

Notes on the genus *Frailea* (Cactaceae)–diversity, biology, and nomenclatural adjustments

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Summary: The many published names for the genus *Frailea* is a consequence of the high interpopulational diversity. This can be explained by the specific reproduction biology and ecology, in this combination unique within the family Cactaceae. Fraileas can be classified ecologically as stress-tolerant ruderals. The recently published *Frailea mammifera* subsp. *angelesiae* is presented here in detail, and a species from Paraguay, *Frailea alexanderi*, is described here as new to science. Several *Frailea* names are typified here to stabilize use of the names.

Introduction

The genus *Frailea* Britton & Rose (Cactaceae) is a group of small globular to short columnar cacti occurring in S Brazil, Uruguay, NE Argentina, Paraguay and E Bolivia. It was established in 1922 by Britton & Rose, including eight species at that time. An increase of species names happened mainly in the 1970s when several cactus collectors and amateur botanists travelled through South America and published their results of cactus hunting in several cactus journals (Figure 1). 48 valid species names have been published up to 2005, three of them now applied to species of other genera. About 300 names at specific and infraspecific ranks have been published in the cactus literature, name- and trade lists, most of them are invalid or were only provisional names. 217 names at specific and infraspecific ranks are listed by the International Plant Names Index (IPNI, 2005). In a survey of the genus the Dutch cactus collector Prestlé (1997) presents an extreme splitters concept, dividing the genus in 3 subgenera, 8 sections with 27 subsections and 65 species (not to mention umpteen of infraspecific names). In the same publication he published 178 new names—only 13 of them valid. As true for many other genera of the Cactaceae, the number of published names at specific and infraspecific rank is much higher than the number of acceptable taxa, but a modern revision of the genus *Frailea* is still lacking. The most recent checklist compiled by Hunt (1999) accepts only 11 (plus 6 provisionally) species, whereas Anderson (2001, 2005) lists 17 species (Figure 1).

The high number of mostly weakly characterized names, and moreover lacking type material for several taxa are stumble stones on the way to a new revision of the genus. In this paper we try a step towards a new revision by explaining patterns and causes of diversity within the genus, establishing a new name and typifying five names.

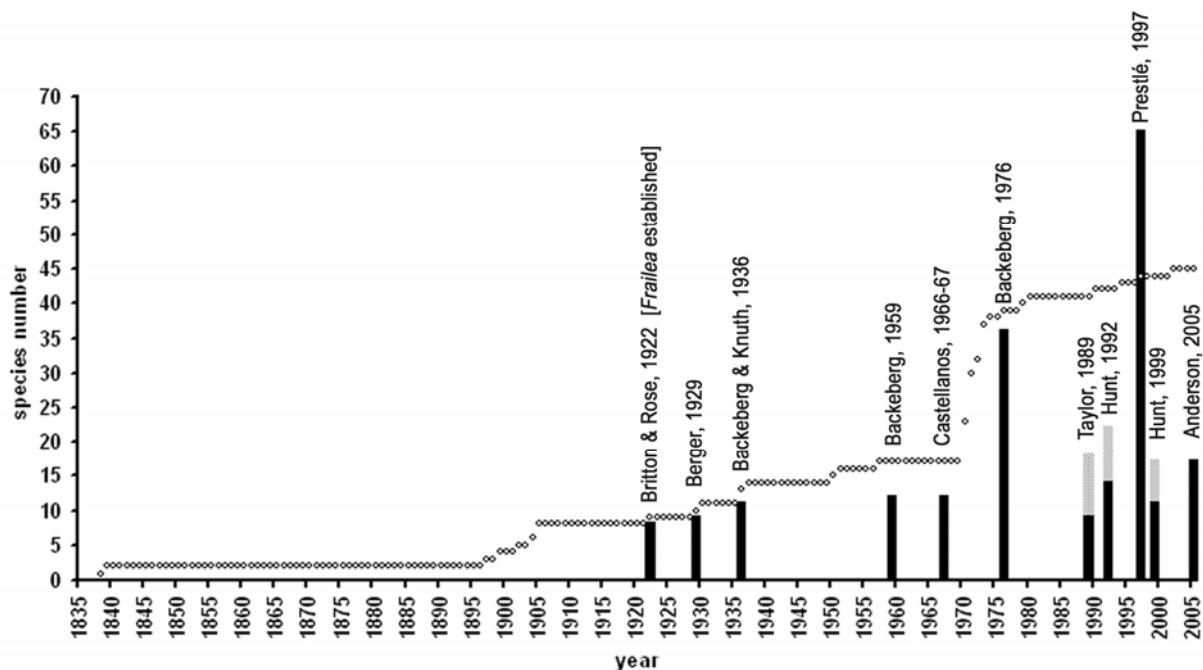


Figure 1. Species numbers in the genus *Frailea*. a) Increase of valid names between 1835 and 2005 (dots), and b) number of accepted (black columns) or provisionally accepted (grey columns) species in selected treatments.

Diversity and biology of *Frailea*

Strecker (1992) studied the diversity of cacti and found for the genus *Frailea* one centre of diversity in the southern part of Rio Grande do Sul (Brazil) and adjacent areas of Uruguay, as a second centre in the low mountain area of SE Paraguay, too. Figure 2 shows the number of species in a degree grid, based on a wide species concept (12 accepted species), but this basal pattern of species diversity would be reflected also by application of a narrow species concept. At least four species has been reported from a third centre of diversity, the low mountains in SE-Bolivia (Sra. de San Jose, Sra, de Santiago). The distribution in the Chaco is certainly underestimated, where only one taxon, *Frailea schilinzkyana* subsp. *concepcionensis* (Buining & Moser) P. J. Braun & Esteves (Synonyms: *Frailea pilzii* Prestlé, nom. inval., *Frailea klinglerana* Prestlé, nom. inval.), grows in the dry forest. One species has been described from Colombia, *Frailea colombiana* (Werdermann) Backeberg, probably from a synanthropic and now extinct population far out from the natural genus range (therefore not indicated in Figure 2).

The recent disjunct area of the genus or particular species, and the restriction to extrazonal habitats indicate rather a wider distribution of *Frailea* in the past, when the climate was more arid after the last glacial period (cf. Pennington *et al.*, 2000; Prance, 1982), than the colonization of suitable patchy habitats by long distance dispersal. .

