A New Hard Pine (*Pinus*, Pinaceae) from Taiwan

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**ABSTRACT.** *Pinus fragilissima* Businsky (Pinaceae), a new species of *Pinus* subg. *Pinus*, is described from southeastern Taiwan. Comprised of trees with very sparse crown and fragile, symmetrical, 6–9 cm long cones with often flat apophyses, it appears to be most closely related to *P. luchuensis* Mayr, endemic to the Nansei Islands, and to *P. taiwanensis* Hayata. The latter is circumscribed here as a Taiwan endemic with the exclusion of superficially similar but probably unrelated mainland Chinese pines. These three allied species are classified here as the sole representatives of *Pinus* subg. *Pinus* ser. *Luchuenses* E. Murray.


The author has been studying natural populations of Eurasian pines for more than ten years, concentrating on East Asia. The main object of the study is a taxonomic revision of *Pinus* in that region, the Revision of Pines of East Asia (REPEA) Project. Within the framework of this project, the author undertook a series of research expeditions to East Asia: eight to the People’s Republic of China (1990–2001), two to Japan (1991 and 1997), two to Vietnam (1994 and 1997), and one to Taiwan (1991), Indonesia (1994), and the Philippines (2000). The study has been designed to obtain good field knowledge, above all of variability within and between populations, and to collect representative herbarium and photographic material of all Asian species of the genus *Pinus*, allowing a more uniform approach to classification (see also Businsky, 1999).

**TAXONOMY**

During an exploration in 1991 of forest stands in southern Taiwan, on the eastern (Pacific) side of the island’s central mountain range, a remarkable population of a hard pine (= *Pinus* subg. *Pinus*) near Wulu village in the northern part of Taitung County was found. The only species known from Taiwan showing certain resemblance in general tree habit, external leaf characters, and some cone characters to this population is *Pinus massoniana* Lambert, Critchfield and Little (1966), using unpublished data at the Taiwan Forest Research Institute, reported *P. massoniana* only from northern Taiwan. However, Liu (1966) and Li (1975) also reported *P. massoniana* in the south, but only from the eastern coastal hills along the border between Taitung and Hualien Counties. Liu (1966: fig. 33) listed only one species of hard pine, *P. taiwanensis* Hayata, in the Wulu region. In a narrow taxonomic concept (excluding *Pinus hwangshanensis* W. Y. Hsia, see below), *P. taiwanensis* is confined to middle and high altitudes of Taiwan, widespread mainly between 2200 and 2900 m. However, the pine from the vicinity of Wulu occurs near or below 900 m, and differs from *P. taiwanensis* in several morphological characters (Table 1). No other indigenous hard pine is known from Taiwan. Outside of Taiwan, the Wulu population approaches *P. luchuensis* Mayr in some characters (leaf morphology and anatomy, distinctly broad tree crown); this is a species endemic to the nearby flat islands of the Nansei (Ryukyu) Archipelago, northeast of Taiwan (cf. Critchfield & Little, 1966; Yamazaki, 1995). The character set found in the Wulu pine is different from that of the three geographically closest spe-
cies: *P. massoniana*, *P. taiwanensis*, and *P. luchuensis*. The Wulu pine also cannot be equated with any other pine indigenous to East Asia, either; so as discussed below it is described here as a new species.

**Pinus fragilissima** Businsky, sp. nov. TYPE: Taiwan. Taitung County: below the great bend of Southern Cross-Island Highway on S slopes about 1 km N of Wulu village, in mixed forest on W declivity of a stony ridge descending S, alt. 930 m, 23°10'40"N, 121°02' E, 18 Dec. 1991, R. Businsky 32172 (holotype, PR; isotypes, B, BM, C, G, MO, P, PE, TAI & Herbarium of the RILOG). Figure 1.

Arbor usque 30 m alta, corona conspicue sparse diffusa, lata; folia (12±20–22) cm longa, canaliulis resiniferis 4 ad 67, plerumque mediolis et interdum (sub)marginalibus; strobili ovuliferi hornoti 9–10 mm lati, pedunculis 5–10 mm longis, squamis mucronatis praeter partem strobilorum basalem; strobili maturi 5–9–10 cm longi, fragiles, patentes vel leviter reflexi; apophyses plerumque prominentes, non tumidae. *A Pinus massoniana* differt imprimis canaliulis resiniferis foliorum plerumque mediolis et umbonibus strobilorum maturorum plerumque prominentibus, non planis et concavis; a *P. taiwanensis* differt imprimis foliis longioribus, strobilis maturis longioribus, fragilibus et coronis arborum sparse diffusis; a *P. luchuensis* differt imprimis foliis latis, strobilis maturis longioribus, fragilibus et coronis arborum sparse diffusis; a *P. fragilis* differt imprimis foliis latus, strobilis maturis longioribus et fragilibus, non suberectis, apophysis plerumque pyramidalibus, non rotundatis vel tumidis et coronis arborum sparse diffusis.

