, similar to glume awn in shape and usually shorter in length, lemma awn 2-3 in number.

Caryopsis: Free threshability.

Distribution: Greece, Turkey, Syria, Iraq, Iran, USSR.

Distinctive characters: Rachis segment of upper spikelet is longer than adjacent spikelet. Glumes of lower spikelet have more than 3 awns.

Promising traits for utilization: Source for rust resistance genes *Lr76* and *Yr70* (Bansal *et al.* (2017).



Plate. 3.14.1. Field photograph of *Ae. umbellulata*



Plate. 3.14.2. Distribution map of *Ae. umbellulata* (downloaded from iucn.org)



Plate. 3.14.3. Spike of *Ae. umbellulata* (x2)

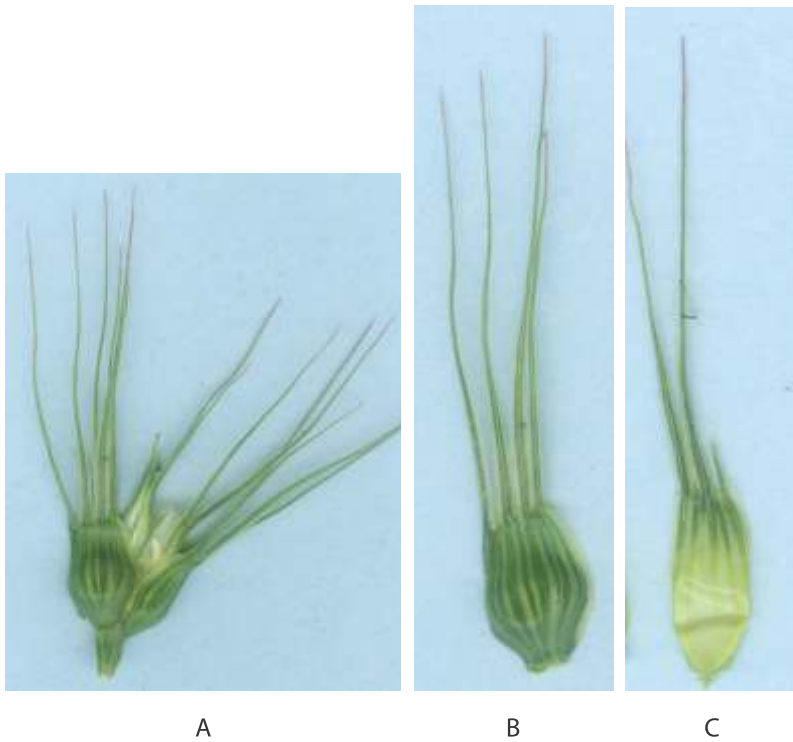


Plate. 3.14.4. *Ae. umbellulata* : A. Lower spikelet (x4);
B. Glume of lower spikelet (x4); C. Lemma of lower spikelet (x4)

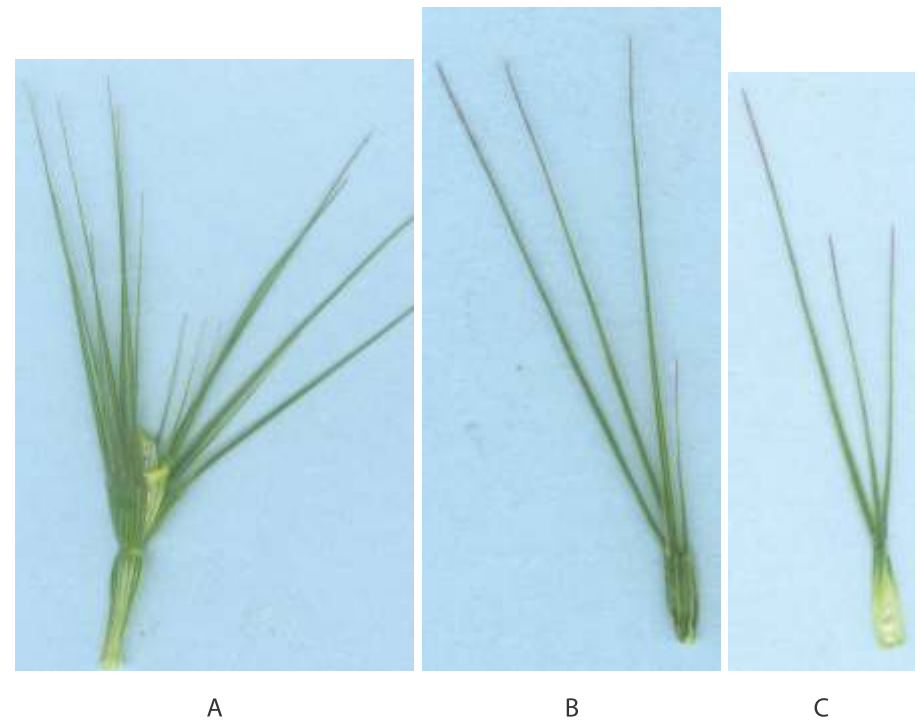


Plate. 3.14.5. *Ae. umbellulata* : A. Apical spikelet (x4);
B. Glume of apical spikelet (x4); C. Lemma of apical spikelet (x4)

3.15. *Aegilops ventricosa* Tausch.

