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Full Length Research Paper

Taxonomic revision of genus *Hordeum* L. (Gramineae) in Egypt

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This study was conducted to revise the taxonomic identity and clarify inter- and intra-specific relationships among the studied wild and cultivated *Hordeum* taxa in Egypt. The studied taxa included *Hordeum marinum* subsp. *gussoneanum*, *H. marinum* subsp. *marinum*, *H*. *Hordeum leporinum*, *Hordeum glaucum*, *Hordeum spontaneum* and *Hordeum vulgare*. The results revealed that unweighted pair group method with arithmetic mean (UPGMA) dendrogram showed a considerable degree of dissimilarity among the studied *Hordeum* taxa at 1.50 dissimilarity distance. It divided the studied taxa into four groups at 1.33. Group 1 included *H. marinum* subsp. *gussoneanum* and *H. marinum* subsp. *marinum*. Group 2 included *H. leporinum*. Group 3 included *H. glaucum*. Group 4 included *H. spontaneum* and *H. vulgare* which is related to the other groups (1, 2, and 3). Moreover, by using UPGMA dendrogram, *H. leporinum* and *H. glaucum* are located in transitional position between *H. marinum* and both of *H. vulgare* and *H. spontaneum* forming a transitional step between the taxa of Group 1 and 4. This work provided a taxonomic key and separated the two subspecies of *H. murinum* into different species namely *H. glaucum* and *H. leporinum*. Moreover, the morphological similarities among *Hordeum* taxa have been proved.

Key words: Taxonomy, *Hordeum marinum, Hordeum leporinum, Hordeum glaucum, Hordeum spontaneum, Hordeum vulgare,* unweighted pair group method with arithmetic mean (UPGMA) dendrogram, Egypt.

INTRODUCTION

The variability in this genus has been a source of controversy among botanists for over a century. There is still no complete agreement as to the status of the various forms. This is clearly expressed by the more than forty taxa that exist (Bothmer and Jacobsen, 1985; Bothmer, 1992; Kochieva et al., 2001).

The taxonomic delimitation of the genus is still not satisfactorily resolved and there is still much disagreement among botanists and cytogeneticists concerning generic concepts. Based on morphology, genus *Hordeum* L. is divided into four sections: *Hordeum, Anisolepis, Critesion* and *Stenostachys*. Section *Hordeum* consisted of perennial and annual species and has a Eurasian distribution ranging from the Mediterranean area to West-Central Asia and included three species namely: *Hordeum vulgare* L., *Hordeum bulbosum* L. and *Hordeum murinum* L. (Bothmer and Jacobsen, 1985; Zohary and Hopf, 1988; Bothmer, 1992).

Section *Anisolepis* Nevski included perennial and annual species native to South and North America and represented eight species (Bothmer and Jacobsen, 1985). Section *Critesion* (Rafinesque) Nevski characterized by setaceous, long and spreading glumes and included six species (Bothmer and Jacobsen, 1985).

Section *Stenostachys* Nevski is the largest group of taxa in genus *Hordeum* L. with wide distribution. This section included eleven species, among of them: *H. marinum* Huds. with two subspecies: subsp. *gussoneanum* (Parl.) Thell. and subsp. *marinum* (Bothmer and Jacobsen, 1985). Bothmer (1992) treated genus *Hordeum* as thirty two species among of them: *H. marinum* (subsp. *Marinum* and

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Table 1. Number of surveyed localities (L), fresh examined specimens (F.S) and checked herbarium specimens (H.S) of studied *Hordeum* L. taxa in Egypt.

***Hordeum* taxa**	**L**	**F.S**	**H.S**
H. vulgare	3	30	20
H. spontaneum	0	0.0	12
H. marinum subsp. *marinum*	3	30	18
H. marinum subsp. *gussoneanum*	3	30	13
H. murinum glaucum	3	30	30
H. murinum leporinum	3	30	22
Total number	15	150	115

subsp. *gussoneanum*), *H. murinum* (subsp. *leporinum*, subsp. *glaucum* and subsp. *murinum*), and *H. vulgare* (subsp. *spontaneum* and subsp. *vulgare*).

Feinbrun-Dothan (1986) treated genus *Hordeum* as seven species among of them: *Hordeum spontaneum, Hordeum glaucum, H. marinum,* and *H. vulgare.* Humphries (1996) treated genus *Hordeum* as eleven species among of them: *Hordeum spontaneum*, *H. vulgare*, *H. murinum* (subsp. *murinum*, subsp. *glaucum* and subsp. *leporinum*), and *H. marinum*. Stace (1997) treated genus *Hordeum* as 10 species among of them: *H. vulgare*, *H. murinum* (subsp. *murinum*, subsp. *glaucum* and subsp. *leporinum*), *H. marinum* and *Hordeum geniculatum*.

Many taxonomists treated *Hordeum murinum* complex into different species: Baum and Bailey (1984a, b, 1989) treated *H. murinum* group as three species namely: *H. glaucum, H. murinum* and *Hordeum leporinum* (var. *leporinum* and var. *simulans*). Rajhathy and Morrison (1962) treated *H. murinum* group as two species (*H. glaucum* and *H. murinum*).

Jasska (1992) treated it as three species namely: *H. glaucum*, *H. murinum* and *Hordeum hrasdanicum* Gandilyan. Later, Mizianty (2006), El-Rabey and Al-Malki (2011) and Sardou et al. (2011) treated it as two different species. On the other hand, Booth and Richards (1976), Melderis (1985), Bothmer et al. (1991), Boulos (1995, 2005, 2009), Jacobsen and Bothmer (1995), Humphries (1996), and Jahan and Vahidy (2007, 2011) treated *H. murinum* complex as three subspecies of one species namely: *H. murinum* (subsp. *leporinum*, subsp. *glaucum* and subsp. *murinum*).

In Egypt, *Hordeum* taxa were treated by many authors among of them: Täckholm (1974) treated *Hordeum* L. taxa as six species (*H. spontaneum* C. Koch, *H. murinum* L., *H. leporinum* Link, *H. glaucum* Steud., *H. marinum* Huds., and *H. geniculatum* All.). Last treatments of *Hordeum* L. taxa in Egypt (Cope and Hosni, 1991; El-Hadidi and Fayed, 1994/1995; Boulos, 1995, 2005, 2009) treated the genus as four species; some of these species included infra-specific taxa. These species are: *H. vulgare* L. represented as four cultivars (Giza 123, Giza 124, Giza 125, and Giza 126), *H. spontaneum* C. Koch., *H. marinum* (subsp. *gussoneanum* and subsp. *marinum*), and *H. murinum* (subsp. *glaucum* and subsp. *leporinum*).

The present study aimed to derive data from macro- and micro-morphological attributes and used to revise the taxonomic identity of *Hordeum* taxa in Egypt. The retrieved data will be subjected to statistical analysis to clarify inter- and intra-specific relationships among the studied *Hordeum* taxa and confirmed the separation of *H. murinum* complex into *H. glaucum* and *H. leporinum.* Moreover, taxonomic key, for *Hordeum* taxa in Egypt, constructed to distinguish among studied taxa

MATERIALS AND METHODS

Field trips were carried out and 150 examined specimens were collected from 15 localities and 115 herbarium specimens were checked at Egyptian herbaria (Table 1). Phytogeographical distribution (longitude and latitude) of the studied *Hordeum* taxa were identified (Table 2). The fresh and herbarium specimens were subjected to taxonomic revision based on macro- and micro-morphological characters.

