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Taxonomic studies in Eremopyrum (Poaceae)

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Eremopyrum (tribe Triticeae) is revised and 4 species are recognized: *E. triticeum* (2n = 14), *E. orientale* (2n = 28), *E. distans* (2n = 14) and *E. bonaepartis* (2n = 14, 28). A key and maps showing the distribution of the species are presented. The relationships within *Eremopyrum*, including the origin of the tetraploids, and the relationships between *Eremopyrum* and other genera of the Triticeae are discussed.

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Introduction

Eremopyrum (Ledeb.) Jaub. & Spach, tribe Triticeae Dumort., includes annual species only. They are widely distributed in dry areas from Morocco in the West to western China in the East. *Eremopyrum* belongs to a group of genera with 1 spikelet per node and for that reason it was earlier included in *Triticum* L. or *Agropyron* Gaertner s. lat., often in a section including the perennial crested wheatgrasses (*Agropyron* s. str.) as well (Koch 1848; Ledebour 1853).

Eremopyrum is a well-defined genus but there has been no general agreement concerning the number of species. 18 species-epithets have been published for taxa which undoubtedly belong to the genus and the number of species accepted varies from 4 or 5 (cfr. Tzvelev 1976; Sakamoto 1979) to 9 (Löve 1984). Besides, a large number of subspecific taxa have been proposed and several taxa, which obviously not belong to the genus, are sometimes included in *Eremopyrum*. Thus, a revision is strongly needed.

Material and methods

Material from the following herbaria was studied: BC, BOLO (photo of type specimen of *Hordeum hirsutum* Bertol.), C, E, G, GOET, JE, K, LD, LE, M, MPU, P, TUB, U, W. A list of material studied is kept in C and will be sent on request.

Moreover microfiche of Linnaeus' herbarium in LINN (IDC without number) and S (IDC 5075), Smith's herbarium in LINN (IDC 5073), Thunberg's herbarium in UPS (IDC 1036) and Willdenow's herbarium in B (IDC 7440) were consulted. The sub-number of the cited specimens from Willdenow's herbarium is in accordance with the order of the specimens in IDC 7440.

The term paralectotype is used in accordance with Hansen & Seberg (1984).

Measurements were made on herbarium material, on the specimen with the largest, complete spike on each sheath; the fifth spikelet from below was normally measured.

The morphological variation pattern in *Eremopyrum bonaepartis* (Sprengel) Nevski was analysed both using a scatter diagram and a Wells distance diagram (Wells 1980) modified according to Seberg (1989a). These analyses included 50 collections (Appendix 1). The reference points of a Wells distance diagram have to be based on homogeneous populations or taxa (often "pure" species). In the present investigation the reference points were defined by selecting 10 specimens from each of the 2 morphologically most divergent taxa that are here included in *E. bonaepartis*. This method was chosen as all the supposed taxa are sympatric and as the variation range published in floras (Bor 1968, 1970;

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Tab. 1. Characters used to separate taxa included in *Eremopyrum bonaepartis*.

1. Spikelet length (cm)
2. Spikelet width (cm)
3. Florets number per spikelet
4. Glume length (mm, accurate to 0.5 mm)
5. Glume awn, length (mm, accurate to 0.5 mm)
6. Lemma length (mm, accurate to 0.5 mm)
7. Lemma awn, length on lowest lemma (mm, accurate to 0.5 mm)

Melderis 1985), to a large extent were based on the same specimens as included in the present investigation. All characters traditionally used to separate the taxa were included (Tab. 1), except indumentum characters, which were omitted as they are difficult to quantify and seem to show a large variation within the same taxon.

Anatomic observations on glumes were made on hand-sectioned material in the middle of the body of the glume.

Live material (Tab. 2) was grown in greenhouse at the Botanical Garden, University of Copenhagen. Voucher specimens of cultivated material will be kept at C.

Mitotic preparations were made according to Frederiksen (1986). Chromosome numbers given in the literature are omitted, unless the identity of the material is unquestionable.

Relationships between Eremopyrum and other genera in the Triticeae

Eremopyrum triticeum (Gaertner) Nevski was proposed as one of the parents of the allotetraploid *Triticum spelta* L. based on morphological characters observed in *T. spelta* but not in the other hypothetic parent, *T. monococcum* L. (McFadden & Sears 1946). The theory was later rejected, especially because of the telocentric chromosomes found in *Eremopyrum*, but never in cultivated wheat (Sarkar 1958).

Another early hypothesis about relationships between *Eremopyrum* and species from other genera was expressed by Avdulov (1931). He regarded *E. orientale* (L.) Jaub. & Spach as an allotetraploid originated from diploid *E. triticeum* and probably diploid *Agropyron* s. str. His idea was based on the fact that all chromosomes of *E. triticeum* are telo- or subtelocentric, while both telocentric and meta- or submetacentric chromosomes exist in *E. orientale*. Sarkar (1955, 1958) and Schulz-Schaeffer & Jurasits (1962) supported this theory. Later studies have shown the other diploid members of *Eremopyrum* to possess both types of chromosomes (Sakamoto & Muramatsu 1965) and thus it is not necessary to assume species from other genera to be involved in the speciation of *Eremopyrum*. Moreover, artificial hybrids between *Eremopyrum* and different perennial species are found to sustain perenniality (Sakamoto 1967, 1974).

Only few attempts of intergeneric hybridization with *Eremopyrum* are reported. Sakamoto (1967) mentioned crossings with *Triticum* to be unsuccessful, but did not indicate which species he used. Successful attempts including the following species are reported: *Agropyron tsukushiense* (Honda) Ohwi (6×), *Aegilops squarrosa* auct. non L. (2×), *Henrardia persica* (Boiss.) C. E. Hubb. (2×), *Heteranthelium piliferum* (Banks & Soland.) Hochst. (2×), *Hordeum depressum* (Scribn. & Sm.) Rydb. (4×) and *Taeniatherum caput-medusae* (L.) Nevski (2×). The chromosomes at metaphase I in the PMCs of the hybrids always showed univalents as the absolutely most common configuration (Sakamoto 1967, 1968, 1972, 1974; Frederiksen & Bothmer 1989); the bivalents recorded in *Eremopyrum* × *Hordeum depressum* was ascripted to autosyndesis of the *Hordeum* chromosomes (Sakamoto 1974). Thus, the genome of *Eremopyrum* is distinct at least from the genomes involved in the hybrids mentioned and Löve (1984) classified it as the F haplome.

Morphologically *Eremopyrum* looks similar to *Agropyron* s. str. They are often supposed to be close relatives (Clayton & Renvoize 1986) and, as a consequence, they were earlier included in the same genus, but modern authors prefer to distinguish between the annual *Eremopyrum* and the perennial *Agropyron*. According to Kellogg (1989) *Eremopyrum*, *Agropyron* s. str., *Crithodium* Link (the diploid part of *Triticum* including *T. monococcum*), *Dasypyrum* (Cosson & Durieu) T.

Tab. 2. Origin, chromosome number and source of live material of *Eremopyrum*. * Counted by Sakamoto & Muramatsu (1965), Sakamoto (1979) or Sakamoto unpublished; ** Podlech unpublished.

Species and acc. no	2n	Origin	Source
E. triticeum H 5553	14*	Turkey, 12,3 km SW from Kars to Erzurum	Sakamoto 82–8–7–2–4
E. orientale H 5555	28*	Iran, Ardabil-Tabriz	Sakamoto 7566/1955
E. orientale H 7719	28	China, Xinjiang, 11 km SW of Urumqi	coll. Baden & Salomon
E. bonaepartis H 5551	14*	Iran, Esfahan	Sakamoto 7563/1955
E. bonaepartis H 3131	28**	Afghanistan, Herat, road Herat to Thoraghundi	Podlech 29528/1977
E. bonaepartis H 5554	28*	Iran, Marand-Tabriz	Sakamoto 7564/1970
E. distans H 5552	14*	Iran, Mianeh-Zanjan	Sakamoto 7565/1970