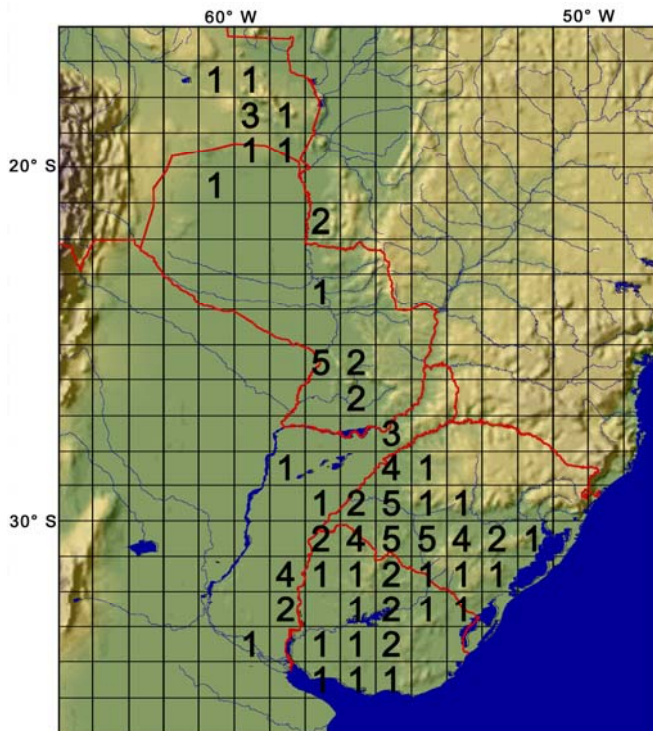


Figure 2. Number of *Frailea* species per degree square in South America.

In nature the morphological similarity within one population of *Frailea* usually is often quite high, whereas different populations often can be distinguished by the overall appearance of the plants: the infrapopulation diversity is usually lower than the interpopulation diversity. This diversity pattern is a result of the reproductive and ecological strategy, which can be characterized by the following traits:

- longevity: the plants mostly have a longevity of only a few years, although some taxa in cultivation can become 15 or more years old.
- cleistogamy: the reproductive behaviour of the genus *Frailea* is characterized by cleistogamy, fruits are developed after self-fertilisation without anthesis (Britton & Rose, 1922: 208; Förster, 1846: 281; Schumann, 1898: 394). This is the main mode of generative reproduction in *Frailea*. Exceptions are some populations from SE Bolivia, e.g. *Frailea chiquitana* Cardenas and *F. larae* R. Vasquez—plants of these taxa show no cleistogamous flowers.
- cross pollination: all *Frailea* species are able to form full developed flowers, too. These flowers are open for a few hours a day only [although flowers opened two days have been observed in cultivation as exception (Köhler, 1968)]. Own observations in cultivation shows high synchronic flowering, which obviously is controlled by sunshine and warm temperatures (cf. Castellanos, 1966–67; Kiesling, 1975), soil moisture and air humidity. Under such conditions nearly all plants of the same cohorte open their flowers at the same day. In nature synchronisation of anthesis increases the pollination success and fruit setting, caused by higher attractiveness to the pollinators and higher probability of pollination (Schlindwein & Wittmann, 1995).
- fruit setting: fruits can be developed early in the live stage, sometimes already in the year after germination. Young plants firstly set fruits from cleistogamous flowers, only later they are able to develop full flowers (Simon, 1966, Pearce, 1978).

- dormancy: the seeds show enforced dormancy, the seeds are able to germinate immediately after fruit ripening, supposed that the environmental conditions (moisture, temperature, light) are sufficient for germination. Seeds may germinate already in the fruit sometimes (Förster, 1846: 301).
- seed longevity: seeds of *Frailea* have a short longevity. Usually the seeds lose their viability after a few months, although there are a few reports of successful sowing (but low germination rates) of few years old seeds (Havlíček, 1996; Hefti, 1996; Pearce, 1978; Rojas-Aréchiga & Vázquez-Yanes, 2000).
- dispersal: seeds are mainly dispersed by ants (synzoochory, short distances) or by floating after heavy rainfall or inundation along rivers (hydrochory, short to medium distances) (cf. Bregman, 1988). Dispersal by anemochory has been discussed, too. Ritter (1980: 477) assumed that the seed shape of *Frailea* is an adaptation to anemochory, which was denied by Bregman (1988). However it can't be excluded that seeds (or even dry berries) can be blown above the ground over more or less short distances. This has been reported already by Hassler (in Schumann, 1903b). The mechanism for occasional long distance dispersal of *Frailea* seeds has not been studied up to now, but epizoochory seems to be most probable (eg. fruits attached to the fells of animals, or seeds in mud adherent the feet of cattle).
- succulence: plants are able to tolerate arid periods of the microclimate (characteristic for nearly all cacti). During dry periods the plants of some species can be sunken into the soil, such reducing water loss by transpiration.
- ecology: most species of *Frailea* are restricted to more or less unproductive extrazonal habitats where moderate disturbances occur frequently, such as rock outcrops within semi-evergreen vegetation and dry forests and grasslands (pampa), or inundation areas of rivers and streams (Castellanos 1966–67; Esser, 1982; Ibisch *et al.*, 1995; Kiesling, 1975; Metzging, 1994; Navarro, 1996; Navarro & Maldonado, 2002: 138).
- isolation: the scattered occurrence of suitable habitats results in more or less small isolated populations and such to restricted gene-flow.

Low diversity within a single population, but comparable high diversity between the populations are results of founder effects and the (at least today) scattered populations of *Frailea*, and are the reason for the creation of the high number of names.

The ecological behaviour of plant species has been characterized by defining three primary ecological strategies (Grime, 1979). Competitors (c-strategy) are competitive plants at constant or predictable habitats with abundant resources (eg. trees), ruderals (r-strategy) grow in habitats with high level of disturbance, but sufficient resources (eg. weeds), whereas stress-tolerators (s-strategy) are adapted to habitats with scarce resources and severe (extreme) conditions (eg. succulents, halophytes). These primary strategies are connected by intermediate strategies (eg. cr-strategy of competitors/ruderals). The adaptation to the different types of habitats is evident in specific anatomical, morphological and ecological characteristics of the plants. Short longevity and life cycle, a high reproduction rate, cleistogamy, low competition and the ability to colonize suitable habitats quite fast characterize r-strategies, whereas succulence and the small plant size are attributes of s-strategies. The species of *Frailea* (at least these with cleistogamy) has to be classified as sr-strategies. The combination of these characters is represented within the Cactaceae only by the genus *Frailea*, although some short living and selfing *Rebutia* species may also be classified as sr-strategies.

A new subspecies of *Frailea mammifera*

Frailea mammifera Buining & Brederoo is distinguished from other *Frailea* species by their distinct tubercles with dark violet spots below the areole (corresponding the podarium), arranged in vertical rows (ribs). The species has been originally described from S Brazil (Buining, 1972), but occurs in NE Argentina, too (Kiesling, 1999; Kiesling & Ferrari, 2005). Whereas the Brazilian population is characterized by the yellow spination, the Argentinian populations have reddish brown spines. Plants from the latter populations are already well presented in private collections in Europe and United States, where it were distributed by seed nurseries under the name “*Frailea angelesii* n. n.”. It has been regarded as a separate species (Knutti & Hefti, 1997; Prestle, 1997b), but no valid description has been published up to now. Comparison with the Brazilian populations of *Frailea mammifera* shows no markable differences in morphology of stem, flower and seeds, thus indicating the close relationship of both population groups. No intermediate populations have become known up to now. The disjunct distribution area, and the good distinguishing characters allow to classify the Argentinian population as a subspecies of *Frailea mammifera*. To make the name available for the new Cactus Lexicon (Hunt, in press), the formal description without illustrations has been published recently by us (Kiesling & Metzger, 2006). A more detailed description will be given here.