Distribution map is provided based on the specimen's distribution for each species/subspecies according to the ecological territories. Within each territory, specimens are distributed according to the sequence of the location from West to East, and from North to South (Figure 1). *Hordeum* specimens are distributed mainly along the Mediterranean Sea Strip (Map 1 and Table 2). However *H. marinum* subsp. *gussoneanum* (28° 59′ 18″ N° to 31° 11′ 54″ N°) and *H. murinum* L. subsp. *glaucum* and *H. murinum* L. subsp. *Leporinum* (29° 49′ 11″ N° to 31° 33′ 49″ N°) distributed southern of this limited area.

Data collection

Data collections for investigation and identification criteria of the studied taxa were based on the authentic flora and taxonomic (Cope and Hosni, 1991; Boulos, 1995, 2005, 2009). The identification of the studied *Hordeum* L. taxa was based on macro- and micro-morphological comparison among the examined specimens.

Voucher specimens kept at the studied herbaria among of them: Flora and Phytotaxonomy Researches Department Herbarium Agriculture Research Center a (CAIM), and Cairo University Herbarium (CAI). Description of *H. spontaneum* C. Koch, in this work, was based on the data retrieved from the herbarium, due to the lack of fresh specimens during the study years.

Statistical analysis

Statistical analysis of the differential characters was carried out. The output retrieved in dendrogram form was used to construct

Table 2. Phytogeographical distribution (latitude and longitude) of studied *Hordeum* L. taxa in Egypt.

***Hordeum* Taxa**	**Latitude (Nº)**	**Longitude (Eº)**
H. vulgare	30º 10′ 48″ to 31º 38′ 12″	25º 53′ 53″ to 29º 02′ 48″
H. spontaneum	30º 39′ 16″ to 30º 49′ 06″	27º 15′ 55″ to 33º 48′ 30″
H. marinum subsp. *marinum*	30º 59′ 30″ to 31º 27′ 02″	30º 03′ 03″ to 31º 34′ 33″
H. marinum subsp. *gussoneanum*	28º 59′ 18″ to 31º 27′ 02″	30º 03′ 03″ to 31º 34′ 33″
H. glaucum	29º 49′ 11″ to 31º 27′ 02″	25º 46′ 25″ to 34º 14′ 27″
H. leporinum	29º 49′ 11″ to 31º 27′ 02″	27º 15′ 55″ to 34º 14′ 27″

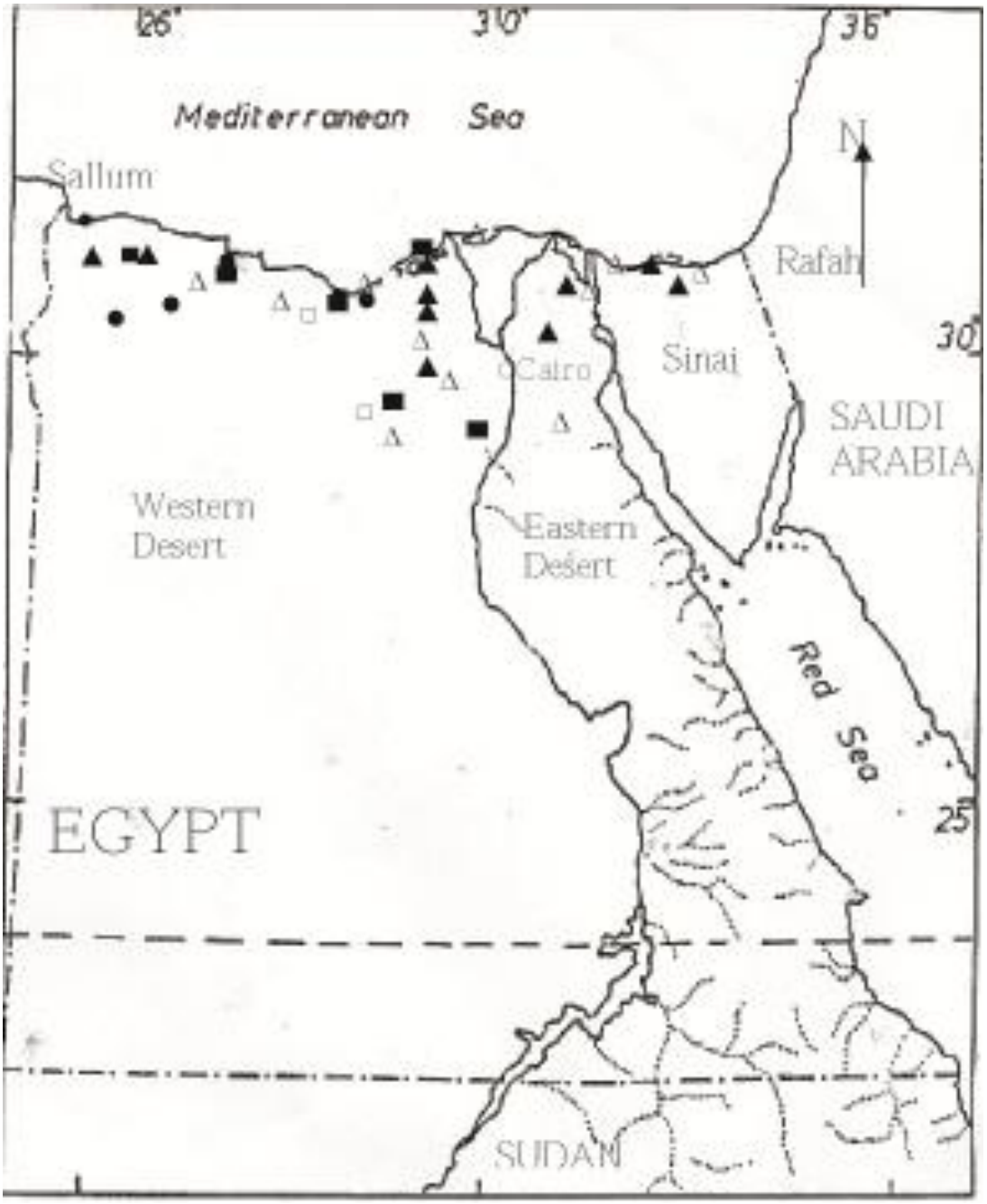

Figure 1. Distribution of *Hordeum* taxa collected during this study; *H. marinum* subsp. *gussoneanum* (▪); *H. marinum* subsp. *marinum* (□); *H. glaucum* (▲); *H. leporinum* (Δ) and *H. vulgare* (●).