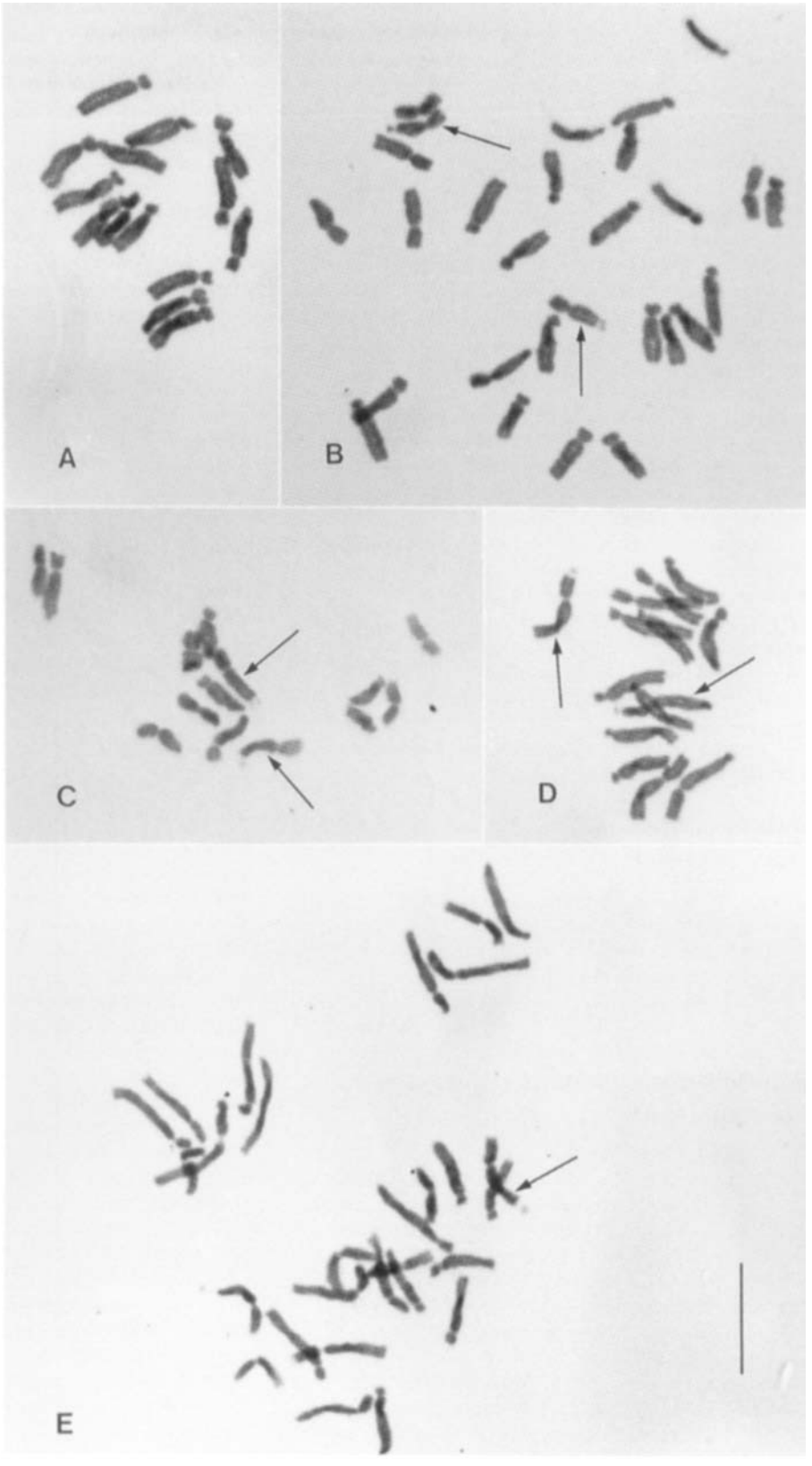


Fig. 1. Somatic metaphases of *Eremopyrum*. – A: *E. triticeum* (H 5553), 2n = 14. – B: *E. orientale* (H 5555), 2n = 28. – C: *E. distans* (H 5552), 2n = 14. – D: *E. bonaepartis* (H 5551), 2n = 14. – E: *E. bonaepartis* (H 5554), 2n = 28. – Arrows indicate SAT-chromosomes. – Bar: 10 μm.

Durand and *Australopyrum* (Tzvelev) Löve seem to represent the only diploid genera of the tribe with keeled glumes. However, keeled glumes are without doubt two different character states, as the glumes are 2-keeled in *Dasypyrum* and *Crithodium*, and 1-keeled in *Agropyron, Eremopyrum* (Frederiksen in press) and *Australopyrum*. Kellogg's cladogram (1989) is based on few characters only, thus, a reexamination could probably demonstrate a closer connection between *Agropyron* and *Eremopyrum*.

Contrary to the meta- or submetacentric chromosomes usually found within the Triticeae, and consequently too in *Agropyron* s. str. (Schulz-Schaeffer & Jurasits 1962), the chromosomes of *Eremopyrum* are predominantly telo- or subtelocentric. Because of this peculiarity *Henrardia* C. E. Hubb. is a genus of interest when the relationships of *Eremopyrum* are discussed. Based on morphology *Henrardia* is sometimes included in *Aegilops* L. s. lat. (Kellogg 1989). Nevertheless, the very special spike morphology with the spikelets embedded in the rachis and protected by the coreaceous glumes could be a matter of convergence as it is also known in *Parapholis* C. E. Hubb., a genus definitely not included in the Triticeae (cfr. Hubbard 1946). Besides in *Eremopyrum*, a considerable number of telocentric chromosomes are only found in *Henrardia* and in a few species of *Aegilops*. In *Henrardia* all chromosomes are telocentric (Sakamoto & Muramatsu 1965), in *Aegilops* always less than half of them are telocentric, the rest being meta- or submetacentric as all chromosomes in most species of *Aegilops* (Chennaveeraiah 1960). As telocentric chromosomes are uncommon within the Triticeae and unknown in the genera found most plesiomorphic by Kellogg (1989), they are considered as the advanced character state (versus metacentric chromosomes). Thus, the chromosome morphology form an argument against including *Henrardia* in *Aegilops* and favours a close connection with *Eremopyrum* in spite of the deviating morphology.

Relationships among the species of Eremopyrum

The diploid species of *Eremopyrum*, viz. *E. triticeum* and *E. distans* (K. Koch) Nevski, and the diploid cytotype of *E. bonaepartis* were found to possess chromosomes morphologically deviating from each other (Sakamoto & Muramatsu 1965; Fig. 1A, C, D), and chromosome pairing in the PMCs of hybrids between the diploids were found rather low (Sakamoto 1979).

The exclusively tetraploid species, *E. orientale*, was by Sakamoto (1979) proposed to be an allopolyploid involving *E. distans* and *E. triticeum*. The theory was especially based on the chromosome pairing in PMCs of hybrids between *E. orientale*, and its suggested parents, which always showed about 7 bivalents and 7 univalents (Sakamoto 1979), indicating 2 of the included genomes to be homologous. It is also supported by the number of metacentric chromosomes being the same in *E. distans* and *E. orientale*, while all chromosomes are telocentric in *E. triticeum*, and by the SAT-chromosomes of *E. orientale*, which look similar to the SAT-chromosomes of *E. distans* (Fig. 1B, C).

Morphologically *E. orientale* is a well defined species, which possesses some similarities in common with the proposed parents (e.g. the somewhat hooded glumes as in *E. triticeum* and the densely haired glumes and lemmas as in *E. distans*). In addition, Sakamoto (1979) found the morphology of the spike and spikelets of hybrids between *E. distans* and *E. triticeum* to be very similar to those of *E. orientale*. So, for several reasons *E. orientale* most probably is an allopolyploid.

Sakamoto (1973, 1979) supposed *E. orientale* to be young, as he in Asia found it sympatric with the supposed parents. The total range of the species, nevertheless, indicates *E. orientale* to be rather old, as it is common in North Africa far outside the extension of the supposed parents (Figs 3, 4, 5).

Tetraploid *E. bonaepartis* was likewise by Sakamoto (1979) proposed as an allopolyploid, and the parents were suggested to be *E. distans* and diploid *E. bonaepartis*. Studies of chromosome pairing in PMCs in hybrids between the tetraploid *E. bonaepartis* and the supposed parents showed the same result as found in hybrids between *E. orientale* and its supposed parents and thus favour the theory. Concerning chromosome morphology the same numbers of metacentric chromosomes were found in both supposed parents and twice as many in tetraploid *E. bonaepartis* (Fig. 1C, D, E), thus from this point of view both auto- and allopolyploidization is a possibility. It has been impossible to get a clear idea of number and appearance of the SAT-chromosomes of the tetraploid *E. bonaepartis* (cfr. Sakamoto & Muramatsu 1965; Fig. 1E).

The analysis of Sakamoto (1979) was based on a single collection of diploid *E. bonaepartis* (actually identical with *T. sinaicum* Steudel), which showed a low crossability, possibly preventing some of the crosses to succeed. Thus, hybridization between the supposed parents failed (Sakamoto 1979) and the morphology of a hybrid is for that reason unknown. If tetraploid *E. bonaepartis* really is an allotetraploid, it is hard to understand why no clear morphological discontinuity is observed between the diploid (= *T. sinaicum*) and tetraploid *E. bonaepartis* (cfr. Figs 6, 7) but only between *E. bonaepartis* and *E. distans*.

As the hypothesis of allopolyploidization is mainly based on genome analysis and as the applicability of this method in phylogeny is under dispute (Baum et al. 1987; Kellogg 1989; Seberg 1989b), the origin of tetraploid *E. bonaepartis* still seems obscure and for that reason it was preferred to keep the cytotypes in one species.