***Frailea mammifera* Buining & Brederoo**, in H. Krainz: *Die Kakteen*, Liefg. CVIe. 1972.

Type: Brazil, Rio Grande do Sul, N of Dom Pedrito, L. Horst & W. Uebelmann *HU* 345, 250 m [ZSS! (holo), B!, U!]. Further studied material: Brazil, Dom Pedrito, Norbert Gerloff *Gf* 223 (living material).

1 Spines yellow, spine surface with elongated tubercles (“hairy”), floral areoles with pure white felt and yellowish bristles. Distribution: S Brazil, Rio Grande do Sul, near Dom Pedrito

Frailea mammifera* subsp. *mammifera

1* Spines reddish brown, spine surface smooth, floral areoles with whitish grey felt and reddish brown bristles. Distribution: NW Argentina, Prov. Entre Rios, Concordia.

Frailea mammifera* subsp. *angelesiae

Frailea mammifera* subsp. *angelesiae R. Kiesling & Metzger, *Cactaceae Syst. Init.* No. 21: 39. 2006. **Holotype:** Argentina, Prov. Entre Rios, Dep. Concordia, Concordia, coll. 1983, prep. ex cult. 1985, *Kiesling & Lopez* 5930 (SI). **Synonym:** *Frailea angelesii* R. Kiesling ex Prestlé, *Die Gattung Frailea* (Br. & R.) Prestlé [sic!]. Ed. 2: 52. 1997. Nom. inval. (36.1, 37.1).

Diagn.: Distinguished from *Frailea mammifera* Buining & Brederoo subsp. *mammifera* by the reddish brown spines, more greyish felt of the flower areoles, and smooth spine surfaces.

Description: Plants usually solitary, rarely sprouting basally. Stem short cylindrical, up to 4 cm high and 3 cm in diameter. Epidermis dark green to dark reddish, glossy. Ribs usually 13–17, forming distinct tubercles. Tubercles up to 15 or more at each rib, 3–6 mm in diameter and 1–3 mm high, at the upper side with a distinct, dark violet brown spot. Areoles on upper side of the tubercle, 2–5 mm apart, oval, 0.5–1.0 mm broad and 1.0–1.8 mm long with short whitish felt. Spines 5–7 at each areole, erect or sometimes slightly irregularly curved, reddish brown, at the base sometimes light brown, 2–7 mm long, 0.1–0.4 mm diameter, spine surface smooth or sometimes with only very short elongated tubercles (< 30 µm). Flower funnel-shaped, 2.5–4 cm long and 2.5–3.0 cm in diameter. Pericarpell (hypanthium) 0.6–0.9 cm long, areoles of the pericarpell scales with dense grey whitish felt and 3–5 brownish bristle like spines, these up to 1.4 cm long. Scales light green at the base and reddish brown at the tip, transient to the perianth segments. Perianth segments spatulate, acuminate yellow, with reddish tip, up to 1.8 cm long

and 0.4 mm broad. Filaments 0.8–1.2 cm long, whitish to pale yellowish. Anthers 1.0–1.5 mm long, pollen yellowish. Style 1.3–1.5 cm long (incl. stigma), 0.7–0.8 mm broad; 5–7 stigma branches 0.5 cm long, yellowish white. Ovary 0.5 cm long and 2.0–2.5 mm in diameter. Ovules in vertical rows, funiculi not branched. Fruit is a thin walled roundish berry, becoming dry and dehiscent when ripe, 0.5–1.0 mm in diameter, with persistent flower remains 1.5–1.7 cm long, cleistogameous fruits shorter, areoles (as of the pericarpell) with grey whitish felt and brownish bristles, dehiscent. Seeds hat shaped, 1.8–2.0 mm long, 1.2–1.4 mm broad and 1.5 mm high, HMR deeply impressed, testa brown, ± glossy with small papillae (par-domed).

Frailea mammifera subsp. *angelesiae* grows on stony places near Concordia (Prov. Entre Rios, Argentina), at ca. 15–20 m, between grass and small bushes. This subspecies is known from only two small populations near Concordia. One of these, with about 40 specimen in 20 x 20 square meters, were located in front of a house under construction in 1999 and is probably extinct today. Although all cleistogameous *Frailea* species can establish new populations based even on a single seed (see above), the pressure of farming and building projects leads to potential threat of this subspecies. Because of the small population(s) and the limited geographic range it has be regarded as critically endangered (CR) according to the categories of the IUCN (IUCN Species Survival Commission, 2001).

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Figure 3. *Frailea mammifera* subsp. *mammifera*.



Figure 4. *Frailea mammifera* subsp. *angelesiae*.

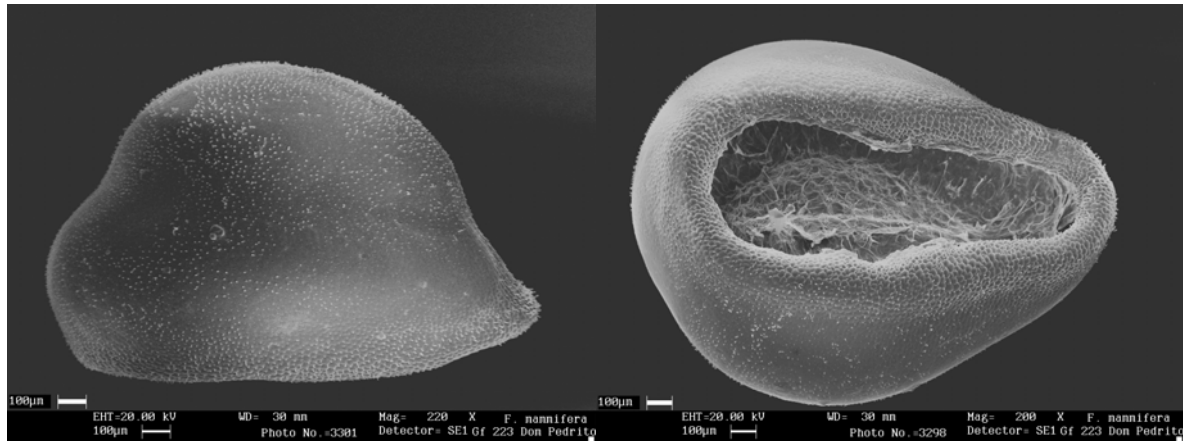


Figure 5. Seed of *Frailea mammifera* subsp. *mammifera*; lateral view (left), Hilum-Micropylar-region (right)

