Taxonomic study of *Broussonetia* (Moraceae) in Korea

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한국산 닭나무속(*Broussonetia*, 뿡나무과)의 분류학적 연구

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**ABSTRACT:** Three Korean *Broussonetia* species (Moraceae) were reexamined based on morphological characters. The plants which have been used for making traditional paper Hanji in Korea are considered hybrid species between *B. kazinoki* and *B. papyrifera*, its natural habitat was first discovered in Is. Gageo (Jeonnam Province). Thus it is newly described as *B. × hanjiana* M. Kim. Its Korean name is changed into Daknamu instead of Kkujidaknamu. Therefore, Korean name for *B. kazinoki* is also changed into Aegidaknamu instead of Daknamu. Dioecious plants of *Broussonetia kazinoki* which were found in Is. Gageo are named as *B. kazinoki for. coreana* M. Kim (Gageo-Aegidaknamu).

**Keywords:** Broussonetia, Moraceae, Korean paper mulberry, Hanji

**적 요:** 한국산 닭나무속 식물의 분류학적 특징을 재검토하였다. 한지를 만드는데 사용해 온 닭나무와 무지나무의 교잡종인 무지닭나무가 전남 신안군 후산면 가거도에서 자생하고 있어 새로운 *Broussonetia × hanjiana* M. Kim으로 명명하였다. 무지닭나무는 그동안 일반인들이 닭나무라고 알고 있던 기 때문에 무지닭나무 대신에 닭나무라고 하였다. 따라서 *Broussonetia kazinoki*는 닭나무 대신에 애기닭나무라고 변경하였다. 또한 가거도에서 발견된 자생이주인 애기닭나무를 가기애기닭나무 (*B. kazinoki for. coreana* M. Kim)라고 새로이 명명하였다.

**주요어:** 닭나무, 뿡나무과, 한지

*Broussonetia* occurs worldwide in temperate, subtropical, and tropical climatic zones (Chung, 2007). This is a small genus in Moraceae, as containing about eight deciduous taxa (Kim et al., 1992). Of them, three taxa, *B. kazinoki*, *B. kazinoki × B. papyrifera* and *B. papyrifera*, have been known to be distributed in Korea (Kim et al., 1992).

*Broussonetia* is distinguished from the other genera within the family by male catkin with globose or cylindrical shape, female catkin with globose shape, inflexed filaments, connate calyx lobes, 3-nerved leaf veins, toothed leaf-margain, and thornless stems (Zhou and Gilbert, 2003).

Based on a study of pollen morphology on *Broussonetia* (including Section *Allaeanthus*), the genus *Allaeanthus* may be shifted into the genus of *Broussonetia* (Kim and Zavada, 1993). In a morphometric study on Korean *Broussonetia* species, it was found that most individuals known as *B. kazinoki* are a hybrid between *B. kazinoki × B. papyrifera* (Kim et al., 1992). This hybrid was firstly recorded by Kim et al. (1992). Matthews(1996) has reviewed about the origin and ethnobotany of *B. papyrifera* in Polynesia.

The natural habitats of *B. kazinoki × B. papyrifera*, a hybrid taxon, from Is. Gageo located in the most southwestern part of Korea was discovered. We here described *Broussonetia × hanjiana* M. Kim as a new hybrid. Also, we reviewed the Korean names of the species of *Broussonetia* in Korea in order to make a correction that have been controversial among species.

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Materials and methods

Living materials of three species of *Broussonetia* were collected from Is. Gageo, Byeonson, Mt. Naegang, etc. in Korea. The vouchers were deposited in JNU. Ten diagnostic characters from the twenty individuals of each species studied were measured to test relationships among species (Table 1).

Results

1. Morphological study

Morphological characters of three Korean *Broussonetia* species were compared in Table 2.

**Leaf:** The leaf of *B. × hanjiana* have the intermediate size between *B. papyrifera* and *B. kazinoki*. Leaf petiole and stipule size of *B. papyrifera* and *B. × hanjiana* are more than 1 cm long, but those of *B. kazinoki* less than 1 cm.

