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Research Article

Evaluation of Diagnostic Reproductive and Vegetative Characters among Tetraploid *Triticum* L. Species (*Poaceae; Triticeae*) in Iran

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Abstract: This study concerns the evaluation of 19 vegetative and reproductive characters (7 qualitative and 12 quantitative) among 45 accessions belonging to wild and cultivated tetraploid *Triticum* L. species: *T. turgidum* L., *T. durum* Desf., *T. dicoccum* (Schrank) Schrebler and *T. dicoccoides* (Koern. ex Aschers. et Graebn.) Aaronsohn, occurring in Iran. The results of this study show that *T. turgidum* is a distinct species from *T. durum*, and *T. dicoccum* showed high similarity to *T. dicoccoides.* The strong relationship between the latter pair of species may result from a high degree of gene flow between them. The diagnostic characters between *T. turgidum* and the other 3 species are the number of awns in the uppermost spikelet, form of the keel of the glume, leaf indumentum, spike shape, lodicule form and quality of the endosperm.

Key Words: Tetraploid wheat, *Triticum*, Iran

Introduction

There have been always debates surrounding the taxonomy of the genus *Triticum* L. among wheat researchers. Allopolyploid origin, along with natural and artificial hybridisation, has obscured the morphological limits of the species and caused taxonomic confusions in the genus *Triticum*; in particular the issue seems to be more complicated in the *Triticum-Aegilops* group. The taxonomic confusions, lectotypification problems, and nomenclature debates encountered in the genus and the group have been well illustrated and discussed by Morrison (1993 a, 1993 b, 1998). Accordingly, the taxonomic status of the tetraploid *Triticum* species has been the matter of debates and disagreement among *Triticum* researchers for a long time. Table 1 summarises the historical taxonomic background of the matter. Different taxonomic treatments on the genus are not in agreement with each other.

The taxonomic status of the genus *Triticum* in Iran, particularly considering the situation of the tetraploid taxa, has been treated in different ways. Boissier (1885), who was the first to study the genus in Iran, recognised 3 *Triticum* species for this country, none of which are tetraploid. Rozhevitz & Shishkin (1933) in Flora of the USSR, reported *T. dicoccoides* (Koern. ex Aschers. et Graebn.) Aaronsohn (wild emmer) for Iran; that is a tetraploid. In his Flore de l'Iran, Parsa (1954) described 10 *Triticum* species for this country of which 6 are tetraploids: *T. dicoccum* (Schrank) Schrebler (cultivated emmer), *T. dicoccoides*, *T. durum* Desf., *T. orientale*, *T. polonicum* L. and *T. turgidum* L. (cultivated emmer). In his account on the genus, Bor (1970) reported 11 *Triticum* species including 6 tetraploid ones occurring in Iran: *T. dicoccum*, *T. dicoccoides*, *T. turgidum*, *T. durum*, *T. polonicum* and *T. carthlicum* Nevski.

Regarding misidentifications, incomplete collections, poorly constructed keys particularly in local Flora and nomenclature problems, the necessity for more hard work and serious taxonomic and biosystematics investigations on the genus *Triticum* seems to be very urgent and of high importance in Iran, part of the fertile crescent (Morrison, 1998; Morrison & Raupp, 1999).

The aims of this study were: (1) to collect as completely as possible the germplasm of the tetraploid wheat landraces and wild populations, (2) to clarify the taxonomic status of tetraploid *Triticum* spp. in Iran, using

Table 1. The classifications of the tetraploid *Triticum* species, based on the morphological and genomical data.

Refrences (based on morphological data)	Section	Species
Nevski (1934)	*Orthatherum*	*T. dicoccoides, T. turgidum, T. durum*
Mackey (1966)	*Dicoccoides*	*T. turgidum, T. dicoccum, T. dicoccoides*
Bor (1970)	*Dicoccoides*	*T. durum, T. turgidum*
Based on genomical data	Tetraploid groups 2n= 4x= 28 (AABB)	Species
Flaksberger (1935)		*T. turgidum, T. durum, T. dicoccum, T. dicoccoides*
Mackey (1988)		*T. turgidum, T. turgidum* subsp. *durum, dicoccum, dicoccoides*
Dorofeev et al. (1979)		*T. turgidum, T. durum, T. dicoccum, T. dicoccoides*
Waines & Barnhart (1992)		*T. turgidum, T. durum, T. dicoccum T. dicoccoides, T. carthlicum*
Slageren (1994)		*T. turgidum, T. turgidum* subsp. *durum, dicoccum, dicoccoides*

the most available and discriminating morphological characters and (3) to construct a taxonomic key for tetraploid *Triticum* species in Iran.