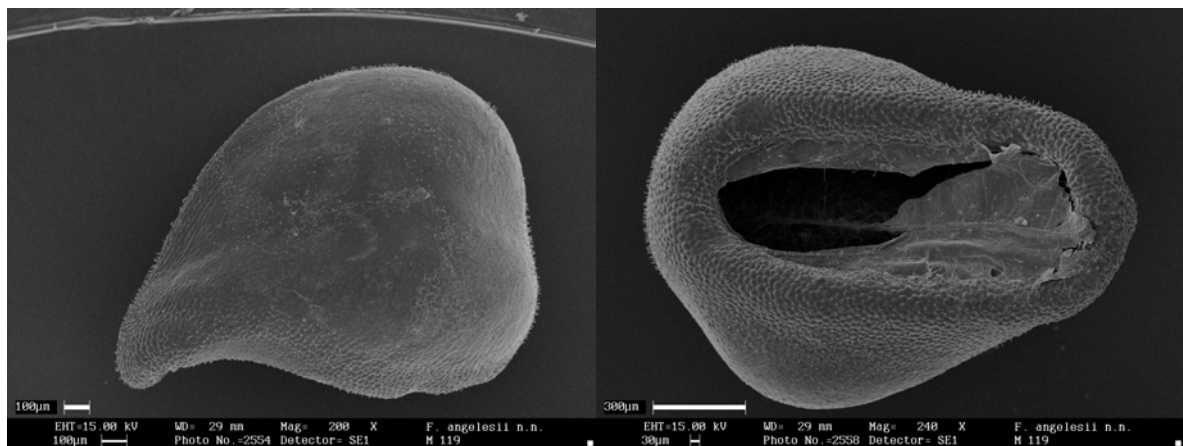


Figure 6. Seed of *Frailea mammifera* subsp. *angelesiae*; lateral view (left), Hilum-Micropylar-region (right)

Typification of *Frailea pumila*

Echinocactus pumilus Lemaire is the oldest species today classified under *Frailea*, but no type has been designated up to now. A survey of the current literature, esp. floras and general treatments, shows that there is a general agreement about the application of the name. *F. pumila* (Lemaire) Britton & Rose is probably the most common species of the genus in hobbyistic and commercial cultivation. One character listed in the protologue of *E. pumilus* should be discussed, it mentions one character (“sub areolis violacei”), which was neglected or omitted in subsequent descriptions (e.g. Schumann, 1898; Britton & Rose, 1922; Backeberg, 1959). Violet spots, which may be quite distinct stamp of the “podarium”, are typical characters of some taxa (e.g. *F. cataphracta*, *F. mammifera*, *F. moseriana*). The plants distributed currently under the name *F. pumila* don’t have this character. However in a few populations we saw plants, which had reddish violet spots below the areole due to exposition to the sun, although less marked as in the species mentioned above. We don’t know which kind of lilac spots the original material of Lemaire had. There are two alternatives: to interpret “sub areolis violacei” as indication of anatomical distinct marks (as present e. g. in *Frailea cataphracta*) or to accept the lilac colour as discolouration of

the epidermis effected by sun.

The first case would lead to a changed interpretation of the name *E. pumilus*, different from the current use. In this case we had to accept *F. colombiana* (Werdermann) Backeberg to be the oldest available name for *Frailea pumila* s. mult. auct.

The second case would support stabilize the current use of the name *F. pumila*. As there are no evidences that the protologue is contradictory to the second view we favour to keep the name as in current use and to avoid name changes of this common species. For the extensive synonymy of the species see Hunt (1999).

Frailea pumila (Lemaire) Britton & Rose, *The Cactaceae* 3: 209. 1922 \equiv *Echinocactus pumilus* Lemaire, *Cact. Aliq. Nov.* 21. 1838. **Neotype** (designated here):

Identity of *Frailea knippeliana* and description of a new species

Frailea knippeliana (Quehl) Britton & Rose has been described as *Echinocactus knippelianus* by Quehl in 1902, based on material collected by Hermann Grosse 1899 in Paraguay. Unfortunately no type was deposited, and neither illustration nor exact locality has been provided in the original description. A description of the flower was published 11 years later by Quehl (1913). A poor illustration was published in a seed catalogue of the Fa. Knippel and reproduced in Schelle (1907). It does not show many details, but the illustrated plant has about 25 ribs (13 visible), whereas the description mentions only 15 ribs. Hence this illustration can't help in the interpretation of the name *Frailea knippeliana*. In the following the species became a mystery, the species was considered as lost or confused with *Frailea pumila* (Simon, 1970).

The original description characterizes a short columnar plant with yellow spination. In a key Quehl (1902) distinguished *Echinocactus knippelianus* from *E. gracillimus* Lemaire [= *Frailea gracillima* (Lemaire) Britton & Rose] by the fussy and grass green stem. The latter species, *F. gracillima* was reported for Paraguay by Schumann (1903a: 108), but no documented material or recent collections of this (Brazilian) species from Paraguay are known today (Pin & Simon, 2004).

In the 1971 the Paraguayan collector A. F. M. Friedrich sent a couple of cacti from Paraguay (collected nw of Atyra, Prov. Cordillera) to the Austrian cactus enthusiast G. Moser, which were believed to represent *Frailea knippeliana* (Moser, 1977). Buining (1974) emendated *Frailea knippeliana* based on this material and deposited a "lectotype" in U (which is in fact would be a neotype, ICBN Art. 9.8). However, he failed to specify the specimen clearly in the publication, which invalidates the (neo-)typification.

In the 1980s the Paraguayan amateur botanist Alexander Arzberger searched for cacti in Paraguay and found more populations of similar, yellow spined Fraileas in the Dptos. Cordillera and Paraguari. Collections are known from at least three localities (studied material in brackets): NW of Atyra (*Friedrich s. n.*), W of Valenzuela (*A. Arzberger 123, J. Piltz 450, D. Metzinger et al. M 38*), E of Valenzuela, Itá Moroti (*A. Arzberger 23, A. Arzberger 35*), and Parque Nacional de Ybycu'i (*A. Arzberger 114*) (Arzberger, pers. comm.; Buining, 1974; Metzinger, 1994; Moser, 1977; Pin, 1996). Material from the mentioned collections could be studied by us either in the field, in cultivation or in the herbarium. In spite of the overall similarity of plants from these populations there are two taxa clearly distinguishable, based by micromorphological characters of spines and seeds.

The first taxon (Atyra, Ybycu'i) is characterized by spines with insignificant tubercles, and smaller seeds (1.0–1.8 mm Ø) with glossy testa. This taxon is also represented by Buining's "lectotype" deposited in U. The second taxon (Valenzuela and Itá Moroti) has tuberculate spines

with elongated tubercles, bigger seeds (1.5–2.0 mm Ø) with matt to weak glossy testa. Hitherto this taxon has been identified as *F. knippeliana*, too (cf. Metzging, 1994; Prestlé, 1997b). Valenzuela was mentioned by Chodat & Hassler (1903) as locality of *E. knippelianus*, but not in the protologue by Quehl (1902). We can't judge today whether both Quehl and Hassler have seen the same material or whether Grosse has sent material of both taxa. The characters of both taxa—in regard of the natural variability—match with the protologue of Quehl (1902). Both taxa can form short columnar stems as described by Quehl, especially when several seedlings grow together and forming small tufts.