**Inflorescence:** Male plants of *B. papyrifera* and *B. × hanjiana* have cylindrical catkin inflorescence, but *B. kazinoki* have globose heads. Female plants of *B. papyrifera* (1.1-1.3 cm) have larger inflorescence in diameter than those of *B. × hanjiana* and *B. kazinoki*.

**Flowers:** Staminate flowers of three *Broussonetia* species have calyx tube with four lobes. Four filaments of three species are inflexed in bud. Pistillate flowers of three *Broussonetia* species have filiform style with stigmatic hairs.

**Fruit:** Three *Broussonetia* species is sorosis with globose shape, and its fruits are matured on June to July.

2. Taxonomic study

1) *Broussonetia papyrifera* (L.) L’Her. ex Vent. in Tabl. Regne. Veg. 3: 548 (1799), Fig. 1-A, B

Korean name: **Kkujinamu 푸짜나무**

English name: Paper Mulberry

Trees deciduous, dioecious. Twig 0.5-0.7 cm diameter. Leaves simple, alternate; blade ovate 14-16 cm long, 9-11 cm wide; margin coarsely serrate, sometimes 3-5 lobed, more or less scabrous; petiole 3-4 cm long. Stipules ovate, free, 1.6-2.0 cm long, 1.0-1.4 cm wide. Staminate inflorescence axillary, cylindrical, 5-7 cm long, bracts lanceolate, peduncle 0.9-1.4 cm long. Pistillate inflorescences globose heads, 1.1-1.3 cm diameter, bracts clavate, 1.7-2.1 mm long, peduncle 0.4-0.9 cm long. Staminate flowers: calyx tubular, 4 lobes; stamen 4, filaments

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**Table 1.** Collection data of *Broussonetia kazinoki × B. papyrifera* with related taxa.

<table>
<thead>
<tr>
<th>Scientific name (Korean name)</th>
<th>Date</th>
<th>Locality</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Broussonetia papyrifera</em></td>
<td>May 15, 2007</td>
<td>Byunsan (Jeonbuk)</td>
</tr>
<tr>
<td><em>B. kazinoki × B. papyrifera</em></td>
<td>May 20, 2008</td>
<td>Is. Gageo (Jeonnam)</td>
</tr>
<tr>
<td><em>B. kazinoki</em></td>
<td>May 14, 2007</td>
<td>Jeonju (Jeonbuk)</td>
</tr>
<tr>
<td></td>
<td>May 15, 2007</td>
<td>Mt. Chirisan (Jeonnam)</td>
</tr>
<tr>
<td></td>
<td>May 20, 2008</td>
<td>Is. Gageo (Jeonnam)</td>
</tr>
<tr>
<td><em>B. kazinoki</em></td>
<td>May 14, 2007</td>
<td>Jeonju (Jeonbuk)</td>
</tr>
<tr>
<td></td>
<td>May 14, 2007</td>
<td>Mt. Naegang (Jeonbuk)</td>
</tr>
<tr>
<td></td>
<td>May 20, 2008</td>
<td>Is. Gageo (Jeonnam)</td>
</tr>
</tbody>
</table>

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**Table 2.** Morphological characters of *Broussonetia kazinoki × B. papyrifera* with its related taxa.