Tall trees attaining a height of 30 m with conspicuously sparse crowns 20 m or more wide, branches spreading, remarkably frangible, with leaves falling during the second to third year. Bark developing late, initially irregularly scaly, on trunks of old trees conspicuously thick, deeply longitudinally fissured and forming ribs often around 10 cm thick. Annual *branches* unimodal, relatively long; shoots of the current year relatively thin (fertile shoots with conelets 3–6 mm thick), yellow-brown, initially slightly pruinose, glossy, with inconspicuous shallow and narrow grooves formed by the decurrent bases of the primary bracts; areolae among them low and relatively flat. Shoots of the previous year gray-brown. *Buds* cylindrical, up to 3 cm long, with scales in the upper half loose to erecto-patent, narrowly lanceolate, with inconspicuous dorsal keel, brown in the middle, paler toward the lacerate margins, with long white fringes; scales not persistent at the bases of shoots. *Leaves* in fascicles of 2, occasionally in 3s on fertile shoots, (12–20–22) cm long, (0.9–1.0–1.2–1.35) mm wide (fresh), pale green, relatively fine and flexible, straight or slightly bent; amphistomatic; edges irregularly and rather densely acute-serrate, with (35 to)45 to 65(to 80) teeth per cm in the middle part; sheaths (8–10)–13–(15) mm long in the first year. Leaf resin ducts 4 to 6(7); two ducts near leaf edges always median, of largest diameter; 1 to 3(4) ducts dorsal, usually of smaller diameter, median or 1 to 2 of them marginal, occasionally submarginal, or near endodermis; usually one duct near the ventral side of small diameter, median to marginal (rarely larger and septal). Leaf hypodermis formed mostly by one layer of cells with relatively thin walls, sometimes a second layer in scattered patches on the dorsal side. *Pollen cones* ca. 2.5 cm long. *Ovulate cones* after the first growing season (conelets) on 5–10 mm long peduncles, 13–18(–20) mm long and ca. 9–10 mm wide, ovoid to elliptic cylindrical, erect, subterminal, usually in whorls of 3 to 5. The exposed part of the scales of the basal quarter of the conelet rounded, without a distinct keel or mucro; the other scales often show a considerably elevated area with a distinct transverse keel without discernible apex, dorsally depressed, with short mucro situated eccentrically on the ventral side, beginning from the swollen decurrent base and oriented backward over the keel. Mature *seed cones* spreading or slightly reflexed on slender 5–10 mm long peduncles, symmetrical, ovoid to oblong conical, fragile, (5–9–10) cm long, 5–8 cm wide when open; usually persistent for a few years, falling mostly without peduncle. Cone scales thin, densely arranged, 120 to 220, the largest 20–30 mm long and 12–15 mm wide, with length/width ratio 1.5–2.5, often broader below the middle than the apophysis width. *Apophyses* cinnamon brown, in outline irregularly transverse obtuse, 11–14 mm wide, with rounded to broadly cuneate distal edge, ± broadly pyramidal (not rounded or tumid), with conspicuous, sharp transverse keel and generally concave, depressed proximal side (often with raised proximal corner). Umbo slightly sunken, but usually prominent, transverse, (2–3)–4(–5) mm wide on seed scales, pyramidal or rostrate, keeled, often depressed on the proximal side, with minute, slender, ca. 0.2–0.5 mm long, erect or recurved mucro. *Seeds* ca. 4–5.5 × 2.2–3 mm, with wings 11–25 × 4.5–7.5 mm.

**Etymology.** The specific epithet (denoting "fragilest") refers to the remarkably frangible branches and branchlets, more so than for all other East Asian pines, and to the fragile consistency of the scales of mature seed cones.

**Distribution and Ecology**

*Pinus fragilissima* was observed only in a relatively small valley system of the Hsinwulu River,
Figure 1. *Pinus fragilissima* Businský. —A. Fertile branchlet in winter season (current shoot, with top of previous year’s shoot) with leaf fascicles, terminal bud and ovulate cones. —B. Mature closed cone. —C. Open seed cone. —D. Cross sections at the middle of leaves showing position of resin ducts. —E. Open seed cone of another individual. A–D from R. Businský 32172, holo- and isotypes, and E from R. Businský 32173, paratype. A, B, C, E: the same scale bar. All drawn by Ludmila Businska.
Table 1. Comparison of *Pinus fragilissima* with three morphologically most similar species: *P. taiwanensis*, *P. luchuensis*, and *P. massoniana* (compiled from the author’s field collections of natural populations, see Appendix 1).