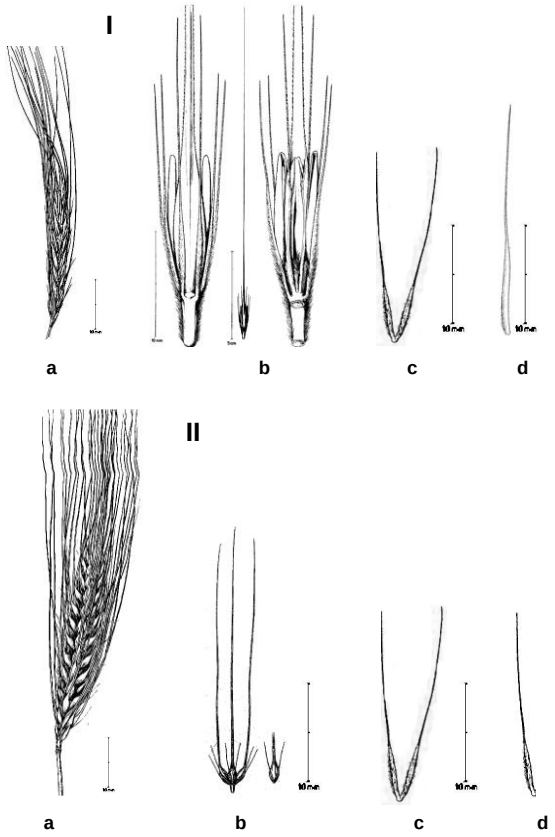

Figure 2. Detailed line drawing of *H. spontaneum* (I) and *H. vulgare* (II): a = spike, b = triplet of spikelets, c = two glumes of spikelets, = glume of the lateral spikelets (after Bor, 1968, 1970).

inter- and intra-specific relationships among the studied *Hordeum* taxa. The constructed dendrogram was based on macro- and micro-morphological data (Table 4). The macro-morphological data included habit, leaf color and spike shape and color.

In addition to, micro-morphological data included anther length and color; glume shape and surface; rachilla color and surface. Each taxon is provided with a detailed line drawing for the following characters: spike morphology, triplet of spikelets (figure 2,3 and 4) and lateral glumes to distinguish between wild and cultivated *Hordeum* taxa. The use of substantial number (1 = presence, 0 = absence) of attributes twenty five macro- and micro-morphological characters for the studied wild and cultivated *Hordeum* taxa (Table 4). The data treated as a binary character in a data matrix (Table 4) using NTSYS-PC version 1.50 program (numerical taxonomy and multivariate analysis system; Rohlf, 1988). Clustering was performed using the unweighted pair-group arithmetic mean method (UPGMA) (Sneath and Sokal, 1973; Dunn and Everitt, 1982). The output was plotted in the form of dendrogram (Figure 5).

RESULTS

Diagnostic features of the studied *Hordeum* taxa

Hordeum L., Sp. Pl. ed. 1: 84 (1753), Gen. Pl. ed. 5: 37 (1754)

Annual or perennial herbs with flat leaf-blades and auricled base. Inflorescence an erect or nodding distichously compressed spike, spikelets are in triplets, each with one floret. The central spikelet is bisexual, the laterals are bisexual, male or sterile. Cultivated barley, each triplet consisting of a central sessile spikelet flanked by two sessile ones, while, in wild barley the central sessile spikelet flanked by two pedicelled lateral ones.

Glumes narrow, 1 to 3-veined, long awned, sometimes expanded at the base. Lemma of the bisexual florets 5-veined awned or awnless. Palea 2-nerved, narrowly ovate and keeled. The grain with adhered lemma and palea, the later may be free. Stamens 3, Lodicules 2, wedge-shaped or spathulate and densely ciliate in cultivated species, while, in the wild species are lanceolate, or with an additional lateral tooth slightly ciliate above. Fruit elliptic caryopsis, deeply furrowed ad-axially, subtended by apical hairy appendage. Key to the studied *Hordeum* taxa is shown in Table 3.

***H. vulgare* L., Sp. Pl., ed. 1, 84 (1753). Syns. *H. hexastichon* L., Sp. Pl., ed. 1, 85 (1753); *H. sativum* Pers., Syn. Pl. 1: 108 (1805):** Annual grass, culms solitary or loosely fasciculate, up to one meter tall, erect smooth and glabrous. Leaf-blades flat, linear-acute up to 45 cm long, glabrous, scaberulous margins on both surfaces. Spike, excluding the awn, 6 to 10 x 1.5 to 2 cm, square or hexagonal in section, all spikelets fertile. Central spikelet sessile, glumes flattened, usually 10 to30 mm long. Lemma glabrous or scabrid, mostly near the apex, awn of lemma 30 to 180 mm long, usually scabrid. Anthers 6 to 10 mm long, yellowish. Rachilla up to half the length of the palea, with long or short hairs. Lateral spikelets usually sessile. Glumes linear-lanceolate produced into a fine, scabrid awn. Lemmas broadly ovate-lanceolate, strongly 5-nerved, armed with a stiff awn up to 15 cm long.

***H. spontaneum* C. Koch, Linnaea, 21: 430 (1848). Syns. *H. ithaburense* Boiss., Diagn. Pl. Or. Nov. Ser. 1, 13: 70 (1873); *H. spontaneum* var. *ithaburense* (Boiss.) Nab. in Publ. Fac. Sci. Univ. Masaryk 111: 32 (1929):** A robust, annual grass. Culms usually solitary, erect, or loosely fasciculate, up to 80 (to 100) cm tall, glabrous, with brown nodes. Leaf-blades linear-acuminate, flat, somewhat flaccid, up to 15.0 x 0.4 to 0.8 cm. Leaf-blades scaberulous on the upper surface and30 mm long. Lemma glabrous or scabrid, mostly near the apex, awn of lemma 30 to 180 mm long, usually scabrid. Anthers 6 to 10 mm long, yellowish. Rachilla up to half the length of the palea, with long or short hairs. Lateral spikelets usually sessile. Glumes linear-lanceolate produced into a fine, scabrid awn. Lemmas broadly ovate-lanceolate, strongly 5-nerved, armed with a stiff awn up to 15 cm long.

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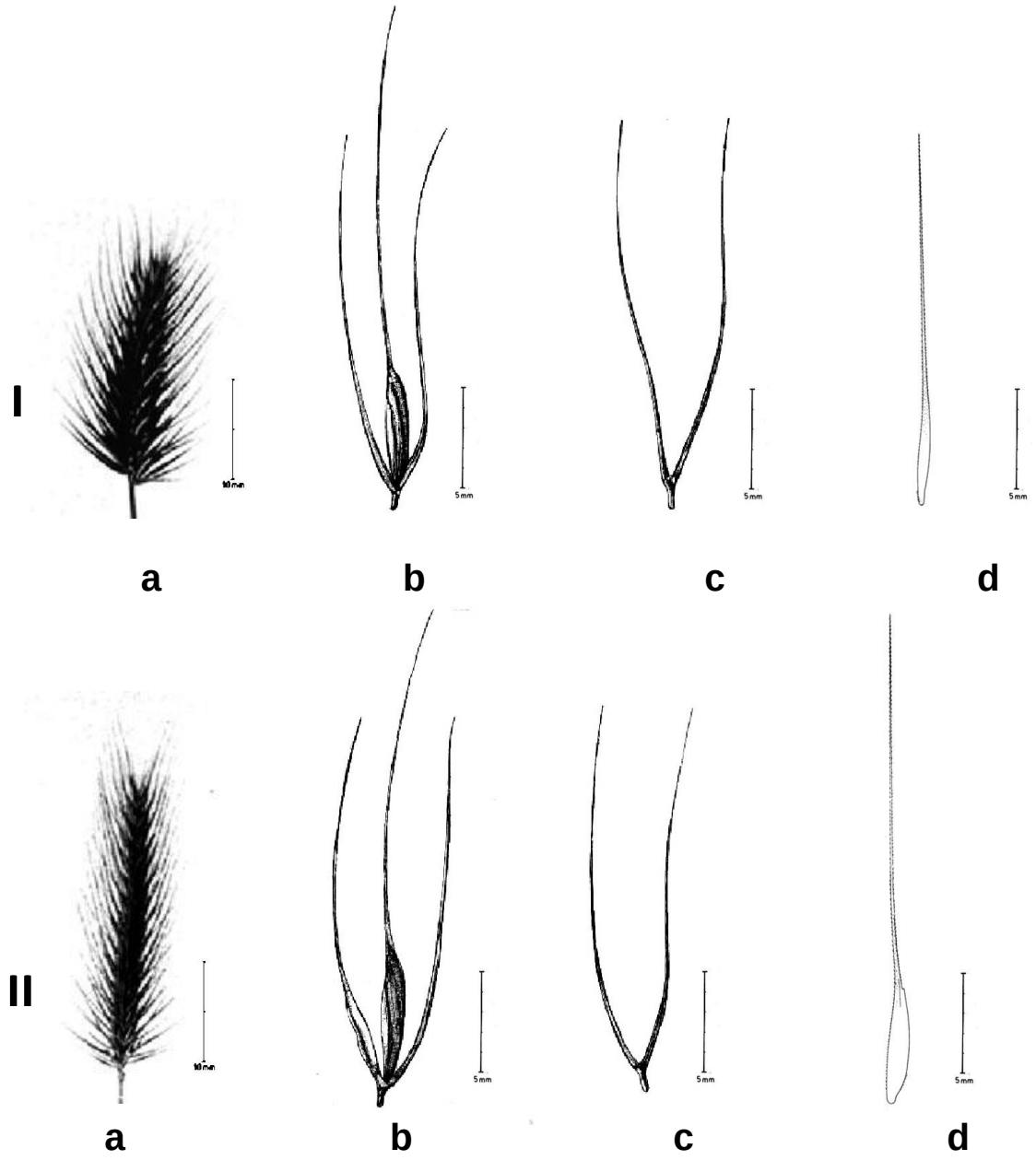