With the exception of seed length unfortunately none of the micromorphological characters was mentioned in the protologue of *E. knippelianus*. The seed length was given by Quehl (1902) as “1–2 mm”, whereas Buining (1974) measured only “0.9–1 mm”. Own measurements of Buining's “lectotype” material (in U) resulted in seed lengths up to 1.4 mm. Seeds harvested from living plants of the same collection (*Friedrich s. n.*, provided by G. Moser) show a length up to 1.8 mm. It is now hardly to verify, whether Quehl really measured a seed length of up to 2.0 mm or whether “1–2 mm” better should be interpreted as “seed length between 1 to 2 mm”. We second the last view and see no evidence that the material described by Buining (1974) could be in conflict with the protologue of *E. knippelianus*. We follow the interpretation of Buining concerning application of the name *E. knippelianus* (*F. knippeliana*). Consequently we will validate the typification proposed by Buining (1974) here to make the name applicable to known natural populations and preserved material.

However, *F. knippeliana* as described by Buining can't be distinguished by any morphological character from *Frailea pumila*. Therefore it falls into the synonymy of the latter species:

Frailea pumila (Lemaire) Britton & Rose. Synonym: *Frailea knippeliana* (Quehl) Britton & Rose, *The Cactaceae* **3**: 211. 1922 ≡ *Echinocactus knippelianus* Quehl, *Monatsschr. Kakteenkunde* **12**: 9. **Neotype** (here designated): Paraguay, Atyra, *Friedrich s. n.* (U!).

It should be mentioned, that even Buining probably mixed material of both taxa (*F. knippeliana* and *F. alexanderi*): the seed illustrated in Buining (1974) shows the seed shape of *Frailea alexanderi*, but the material deposited in U (areole and seeds) definitively belongs to *F. knippeliana* as defined above.

In the population from Parque Nacional de Ybycu'i (*A. Arzberger 114*) plants can be found with longer spination (up to 10 mm). These plants were also distributed in cultivation under the name “*F. knippeliana* var. *arzbergeri* nom. nud.” (Berka, 2004).

For the second taxon a name is not yet available. Hence we will describe it here as a new species:

***Frailea alexanderi* Metzging & R. Kiesling, nov. sp.**

Lat. diagn.: Differt a *Frailea pumila* spinis breviter pinnatis, seminibus maiores latere dorsale minus ulcatisque et superficie cellularum testae leviter convexa et papillis brevioribus.

Holotype: Paraguay, Prov. Paraguari, 5 km w of Valenzuela, *D. Metzging & al. M 38*, 7. August 1988 (HBG).

Description: Plants at first solitary, later sprouting basally and from the side. Stem globose to short columnar, 1.5–3.0 cm Ø, up to 7 cm high. Epidermis dark green (or reddish in full sun). Areoles situated on ca. 15 ribs, these divided in small tubercles, 3–5 mm Ø and 1–3 mm high. Areoles short oval, 1–2 mm long, with short whitish to pale felt. Spines straight, yellowish or pale brown at the base, later becoming greyish, tuberculate with elongated ca. 50–120µ long tubercles (pinnate). 13–15 marginal spines, 2–4 mm long, 2–4 central spines, up to 6 mm long. Flower funnel-shaped, (15–) 20–25 (–30) mm long and 20–25 mm in diameter. Pericarpell (hypanthium) about 10 mm long, reddish, green at the base, areoles of the pericarpell with whitish felt and 1–8 pale yellow to reddish brown bristle like spines, these up to 6 mm long.

Lower receptacle areoles with distinct scales, up to 2.5 mm long, transient to the perianth segments, bristle like spines up to 8 mm long. Outer perianth segments yellow, spatulate, acuminate, up to 2 mm broad and 5–10 mm long, with a darker central stripe at the upper part and a reddish tip. Inner perianth segments up to 15 mm long and 3 mm broad, pure yellow. Inner tube carmine at the base, where fused with the filaments. Filaments 4–7 mm long, carmine, inner filaments shorter and pale yellow. Anthers ca. 0.5 mm long, anthers and pollen yellowish. Style whitish, at the base 0.5–0.9 mm diameter, more narrow to the top, 6–8 mm long, stigma branches 2–3 mm long. Ovary 3–4 mm and 2–3 mm in diameter. Ovules situated in vertical rows, funiculi not branched. Fruit thin walled roundish reddish berry, becoming dry and dehiscent when ripe, 0.5–0.8 mm in diameter, up to 15 mm long. areoles (as these of the pericarpel) with bristle like spines. Seeds hat shaped, 1.5–1.8 mm high, 1.2–1.4 mm broad and up to 2.0 mm long, HMR oval, deeply impressed, testa brown, semi-matt, relief convex, low domed, with small 10–25 μ long papillae (par-domed), cuticular striation fine regular to hardly visible, with small papillae (par-domed). The visible cuticular folding pattern of the seeds of this species is unique within the genus, where the testa usually has no distinct cuticular foldings (Metzing & Thiede, 2001).

Etymology: Named for Alexander Arzberger (Asuncion), who found the plants at first in 1985. We use the forename for naming the species, to avoid confusion with the plants of *Frailea pumila* distributed as “*F. knippeliana* var. *arzbergeri* nom. nud.”.

Habitat and distribution: At rocky outcrops in the surrounding of Valenzuela (Prov. Paraguari), in shallow soil. Endemic in SE Paraguay.



Figure 7. *Frailea alexanderi*.

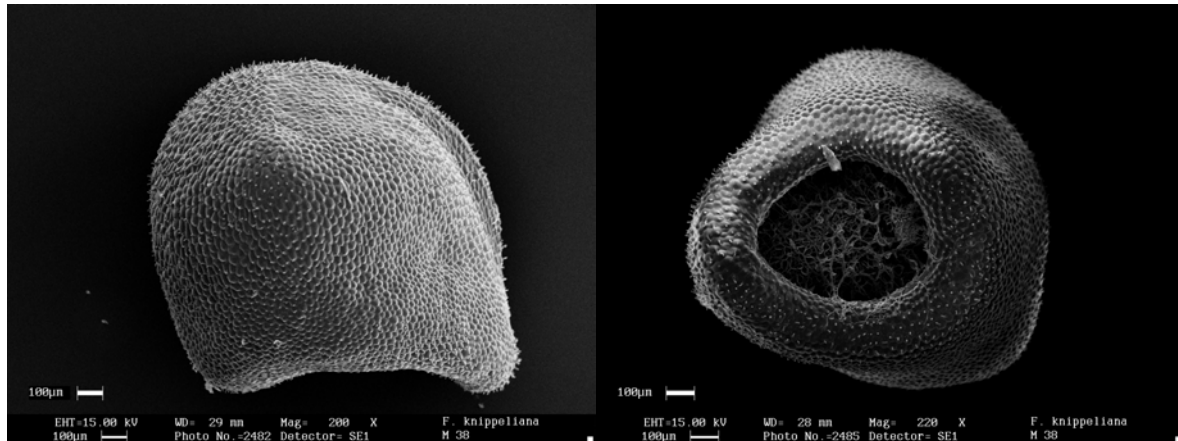


Figure 8. Seed of *Frailea alexanderi*, lateral view (left), Hilum-Micorpylar-region (right).