Materials and Methods

Nineteen morphological characters (7 qualitative and 12 quantitative) (Table 2) were evaluated in 10-30 individuals from each accession (45 accessions and 451 individuals) (Figure 1). In order to provide enough plant materials for the morphological and taxonomic studies, all the accessions were grown in the research field of Isfahan University in October 1998, 2000 and 2002. Voucher specimens from each population are deposited in the herbarium of Isfahan University. In addition, all the specimens in the herbaria TARI (Research Institute of Forests and Rangeland, Tehran), IRAN (Plant Pest and Diseases Research Institute of Evin) and TUH (Tehran University) were studied (abbreviations from Holmgren et al., 1990). Morphological terms are based on those given by Stearn (1992).

Results

The results showed that the tetraploid *Triticum* genome in Iran belongs to 3 cultivated species, *T. turgidum*, *T. durum* and *T. dicoccum*, and 1 wild species, *T. dicoccoides* (Figure 1).

The measurements of the quantitative and qualitative characters among the studied species are shown in Table 2. Based on these results, the overall similarity between *T. dicoccum* and *T. dicoccoides* is notably high. In addition, they are similar in the number of awns of the uppermost spikelet, the number of seeds in each spikelet, length and width of caryopsis, length of glume, keel of glume, form of spike, endosperm and indumentum of leaf (Table 2, Figures 2 & 3). *T. turgidum* differs from the other species based on the general spike morphology (Table 2), length of spike, length of spikelet, length of awn, glume and lemma, number of awns in the uppermost spikelet, number of seeds in the spikelet, form of the keel of the glume, form of spike and quality of endosperm. Based on the length of spikelet, length and width of glume, number of awns in the uppermost spikelet, margin of rachis (ciliate or not ciliate), form of the keel of the glume, indumentum of leaf, form of lodicule and quality of endosperm, *T. durum* was similar to *T. dicoccum* (Table 2).

Discussion

Based on the results of this study we recognised 4 tetraploid *Triticum* species (see Results) occurring in Iran. Neither *T. polonicum* nor *T. carthlicum*, which had been mentioned by Bor (1970) as 2 cultivated wheats for the flora of Iran, were recognised among the materials

Table 2. Morphological, reproductive and vegetative characters studied among cultivated and wild tetraploid *Triticum* spp. in Iran.

Species Characters	*T. turgidum*	*T. durum*	*T. dicoccum*	*T. dicoccoides*
Length of spike (cm)	9- 23.1	9.1- 21.6	4- 8.6	11- 20.3
Length of spikelet (mm)	1- 1.9	1.1- 2	1- 1.2	1.7- 2
Length of glume (mm)	1.2- 1.8	0.8- 1.2	0.8- 1.1	1- 1.9
Width of glume (mm)	0.5- 2.1	0.4- 0.7	0.4- 0.5	0.5- 0.7
Length of awn of the glume (mm)	0.1- 1.9	0.01- 1.7	0.01- 0.1	0.01- 0.1
Length of awn of the lemma (cm)	0.5- 10	3- 18.2	7.2- 13.9	6.3- 16.5
Number of awns in uppermost spikelet	2	2-awned / 1-awned and 1-toothed	1- or 2-awned and 1-toothed / 1-awned and 1-toothed, (in lowermost spikelet 1-awned and 1-toothed)	1-awned and 1-toothed / 2-awned and 1-toothed
Number of awns in middle spikelet	2	2	2	2
Length of caryopsis (mm)	0.2- 0.95	0.65- 1	0.95- 1.1	1- 1.1
Width of caryopsis (mm)	0.25- 1	0.25- 0.8	0.2- 0.3	0.25- 0.3
Number of florets in spikelet	2- 7	3- 8	3- 6	4- 5
Number of seeds in spikelet	3	4- 5	2	2
Ciliate of rachis	Median	Less to median	Median	Abundance
Keel of glume	Definitely keeled, outer face convex	Sharply keeled	Sharply keeled	Sharply keeled
Indumentum of leaf	Median to abundance / less hairy	Abscent	Abscent	Abscent / median / less hairy
Indumentum of nodes	Abscent / less to median	Abscent	Less to median	Abscent or rarely hairy
Form of spike	Oblong- ovate	Ovate	Slender/ linear	Slender/ lanceolate
Form of lodicule	Narrow	Broad	Broad	Narrow
Endosperm	Mealy	Flinty	Flinty	Flinty

studied in this investigation. Regarding cultivation, it is more likely that these 2 wheat species are not cultivated in this country any more.