The extension of diploid (= *T. sinaicum*) and tetra-

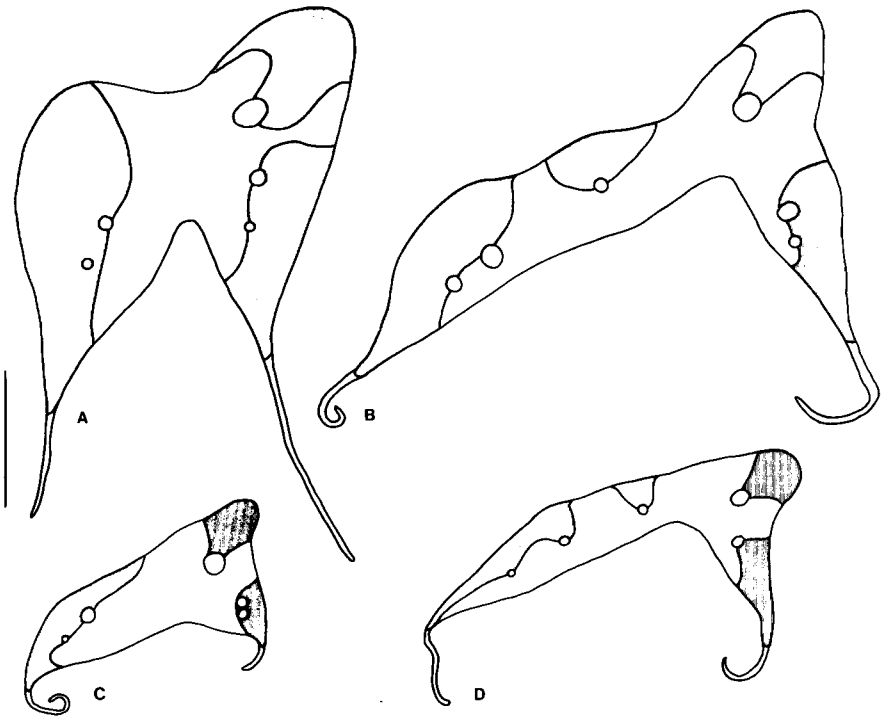


Fig. 2. Cross sections of glumes of *Eremopyrum*. – A: *E. triticeum* (Haussknecht, Tbilisi (JE)). – B: *E. orientale* (coll.?, 12 May 1952. Azerbeidsjan (LE)). – C: *E. distans* (K. H. Rechinger, 57328 (G)). – D: *E. bonaepartis* (Podlech, 31320 (G)). – Sclerenchyma grey hatched. Side near rachis to the right. – Bar: 0.4 mm.

ploid *E. bonaepartis* is found to be sympatric, favouring the junction of the cytotypes, while the extension in North Africa is far outside the area of *E. distans* (Figs 5, 6).

The sections of Eremopyrum

Based on differences in disarticulation of spike and spikelets Nevski (1936) divided *Eremopyrum* into 2 sections. Outgroup comparison (cfr. Kellogg 1989) shows the tough rachis of the only species in section *Micropyron* Nevski (*E. triticeum*) to represent the plesiomorphic character state within the Triticeae, while the fragile rachis of the remaining 3 species in section *Eremopyrum* then represents the apomorphic state.

The inheritance of tough versus fragile rachis have been studied in cultivated barley and fragile rachis is here connected with 2 recessive genes (cfr. Konishi 1987). Moreover, the asiatic *Hordeum bogdani* Wilensky is stated with tough or in some populations with fragile rachis (Bothmer & Jacobsen 1985). Nothing is known about the inheritance within *Eremopyrum* and for that reason the grouping in 2 sections are maintained here.

No differences are observed concerning crossability and chromosome pairing in PMCs of hybrids between the species from the same section and species from different sections (cfr. Sakamoto 1979).

Eremopyrum (Ledeb.) Jaub. & Spach

Ill. Pl. Or. 4: 26 (1851) p.p. – *Triticum* L. sect. *Eremopyrum* Ledeb., Fl. Alt. 1: 112 (1829) p.p. – *Agropyron* Gaertner sect. *pycnopyrum* K. Koch, Linnaea 21: 425 (1848) p.p. – Type: *E. orientale* (L.) Jaub. & Spach. (lectotype, selected by Nevski, Trudy Bot. Inst. Akad. Nauk SSSR, ser. 1, 2: 63 (1936)).

Annuals with flat leaf blades. Young leaf sheaths of innovations connate, but split later. Auricles small or inconspicuous. Spike dense with short internodes and 1 spikelet per node. Spikelets with 2–8 florets. Glumes equal, asymmetrically 1-keeled and normally with membranaceous edges (Fig. 2). Glumes either broad, and mostly with a pointed tip, or slender and gradually tapering into an awn. Nerves discrete, embedded in sclerenchyma (Fig. 2). Lemmas mostly acute-acuminate and often with a more or less distinct awn. Exact measurements of awn and body of glume/lemma are often prevented, as a clear limit between the bract and its awn is lacking. Palea 2-keeled, more or less bifid. Anthers yellow, 0.4–1.4 mm long. Caryopsis at maturity adherent to palea and lemma. On account of the short anthers the species are probably predominantly autogamous.

Chromosomes: *Eremopyrum* includes diploids and tetraploids. The chromosomes are predominantly telo- or subtelocentric and in all the species except *E. triticeum* at least 1 pair of SAT-chromosomes with minute

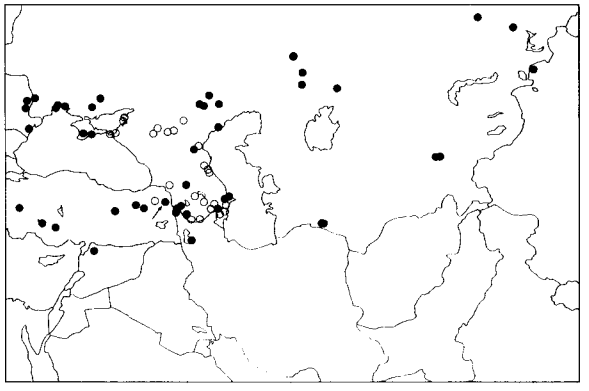


Fig. 3. Distribution of *Eremopyrum triticeum* (dots: studied specimens; rings: specimens cited by Grossheim 1939). Arrow indicates a live collection.

satellites is reported (Avdulov 1931; Sarkar 1955; Sakamoto & Muramatsu 1965; Sakamoto 1979).

Distribution: The distribution of the species are either exclusively Asiatic or nearly so (Figs 3, 5) or Asiatic and North African with a disjunction between Asia and Northwest Africa (Figs 4, 8). The disjunction probably is caused by the very dry climate in the lowlands of Libya and Egypt.

Key to the sections and species of Eremopyrum

1. Spike short, 1.3–2.4 cm long. Rachis tough and rachilla fragile, disarticulating at the base of each floret. Glumes persistent at rachis, strongly curved, hooded, totally 5.0–7.5 mm long, abruptly ending in a short awn, 0.5–2.0 mm long ..... (1. sect. *Micropyrum*) 1. *E. triticeum*
1. Spike usually longer, 1.5–5.4 cm long. Rachis fragile, disarticulating above each spikelet. Rachilla tough. Shape and length of glumes varying. Glumes with or without an awn ..... (2. sect. *Eremopyrum*) 2
2. Palea at least as long as body of lemma, protruding during flowering. Palea with a prominent cleft, 0.6–1.8 mm deep, with acuminate or awned teeth. Glumes and lemmas always densely covered by long hairs. Glumes erect, totally 10.0–20.0 mm long, gradually tapering into an awn, 2.5–10.0 mm long ..... 3. *E. distans*
2. Palea shorter than body of lemma, not protruding. Palea with a low cleft, 0.1–0.8 mm deep, with acute, never awned teeth. Glumes and lemmas glabrous or densely covered by long hairs. Glumes erect or curved, with or without an awn 3
3. Glumes strongly curved, totally 5.5–12.0 mm long, shortly tapering into a short awn, 0.5–3.0 mm long. Glumes and lemmas always densely covered by long hairs. Spikelets somewhat canaliculate ..... 2. *E. orientale*
3. Glumes erect, totally 4.0–19.0 mm long, abruptly ending in or long tapering into an awn 0.0–10.0 mm long. Glumes and lemmas glabrous or densely covered by long hairs. Spikelets flat ..... 4. *E. bonaepartis*

1. Sect. Micropyrum Nevski

Trudy Bot. Inst. Akad. Nauk SSSR 1, 2: 63 (1936). – Type: *E. triticeum* (holotype, the section established as monotypic by Nevski (1936)).

Rachis tough and rachilla fragile. Glumes persistent on the rachis. The spike is sometimes stated to break at the base (cfr. Tzvelev 1976), but at least in culture this is not the case.

1. Eremopyrum triticeum (Gaertner) Nevski

Acta Univ. Asiae Med. ser. 8b, Bot. 17: 52 (1934). – *Agropyron triticeum* Gaertner, Nov. Comm. Acad. Sci. Petropol. 14, 1: 540 (1770). – Type: Gaertner, Nov. Comm. Acad. Sci. Petropol. 14, 1: Tab. 19, Fig. 4 and 5 (lectotype, selected here).

Eremopyrum prostratum (Pallas) Candargy, Arch. Biol. Vég. Pure Appl. 1: 32, 58 (1901). – *Secale prostratum* Pallas, Reise Russ. Reich. 1: 485 (1771). – *Triticum prostratum* (Pallas) L. f., Suppl. 114 (1781). – *Agropyron prostratum* (Pallas) Roemer & Schultes, Syst. Veg. 2: 757 (1817). – *Secale reptans* Pallas, Reise Russ. Reich. 1: 168 (1771) nom. illeg. – Type: Pallas, in desertis Caspiis (LINN 104, 18 lectotype, selected here, JE isolectotype).

Agropyron prostratum var. *biflorum* K. Koch, Linnaea 21: 425 (1848). – Type: K. Koch, upper part of Kur, Gaue Artahan, alt. 5000′–6000′; Eastern Kaukasus, Apscheron, alt 500′–1200′. n.v.

Triticum pumilum L. f., Suppl.: 115 (1781). – *Secale pumilum* Pers., Syn. 1: 109 (1805). – *Agropyron pumilum* P. Beauv., Ess. Agrost.: 146 (1812). – Type: sine coll. & loc. (LINN 104, 20 neotype, selected here).