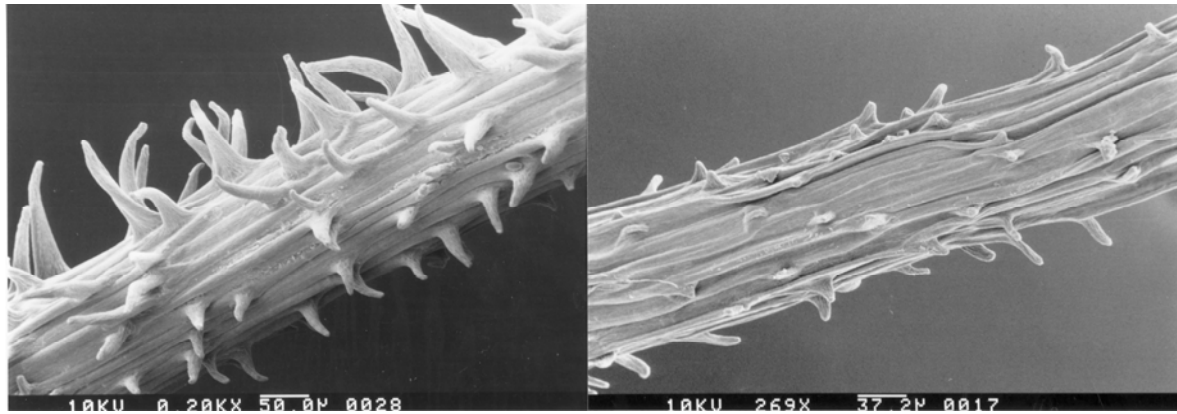


Figure 9. Spine surface of *Frailea alexanderi*

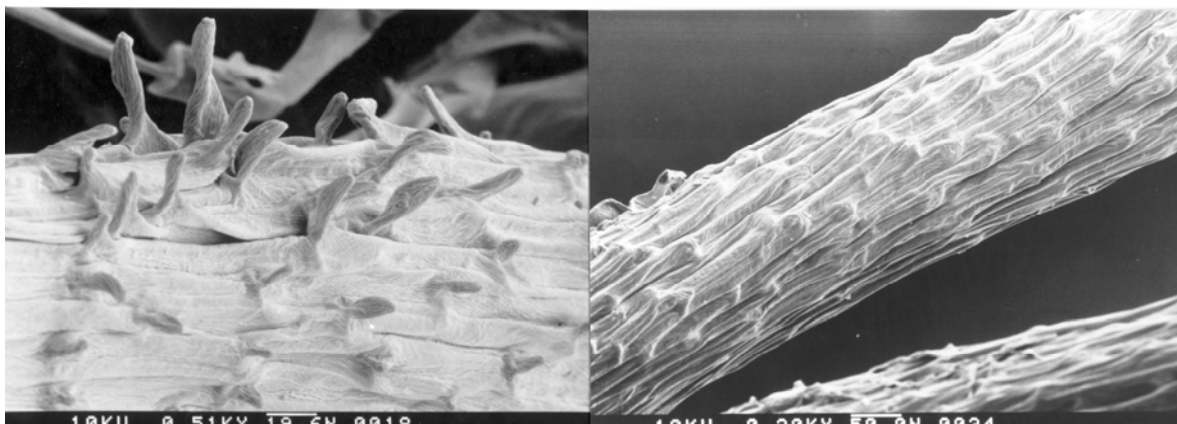


Figure 10. Spine surface of *Frailea alexanderi* (left) and *Frailea pumila* (AA 114, Sra. de Ybycui; right)

Typification of *Frailea castanea* and *Frailea asterioides*

Frailea castanea was described by Backeberg (in Backeberg & Knuth 1936), based on small plants which he received from Uruguay in 1935 (Backeberg, 1959). No type material was mentioned or preserved. The description of *Frailea asterioides* by Werdermann (1937), which

was collected by Blossfeld & Marsoner in S Brazil near Alegrete, was much more detailed as that from Backeberg, but without type indication, too. Unfortunately Werdermann's study room with his notes and almost all herbarium specimens of Cactaceae were destroyed during the war in 1943 (Werdermann, 1949; Leuenberger, 1978), and no existent original material is known today.

After publication of both descriptions a long discussion arose whether both species are identical or not. Werdermann (1937) expressed his uncertainty about the identity of *F. castanea* known to him only from the literature. Krainz (1959) accepted the name *F. asterioides*, but disqualified *F. castanea* as nomen dubium (due to lacking original material, illustration and description of flower). Backeberg himself (1959) illustrated his *F. castanea*, emended the description and cited *F. asterioides* as synonym. Ritter (1979) confirmed that *F. castanea* and *F. asterioides* are two names for the same species, but followed the argumentation of Krainz, rejecting the name *F. castanea*, and described two new varieties for *F. asterioides*. Prestlé (1978) brought new confusion in the discussion, when he denied the identity of both taxa, accepted *F. asterioides* in the current sense, but gave a new interpretation of the name *F. castanea*. This was repeated by him in 1997, where he mentioned a "Typenpflanze" deposited in U (sub PR 58) (Prestlé, 1997a, b). In fact this specimen, originating from Cuchilla de Belen (Artigas, Uruguay) should be accepted according to the Code (ICBN, Greuter *et al.* 2000) as neotype, but the protologue of *F. castanea* and the description of *F. castanea* sensu Prestlé doesn't match, as stated already by Hofacker (1998). Whereas Backeberg describes a plant without tubercles, the ribs of *F. castanea* sensu Prestlé are divided in small tubercles. The 8 marginal and one central spines are 1 mm long according to Backeberg (1936; up to 1.5 mm in Backeberg 1959), whereas Prestlé's plants have marginal spines with 4.5–5.0 mm and 2 central spines. These differences can't be explained by variability of the species, moreover Backeberg (1959) shows very clearly how his name *F. castanea* should be applied. It has to be concluded, that the (neo-) type for *F. castanea* designated by Prestlé is in serious conflict with the protologue, and the concept of Backeberg, too. The neotype designated by Prestlé has to be superseded therefore (cf. Art. 9.17b, Greuter *et al.* 2000). Most recent reference works (Taylor, 1989; Hunt, 1999; Kiesling, 1999; Anderson, 2001) accept *F. castanea* and cite *F. asterioides* as synonym. To stabilize current use of the names *F. castanea* and *F. asterioides* they will be typified here:

***Frailea castanea* Backeberg** in Backeberg & Knuth: *Kaktus-ABC*: 248, 415. 1936. **Neotype** (designated here): Uruguay, Artigas, str. da ruta 30 a Cuaro', ca. 11 km N Cuaro, 30° 31' 55" S 56° 50' 28" W, 6.XI.1999, *Massimo Meregalli (MM)* 230 (HBG). **Synonyms:** *Frailea asterioides* Werdermann, Feddes Repert. Spec. Nov. Regni Veg. **42**: 6–7. **Neotype (designated here):** (designated here): Brazil, Rio Grande do Sul, ruta 290 km 543, 29° 57' 39" S 55° 27' 24" W, 4.XI.1999, *Massimo Meregalli (MM)* 212 (HBG). – *Frailea asterioides* var. *backebergii* F. Ritter. *Kakt. Südamer.* 1: 210–211. 1979. **Type:** Brazil, Rio Grande do Sul, Quarai, 1965, *F. Ritter 1363a* (U!). – *Frailea asterioides* var. *harmoniana* F. Ritter, *Kakt. Südamer.* 1: 211. **Type:** F. Ritter 1363, 1965, Brazil, Rio Grande do Sul, Harmonia, 1965, *F. Ritter 1363* (U!) ≡ *Frailea castanea* subsp. *harmoniana* (F. Ritter) P. J. Braun & Esteves, *Succulenta* **74**: 130. 1995. – Non *Frailea castanea* sensu Prestlé, *Mitteilungsbl. Frailea* **2**: 9–10. 1997. **Neotype** (to be rejected): Uruguay, Cuchilla de Belen, K.-H. Prestlé, PR 58 (U).

Further studied specimen: Brazil, near Guarai [sic!], 1969, Buining, *HU 56* (U!). Note: under the field number HU 56 plants from different populations were collected. According to the field number list (Uebelmann, 1996) the population from Quarai has the number HU 56b.

F. castanea is a very distinct taxon within the genus, well defined by the habitus as well as by the autapomorphy of branched papillae on the testa (Metzing & Thiede, 2001).

Typification of *Frailea pygmaea*

Frailea pygmaea (Spegazzini) Britton & Rose is distributed in Uruguay, S-Brazil, NE-Argentina and Central Paraguay. No preserved specimen from the original material of *Echinocactus pygmaeus* Spegazzini is known to be existing. A photo deposited in LPS (Kiesling, 1984: 220) has to be considered as original material and we designate this as lectotype here. To achieve more precision in the application of the name we designate an epitype here, too.

Frailea pygmaea (Spegazzini) Britton & Rose, *The Cactaceae* **3**: 210–211. 1922 ≡ *Echinocactus pygmaeus* Spegazzini, *Anal. Mus. Nac. Buenos Aires* **3**(4): 497–498. 1905. – **Lectotype** (here designated): [unpublished photographic icon] LPS 23075 “*Echinocactus pygmaeus* Speg. sp. nov. Ejemplar fruto verde, Herbario de J. Arechavaleta”. **Epitype** (designated here): Uruguay, Dept. Montevideo, Loc. Distr. Pajes Blancas, 4.1953, *G. Herter 957*, Pl. Ur. Nr. 1722b (U: 31071A!)

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References

- ANDERSON, E. F. (2001): *The cactus family*. Timber Press, Oregon.
- ANDERSON, E. F. (2005): *Das große Kakteen-Lexikon*. E. Ulmer, Stuttgart.
- BACKEBERG, C. (1959): *Die Cactaceae. Handbuch der Kakteenkunde, Vol. 3: Cereoideae (Astrocactinae)*. VEB G. Fischer, Jena.
- BACKEBERG, C. (1976): *Das Kakteenlexikon*. Ed. 3 (mit einem Anhang von Walter Haage). G. Fischer, Stuttgart.
- BACKEBERG, C. & KNUTH, F. M. (1936): *Kaktus-ABC*. Nordisk Forlag, Kopenhagen.
- BERKA, L. (2004): Die Gattung *Frailea* Britton et Rose und was ich über die Gattung weiß. *Kaktusy* **40**(special 1): 1–32.
- BRITTON, N. L. & ROSE, J. N. (1922): *The Cactaceae. Descriptions and Illustrations of Plants of the Cactus Family. Vol. 3*. Carnegie Institution, Washington.
- BUINING, H. (1972): *Frailea mammifera* Buining et Brerderoo spec. nova. In: KRAINZ, H. (ed.), *Die Kakteen*. Liefg. 50–51: CVIe.
- BUINING, H. (1974): *Frailea knippeliana* (Quehl) Britton et Rose. In: KRAINZ, H. (ed.), *Die Kakteen*. Liefg. 59: CVIe.
- CASTELLANOS, A. (1966–67): Revision de las Cactáceas Argentinas, III. *Frailea*. *Revista Fac. Ci. Agrar. Univ. Nac. Cuyo* **13**: 13–28.
- CHODAT, R. & HASSLER, E. (1903): Plantae Hasslerianae soit énumération des plantes récoltés au Paraguay par le Dr. Emile Hassler de 1885-1902. *Bull. Herb. Boissier*, sér. 2, **3**: 239–255.
- ESSER, G. (1982): Vegetationsgliederung und Kakteenvegetation von Paraguay. *Trop. Subtrop. Pflanzenwelt* **38**: 1–113.
- FÖRSTER, C. F. (1846): *Handbuch der Cacteenkunde*. I. T. Wöller, Leipzig.
- GREUTER, W., MCNEILL, J., BARRIE, F. R., BURDET, H. M., DEMOULIN, V., FILGUEIRAS, T. S., NICOLSON, D. H., SILVA, P. C., SKOG, J. E., TREHANE, P., TURLAND, N. J. & HAWKSWORTH, D. L. (eds.) (2000): International Code of Botanical Nomenclature (Saint Louis Code) Adopted by the Sixteenth International Botanical Congress St. Louis, Missouri, July–August 1999. *Regnum Veg.* 138: i–xviii, 1–474.
- GRIME, J. P. (1979): *Plant strategies and vegetation processes*. Wiley, Chichester.
- HAVLÍČEK, R. (1996): Aussaaten der Kakteen und anderer Sukkulente: Die Gattung *Frailea*. *Mitteilungsbl. Frailea* **1**: 52–54.