Figure 3. Detailed line drawing of *Hordeum marinum* subsp. *gussoneanum* (I) and *H. marinum* subsp. *marinum* (II): a =: spike, b = lateral of spikelet, c = lateral glumes with rachis, and d = inner glume of the lateral spikelets.

erect, or loosely fasciculate, up to 80 (to 100) cm tall, glabrous, with brown nodes. Leaf-blades linear-acuminate, flat, somewhat flaccid, up to 15.0 x 0.4 to 0.8 cm. Leaf-blades scaberulous on the upper surface and glabrous lower one, margins rough scabrid. Leaf sheath auricled at the mouth. Ligules about 1.5 mm long. Spike (excluding the awns) 4 to 10.0 x 0.7 to 1.0 cm, dense, erect, and distichously. Spikelets one flowered.

Rachis dens silky-villose along margins, fragile, and readily disarticulating. Rachilla prolongation more than 1/2 length of lemma. Glumes linear-lanceolate, silky-villose, each ending in a fine awn longer than glume proper. Central spikelet hermaphrodite and sessile.

Lemma lanceolate, ending in a long tough awn; awn stout, flattened, scabrous, straight, 8 to 14 (to 20) x 0.15 cm. Lateral spikelets staminate, neuter or vestigial, subtended by short pedicel. Lemma awnless, with rounded-obtuse apex.

Hordeum spontaneum C. Koch, not traced in Egypt during the course of study. However, the last collections from this nearly extinct species were recorded during 1988 in Wadi Habis 60 km southern Mersa Martuh city

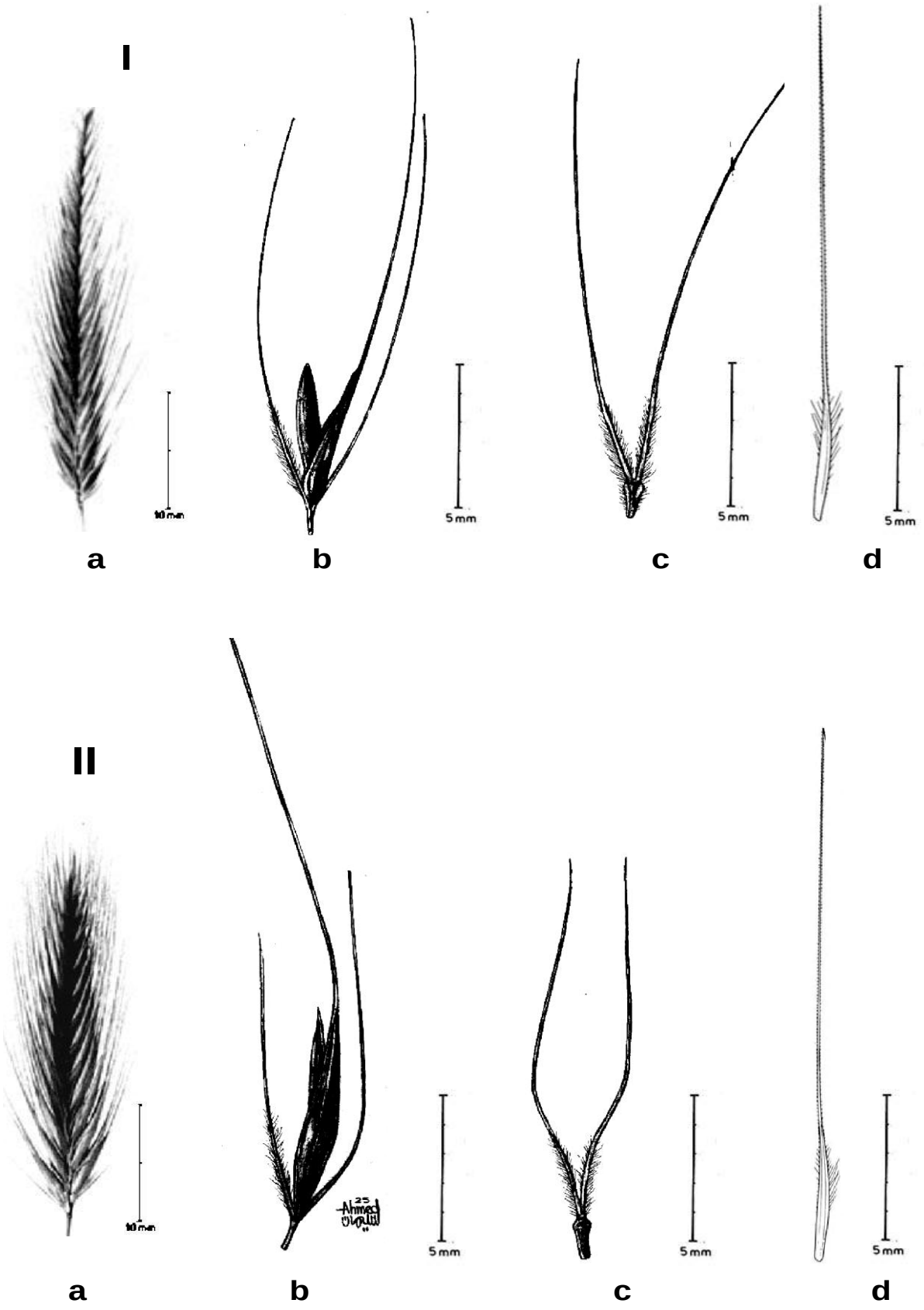

Figure 4. Detailed line drawing of *H. glaucum* (I) and *H. leporinum* (II): a = spike, b = lateral of spikelet, c = lateral glumes with rachis, d = inner glume of the lateral spikelets.