This study showed that the tetraploid wheat species occurring in Iran are mainly restricted to western, northern, south-western and central areas of the country (Figure 1). *T. dicoccoides* and *T. dicoccum,* which have been mentioned by Bor (1968) as 2 sympatric species in the area, showed limited distribution in Iran (Figure 1), possibly due to restriction to the highlands habitat in the former and not being cultivated in the latter (Perrino et al., 1995). Chabano & Valkoun (2001) suggested that these 2 species originated in Palestine and Russia respectively. *T. dicoccoides*, which grows around non-irrigated farms of tetraploid wheat species, is a wild tetraploid emmer assumed to be the progenitor for *T. dicoccum* and other tetraploid wheat species (Vavilov, 1992; Van Slageren,1994).

T. turgidum and *T. durum* are widely cultivated sympatrically in Iran (see Figure 1). These 2 tetraploid wheat species are thought to be closely related by some wheat researchers (Magness et al., 1971; Van Slageren, 1994), but our results showed that they are morphologically 2 distinct species, in accordance with Tackholm & Tackholm (1941), Waines & Barnhart (1992) and Rahiminejad et al (2001).

Although in *T. dicoccoides* and *T. dicoccum* the dispersal of seed is easy, their spikelets are dispersed and palea and caryopsis are tightly fused (Szabott & Hammer, 1995). On the other hand, Chabane & Valkoun (2001), using molecular data (AFLP), showed that these 2 species are clustered together and both are related to *T. durum*; in addition, all these 3 species are free threshing. Rahiminejad et al (2001), using morphological data, showed that *T. turgidum* stands closer to *T. aestivum* (a hexaploid wheat) than any of them are to *T. durum*, which is in accordance with the point that *T. turgidum* is a subset of *T. aestivum* L. (Hanelt et al., 1983). Tubb & Hadson (1993) observed that the number and diameter of inflorescence papillae showed high similarity between