<table>
<thead>
<tr>
<th>Character</th>
<th><em>B. papyrifera</em></th>
<th><em>B. kazinoki × B. papyrifera</em></th>
<th><em>B. kazinoki</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Habit</td>
<td>Tree</td>
<td>Small tree</td>
<td>Shrub</td>
</tr>
<tr>
<td>Twig diameter</td>
<td>0.5-0.7 cm*</td>
<td>0.3-0.5 cm</td>
<td>0.1-0.3 cm</td>
</tr>
<tr>
<td>Petiole length</td>
<td>3-4 cm</td>
<td>1-2 cm</td>
<td>0.5-1.0 cm</td>
</tr>
<tr>
<td>Lamina length</td>
<td>14-16 cm</td>
<td>10-12 cm</td>
<td>7-9 cm</td>
</tr>
<tr>
<td>Lamina width</td>
<td>9-11 cm</td>
<td>6-8 cm</td>
<td>3-5 cm</td>
</tr>
<tr>
<td>Stipule length</td>
<td>1.6-2.0 cm</td>
<td>1.1-1.5 cm</td>
<td>0.5-0.7 cm</td>
</tr>
<tr>
<td>Stipule width</td>
<td>1.0-1.4 cm</td>
<td>0.5-0.7 cm</td>
<td>0.1-0.3 cm</td>
</tr>
<tr>
<td>Inflorescence</td>
<td>Dioecious</td>
<td>Dioecious</td>
<td>Monoecious</td>
</tr>
<tr>
<td>Male inflorescence</td>
<td>Cylindrical</td>
<td>Cylindrical</td>
<td>Globose</td>
</tr>
<tr>
<td>Female inflorescence</td>
<td>5-7 cm</td>
<td>2-3 cm</td>
<td>0.7-0.8 cm</td>
</tr>
<tr>
<td>Female flower</td>
<td>1.1-1.3 cm</td>
<td>0.6-0.9 cm</td>
<td>0.2-0.4 cm</td>
</tr>
<tr>
<td>Fruit</td>
<td>1.7-2.1 mm</td>
<td>1.1-1.5 mm</td>
<td>0.7-0.9 mm</td>
</tr>
<tr>
<td>Fruit diameter</td>
<td>1.7-2.2 cm</td>
<td>1.0-1.5 cm</td>
<td>1.0-1.5 cm</td>
</tr>
</tbody>
</table>

* Minimum-maximum
inflexed in bud. Pistillate flowers: calyx pipelike, ovary ovoid, style filiform with stigmatic hairs, 1.0-1.2 cm long. Fruit orange-red when mature, 1.7-2.0 cm diameter, stalk 0.3-0.4 cm long. Fl. May.

Distribution: Korea, Japan, China, Taiwan, Malaysia, Laos, Myanmar, Thailand, Vietnam

Remark: This plant has often been cultivated in China to use as a material for making traditional paper, Gou shu.


2) **Broussonetia x hanjiana** M. Kim, hybrid nov. Fig. 1-D, E. TYPE: Korea, Province Jeonnam, Is. Gageo, 16 May 2008, M. Kim 9944 (holotype, JNU).


Korean name: **Daknamu** 독나무, Kkujidaknamu (Kim et al., 1992)

English name: Korean Paper Mulberry

Parvus arbor 6-8 m alta; Folia simplex alternus, lamina ovatae 10-12 cm longa, 6-8 cm lata, petioli 1-2 cm longi, margine serratus, secundaris vulgo 5-6, stipulae ovatus 1.1-1.5 cm longi, 0.5-0.7 cm lata; Flos dioecia. Aprilis-Maium florens; Amenta mascula cylindrica 2-3 cm longi, 0.8-1.0 cm diametro, pedicello 1.5-3.0 cm longi, bracteae linearis, calycis lobi 4, stamina 4, filamentosis curvatis 3-4 mm longa, antherae
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alba; Amenta feminea globosum 0.6-0.9 cm diametro, pedicello 0.4-0.7 cm longi, bracteae cylindricus 1.1-1.5 mm longi, ovarium dimidio superiore pilosum, styli filiformis 0.8-1.2 cm longi; Fructus rubrac, 1.0-1.5 cm diametro, pedicello 0.5-0.6 cm.