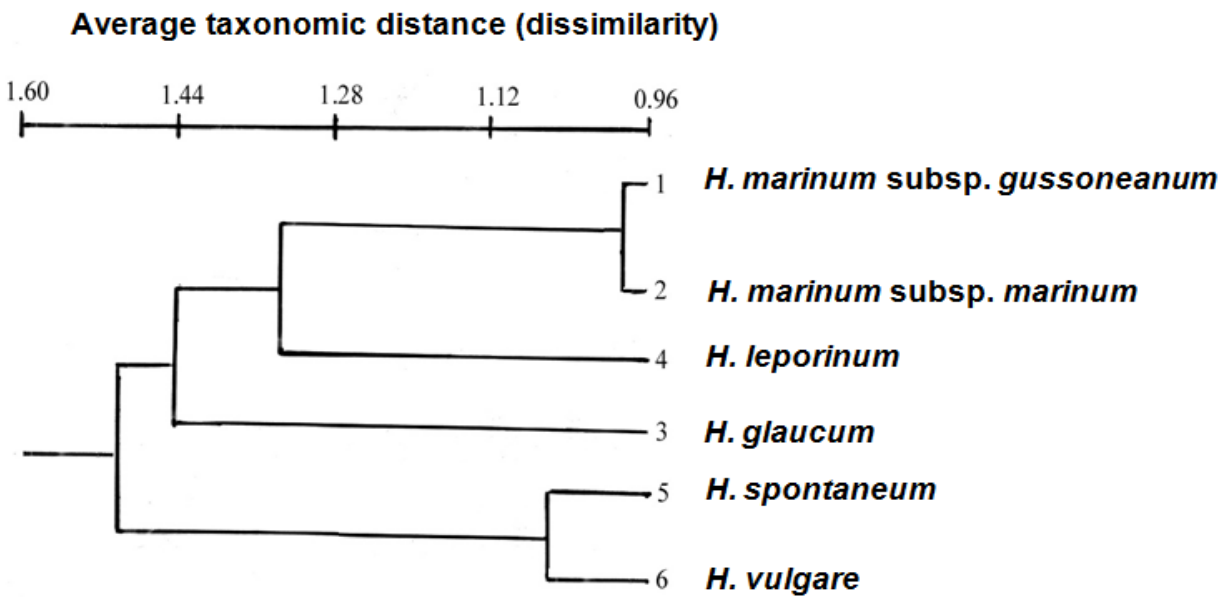

Figure 5. UPGMA dendrogram based on the studied 25 macro-and micro-morphological characters illustrating average taxonomic distance (dissimilarity) among *Hordeum* taxa in Egypt.

Table 3. Key to the studied *Hordeum* taxa.

1	Spike in four or six-rowed, rachis tough not breaking and articulating at maturity.	*H. vulgare*
+	Spike in two rows, rachis fragile articulating at maturity.	2
2	Awn of central lemma stout, 5-12 cm long; lemmas of the two lateral spikelets awnless	*H. spontaneum*
+	Awn of central lemma slender, up to 3 cm long; lemmas of the two lateral spikelets awned.	3
3	Glumes of central spikelets glabrous; spike up to 3 cm, central spikelet sessile.	4. *H. marinum*
+	Glumes of central spikelets hairy; spike up to 8 cm, central spikelet pedicel.	5. *H. murinum*
4	Inner glume of the lateral spikelets winged on one side	*H. marinum* subsp. *marinum*
+	Both glumes of the lateral spikelets wingless	*H. marinum.* subsp. *gussoneanum*
5	Rachilla yellowish–brown and ciliated; anther of central spikelet blackish, heteromorphic and not exserted at anthesis	*H. glaucum*
+	Rachilla green and non-ciliated; anther of central spikelet yellowish or brownish, isomorphic and exserted at anthesis	*H. leporinum*

along the western desert. Taxonomic revision and macro- and micro-morphological description of *H. spontaneum* C. Koch, were based on authentic herbarium samples deposited in the Egyptian herbaria.

***H. marinum* Huds., Fl. Angl., ed. 2, 1. 57 (1778). Syn. *H. maritimum* With., Arr. Br. Pl. ed. 2, 1: 127 (1787); Fl. Orient. 5: 687 (1884):** Annual grass with loosely tufted of solitary culms, erect or ascending. Stem 10 to 40 (to 60) cm tall, smooth and glabrous. Leaf-blades linear acuminate, 6 to 8 x 0.15 to 0.4 cm, scaberulous to smooth on the margins.

Sheaths auricled at the mouth, glabrous on the upper part of the stems. Spike 2 to 5 cm long (excluding awns), very bristly oblong, tapered toward the apex, greenish or purplish. Spikelets one flowered glabrous or hairy. Central spikelet sessile and much longer than the lateral spikelets. Glumes of the central spikelet equal, scabrid, setaceous, 10 to 25 mm long. Lemma, elliptic-oblong, acute, sessile, tipped when an awn up to 25 mm long, 5-nerved. Palea narrows, as long as the lemma, 2-nerved. Lateral spikelets glumes scabrous, bristle-like, unequal, the lower with an awn up to 25 mm long, the inner with a wing (0.6 to 1.4 mm) broad at the base and with the awn

Table 4. Summary table of 25 macro- and micro-morphological characters studied among *Hordeum* taxa: *H. marinum* subsp. *gussoneanum* (a), *H. marinum* subsp. *marinum* (b), *H. glaucum* (c), *H. leporinum* (d), *H. vulgare* cv. Giza 123 (e) and *H. spontaneum* (f) with their code for statistical analysis (1=presence, 0=absence).