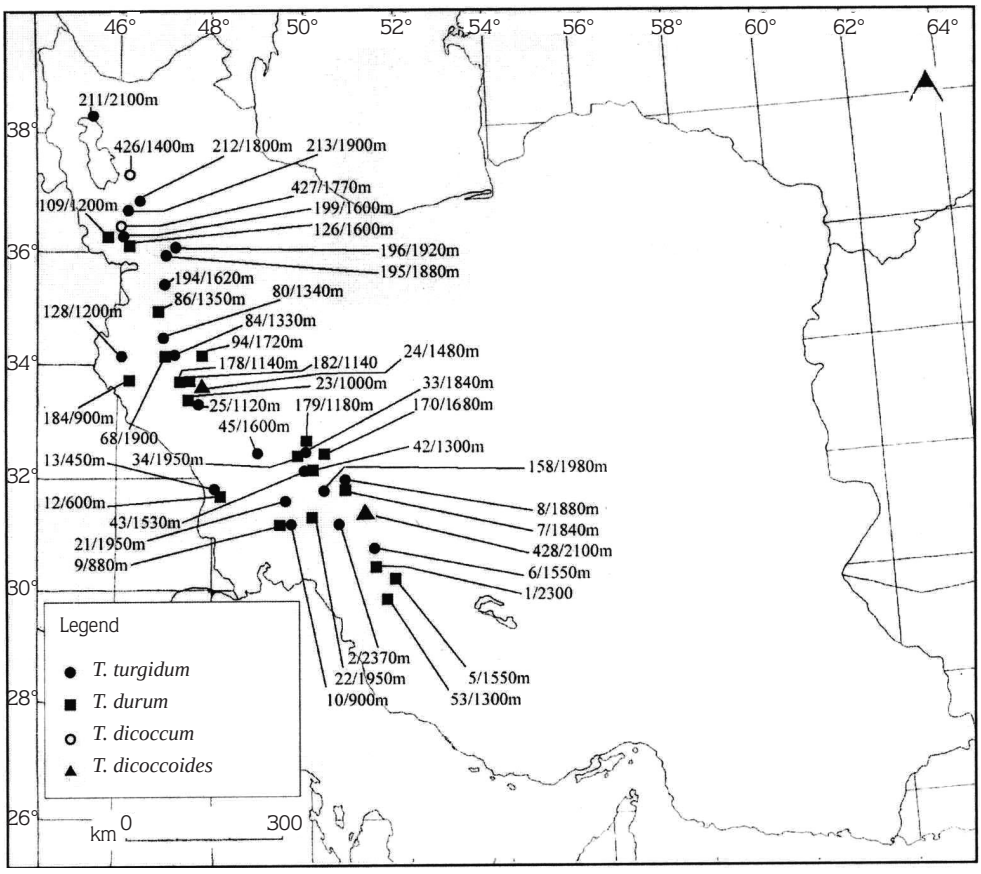


Figure 1. Localities of the 45 accessions of cultivated and wild tetraploid species of *Triticum* in Iran.

T. dicoccum and *T. dicoccoides,* while *T. turgidum* differed from *T. durum*. According to the results of this study (Table 1, Figures 2-5), it is obvious that the 3 species *T. dicoccum*, *T. dicoccoides* and *T. durum* cannot be considered subspecies of *T. turgidum* as suggested by Van Slageren (1994). It is noteworthy that based on the number of awns in the uppermost spikelet, keel of glume, indumentum of leaf and endosperm (Table 1) *T. durum* is similar to *T. dicoccooides* and *T. dicoccum*, and *T. turgidum* stands apart.

This study showed that the Zagros area, from Azerbayjan to north of Khuzistan, includes the main part of the genepool of cultivated and wild *Triticum* species in Iran. The high variability of these taxa stipulates the urgency of collecting and identifying the genepool of this group using molecular data in Iran and adjacent areas, i.e. Turkey, Armenia, Iraq, etc.

Based on the results of this study, the following key is given for the *Triticum* species occurring in Iran:

A key to the wild and cultivated tetraploid *Triticum* species in Iran:

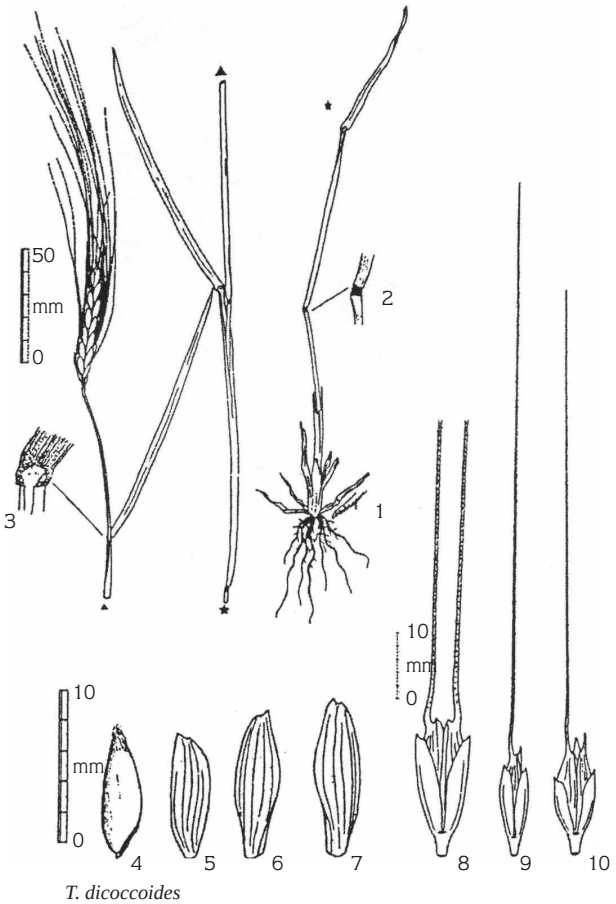
1- Seed not separated from palea at maturity (hulled). Rachis fragile or tough; spikelet with 1-2 seeds, narrow and falling. Node hairy or ciliate, brown or violet 2