- HEFTI, C. (1996): Einige Gedanken und Bemerkungen zum vorhergehenden Artikel. *Mitteilungsbl. Frailea* **1**: 55.
- HOFACKER, A. (1998): „Eine unendliche Geschichte“ oder „Nochmals zu *Frailea castanea* Backeberg und *Frailea asterioides* Werdermann. *Mitteilungsbl. Frailea* **2**: 57–61.
- HUNT, D. R. (1999): *CITES Cactaceae checklist*. Ed. 2. Royal Botanic Gardens & IOS, Kew.
- IBISCH, P. L., RAUER, G., RUDOLPH, D. & BARTHLOTT, W. (1995): Floristic, biogeographical, and vegetational aspects of Pre-Cambrian rock outcrops (inselbergs) in eastern Bolivia. *Flora* **190**: 299–314.
- IPNI (2005): International Plant Names Index. <http://www.ipni.org> [accessed 22.01.2006].
- IUCN SPECIES SURVIVAL COMMISSION (2001): *IUCN Red List Categories and Criteria: Version 3.1*. IUCN, Gland & Cambridge.
- KIESLING, R. (1975): Los generos de Cactaceae de Argentina. *Bol. Soc. Argent. Bot.* **16**: 197–227.
- KIESLING, R. (1999): Cactaceae. In: ZUOLAGA, F. O. & MORRONE, O. (eds.), Catálogo de las plantas vasculares de la República Argentina II. *Monogr. Syst. Bot. Missouri Bot. Gard.* **74**: 423–489.
- KIESLING, R. & FERRARI, O. (2005): *100 Cactus Argentinos*. Albatros, Buenos Aires.
- KIESLING, R. & METZING, D. (2006): A new subspecies of the genus *Frailea* Britton & Rose. *Cactaceae Syst. Init.* no. 21: in press.
- KNUTTI, B. & HEFTI, C. (1997): *Frailea angelesii* n.n., eine wunderschöne Pflanze aus dem argentinischen Mesopotamien. *Mitteilungsblatt Frailea* **2**: 22–25.
- KÖHLER, U. (1968): Fraileen – und wie lange sie blühen ... *Kakt. and. Sukk.* **19**: 166–167.
- KRAINZ, H. (1959): *Frailea asterioides* Werdermann. In: *Die Kakteen*, Liefg. 12: CVIc.
- LEUENBERGER, B. E. (1978): Type specimens of Cactaceae in the Berlin-Dahlem Herbarium. – *Cact. Succ. J. Gr. Brit.* **40**: 101–104.
- METZING, D. (1994). Cactaceae in Paraguay - specie, ecologia e minacia di estinzione. *Piante Grasse* **13**(4 suppl.): 5–64.
- METZING, D. & THIEDE, J. (2001): Testa sculpture in the genus *Frailea* (Cactaceae). *Bot. J. Linn. Soc.* **137**: 65–70.
- MOSER, G. (1977): *Frailea knippeliana* (Quehl) Br. & R. *Natl. Cact. Succ. J.* **32**: 4–5.
- NAVARRO, G. (1996): Catálogo ecológico preliminar de las cactáceas de Bolivia. *Lazaroa* **17**: 33–84.
- NAVARRO, G. & MALDONADO, M. (2002): *Geografía ecológica de Bolivia*. Centro de Ecología Simón I. Patiño, Cochabamba.
- PEARCE, R. (1978): Forum: *Frailea*. *Cact. Succ. J. Gr. Brit.* **40**: 14–18.
- PENNINGTON, R. T., PRADO, D. E. & PENDRY, C. A. (2000): Neotropical seasonally dry forests and quaternary vegetation changes. *J. Biogeogr.* **27**: 261–273.
- PIN, A. (1996): Las Cactáceas del Parque Nacional Ybycu'i. *Bol. Mus. Nac. Hist. Nat. Parag.* No. 12: 1–28.
- PIN, A. B. & SIMON, J. (2004). *Guía ilustrada de los Cactus del Paraguay*. Presidencia de la República–Secretaría de Ambiente, Asunción.
- PRANCE, G. T. (1982). A review of the phytogeographic evidences for pleistocene climate changes in the Neotropics. *Ann. Missouri Bot. Gard.* **69**: 594–624.
- PRESTLÉ, K. H. (1978): *Frailea castanea*. *Succulenta* **57**: 83–85.
- PRESTLÉ, K. H. (1997a): *Frailea castanea* (Backbg.) Prestlé contra *Frailea asterioides* Werdermann und die damit zusammenhängenden Probleme in der Einteilung dieser Arten. *Mitteilungsbl. Frailea* **2**: 4–11.
- PRESTLÉ, K. H. (1997b): *Die Gattung Frailea (Br. & R.) Prestlé* [sic!]. Ed. 2. Self published by the author, Veghel.

- QUEHL, L. (1902): *Echinocactus Knippelianus* n. spec. *Monatsschr. Kakteenkunde* **12**: 9.
- QUEHL, L. (1913): Beschreibung einiger Kakteenblüten. *Monatsschr. Kakteenkunde* **23**: 129.
- RITTER, F. (1979): *Kakteen in Südamerika, Vol. 1: Brasilien/Uruguay/Paraguay*. Self published by the author, Spangenberg.
- RITTER, F. (1980): *Kakteen in Südamerika, Vol. 2: Argentinien / Bolivien*. Self published by the author, Spangenberg.
- ROJAS-ARÉCHIGA, M. & VÁZQUEZ-YANES, C. (2000): Cactus seed germination: a review. *J. Arid. Environm.* **44**: 85–104.
- SCHELLE (1907): *Handbuch der Kakteenkultur*. E. Ulmer, Stuttgart.
- SCHLINDWEIN, C. & WITTMANN, D. (1995): Specialized solitary bees as effective pollinators of South Brazilian species of *Notocactus* and *Gymnocalycium* (Cactaceae). *Bradleya* **13**: 25–34.
- SCHUMANN, K. (1898): *Gesamtbeschreibung der Kakteen*. J. Neumann, Neudamm.
- SCHUMANN, K. (1903a): *Gesamtbeschreibung der Kakteen. Nachträge 1898 bis 1902*. J. Neumann, Neudamm.
- SCHUMANN, K. (1903b): *Wachstumsverhältnisse einiger Kakteen in Paraguay*. *Monatsschr. Kakteenkunde* **13**: 90–91.
- SIMON, W. (1966): Über die Befruchtungsverhältnisse einiger Kakteen: Kleistogamie. *Kakt. and. Sukk.* **17**: 108–110.
- SIMON, W. (1970): *Frailea knippeliana* verkannt? verschollen? ausgerottet? *Kakt. and. Sukk.* **17**: 108–110.
- STRECKER, S. (1992): Arealgeographie der Familie der Kakteen. Unpubl. diploma thesis, Rheinische Friedrich-Wilhelms-Universität, Bonn.
- TAYLOR, N. P. (1989): *Frailea* Britton & Rose. In: WALTERS, S. M., ALEXANDER, J. C. M., BRADY, A., BRICKELL, C. D., CULLEN, J., GREEN, P. S., HEYWOOD, V. H., MATTHEWS, V. A., ROBSON, N. K. B., YEO, P. F. & KNEES, S. G., *The European garden flora, Vol. 3: Dicotyledons (Part I)*: 265–268. Cambridge University Press, Cambridge.
- UEBELMANN, W. (1996): *Horst & Uebelmann Feldnummernliste*. Self published by the author, Zufikon.
- WERDERMANN, E. (1937): *Frailea asterioides* Werd. nov. spec. *Feddes Repert. Spec. Nov. Regni Veg.* **42**: 6–7.
- WERDERMANN, E. (1949): Aufbau und Schicksal der Dahlemer Kakteen-Sammlungen. *Sukkulantenkunde* **3**: 34–38.