Glumes and lemmas glabrous or scabrous. Glumes broad (Fig. 2A), firm, hooded, strongly curved, including awn 5.0–7.5 mm long. Awn of glume short, 0.5–2.0 mm long. Lemma including awn 5.5–7.5 mm long. Awn of lemma short, 0.0–1.5 mm long. Apex of palea nearly without a cleft.

Chromosomes: The chromosome number has been reported as $2n = 14$, and the chromosomes to be exclusively telo- or subtelocentric without satellites (Avdulov 1931; Bowden 1959; Schulz-Schaeffer & Jurasits 1962; Sakamoto 1979), in accordance with the observations made here (Fig. 1A).

Distribution: The distribution of *E. triticeum* is mostly Asiatic, extending from the eastern Europe and Turkey in the West to the province Xinjiang in China in the East (Fig. 3). Moreover, the species is reported from the Inner Mongolia (Kuo 1987). Judging from the amount of available material the species appears to be rather uncommon but widespread. It has been introduced to Europe (cfr. Thellung 1912) and to North America (collections from Oregon, Colorado and Nevada (C, LD) are studied), and it is reported as naturalized in the western Canada (Bowden 1959). It has also been collected in Canberra, Australia (C).

Taxonomic remarks: Authentic specimens of the type of *Agropyron triticeum* were searched for in vain. Although details concerning florets are lacking in the figures (Gaertner 1770), the identity is beyond dispute because of the very characteristic spike. Tzvelev (1976)

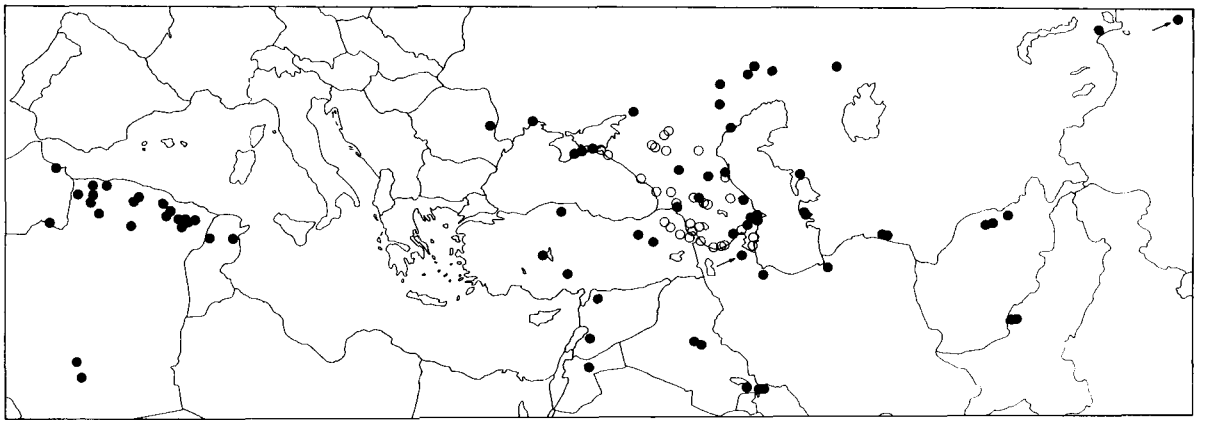


Fig. 4. Distribution of *Eremopyrum orientale* (dots: studied specimens; rings: specimens cited by Grossheim 1939). Arrows indicate live collections.

selected a neotype, as he found the type was not preserved, but he must have overlooked the figures, perhaps owing to the absence of references to them in the text.

No type specimen of *Secale prostratum* was pointed out by Pallas (1771), but the chosen lectotype was annotated by Pallas (cfr. Savage 1945). – The combination *Agropyron prostratum* was used by Palisot de Beauvois (1812), probably for this taxon, but without direct or indirect reference to *Secale prostratum* Pallas. *Secale reptans* was mentioned in a footnote with reference to description 98 (undoubtedly erroneously for description 99) in the supplement (Pallas 1771), which is the description of *S. prostratum*. Thus the name seems to be a synonym finally not accepted by the author.

Type material of *Agropyron prostratum* var. *biflorum* was searched for in vain. It probably has been in B, and then possibly is destroyed (cfr. Lack 1978).

As no material of *Triticum pumilum* with certainty studied by Linné f. seems to exist (cfr. microfiche of Linnaeus', Smith's and Thunberg's herbaria) neotypification was chosen. The selected material does not conflict the protologue of Linné f. (1781) and it is annotated by Smith as *Triticum pumilum* with reference to Linné f. (1781). The typification is in accordance with earlier authors (cfr. Link 1827; Boissier 1881). *Agropyron pumilum* was used by Palisot de Beauvois (1812), probably for this taxon, but without direct or indirect references to *Secale prostratum* L. f.

2. Sect. Eremopyrum

Sect. *Psathyrorhachis*, Nevski Trudy Bot. Inst. Akad. Nauk SSSR 1, 2: 64 (1936) nom. illeg. – Type: *E. orientale* (same type selected by Nevski (1936) for section *Psathyrorhachis*).

Rachilla tough and rachis fragile, disarticulating above each spikelet.

2. Eremopyrum orientale (L.) Jaub. & Spach

Ill. Pl. Or. 4: 27, Tab. 319 (1851). – *Secale orientale* L., Sp. Pl.: 84 (1753). – *Triticum orientale* (L.) M. Bieb., Fl. Taur. – Cauc. 1: 86 (1808). – *Agropyron orientale* (L.) Roemer & Schultes, Syst. Veg. 2: 757 (1817). – *Triticum orientale* var. *typicum* Regel, Act. Hort. Petrop. 7: 588 (1881) nom. illeg. – *Eremopyrum orientale* ssp. *eu-orientale* Maire, Bull. Soc. Hist. Nat. Afrique N. 31: 48 (1940) nom. illeg. – Type: Tournefort 4939, "Gramen secalinum armenium, spica brevi et lata" (P-TO neotype, selected by Bowden 1962: 1701 as lectotype, but not seen by him).

Secale orientale var. *sibirica* Willd., N. Verhandl. Berl. naturf. Freunde 2: 118, Tab. 4, Fig. 3 & 3a (1799). – Type: sine coll. & loc. (B-herb. Willdenow 2321, 2 lectotype, selected here).

Triticum orientale subvar. *macrostachyum* Cosson & Durieu, Expl. Sci. Alg., Phanerog. 2: 205 (1855). – Type: not indicated. – No specimens with this name were found in Cosson's herbarium (P).

Agropyron orientale ssp. *distans* var. *medians* Maire, Bull. Soc. Hist. Nat. Afrique N. 33: 99 (1942). – Type: Sennen et Mauricio 8982, Maroc., Metalza, Aïn Zora, 27 May 1933 (G lectotype, selected here, BC, JE, P isolectotypes).

Glumes and lemmas densely covered by long, white hairs. Glumes rather broad (Fig. 2B), strongly curved, including awn 5.5–12.0 mm long. Awn of glume short, 0.5–3.0 mm long. Lemma acuminate, including awn 5.0–12.0 mm long. Awn of lemma short, 0.5–3.0 mm long. Apex of palea with a low cleft with acute teeth. Spikelet somewhat canaliculate.

Although different taxa on subspecific and lower level were proposed earlier, the variation of the material studied does not support further division.

Chromosomes: The chromosome number has been reported as $2n = 28$, including both telo- and metacentric chromosomes (Schulz-Schaeffer & Jurasits 1962; Sakamoto & Muramatsu 1965; Sakamoto 1979). The report

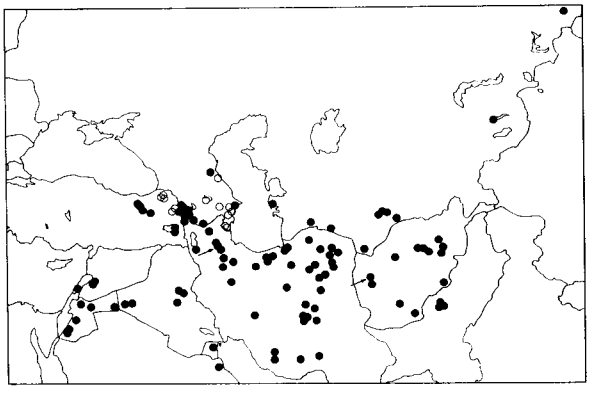


Fig. 5. Distribution of *Eremopyrum distans* (dots: studied specimens; rings: specimens cited by Grossheim 1939). Arrows indicate live collections.

of 2n = 14 (Sarkar 1958) is undoubtedly caused by a misidentification (cfr. Bowden 1962: 1703; Sakamoto 1973: 1). Study of material from China (Tab. 2, H 7719) confirms 2n = 28. 2 pairs of SAT-chromosomes with minute satellites on the short arms were reported by Schulz-Schaeffer & Jurasits (1962). Sakamoto & Muramatsu (1965) too reported 2 pairs of SAT-chromosomes, but with the satellites on the short and the long arm, respectively. This observation is identical with their observation on *E. bonaepartis* and may be due to a misidentification, as the accession number studied later is included in *E. bonaepartis* by Sakamoto (1979). In the material studied here 1 pair of SAT-chromosomes with the satellites on the long arm was observed (Fig. 1B).

Distribution: *E. orientale* is a widespread species, distributed from Morocco in the West to the province Xinjiang in China in the East. Moreover it is reported from the Inner Mongolia (Kuo 1987). It lacks in Libya and Egypt (Fig. 4), but seems very common in North Africa, especially in Algeria.