- Seed separated from palea at maturity (emmer). Rachis tough; spikelet 2-4 seeds, broad and non-falling. Node ciliate, yellow-brown 3

2- Rachis fragile; lemma 2-awned or in the uppermost spikelet 2-awned and 1 tooth; in the lowermost spikelet 2-awned .....*T. dicoccoides*

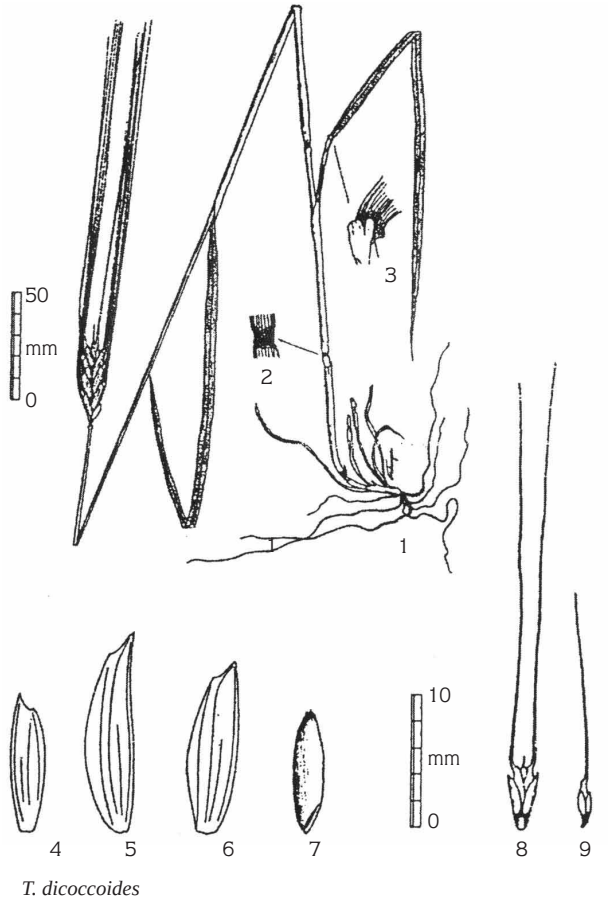
- Rachis tough; lemma of uppermost spikelet 1-2-awned (rarely 2), with 1 tooth or very small awn; in lowermost spikelet 1-2-awned .....*T. dicoccum*

3- Spike in cross section quadrate; spikelets very dense, spike 9.3-21.7 cm long; caryopsis 0.65-1 mm long.



T. dicoccoides

Figure 2. *T. dicoccum*, 1- habitat, 2- indumentum of node, 3- ligule and indumentum of leaf, 4- caryopsis, 5- glume of lowermost spikelet, 6- glume of middle spikelet, 7- glume of uppermost spikelet, 8- middle spikelet with two awns, 9 and 10- uppermost spikelet with one awn and one tooth.



T. dicoccoides

Figure 3. *T. dicoccoides*, 1- habitat, 2- indumentum of node, 3- ligule and indumentum of leaf, 4- glume of lowermost spikelet, 5- glume of middle spikelet, 6- glume of uppermost spikelet, 7- caryopsis, 8- middle spikelet, 9 and 10- uppermost spikelet with two awns and tooth or one awn and one tooth.

Node not ciliate or hairy. Leaf not hairy (rarely hairy). Endosperm flinty..... *T. durum*

- Spike in cross section ovate; spikelet dense or loose. Spike 8.7- 21.1 cm long, caryopsis 0.2- 0.95 mm long. Node ciliate or hairy. Leaf hairy. Endosperm mealy..... *T. turgidum*