Synonyms: *Triticum ventricosum* (Tausch) Ces. Pass. & Gibelli

Ploidy level: $2n=4x=28$ (Tetraploid); **Genomic constitution:** DDNN

Habit: Growth habit spreading, leaf length 10-12 cm, leaf width 8-9 mm & glabrous.

Inflorescence: Spike moniliform with 8-12 spikelets.

Rachis brittleness: Rachis brittleness along with adjacent rachis.

Spikelet: Spikelet barrel or oval shaped.

Glumes: Lower part inflated with two broad teeth separated by broad sinus. Terminal glume three teeth or awns.

Lemma: Lemma awn stronger than glume. Terminal lemma has longer awn.

Caryopsis: Adhere to lemma palea.

Distribution: Spain, France, Italy, Morocco, Algeria, Libya.

Distinctive characters: Spike moniliform, glume two broad teeth separated by broad sinus.

Promising traits for utilization: Source of cereal cyst nematodes resistance gene *Cre2* and *Cre6* (Delibes *et al.*, 1993) and chromosome 6NV genomic region carrying rust resistance genes *Yr17*, *Lr17*, *Sr38* and *Cre5* (Tanguy *et al.*, 2005).



Plate. 3.15.1. Field photograph of *Ae. ventricosa*



Plate. 3.15.2. Distribution map of *Ae. ventricosa* (downloaded from iucn.org)



Plate. 3.15.3. Spike of *Ae. ventricosa* (x2)



Plate. 3.15.4. *Ae. ventricosa* : A. Lower spikelet (x4);
B. Glume of lower spikelet (x4); C. Lemma of lower spikelet (x4)

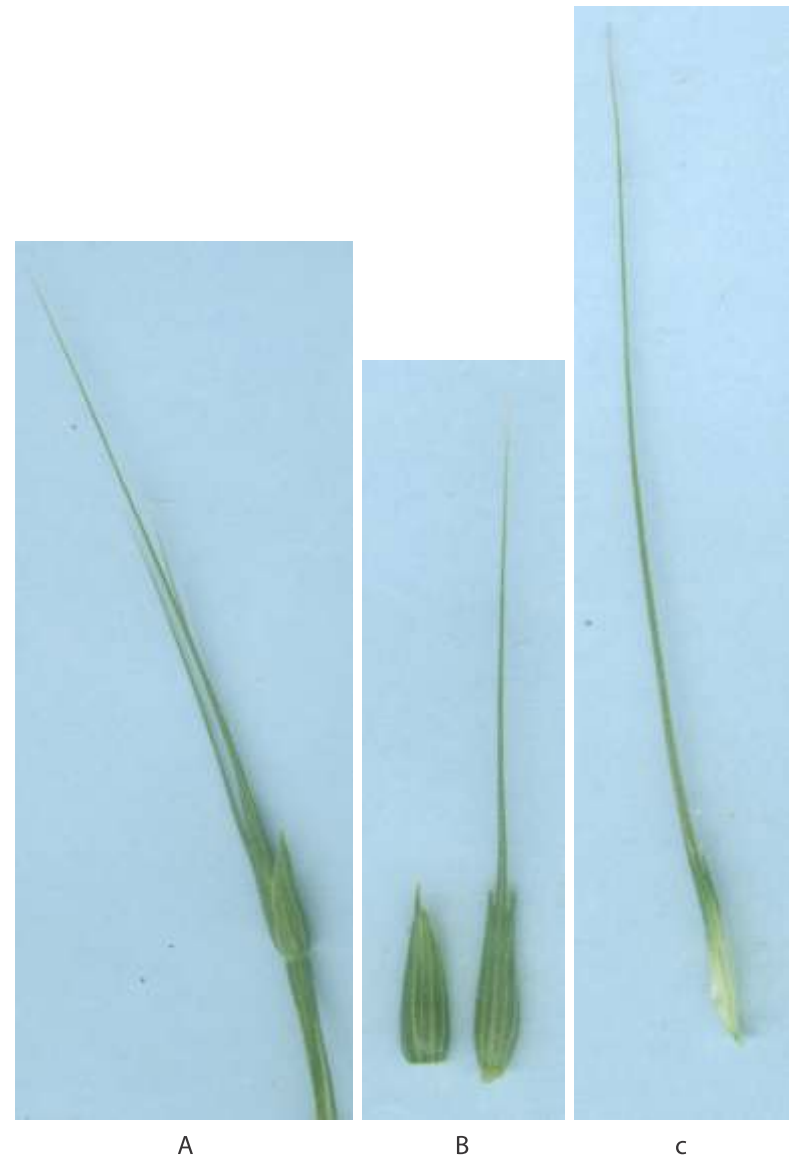


Plate. 3.15.5. *Ae. ventricosa* : A. Apical spikelet (x4);
B. Glume of apical spikelet (x4); C. Lemma of apical spikelet (x4)

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