Taxonomic remarks: Although the description of *Secale orientale* given by Linnaeus (1753) deviates from Tournefort's, no material with certainty studied by Linnaeus seems to exist (cfr. Lindman 1908; Juel 1931, 1936; Savage 1945). As no figures of the species exist in Tournefort (1719) and as no other material is indicated in the protologue, no possible syntypes exist and thus neotypification is necessary.

No specimens of *Secale orientale* var. *sibirica* were cited by Willdenow (1799). The depicted individual (Willdenow 1799: Fig. 3) was found identical with one of the individuals on the cited sheet, but generally no morphological differences between the individuals on the sheet were observed. Although the illustration of the spikelet (Willdenow 1799: Fig. 3a) shows somewhat longer hairs than in typical *E. orientale* (Willdenow 1799: Fig. 3b) the variety is included in *E. orientale*.

3. Eremopyrum distans (K. Koch) Nevski

In Komarov, Fl. URSS 2: 665, Pl. 47a, Fig. 6a–b (1934). – *Agropyron distans* K. Koch, Linnaea 21: 426 (1848). – *Triticum distans* (K. Koch) Walp., Ann. Bot. 3: 782 (1852–53). – *Eremopyrum orientale* ssp. *distans* (K. Koch) Maire, Bull. Soc. Hist. Nat. Afrique N. 31: 47 (1940). – Type: K. Koch 636, Ultra Araxen fluv. apud Amarath, 1838 (LE lectotype, selected here); Armenia apud Archtarak (LE paralectotype n.v.).

Eremopyrum orientale var. *lanuginosum* (Griseb.) Candargy, Arch. Biol. Vég. Pure Appl. 1: 59 (1901). – *Triticum orientale* var. *lanuginosum* Griseb. in Ledeb., Fl. Ross. 4: 337 (1853). – *Agropyron orientale* var. *lanuginosum* (Griseb.) Richter, Pl. Eur. 1: 126 (1890). – Type: Ledebour, Altai (GOET lectotype, selected here, C, K isolectotypes); Claus, in deserto Ross. austr. (GOET paralectotype); K. Koch, prov. Eriwan alt. 3000′ (paralectotype, most likely identical with the type of *E. distans*); Hohenacker, Talüsch (paralectotype n.v.).

Eremopyrum orientale var. *lasianthum* (Boiss.) Candargy, Arch. Biol. Vég. Pure Appl. 1: 33 (1901). – *Agropyron lasianthum* Boiss., Diagn. Pl. Or. ser. 1, 13: 68 (1853). – *Triticum lasianthum* (Boiss.) Steudel, Syn. Pl. Glum. 1: 430 (1854). – *Agropyron orientale* var. *lasianthum* (Boiss.) Boiss., Fl. Or. 5: 668 (1881). – *Triticum orientale* var. *lasianthum* (Boiss.) Asch. & Graebner, Syn. Mitteleur. Fl. 2, 1: 671 (1901). – *Agropyron orientale* ssp. *distans* var. *lasianthum* (Boiss.) Maire & Weiller in Maire, Fl. Afrique N. 3: 312 (1955). – Type: Fischer, Campis Caspiis, 1820 (G lectotype, selected here, JE, sine coll., possible isolectotype); sine coll., Songaria (G paralectotype?).

Agropyron hordeaceum Boiss., Diagn. Pl. Or. ser. 1, 13: 67 (1853). – *Triticum hordeaceum* (Boiss.) Steudel, Syn. Plant. Glum. 1: 430 (1854). – Type: Aucher-Eloy 5422, Aderbidjan (G-herb. Boissier holotype).

Eremopyrum bourgaei (Boiss.) Candargy, Arch. Biol. Vég. Pure Appl. 1: 33, 60 (1901). – *Agropyron bourgaei* Boiss., Fl. Or. 5: 669 (1881). – Type: Bourgeau 717, Armeniae, ad margines agrorum incultorum ad Baibut, 20 Jul 1862 (G-herb. Boissier lectotype, selected here).

Glumes and lemmas densely covered by long, white hairs. Glumes slender (Fig. 2C), including awn 10.0–20.0 mm long. Awn of glume long, 2.5–10.0 mm. Lemma acuminate, including awn 10.0–17.0 mm long. Awn of lemma rather long, 2.0–7.0 mm. Palea as long as body of lemma or longer, protruding during flowering. Palea cleft prominent, 0.6–1.8 mm deep, the teeth often awned.

Chromosomes: The chromosome number has been reported as 2n = 14, including both telo- and metacentric chromosomes, and with 1 pair of SAT-chromosomes with minute satellites on the long arm (Sakamoto & Muramatsu 1965; Sakamoto 1979; Fig. 1C). A report of 2n = 28 (Sarkar 1958) is undoubtedly caused by a misidentification (cfr. Bowden 1962: 1703; Sakamoto 1973: 1).

Distribution: *E. distans* is an Asiatic species, widely distributed from Lebanon and eastern Turkey in the West to Afghanistan and Beluchistan in the East, reaching as far North as the Altai Mountains (Fig. 5). Reports from North Africa (Maire 1955) seem to be based on misidentification, as all material studied here and cited by Maire (1955) belongs to *E. orientale*.

Taxonomic remarks: The only specimen-citation of

Agropyron distans by Koch (1848) is: "prov. Eriwan, ca. 3000'." According to Melderis (1985) the type, in B, is destroyed. However, the citations of Koch (1848) indicate a range rather than a specimen-citation and thus the cited location could easily include several collections from different sites in Eriwan, as e.g. the collections cited above. These collections were earlier mentioned by Tzvelev (1976) as probable syntypes, a point of view which is adhered to here.

The possible paralectotype of *Agropyron lasianthum* is cited "Songaria, Turcz" by Boissier (1853). No collector is given on the available collection, but according to a label, it originates from Boissier's herbarium.

In the herbarium of Boissier two specimens of *Agropyron bourgeai*, Bourgeau 717, exist. The description of the locality and habitat on the sheet is like the locality and habitat given by Boissier (1881) but in French. One of the specimens belongs to *E. distans*, the other to *E. orientale*; the latest is annotated by Boissier as *A. bourgaei*. Nevertheless, according to the protologue the glumes of *A. bourgaei* are lanceolate and long tapering as in *E. distans*, and moreover Boissier (1881) mentions *Agropyron distans* K. Koch as a possible synonym. Consequently, the specimen belonging to *E. distans* was chosen as the lectotype.

4. Eremopyrum bonaepartis (Sprengel) Nevski

Acta Univ. Asiae Med. ser. 8b, Bot. 17: 52 (1934). – *Triticum bonaepartis* Sprengel, Erst. Nachtr. Bot. Gart. Halle: 40 (1801). – *Agropyron bonaepartis* (Sprengel) T. Durand et Schinz, Consp. Fl. Afr. 5: 936 (1894). – *Triticum squarrosum* Roth, Neue Beitr. Bot.: 128 (1802) nom. illeg. – *Agropyron squarrosum* (Roth) Link, Hort. Bot. Berol. 1: 32 (1827). – *Eremopyrum squarrosum* (Roth) Jaub. & Spach, Ill. Pl. Or. 4: 28, Tab. 320 (1851). – *Triticum orientale* var. *squarrosum* (Roth) Regel, Acta Hort. Petrop. 7: 288 (1881). – *Triticum patulum* Willd., Enum. Horti Berol. 1: 134 (1809) nom. illeg. – *Agropyron patulum* (Willd.) Trin., Fund. Agr.: 152 (1820). – *Eremopyrum patulum* (Willd.) Candargy, Arch. Biol. Vég. Pure Appl. 1: 33, 60 (1901). – Type: sine coll. & loc. (B-herb. Willdenow 2335, 1 lectotype, selected here).

Eremopyrum bonaepartis var. *turkestanicum* (Gand.) Tzvelev, Nov. sist. vyssh. rast. 10: 36 (1973). – *Agropyron turkestanicum* Gand., Bull. Soc. Bot. France 60: 420 (1913). – Type: Androssow Herb. fl. Ross. 1899, Turkestan, prov. Merw prope Repetek, 16 Apr 1902 (C lectotype, selected here, G isolectotypes).

Eremopyrum bonaepartis var. *sublanuginosum* (Drobov) Meld. In Rech. f., Ark. Bot. ser. 2, 2: 305: (1952). – *Agropyron orientale* var. *sublanuginosum* Drobov, Tr. Bot. muz. Akad. Nauk, 16: 135 (1916). – *E. bonaepartis* ssp. *sublanuginosum* (Drobov) A. Löve, Feddes Repert. 95: 506 (1984). – Type: A. Zaregradsky, Prov. Syr-Darja, c. urb. Petro-Alexandrowsk, 1914 (LE? n.v.).

Agropyron bonaepartis var. *pilosum* Grossh., Fl. Kavkaza 1: 134 (1928) n.v. – Type?

Eremopyrum squarrosum var. *hirsutum* Candargy, Arch. Biol. Vég. Pure Appl. 1: 33, 59 (1901). – Type: Balansa, Pl. d'Orient, Plaine de Césare (Cappadoce), 1107 m, 29 Jun 1856 (P holotype, G-herb. Boissier isotype).

Triticum squarrosum subvar. *macrostachyum* Cosson & Durieu, Expl. Sci. Alg., Phanerog., 2: 206 (1855). – Type: not indicated. – No specimens with this name were found in Cosson's herbarium (P).