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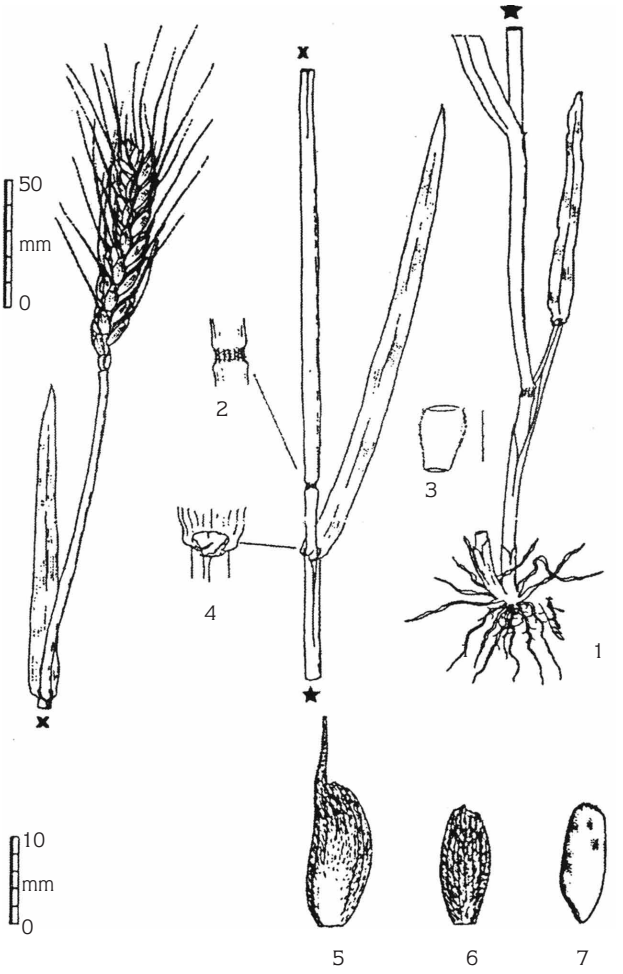
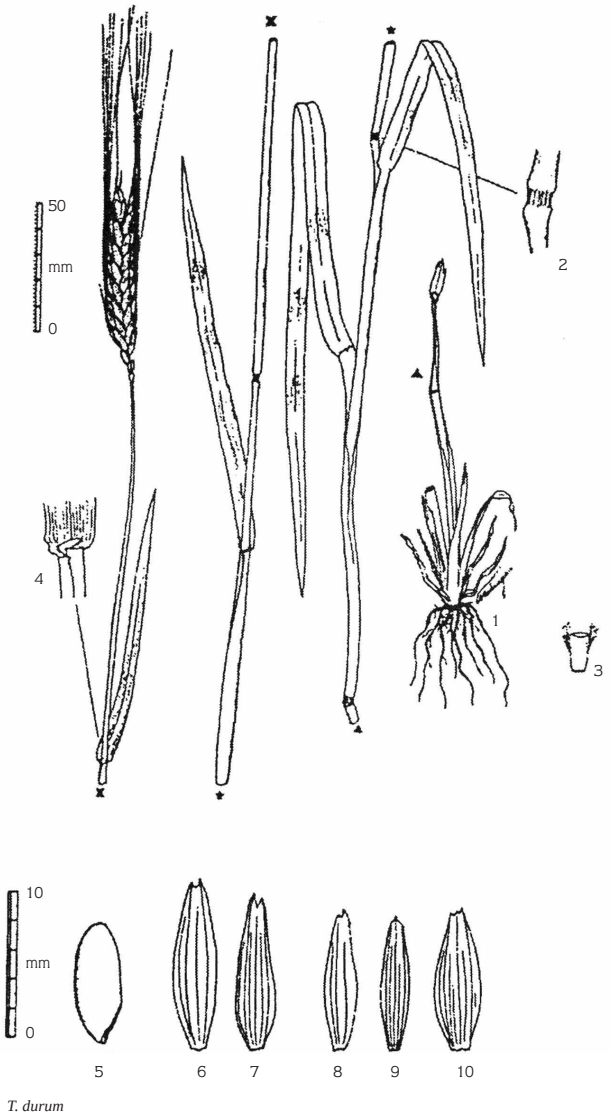


T. turgidum

Figure 4. *T. turgidum*, 1- habitat, 2- indumentum of rachis, 4- ligule and indumentum of leaf, 5, 6- glume of lowermost spikelet, 7- glume of middle spikelet, 8- glume of uppermost spikelet and 9- caryopsis.



T. durum

Figure 5. *T. durum*, 1- habitat, 2- indumentum of node, 3- indumentum of rachis, 4- ligule and indumentu of leaf, 5- caryopsis, 6- glume of lowermost spikelet, 7, 8 and 9- glume of middle spikelet, 10, 11 and 12- glume of uppermost spikelet.

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