Taxa	(a)	(b)	(c)	(d)	(e)	(f)
			Spike			
1. Length (including awns)	Short (0)	Short (0)	Short (0)	Short (0)	Long (1)	Long (1)
2. Shape	Dense (1)	Dense (1)	Not loose (1)	Loose (0)	Dense (1)	Dense (1)
3. Rachis	Brittle (1)	Brittle (1)	Brittle (1)	Brittle (1)	Tough (0)	Brittle (1)
4. Rows	Two-rows (1)	Two-rows (1)	Two-rows (1)	Two-rows (1)	Four-six rows (0)	Two-rows (1)
5.anthesis	Green (1)	Green (1)	Glaucous (0)	Green (1)	Green (1)	Green (1)
			Anther			
6. Length	Isomorphic (1)	Isomorphic (1)	Heteromorphic (0)	Isomorphic (1)	Isomorphic (1)	Isomorphic (1)
7. Color	Blackish (1)	Yellowish (0)	Blackish (1)	Yellowish (0)	Yellowish (0)	Yellowish (0)
8. Anthesis	Not exerted (1)	Not exserted (1)	Not exserted (1)	Exserted (0)	Exserted (0)	Exserted (0)
			Lateral spikelets			
9.pedicel	Pedicelled (1)	Pedicelled (1)	Pedicelled (1)	Pedicelled (1)	Sessile (0)	Pedicelled (1)
10. Awned-lemma	Awned (1)	Awned (1)	Awned (1)	Awned (1)	Awned (1)	Awnless (0)
11. Length (excluding awns)	Same as central spikelet (1)	Same as central spikelet (1)	Same as central spikelet (1)	Longer than central spikelet (0)	Same as central spikelet (1)	Same as central spikelet (1)
12. Glumes size	Isomorphic (1)	Heteromorphic (0)	Isomorphic (1)	Heteromorphic (0)	Isomorphic (1)	Isomorphic (1)
13. Outer glume	With broad base (1)	Without broad base (0)	Without broad base (0)	Without broad base (0)	Without broad base (0)	Without broad base (0)
14. Inner glume	Wingless (0)	Winged (1)	Wingless(0)	Wingless (0)	Wingless (0)	Wingless (0)
15.fertility	Sterile (0)	Sterile (0)	Sterile (0)	Sterile (0)	Fertile (1)	Sterile (0)
16. Palea	Glabrous (1)	Glabrous (1)	Pilose (0)	Pilose (0)	Glabrous (1)	Glabrous (1)
17. Palea and lemma	Glume like (1)	Not so (0)	Not so (0)	Not so (0)	Not so (0)	Not so (0)
			Rachilla			
18. Prolongation- color	Green (1)	Green (1)	Yellowish-brown (0)	Green (1)	Green (1)	Green (1)
19. Surface	Non-ciliated (0)	Non-ciliated (0)	Ciliated (1)	Non-ciliated (0)	Ciliated (1)	Ciliated (1)
Central spikelet						
20. Glumes surface	Glabrous (1)	Glabrous (1)	Ciliated (1)	Ciliated (1)	Ciliated (1)	Ciliated (1)
21. Awn length	Short (0)	Short (0)	Short (0)	Short (0)	Long (1)	Long (1)
22. Pedicel	Sessile (0)	Sessile (0)	Pedicelled (1)	Pedicelled (1)	Sessile (0)	Sessile (0)
			Leaf			
23. Glabrous blade	Not (0)	Not (0)	Not (0)	Not (0)	Glabrous (1)	Glabrous (1)
24. Auricle	Shot (0)	Shot (0)	Long (1)	Long (1)	Long (1)	Long (1)
25. Color	Green (1)	Green (1)	Bluish-green (0)	Green (1)	Green (1)	Green (1)

about 20 mm long. Lemma c.5 mm long, shortly awned.

***H. marinum* subsp*. marinum*. Syns. *H. marinum* Huds., Fl. Angl., ed. 2, 57 (1778), *H. maritimum* With., Arr. Br. Pl. ed. 2, 1: 127 (1787):** Summer or winter annual species. Basal leaf-sheaths with dense short hairs 0.1 to 0.25 mm. Glumes subulate and heteromorphous, inner glume of lateral spikelets expanded into a wing 0.6 to 1.4 mm wide at base.

***H. marinum* subsp*. gussoneanum* (Parl.) Thell., Naturf. Ges. Zürich 52: 441 (1908). Syns. *Hordeum hystrix* Roth, Cat. Bot. 1: 23 (1797); *Hordeum gussoneanum* Parl., Fl. Palerm. 1: 246 (1845); *H. geniculatum* All., Fl. Pedem. 2: 259 (1785):** Similar to subsp. *marinum* but leaf-sheath with hairs 0.5 to 1.0 (to 1.2) mm. Inner glume of lateral spikelets 0.2 to 0.6 (to 0.7) mm wide, wingless, subulate (slightly swollen).

***H. glaucum* Steud., Syn. Pl. Glum. 1: 352 (1854). Syn. *H. murinum* subsp*. glaucum* (Steud.) Tzvelev, Act. Nov. Sist. Vyssh. Rast. 8: 67 (1971):** Leaves glaucous. Spikes 3.0 to 7.0 cm long and not loose. Palea of central spikelet 0.7 to 0.8 times as long as palea of lateral spikelets. Central spikelet glumes subulate, lemma oblong-elliptic, 5 to 6 mm long, tipped with an awn 10 to 25 mm long. Lateral spikelets pedicelled. Glumes subulate; lemma 5 to 8 mm long.

Upper glumes similar to those of the central spikelet. Lower glumes narrower than the upper ones. Lemma longer than that of the central spikelet. Prolongation of rachilla of lateral spikelets stout, yellowish-brown. Rachilla yellowish–brown and ciliated with hairs of 0.25 to 0.75 mm long. Anther of central spikelet blackish, heteromorphic (0.2 to 0.5 mm), not exserted at anthesis.

***H. leporinum* Link, Linnaea 9: 133 (1835). Syn. *H. murinum* subsp. *leporinum* (Link) Arcang., Fl. Ital. 805 (1882):** Leaves green and glabrous on both surface. Spike 4 to 8 x 0.8 to 1.0 cm and loose. Palea of central spikelet 0.7 to 0.9 times as long as palea of lateral spikelets. Central spikelet glumes 25 mm and ciliated on margins, awned 25 mm, lemma and palea are 10 mm long. Lateral spikelets: outer glume 25 mm scarbid; inner glume 20 mm ciliated on both margins; pedicel 2.0 mm, awn 30 mm; lemma and palea are 13 mm. Grain 6.0 x 2.0 mm. Stamens yellowish. Anthers of central spikelet 0.7 to 1.4 mm; Rachilla prolongation slender, green and non-ciliated. Anther of central spikelet yellowish or brownish, isomorphic (0.7 to 1.4 mm), exserted at anthesis.

Major differences between wild cultivated *Hordeum* taxa

The data retrieved in this revision revealed that, the major differences between cultivated and wild *Hordeum* taxa can be summarized as follows: Inflorescence of cultivated barley (*H. vulgare*) is six-rowed, while wild species (*H. marinum, H. murinum* and *H. spontaneum*) are two-rowed barley. *H. spontaneum* is distinguished from the other wild species by awns lateral spikelets are reduced while the central lemma posses long awn. *H. marinum* is characterized by glabrous central glumes and sessile central spikelet. These characters were not observed in *H. murinum* (hairy central glumes and pedicel central spikelets).

The macro-and micro-morphological differences between *H. marinum* subsp. *gussoneanum* and *H. marinum* subsp. *marinum* are shown in Table 4. Whereas, the main differences between the two subspecies: inner glumes of the lateral spikelets winged in subspecies *marinum* but not in subsp. *gussoneanum*. Moreover, palea and lemma reduced to glume like in subsp. *gussoneanum*, while anther color blackish on subsp. *gussoneanum* and yellowish in subsp. *marinum* (Table 4).

The major differences between the *H. glaucum* and *H. leporinum* are: rachilla surface ciliated in subspecies *glaucum*, glabrous in *H. leporinum* and glumes of lateral spikelets isomorphic in *H. glaucum*, but heteromorphic in *H. leporinum*. In addition to, anther length and color are heteromorphic and blackish in *H. glaucum* but isomorphic and yellowish or brownish in *H. leporinum* (Table 4).

Morphological similarities among the studied *Hordeum* taxa

The dendrogram (Figure 5) produced by the statistical analysis, based on twenty five macro- and micro-morphological characters (Table 4) showed that, wild and cultivated *Hordeum* taxa had a highest average taxonomic distance value of 1.50.

At point 1.33, (Table 5 and Figure 5) the studied *Hordeum* taxa was separated into four groups (G1, G2, G3 and G4). The first group (G1) included *H. marinum* subsp. *gussoneanum* and *H. marinum* subsp. *marinum*. The second group (G2) included *H. leporinum*. The third group (G3) included *H. glaucum*. The forth group (G4) included *H. spontaneum* and *H. vulgare*.