Secale pungens Pers., Syn. 1: 108 (1805). – Type: not indicated.

Eremopyrum hirsutum (Bertol.) Nevski, Acta Univ. Asiae Med. 8b, Bot. 17: 52 (1934). – *Hordeum hirsutum* Bertol., Nov. Comm. Acad. Sci. Inst. Bonon. 5: 421, Tab. 40, Fig. 5, 6 (1842). – *E. bonaepartis* ssp. *hirsutum* (Bertol.) Meld., Notes Roy. Bot. Gard. Edinburg 42: 81 (1984). – *E. bonaepartis* var. *hirsutum* (Bertol.) Grossh., Fl. Kavkaza 1: 343 (1939). – *E. bonaepartis* f. *hirsutum* (Bertol.) Bowden, Canad. J. Bot. 40: 1703 (1962). – Type: Chesney's Exped., Pl. Sicc. 196, Euphr., ex oris Euphratis, 1837 (BOLO lectotype, selected here, G, K, LD, P isolectotypes).

Eremopyrum kotschyanum (Boiss.) Candargy, Arch. Biol. Vég. Pure Appl. 1: 33, 59 (1901). – *Agropyron kotschyanum* Boiss., Diagn. Pl. Or. ser. 1, 13: 69 (1853). – *Triticum kotschyanum* (Boiss.) Steudel, Syn. Pl. Glum. 1: 346 (1854). – *Agropyron squarrosum* var. *kotschyanum* (Boiss.) Hackel in Stapf, Denkschr. Acad. Wiss. Wien 50, 2: 11 (1885). – Type: Kotschy 12, ad Teheran, 1843 (G-herb. Boissier lectotype, selected here, G, K, P, TUB isolectotypes); Aucher-Eloy 2970, Persia, 1837 (G-herb. Boissier, G, P paralectotypes).

Eremopyrum confusum Meld. in Rech. f., Anz. math.-nat. Oesterr. Akad. Wiss.: 15 (1964) – Type: Haines 705, Iraq, Nokheib 70 km along Kebate Rd., 15 Apr 1961 (K holotype, E isotype).

E. confusum var. *glabrum* Meld. in Bor, Taxon 16: 68 (1967). – Type: Haines 1930, Iraq, Nokheib, 15 Apr 1961 (K holotype, E isotype).

E. confusum var. *pakistanicum* (Meld.) Meld. in Bor, Taxon 16: 68 (1967). – *Eremopyrum bonaepartis* var. *pakistanicum* Meld. in Bor, Grass. Burm. Ceyl. Ind. Pak.: 697 (1960). – Type: Norris 65a, Pakistan, Quetta, 5 May 1956 (K holotype, E isotype).

Agropyron biforme Figari & de Notaris, Mem. Reale Accad. Torino ser. 2, 12: 260 (1852). – Type: Figari, Sinai, 1849 (E holotype).

Triticum sinaicum Steudel, Syn. Pl. Glum. 1: 346 (1855). – *Dasypyrum sinaicum* (Steudel) Candargy, Arch. Biol. Vég. Pure Appl. 1: 35, 62 (1901). – Type: Schimper 157, Bastan ad radices montis Sinai, 1835 (P ex herb. Steudel lectotype, selected by Frederiksen (1991)), G, G-herb. Boissier, K, M, P, TUB paralectotypes).

Glumes and lemmas glabrous, scabrous or with a more or less dense cover of white hairs. Glumes broad but remarkable asymmetrical (Fig. 2D), erect, truncate-acuminate, including awn, 4.0–19.0 mm long. Awn of glume 0.0–6.0 mm long. Lemma truncate-acuminate, including awn 6.0–24.0 mm long Awn of lemma 0.0–6.0 mm long, sometimes the lowest 1–2 lemmas blunt, the upper with a distinct awn. Apex of palea with a low cleft, teeth without awns.

Analysis of morphological variation in E. bonaepartis: *E. bonaepartis*, as here defined, is morphologically rather variable, and includes 3 groups, earlier by different authors accepted as species: *E. confusum*, *E. bonaepartis* s. str., and a morphologically rather distinct part of *E. bonaepartis* named *Triticum sinaicum* by Steudel (1855). Typical *E. confusum* is characterized by glumes and lemmas having long awns, contrary to typical *E. bonaepartis*, which has awnless but sharp-pointed glumes and lemmas. *Triticum sinaicum* deviates from typical material of *E. bonaepartis* as the glumes and the lower 1–3 lemmas are blunt, while the upper lemmas have a distinct awn. In spite of these differ-

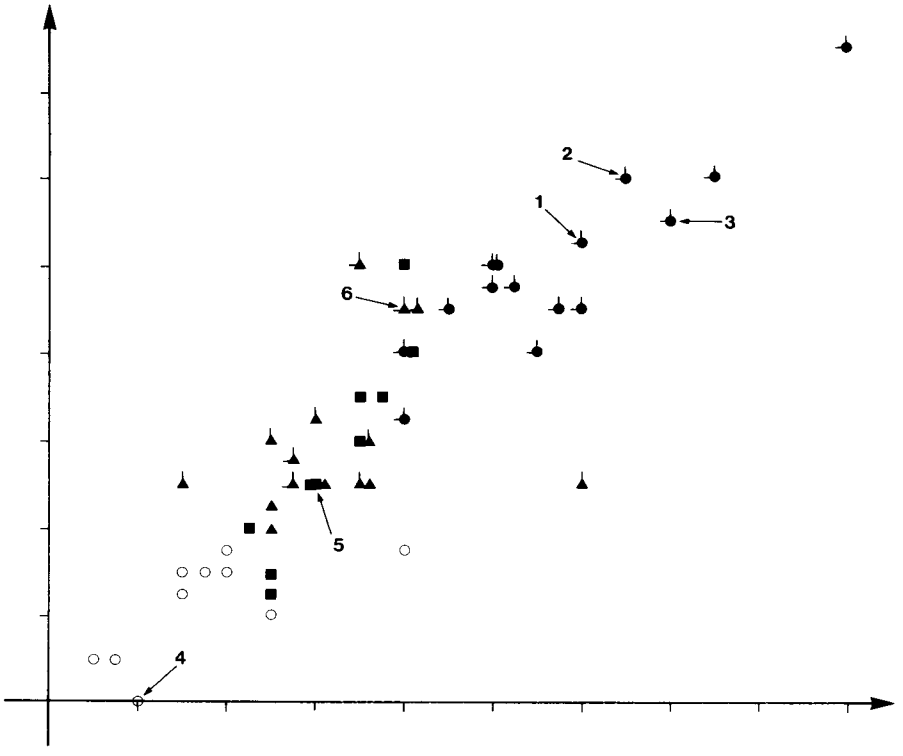


Fig. 6. Scatter diagram of taxa (50 collections) included in *Eremopyrum bonaepartis*: – dots: *Eremopyrum confusum*; rings: *Triticum sinaicum*; squares: *E. bonaepartis* s. str.; triangles: intermediary specimens. – X-axis: lemma length in mm. – Y-axis: glume length in mm. – Horizontal line: glume awn present. – Vertical line: lemma awn present on the lowest lemma. Although not recorded, all specimens of *T. sinaicum* possess awn on the upper lemmas. – Figures 1–6 refer to the type collections of the following taxa: – 1: *E. confusum* var. *pakistanicum*; 2: *E. confusum* var. *confusum*; 3: *E. confusum* var. *glabrum*; 4: *Triticum sinaicum*; 5: *E. kotschyanum*; 6: *E. hirsutum*.

ences, studies of nearly 400 different collections representing all 3 types have shown many collections difficult to determine, as they are intermediary concerning one or more characters of spike and spikelets.

Material morphologically in agreement with the description of *E. confusum* is found to be tetraploid (A 230 as *E. bonaepartis* in Podlech & Dieterle 1969: 190). Typical *E. bonaepartis* is predominantly tetraploid, but some few diploids are observed (Sakamoto 1979), while *Triticum sinaicum* is always diploid (Sakamoto 1979).

In order to demonstrate possible morphological discontinuities between the groups discussed above, 50 collections (Appendix 1) were randomly chosen among material corresponding to: *E. confusum* (15 collections), *E. bonaepartis* s. str. (10 collections), *Triticum sinaicum* (10 collections), and finally 15 collections of the apparently intermediary material were added. Based on character 4 and 6 (Tab. 1), and the existence of glume and lemma awn, a scatter diagram was constructed (Fig. 6). No distinct differences were found between the suggested morphological groups, which most likely seem to be different parts of a continuously variating entity.

In order to consider more characters, a modified

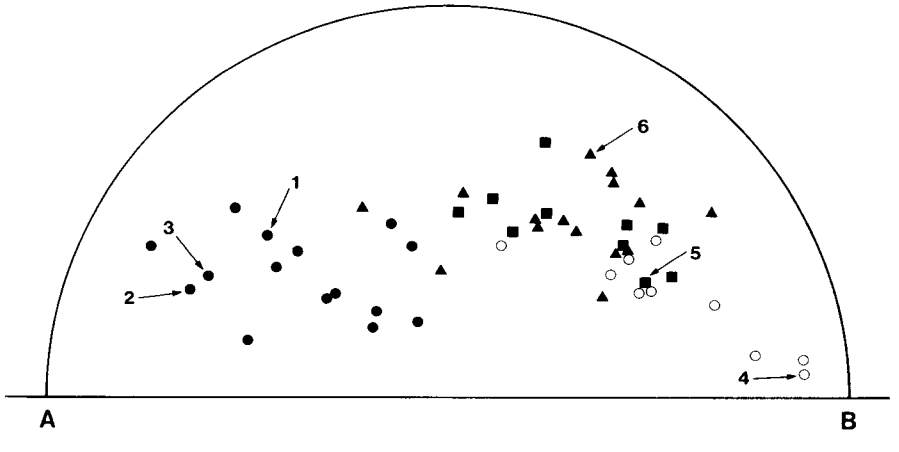


Fig. 7. Wells distance diagram of taxa (50 collections) included in *Eremopyrum bonaepartis*. – A and B: reference points. – For further explanation of signs and figures see Fig. 6.