<table>
<thead>
<tr>
<th>Character</th>
<th><em>P. fragilissima</em></th>
<th><em>P. taiwanensis</em></th>
<th><em>P. luchuensis</em></th>
<th><em>P. massoniana</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree habit</td>
<td>tall trees with conspicuously sparse crown and spreading branches</td>
<td>usually tall trees with medium dense crown</td>
<td>usually low trees with relatively dense crown and conspicuously spreading branches</td>
<td>tall trees with medium dense crown</td>
</tr>
<tr>
<td>Leaf length (cm)</td>
<td>(12–)16–20(–22)</td>
<td>(6.5–)9–14(–17)</td>
<td>(7–)12–18(–21)</td>
<td>(10–)12–20(–22)</td>
</tr>
<tr>
<td>Number of leaf resin ducts</td>
<td>4 to 6(7)</td>
<td>4 to 6(7)</td>
<td>2 to 6(7)</td>
<td>(4)6 to 11(13)</td>
</tr>
<tr>
<td>Position of leaf resin ducts</td>
<td>largely median, some (sub)marginal</td>
<td>largely median, some (sub)marginal</td>
<td>median, rarely some internal or (sub)marginal</td>
<td>always marginal</td>
</tr>
<tr>
<td>Mature seed cone length (cm)</td>
<td>(5–)6–9(–10)</td>
<td>(4–)4.5–6(–8)</td>
<td>4–6(–6.5)</td>
<td>4–7(–9)</td>
</tr>
<tr>
<td>Mature seed cone symmetry</td>
<td>symmetrical</td>
<td>subsymmetrical or asymmetrical</td>
<td>symmetrical</td>
<td>symmetrical or subsymmetrical</td>
</tr>
<tr>
<td>Mature seed cone orientation</td>
<td>spreading or slightly reflexed</td>
<td>± reflexed</td>
<td>suberect to spreading</td>
<td>± reflexed</td>
</tr>
<tr>
<td>Consistency of mature seed cone scales</td>
<td>fragile</td>
<td>firm</td>
<td>fairly firm</td>
<td>rather fragile</td>
</tr>
<tr>
<td>Apophyses</td>
<td>± broadly pyramidal</td>
<td>broadly pyramidal or roundly prominent to tumid</td>
<td>± roundly prominent to tumid</td>
<td>flat or slightly, ± roundly prominent</td>
</tr>
<tr>
<td>Umbo</td>
<td>± pyramidal or roothlike, often with depressed proximal side</td>
<td>± pyramidal or roothlike, sometimes with depressed proximal side</td>
<td>± pyramidal</td>
<td>flat, generally concave as a whole</td>
</tr>
</tbody>
</table>
descending east-southeast from the Kuan Shan massif (3666 m) within the Chungyang Shanmo mountain region, in the vicinity of and below Wulu village in the northern part of Taitung County, Taiwan, on the eastern side of the island's central mountain range. The population of the new pine in the main valley of this system (i.e., along the Southern Cross-Island Highway) occurs in elevations between 500 and 1000 m, but it cannot be excluded that it reaches slightly higher altitudes in some of the side valleys of the system. The valley is characterized by steep, rocky slopes predominantly covered with broad-leaved woodlands. Pinus fragilissima prefers slopes of southern to western exposures, confined to rocky sites with reduced competition from broad-leaved trees. Potentially, the new pine may be found in suitable habitats in other less easily accessible valley systems in the Chungyang Shanmo mountains in Taitung and Hualien Counties.

Another population of pines occurs in similar altitudes eastward, opposite the slopes of the Chungyang Shanmo mountains, i.e., in a narrow belt of coastal hills (situated between ca. 23°00' and 23°25'N) called Haian Shanmo. This population was identified as Pinus massoniana by Liu (1966) and Li (1975). Earlier on, Li (1963) cited a single specimen, Tanaka 10453, from southern Taiwan, at “Taitung,” as P. massoniana. Liu's map (1966: fig. 31) of P. massoniana in Taiwan includes an isolated area in these coastal hills as a narrow strip about 60 km long following the main ridge of the range. A single dot representing a herbarium specimen is in the middle of this strip, in the vicinity of Mt. Xingang Shan (1682 m, on the border of Taitung and Hualien Counties, above the port of Chengkung), about 20 km east of the observed site of P. fragilissima in the Hsinwulu valley. No herbarium specimens are cited by Liu, but Li (1963) is cited, and thus it is presumed here that the dot refers to the specimen cited by Li (Tanaka 10453). A duplicate of Tanaka 10453 (C), determined as P. massoniana by the collector, was examined and undoubtedly is P. fragilissima; consequently the whole population of pines in the Haian Shanmo is considered here belonging to this species. This mountain range reaches the highest elevation in Xingang Shan, which is close to the Hsinwulu River system. The region with P. fragilissima as a whole is characterized by dry winters and wet summers (Walter & Lieth, 1964: part 2.4).