DISCUSSION

Genus *Hordeum* L. was one of the tribe Triticeae genera subjected to several studies, but still there is no complete agreement about its taxonomic delimitation as well as the status of the various forms. The variability in this genus has been a source of controversy among botanists for over a century. Some authors treat the genus to include more than forty taxa among of them: Bothmer and Jacobsen (1985), Bothmer (1992), and Kochieva et al. (2001). The taxonomic delimitation of the genus is still not satisfactorily resolved and there is still much disagreement among botanists and cytogeneticists concerning generic concepts.

Several different proposals for the classification of the

Table 5. Grouping of the studied *Hordeum* taxa based on the UPGMA dendrogram retrieved from the statistical analysis of 25 macro-and micro- morphological characters (d.d = dissimilarity distance, G = group).

***Hordeum* taxa**	**Groups at (1.33 d.d)**
H. marinum subsp. *gussoneanum and H. marinum* subsp*. marinum*	G1
H. leporinum	G2
H. glaucum	G3
H. spontaneum and *H. vulgare*	G4

H. murinum complex members have been put forward. On the basis of morphological characters, this study placed *H. leporinum* and *H. glaucum* in different groups (G2 and G3) (Figure 5 and Table 5). This was confirmed by the dissimilarities in some macro- and micro-morphological characters (Table 4). Among of these dissimilar characters are; anther length of central and lateral spikelets isomorphic in *H. leporinum* and heteromorphic in *H. glaucum*; glumes size of lateral spikelets heteromorphic in *H. leporinum* and isomorphic in *H. glaucum* and rachilla surface non ciliated in *H. leporinum* and ciliated in *H. glaucum.*

Our results are in agreements with cytological studies, where, the two species have different chromosomes numbers (2n=28 or 42 in *H. leporinum* and in *H. glaucum* 2n=14). This notable dissimilarity between two species was in agreements with many authors (Bowden, 1962; Bor, 1970; Cocks et al., 1976; Booth and Richards, 1976; Baum and Bailey, 1984a, b, 1989, 1990; Löve, 1984; Bothmer and Jacobsen, 1985; Melderis 1985; Giles and Lefkoviteh, 1986; Jasska, 1992; Bianchi et al., 2002; Mizianty, 2006; El-Rabey and Al-Malki, 2011; Sardou et al., 2011), where they treated these two subspecies as separate species (*H. glaucum* Steud. and *H. leporinum* Link.).

On the other hand, many authors (Bothmer, 1992; Jacobsen and Bothmer, 1992, 1995; Bothmer et al., 1995; Stace, 1997; Boulos, 1995, 2005; Provan et al., 1999; El-Rabey et al., 2002; Amirouche and Misset, 2003; Jahan and Vahidy, 2007, 2011; Eilam et al., 2010; Tanno et al., 2010; El-Rabey and Al-Malki, 2011; Mavi et al., 2011) treated the *H. murinum* as different subspecies (*glaucum* and *leporinum*).

Treatment of *H. marinum* subsp. *gussoneanum* and *H. marinum* subsp. *marinum* in this study in a same group G1 (Table 5 and Figure 5) confirmed by the studied macro- and micro-morphological similarities between them (Table 4). Among of these similar characters are: the isomorphic anther length; lateral spikelets pedicelled and non-ciliated rachilla surface in the two subspecies. This finding similarity was also confirmed by earlier taxonomist (Bothmer and Jacobsen, 1985; Mandaville, 1990; Cope and Hosni, 1991; Bothmer, 1992; Provan et al., 1999; Sahebi et al., 2004; Boulos, 2005; Jahan and Vahidy, 2010; Ourari et al., 2011).

The treatment of *H. spontaneum* and *H. vulgare*, in the same group (G4) (Table 5 and Figure 5) was attributed to the macro- and micro-morphological similarities between these two similar species, where this study treated these two species as two related species. This was attributed to the macro- and micro-morphological similarities between these two similar species (Table 4). Among of the similar characters are: anther isomorphic and yellowish; glumes sizes of lateral spikelets isomorphic and rachilla surface ciliated. This similarity between the two species of *H. vulgare* was confirmed by earlier treatments. This finding was in agreements with many investigators (Bor, 1970; Davis et al., 1985; Feinbrun-Dothan, 1986; Cope and Hosni, 1991; Humphries, 1996; Badr et al., 2000; Boulos, 2005).

Conclusion

The taxonomic revision based on morphological characters in this study revealed that, the position of *H. marinum* subsp. *gussoneanum* and *H. marinum* subsp. *marinum* in one group "G1" confirmed its taxonomic treatment as two subspecies of the same species. While, *H. leporinum* is located at "G3" and the *H. glaucum* is located in "G4", indicate the dissimilarity between these two species. Similarly, the position of *H. vulgare* in "G4" with *H. spontaneum* confirmed their genetic affinity accordingly; *H. spontaneum* is a promising wild crop-relative for future breeding programs for *H. vulgare*. *H. spontaneum* not traced in Egypt since the latest record in 1988; now it considered as nearly extinct species. The species was collected at that time from Wadi Habis 60 km southern Mersa Martuh city along the Western Desert. Its natural habitats removed during 1990s and substituted by the olive cultivations.

This study recommends that regulations should be developed to protect and conserve the potential species. Wild crop relatives among them must be subjected to national conservation programs. Accordingly, additional molecular researches are needed to fill gaps in our knowledge and to resolve the taxonomic limitations of *Hordeum* species in Egypt.

REFERENCES

Amirouche R, Misset MT (2003). Hordein polymorphism in diploid and tetraploid Mediterranean populations of the *Hordeum murinum* L. complex, Plant. Syst. Evol., 242: 83–99.

Badr A, Mu¨ller K, Scha¨fer-Pregl R, El- Rabey H, Effgen S, Ibrahim HH, Pozzi C, Rohde W, Salamini F (2000). On the origin and domestication history of barley (*Hordeum vulgare*), Mol. Biol. Evol., 17(4): 499–510.