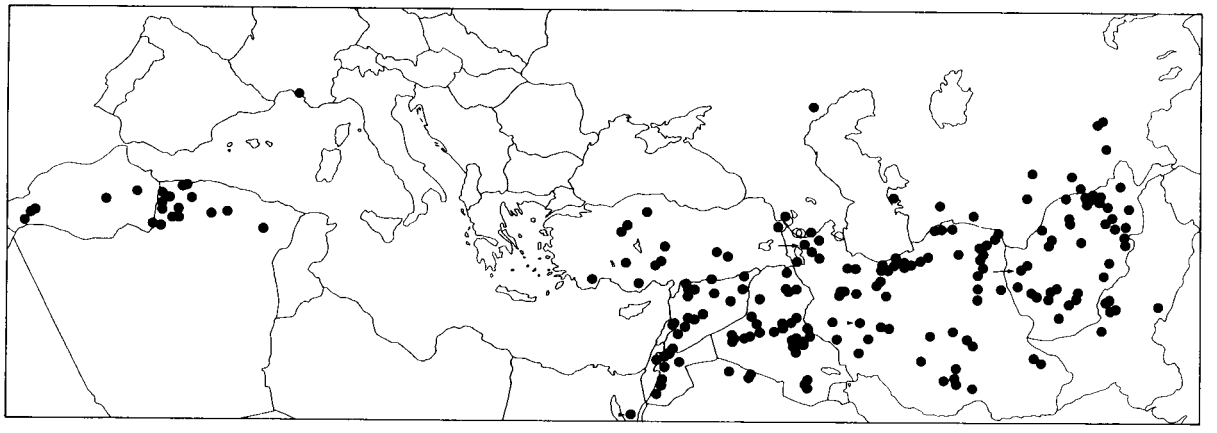


Fig. 8. Distribution of *Eremopyrum bonaepartis* (dots: studied specimens; rings: specimens cited by Grossheim 1939). Arrowheads indicate live collections of diploid specimens, arrows indicate live collections of tetraploid specimens.

Wells diagram (Wells 1980; Seberg 1989a) was constructed, based on the same individuals but including 7 characters (Tab. 1, Appendix 2). The distance diagram (Fig. 7) shows specimens of *E. confusum* in the one and specimens of *T. sinaicum* in the other half of the semicircle, which is in accordance with the criteria used in the selection of the reference points. When adding the remaining collections, the diagram shows the studied specimens to be regularly scattered between the 2 reference points. As the diagram was expected to show 1 or more discontinuities, if the analysis includes 2 or more species, the study supports uniting the taxa into one species (Fig. 7).

As the distribution of the 3 groups is found sympatric, not even a splitting on subspecific level is suggested.

Chromosomes: Both diploid ($2n = 14$) and tetraploid ($2n = 28$) populations exist, and both telo- and metacentric chromosomes were observed (Sakamoto & Muramatsu 1965; Podlech & Dieterle 1969; Kliphuis & Barkoudah 1977; Sakamoto 1979). In the diploid cytotype 1 pair of SAT-chromosomes with a minute satellite on the short arm is reported (Sakamoto & Muramatsu 1965; Fig. 1D). In the tetraploid cytotype 2 pairs of SAT-chromosomes are reported with the minute satellites on the short and the long arm respectively, but they are found difficult to observe (Sakamoto & Muramatsu 1965; Fig. 1E). $2n = 42$ was reported by Schulz-Schaeffer & Jurasits (1962), but as the idiogram published shows no telocentric chromosomes at all, the count obviously is not based on material of *Eremopyrum*; unfortunately it has not been possible to study the voucher specimen.

Distribution: *E. bonaepartis* is widely distributed and apparently the most common of the species. It is collected from Morocco in the West to Afghanistan and Beluchistan in the East, but it lacks in Tunesia, Libya and Egypt (Fig. 8). The few collections from Europe (most of them not indicated on the map) are probably introduced.

Taxonomic remarks: Sprengel (1801) clearly indicate his work to be a survey of new plants in the Botanical Garden of Halle, thus the description of *Agropyron bonaepartis* is probably based on cultivated material originating from Egypt, as also mentioned by Melderis (1985). Sprengel's herbarium has most likely been destroyed (Stafleu & Cowan 1986). In the herbarium of Willdenow 2 sheaths exist annotated as *Triticum bonaepartis*. On the cover a label with the text: "Sprengel W" seems to indicate that they were received from Sprengel and thus most likely are isotypes. No origin is reported. According to Tzvelev (1976) probable isotypes without mentioning of origin are in LE too. One of these was studied and it undoubtedly belongs to the same taxon as the material in B. According to Roth (1802) *Triticum squarrosum* is identical with *T. bonaepartis*, and according to Willdenow (1809) *T. patulum* is identical with *T. squarrosum*.

The type of *Agropyron orientale* var. *sublanuginosum* was apparently not studied by Melderis (1952). According to Tzvelev (1976) this variety is identical with *Hordeum hirsutum* Berol.

According to Grossheim (1939) *Agropyron bonaepartis* var. *pilosum* is identical with *Hordeum hirsutum* Bertol. Tzvelev (1976) suggests it to be a hybrid between *E. bonaepartis* and *E. distans*.

Persoon (1805) with some hesitation connects *Secale pungens* with *Triticum squarrosum* Roth and later authors bring it as a synonym to this taxon (Willdenow 1809; Jaubert & Spach 1851).

Some of the studied type collections of *Hordeum hirsutum* are mixed, and include both individuals with glabrous glumes and lemmas, and individuals with long hairs on the glumes and lemmas. Tab. 40, Fig. 6 in Bertoloni (1842) clearly illustrates the last mentioned form, which is too in accordance with the herbarium

material (BOLO), on which the Table obviously is based.

Collections made by Figari from Sinai of either *Eremopyrum* or *Agropyron biforme* were asked for in vain in FI and GE. The species without doubt belongs to *Eremopyrum*, and by Figari & Notaris (1852) only some minor differences are pointed out separating it from *Triticum squarrosum* (= *E. bonaepartis*). No other collections, which can be identified as *Eremopyrum*, is mentioned by the authors. The collection pointed out as type originates from FI, and is signed by Figari. It is annotated as *A. cristatum*, but apparently not by Figari, *A. cristatum* was not mentioned by Figari & Notaris (1852).

Dubious taxa

Unfortunately, no type material seems available of the taxa below, and a conclusive identification is impossible on account of the descriptions. Nevertheless, they undoubtedly belong to *Eremopyrum*.

Triticum orientale var. *lanuginosum* f. *subacaule* Kuntze, Act. Hort. Petrop. 10: 256 (1887). – Type: Kuntze, Turkmenien. n.v.

Triticum orientale var. *lanuginosum* f. *subuniflorum* Kuntze, Act. Hort. Petrop. 10: 256 (1887). – *Agropyron orientale* var. *subuniflorum* Kuntze ex B. Fedtsch., Bull. Jard. Bot. Pierre Grand 14, Suppl. 2: 97 (1915). – Type: Kuntze, Schamkor n.v.

Triticum orientale var. *ciliatum* Kuntze, Act. Hort. Petrop. 10: 255 (1887). – *Agropyron bonaepartis* (Sprengel) T. Durand & Schinz var. *ciliatum* (Kuntze) Rosch. in B. Fedtsch., Fl. Turkm.: 186 (1932). n.v. – Type: Kuntze, Turkmenien n.v.

Excluded taxa

Eremopyrum cretense (Coustur. & Gand.) Nevski, Acta Univ. Asiae Med. 8b, Bot. 17: 52 (1934). – *Agropyron cretense* Coustur. & Gand. in Gand., Fl. Cret.: 107 (1916).

E. cretense is included as a synonym of *Elymus delileanus* Schultes (= *Crithopsis delileana* (Schultes) Rosch.) by Rechinger (1943) and moreover *Eremopyrum* s. str. has never been reported from Crete (cfr. Melderis 1980).

Eremopyrum olgae (Regel) Candargy, Arch. Biol. Vég. Pure Appl. 1: 33, 59 (1901). – *Triticum olgae* Regel, Act. Hort. Petr. 7: 588 (1881).

According to the protologue most possibly identical with *Heteranthelium piliferum* (Banks & Soland.) Hochst.

The following taxa are according to the authors perennials, they are thus excluded from *Eremopyrum* and most of them belong to *Agropyron* s. str.

Eremopyrum brownei (Kunth) Candargy, Arch. Biol. Vég. Pure Appl. 1: 34, 62 (1901). – *Triticum brownei* Kunth, Rév. Gram. 1: 145 (1829) n.v.

Eremopyrum bulbosum (Boiss.) Candargy, Arch. Biol. Vég. Pure Appl. 1: 34, 61 (1901). – *Agropyron bulbosum* Boiss., Diagn. Pl. Or. ser. 1, 5: 75 (1844).