Paratypes. TAIWAN. Taitung County, below the great bend of Southern Cross-Island Highway on S slopes about 1 km N of Wulu village, in sparse mixed forest on S stony declivity, alt. 930 m, 23°10’40”N, 121°02’E, 18 Dec. 1991. R. Busínky 32173 (PR); Tai to-chó [Taitung], Kaede, 7 Mar. 1931, T. Tanaka 10453 (C).

Discussion

Pinus fragilissima is similar to P. luchuensis, particularly in leaf size and anatomy. However, they otherwise differ morphologically and in their ecological requirements. The new species differs from P. massoniana in several characters, notably in the position of the resin ducts, a character usually given as important in the classification and determination of the Asian hard pines (cf. Gaussen, 1960; Kwei & Lee, 1963; Cheng et al., 1975; Law et al., 1978). On the other hand, both species occupy a similar altitudinal range; according to Liu (1966) and Mirov (1967), P. massoniana in Taiwan is confined to 300–1300 m. The new species is distinct from P. taiwanensis in general habit (sparse broad crowns), but further differences exist in leaf length, cone size, and scale fragility. Although both species occur in the same mountain region, their altitudinal ranges are different and barely overlap. The altitude of 750 m recorded as the lower limit for P. taiwanensis by Li (1963: 51), Liu (1966: 17), and Mirov (1967: 284) is in conflict with field observations of the present author in several regions. Even isolated trees of P. taiwanensis below its main zone of occurrence were above 1500 m in most of these regions. The 750 m record may be a result of the inclusion of P. fragilissima or P. massoniana in the distribution of P. taiwanensis. Sheue et al. (2000) analyzed variation of leaf anatomy attributed to P. taiwanensis in the Tachia river system (mainly in Taichung County on the west side of northern Taiwan) in five localities from an altitude of 700 m (Kukuan) to 3100 m (Konankaun). Li (1963, 1975) and Liu (1966) reported from this region also an occurrence of P. massoniana. The present author studied pine populations and collected samples of trees in the Tachia river system in the mentioned altitudinal range as well. The population of a hard pine in the vicinity of Kukuan (occurring between 500 and 1000 m) is, however, considered to be P. massoniana, comprising also some individuals morphologically transitional to P. taiwanensis (probably of hybrid origin). On the basis of a suite of morphological and anatomical characters, ranges of variability, and the geographic distribution, the trio of Pinus luchuensis, P. taiwanensis, and P. fragilissima appears as a related group, accepted here as the series Luchuenses E. Murray within the typical section and subsection of the genus.

Some Chinese authors, e.g., Law et al. (1978) and Fu and Li in Fu et al. (1999), include mainland populations described (and accepted here) as Pinus
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**Referencias**

- Boletín de Noticias 123
- Artículo 456 de Revista X
- Estudio de caso 789

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**Nota**: Este es un índice ficticio generado para el ejercicio. Las entradas y detalles son completamente inventados y no reflejan la realidad.
Pinus fragilissima from Taiwan

APPENDIX 1. HERBARIUM MATERIAL EXAMINED

HERBARIUM SAMPLES COLLECTED:

List of herbarium samples collected by the author is ordered chronologically below according to localities where natural populations of relevant species were studied and representative trees sampled (month, year, and collection numbers are in brackets; R. B. is an abbreviation of R. Businsky). Collections listed are stored in the herbarium of the Silva Tarouca Research Institute for Landscape and Ornamental Gardening (RILOG), 252 43 Práhonice, Czech Republic.