Baum BR, Bailey GL (1984a). Taxonomic studies in wall barley (*Hordeum murinum*) and sea barley (*Hordeum marinum*). 1. Character investigation: assessment of new and traditional characters, Can. J. Bot., 62: 753-762.
Baum BR, Bailey GL (1984b). Taxonomic studies in wall barley (*Hordeum murinum*) and sea barley (*Hordeum marinum*). 2. Multivariate morphometrics, Can. J. Bot., 62: 2754-2764.
Baum BR, Baily LG (1989). Species relationships in the *Hordeum murinum* aggregate viewed from chloroplast DNA restriction fragment patterns, Theor. Appl. Genet., 78: 311-317.
Baum BR, Bailey GL (1990) Key and synopsis of North American *Hordeum* species, Can. J. Bot., 68: 2433–2442.
Bianchi DS, Senften JK, Felber F (2002). Isozyme variation of *Hordeum murinum* in Switzerland and test of hybridization with cultivated barley, Weed Res., 42: 325–333
Booth TA, Richards AJ (1976). Studies in the *Hordeum murinum* L. aggregate. I. Morphology, J. Linn. Soc. Bot.. 72: 149-159.
Booth TA, Richards AJ (1976). Studies in the *Hordeum murinum* L. aggregate: Disc electrophoresis of seed protein, J. Linn. Soc. Bot., 76: 115-125.
Bor NL (1970). *Flora Iranica*. In: Rechinger, KH. (ed.) Akademishe Druck- u. Verlagsantalt Graz-Austria, 70: 232-242.
Bothmer R (1992). The wild species of *Hordeum*: relationships and potential use for improvement of cultivated barley. In. Shewry, P.R. (ed). Barley: genetics, Biochemistry, Molecular Biology and Biotechnology, CAB international, pp.3-17.
Bothmer R, Jacobsen N (1985). Origin, taxonomy, and related species. In. Rasmusson, DC (ed). Barley. American Society of Agronomy, Crop Science Society of America, Soil Science of America, Publishers, Madison, Wisconsin. ASA Monograph, 26: 19-56.
Bothmer R, Jacobsen N, Seberg O (1991). A new combination in *Hordeum* (Triticeae, Poaceae), Nord. J. Bot., 11: 53.
Bothmer R, Jacobsen N, Baden C, Jorgensen RB, Linda-Laursen I **(**1995). An ecogeographical study of the genus *Hordeum*. International Plant Genetic Resources Institute book, 2nd edition. pp.1-129.
Bothmer R, Jacobsen N, Jørgensen RB, Nicora E (1982). Revision of the *Hordeum pusillum* group, Nord. J. Bot., 2: 307-321.
Boulos L (1995). Flora of Egypt checklist. Al Hadara Publishing Cairo Egypt, 1-283.
Boulos L (2005). Flora of Egypt Vol. IV. Al-Hadara Publishing, Cairo. Egypt, 1-617.
Boulos L (2009). Flora of Egypt checklist. Revised annotated edition. Al Hadara Publishing Cairo Egypt, p.292.
Cocks PS, Boyce KG, Kloot PM (1976). The *Hordeum murinum* Complex in Australia, Aust. J. Bot. 24: 651-662.
Cope TA, Hosni HA (1991). A key to Egyptian grasses. Royal Botanic Gardens, Kew, UK, pp. 1-74.
Davis PH, Mill RR, Ton K (1985). Flora of Turkey and East Aegean Islands. Edinburgh University Press, Great Britain, pp.262-268.
Dunn G, Everitt BS (1982). An introduction to mathematical taxonomy. Cambridge. New York.
Eilam T, Anikster Y, Millet E, Manisterski J, Feldman M (2010). Genome size in diploids, allopolyploids, and autopolyploids of Mediterranean Triticeae. J. Bot., ID 341380, pp.1-12.
El-Hadidi N, Fayed A (1994-95). Materials for excursion flora of Egypt, Cairo University Herbarium. Täeckh, 15: 1-233.
El-Rabey H, Badr A, Scha¨ fer-Pregl R, Martin W, Salamini F (2002). Speciation and species separation in *Hordeum* L. (Poaceae) resolved by discontinuous molecular markers, Plant Biol., 5: 567–575.
El-Rabey H, Al-Malki AL (2011). Application of randomly amplified polymorphic DNA (RAPD) markers and polyphenol oxidases (PPO) genes for distinguishing between the diploid (*glaucum*) and the tetraploid (*leporinum*) accessions in *Hordeum murinum* complex, Afr. J. Biotechnol., 10(61): 13064-13070.
Feinbrun-Dothan N (1986). Flora Palaestina. The Israel Academy of Science and Humanities, 4: 179-183.
Giles BE, Lefkoviteh LP (1986). A Taxonomic investigation of the *Hordeum murinum* Complex *(Poaceae),* Plant Syst. Evol., 153: 181-197.
Humphries CJ (1996). Flora Europaea 5. In Tutin et al. (eds.). Cambridge University Press, pp. 204-205.
Jasska V (1992). Isoenzyme variation in barley *(Hordeum* L.). 2. Aspartate aminotransferase and 6-phosphoglyconate dehydrogenase. Hereditas, 116: 29-35.
Jacobsen N, Bothmer R (1992). Supraspecific groups in the genus *Hordeum*. Hereditas, 116: 21-24
Jacobsen N, Bothmer R (1995). Taxonomy in the *Hordeum murinum* complex (Poaceae), Nord. J. Bot., 15 (5): 449-458.
Jahan B, Vahidy AA (2007). Giemsa N- banding pattern in some wild diploid species of *Hordeum*, Pak. J. Bot., 39(2): 421-429.
Jahan B, Vahidy AA (2010). Giemsa N-banding pattern in tetraploid taxa of *Hordeum marinum* Huds, Pak. J. Bot. 42(2): 833-838.
Jahan B, Vahidy AA (2011). Giemsa N- Banding Pattern in *Hordeum murinum*, Pak. J. Bot., 43(5): 2645-2651.
Kochieva EZ, Goryunova SV, Pomortsev AA (2001). RAPD analysis of the genome in species of the genus *Hordeum,* Russ. J. Genet., 37 (8): 905-910.
Löve A (1984). Conspectus of the *Triticeae*. Feddes Rep. 95: 425-521.
Mandaville JP (1990). Flora of eastern Saudi Arabia. Kegan Paul International London and New York jointly with the National Commission for the Wildlife Conservation and department Riyadh, pp.1-482.
Mavi DO, Doğan M, Cabi E (2011). Comparative leaf anatomy of the genus *Hordeum* L. (Poaceae), Turk. J. Bot., 35: 357-368
Melderis A (1985). *Hordeum* L. Flora of Turkey. In. Davis, P. H. (ed.). Edinburgh University Press. Great Britain, 9: 262-269.
Mizianty M (2006). Variability and structure of natural populations of *Hordeum murinum* L. based on morphology, Plant Syst. Evol., 261: 139-150.
Ourari M, Ainouche A, Coriton O, Huteau V, Brown S, Misset MT, Ainouche M, Amirouche R (2011). Diversity and evolution of the *Hordeum murinum* polyploid complex in Algeria. Genome, 54: 639–654.
Provan J, Russell JR, Booth A, Powell W (1999). Polymorphic chloroplast simple sequences repeat primers for systematic and population studies in the genus *Hordeum*, Mol. Ecol., 8: 505-511.
Rajhathy T, Morrison JW (1962). Cytogenetic studies in the genus *Hordeum.* 6. The *murinum* complex, Canad J. Genet. Cytol., 4: 240-247.
Rohlf JF (1988). NTSYS-pc-numerical taxonomy and multivariate analysis. New York.
Sahebi J, Rahiminejad MR, Ghahreman A (2004). A Taxonomic review of the *Hordeum marinum* Sensu Lato (Poaceae: Triticeae) In Iran, Iranian J. Sci. Technol., 28: (A1) 127-135.
Sardou MA, Baghizadeh A, Tavasoli A, Babaei S (2011). The use of microsatellite markers for genetic diversity assessment of genus *Hordeum* L. in Kerman province (Iran), Afr. J. Biotechnol., 10(9): 1516-1521.
Sneath PH, Sokal RR (1973). Numerical taxonomy. Freeman. San Francisco,pp. 573.
Stace C (1997). New flora of the British Isles 2nd edition. Cambridge University Press, pp 894-897.
Täckholm V (1974). Students' Flora of Egypt (2nd edition). Published by Cairo University. pp. 1-888.
Tanno K, Bothmer R, Yamane K, Takeda K, Komatsuda T (2010). Analysis of DNA sequence polymorphism at the cMWG699 locus reveals phylogenetic relationships and allopolyploidy within *Hordeum murinum* subspecies. Hereditas, 147: 34–42.
Zohary D, Hopf M (1988). Domestication of plants in the old world. Clarendon Press. Oxford, p.56.