Eremopyrum cristatum (Schreb.) Willk. & Lange, Prodr. Fl. Hisp. 1: 108 (1861). – Presumably based on *Bromus cristatus* L., Sp. Pl.: 78 (1753) (cfr. Chase & Niles 1962).

E. cristatum var. *typicum* (Regel) Candargy, Arch. Biol. Vég. Pure Appl. 1: 34, 61 (1901). – *Triticum cristatum* Schreb. var. *typicum* Regel, Act. Hort. Petr. 7: 589 (1881) nom. illeg.

E. cristatum var. *imbricatum* (M. Bieb.) Candargy, Arch. Biol. Vég. Pure Appl. 1: 61 (1901). – *Triticum imbricatum* M. Bieb., Fl. Taur.-Cauc. 1: 88 (1808).

E. cristatum var. *pectinatum* (M. Bieb.) Candargy, Arch. Biol. Vég. Pure Appl. 1: 61 (1901). – *Triticum pectinatum* M. Bieb., Fl. Taur.-Cauc. 1: 87 (1808).

E. cristatum var. *villosum* Willk. & Lange, Prodr. Fl. Hisp. 1: 108 (1861) – based on *Agropyron cristatum* Roemer & Schultes var. *puberulum* Boiss., Diagn. Pl. Or. ser. 1, 13: 67 (1853).

Candargy (1901: 61) subdivided both *E. cristatum* var. *typicum* and var. *pectinatum*. In both varieties he used the epithets pubescens and glabriglume. No diagnosis exist as none of them are included in the key.

Eremopyrum dasyanthum (Sprengel) Candargy, Arch. Biol. Vég. Pure Appl. 1: 34, 62 (1901). – *Triticum dasyanthum* Ledeb. ex Sprengel, Syst. Veg. 1: 326 (1825).

Eremopyrum dasyphyllum (Schrenk) Candargy, Arch. Biol. Vég. Pure Appl. 1: 34, 60 (1901). – *Triticum dasyphyllum* Schrenk, Bull. Sc. Acad. St. Petersb. 10: 356 (1842).

Eremopyrum fibrosum (Schrenk) Candargy, Arch. Biol. Vég. Pure Appl. 1: 34 (1901). – *Triticum fibrosum* Schenk, Bull. Cl. Phys.-Math. Acad. Imp. Sci. Saint-Petersbourg ser. 2, 3: 209 (1845).

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E. sibiricum var. *glabrum* Candargy, Arch. Biol. Vég. Pure Appl. 1: 34, 60 (1901).

E. sibiricum var. *hirsutum* Candargy, Arch. Biol. Vég. Pure Appl. 1: 34, 60 (1901).

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Appendix 1

List of specimens used in constructing the scatter diagram and the Wells distance diagram (the numbers in brackets refer to the numbers in Appendix 2).

Eremopyrum confusum Meld. in Rech.

K. H. Rechinger, 29237 (1; G). – Norris, 65a (2; K). – Podlech, 12812 (3; E). – Wilson, 662 (4; K). – Wilson, 1028 (5; K). – Townsend, 69/181 (6; K). – Threefall, s.n./1889 (7; E). – Olivier, s.n./Orient (8; G-herb. Boissier). – Stewart, 27943 (9; E). – Haines, 705 (10; K). – Rawi, 20892 (11; K). – Rawi & al., 14022 (12; K). – Neustrueva & al., s.n./29 May 1958 (13; M). – Sintenis, 2240 (14; LD). – Haines, 1930 (15; K). – No. 1–10 used in constructing reference point A.

Triticum sinaicum Steudel

Peyron, s.n./16 Apr 1889 (16; G). – Dinsmore, 17040 (17; G). – Bunke, 3906 (18; JE). – Hunting Aero Survey, 171 (19; E). – sine coll., 41660, 12 Apr 1974 (20; K). – Pabot, s.n./1 May 1955 (21; G). – Snogerup & al., 2797 (22; LD). – Schmid, 5658 (23; G). – Schimper, 157 (24; G-herb. Boissier). – Post, s.n./6 May 1886 (25; G). – No. 16–25 used in constructing reference point B.

Eremopyrum bonaepartis (Sprengel) Nevski

Kotschy, 12 (26; G). – Kamelin & al., 728 (27; LE). – Hewer, 1065 (28; K). – Hamid, 39208 (29; K). – Haines, 1931 (30; E). – Grossheim, s.n./21 May 1923 (31; M). – Grey-Wilson & al., 1181 (32; K). – Furse, 7595 (33; K). – Gillet, 15942 (34; K). – Szovitz, s.n./Azerbeidsjan (35; G).

Eremopyrum bonaepartis, intermediary specimens

Hochreutiner, 178 (36; G). – Hewer, H 3794 (37; E). – Trabut, s.n./Apr 1892 (38; G). – Coode & al., 916 (39; E). – Chesney's exp., 196 (40; G). – Bornmüller, 2558 (41; M). – Battandier & al., s.n./Apr 1886 (42; LD). – Balansa, s.n./29 Jun 1856 (43; G-herb. Boissier). – Aitchinson, 561 (44; G-herb. Boissier). – Podlech, 17797 (45; M). – Bowles exp., 2349 (46; K). – Bowles exp., 2131 (47; K). – Kamelin & al., 676 (48; LE). – Haussknecht, s.n./2 Apr 1865 (49; JE). – Kihara, 7038 (50; K).

Appendix 2

Data matrix of the characters used in the construction of the scatter diagram and the Wells distance diagram. OTU numbers refer to Appendix 1. Character numbers refer to Tab. 1.

OTU	Characters							Distance from	
	1	2	3	4	5	6	7	confusum A	sinaicum B
E. confusum									
1	3.5	2.5	4	13	2	15	2	0.42	0.49
2	5.4	2.5	8	14.5	1.5	18	3	0.31	0.68
3	3.0	2.5	4	13	3	17.5	4	0.38	0.54
4	4.5	2.7	4	10.5	2.5	14	3	0.37	0.54
5	4.4	2.6	4	14	2.5	16	3.5	0.34	0.59
6	5.0	3.3	4	13.5	2	16.5	2.5	0.32	0.64
7	4.4	3.0	3	16	5	21	6	0.30	0.72
8	4.2	3.8	4	19	6	24	6	0.21	0.80
9	3.0	2.4	3	14	3	16	5	0.43	0.55
10	5.2	3.3	4	16	5	19	5	0.22	0.75
11	4.5	3.3	5	13	3	18	5	0.23	0.68
12	4.8	2.7	4	13.5	4	16	6	0.29	0.66
13	4.7	2.5	4	12	3	17	4	0.33	0.60
14	4.4	2.6	3	12	2	14	2	0.44	0.52
15	5.0	3.4	4	15	3	20	6	0.22	0.73
T. sinaicum									
16	3.0	2.7	3	7.5	0	14	4	0.54	0.43
17	3.2	2.3	3	7.5	0	10	0	0.65	0.30
18	2.1	1.6	3	5	0	7	0	0.85	0.06
19	2.5	1.7	3	5	0	7.5	0	0.80	0.11
20	3.7	1.7	3	6.5	0	9	0	0.71	0.28
21	2.4	1.6	3	7	0	9.5	0	0.76	0.18
22	2.8	2.2	4	7	0	9	0	0.67	0.26
23	2.7	2.2	3	7	0	10	0	0.69	0.25
24	2.0	1.7	3	4	0	8	0	0.85	0.05
25	2.8	2.5	3	6	0	11	0	0.67	0.29
E. bonaepartis									
26	2.8	1.7	4	8	0	10.5	0	0.68	0.26
27	2.8	1.7	3	7	0	11	0	0.71	0.24
28	3.7	2.6	4	14	0	14	0	0.51	0.49
29	3.2	1.7	3	9	0	12	0	0.67	0.31
30	2.7	1.5	3	9	0	12	0	0.72	0.28
31	3.8	2.5	3	12	0	14	0	0.55	0.46
32	3.8	1.9	5	11	0	13	0	0.56	0.42
33	3.9	2.0	3	10	0	13	0	0.60	0.40
34	4.0	1.7	3	6.5	0	11	0	0.68	0.32
35	3.6	2.5	2	11	0	13.5	0	0.63	0.45
E. bonaepartis intermediary specimens									
36	3.0	2.0	4	8.5	0	11	0	0.63	0.30
37	3.5	2.0	3	10	0	11	0.5	0.68	0.36
38	3.0	1.8	3	9	1	11.5	1	0.67	0.30
39	3.0	2.2	4	14	4	13	2	0.46	0.48
40	2.5	1.9	4	13	1	14	2	0.58	0.40
41	4.0	2.0	2	9	0	13	1	0.67	0.40
42	2.7	1.8	3	9.5	0.5	11	2	0.70	0.32
43	3.2	1.9	3	10	0	13	0.5	0.68	0.37
44	3.4	2.0	3	10.5	0	12	1	0.62	0.36
45	2.7	1.7	3	9	0	9	0.5	0.77	0.26
46	4.2	2.3	3	8	0	11	0	0.61	0.38
47	2.8	2.0	3	9	0	12	0	0.66	0.30
48	2.8	1.8	3	13	3	14	5	0.52	0.49
49	4.2	3.0	4	9	0	18	6	0.41	0.59
50	4.0	2.4	3	9	0	13	0	0.58	0.41