Pinus taiwanensis Hayata:
- Central Cross-Island Highway SSE near Lishan, Nantou Co., Taiwan; alt. about 2050 m [Nov. 1991: R. B. 32137]
- Hsuelshan massif (3284 m), SE slopes, Taichung Co., Taiwan; alt. 2400–3400 m [Nov./Dec. 1991: R. B. 32140, 32141a–d, 32142, 32144a–i]
- Central Cross-Island Highway at Tayuling, Hualien Co., N part, Taiwan; alt. about 2000 m [Dec. 1991: R. B. 32146, 32147, 32148, 32158, 32159]
- Along the road from Tayuling to Wushe, Nantou & Hualien Co. boundary, N part, Taiwan; alt. 2700–3200 m [Dec. 1991: R. B. 32152, 32153, 32154, 32155]
- Both sides of central ridge along the Southern Cross-Island Highway, Kaohsiung & Taitung Co., Taiwan; alt. 2600–2800 m [Dec. 1991: R. B. 32164, 32165, 32166, 32167]

Pinus luchuensis Mayr:
- Naha City suburbs, Okinawa Island, Nansei Islands, Japan; alt. 20–30 m [Nov. 1991: R. B. 32120, 32121, 32122, 32123, 32124]
- Ishigaki town environs, Ishigaki Island, Nansei Islands, Japan; alt. 80 m [Nov. 1991: R. B. 32125, 32126, 32127]

Pinus massoniana Lambert:
- Kukuan environs, Tachia valley, Taichung Co., Taiwan; alt. 500–1000 m [Nov. 1991: R. B. 32131, 32132, 32133]
- Xingshan Co., W Hubei, China; alt. about 1400 m [July 1995: R. B. 42113]
- Tianzhu Shan massif (1438 m), Qianshan Co., SW Anhui, China; alt. 300–700 m [July 1995: R. B. 42116]
- Between Longning & Shangying, Tiandeng Co., SW Guangxi, China; alt. 600 m [Aug. 1998: R. B. 46124]
- Daming Shan Mts., S slopes, Wuming Co., Guangxi, China; alt. 400–1000 m [Sep. 1998: R. B. 46126, 46127]

Pinus hwangshanensis W. Y. Hisia:
- SW boundary of Rucheng Co. (Hunan) with Guangdong, China; alt. 1500 m [Jan. 1994: R. B. 39126, 39128, 39129]
- Tianzhu Shan massif (1438 m), Qianshan Co., SW Anhui, China; alt. 600–1450 m [July 1995: R. B. 42117, 42118, 42119]
- Miaodao Shan massif (1432 m), Yueyi Co., SW Anhui, China; alt. 800–1400 m [July 1995: R. B. 42120, 42121]
- Mt. Tianzhanghai (1729 m), Yingshan Co., E Hubei, China; alt. 700–1500 m [July 1995: R. B. 42124, 42125, 42126]
- Between Laibang and Huo Shan massif, Dabie Shan Mts., Yueyi Co., Anhui, China; alt. 1300 m [Sep. 1998: R. B. 46144, 46145]

Pinus fragilissima Businsky—additional field label information:
- R. Businsky 32172 (holotype)—old tree with 270 cm trunk circumference (at 1.3 m height), 23 m high, crown about 20 m in diameter
- R. Businsky 32173 (paratype)—old tree with 220 cm trunk circumference, branches to 12 m long

OLDER SPECIMENS EXAMINED:

Pinus hwangshanensis W. Y. Hisia:
- Mt. Tianzhanghai (1729 m), Yingshan Co., E Hubei, China; alt. 1729 m [July 1995: R. B. 42124, 42125, 42126]

List of species (Pinaceae). Pl. 52.
Feng, 6200 ft.; 4.10.1933. Det. as *P. tabulaeformis* Carr. by W. C. Cheng, and as *P. hwangshanensis* by W. Y. Hsia / H. H. Hu. [PE: two specimens]


P. C. Tsoong 3461: Anhwei [= Anhui], upper slope of Mt. Tientu near summit; 13.6.1936. Det. as *P. hwangshanensis*. [PE]

P. C. Tsoong 3919: Anhwei [= Anhui], on approaching Shin-Jin, in wood; 9.7.1936. Det. as *P. thunbergii*, and later, in 1956, as *P. hwangshanensis*. [PE]

X. Y. He 30300: Zhejiang, Tianmu Shan; s. a. Det. as *P. hwangshanensis* in 1964. [In Chinese; PE: specimens of five individuals]

*P. taiwanensis* Hayata:

T. Kawakami & U. Mori 2097: Taiwan, Central Mts; Nov. 1906. Lectotype of *P. taiwanensis* Hayata, designated by A. Farjon, 4.3.1992. [TI]

B. Hayata & U. Mori 7142: Taiwan, Randaizan; 9.8.1908. Syntype of *P. taiwanensis* Hayata. [TI]

U. Mori, s. n.: Taiwan; s. a. Type of *P. brevispica* Hayata. [TI]