Small trees deciduous, dioecious. Twig 0.3-0.5 cm diameter. Leaves simple, alternate; blade ovate 10-12 cm long, 6-8 cm wide, margin coarsely serrate, sometimes 3-5 lobed, more or less scabrous; petiole 1-2 cm long. Stipules lanceolate, free, 1.1-1.5 cm long, 0.5-0.7 cm wide. Stamine inflorescence axillar, cylindrical, 2-3 cm long, bracts lanceolate, peduncle 1.5-3.0 cm long. Pistillate inflorescences globose heads, 0.6-0.9 cm diameter, bracts clavate, 1.1-1.5 mm long, peduncle 0.4-0.7 cm long. Stamine flowers: calyx tubular, 4 lobes; stamen 4, filaments inflexed in bud. Pistillate flowers: calyx petalike, ovary ovoid, style filiform with stigmatic hairs, 0.8-1.2 cm long. Fruit orange-red when mature, 1.0-1.5 cm diameter, stalk 0.5-0.7 cm long. Fl. May.

Distribution: Is. Gageo in Korea

Etymology: The specific epithet is derived from Korean traditional paper Hanji.

Habitats: Is. Gageo is located in most southwestern part of Korean Peninsula, and has the most natural vegetation and evergreen broad-leaved forest comprising with Castanopsis cuspidata var. sieboldii, Quercus acuta, Dendropanax morbifera, Illex integra, Daphniphyllum macropodium, etc. The natural habitats of Broussonetia x hanjiana were discovered at western side in the south part of Is. Gageo. This plants grow with dominant species Machilus thunbergii in canopy layer, and in shrubby zone with Mallotus japonicus, Eucaphis japonica, Callicarpa japonica. Also it makes herbaceous zone with dominant species: Miscanthus sinensis, Carex lanceolata, Phoropus globosa, and minor elements: Trachelospermum asiaticum var. majus, Hedera rhombea, Ardisia japonica, Kadsura japonica, Paederia scandens, Rubus hirsutus, Ficus nipponica, etc.

Remark: Without latin description and defining holotype, B. kazinoki × B. papyrifera was described by Kitamura and Murata at 1981. Thus, the name of B. kazinoki × B. papyrifera was not validly published under the rules of the International Code of Botanical Nomenclature. Until now this species has been cultivated, and the natural habitats were unknown, but through this study its natural habitats were discovered by the authors from Is. Gageo in Jeonnam, Korea. Thus, the authors newly described the hybrid as a new taxon, Broussonetia × hanjiana M. Kim. This species has been mostly used for making traditional paper Hanji in Korea. Therefore Its Korean name is changed into Daknamu instead of Kkujiaknamu (Kim et al., 1992).

3) Broussonetia kazinoki Siebold in Verh. Batav. Genootsch. Kunstcn 12: 28 (1830). Fig. 1-C.

B. kazinoki var. humilis Uyeki in Woody Pl. 27 (1940). nom. nud.

Korean name: Aegidaknamu 아기타나무, Daknamu (Lee, 1996; Lee, 2003)

English name: Small Paper Mulberry

Shrubs deciduous, monoecious. Twig 0.1-0.3 cm diameter. Leaves simple, alternate; blade ovate 7-9 cm long, 3-5 cm wide; margin coarsely serrate, sometimes 3-5 lobed, more or less scabrous; petiole 0.5-1.0 cm long. Stipules linear-lanceolate, free, 0.5-0.7 cm long, 0.1-0.3 cm wide. Stamine inflorescence axillar, globose, 0.7-0.8 cm diameter, bracts lanceolate, peduncle 0.9-1.0 cm long. Pistillate inflorescences globose heads, 0.2-0.4 cm diameter, bracts clavate, 0.7-0.9 mm long peduncle 0.4-0.5 cm long. Stamine flowers: calyx tubular, 4 lobes; stamen 4, filaments inflexed in bud. Pistillate flowers: calyx petalike, ovary ovoid, style filiform with stigmatic hairs, 0.5-0.8 cm long. Fruit orange-red when mature, 1.0-1.5 cm diameter, stalk 0.3-0.4 cm long. Fl. May.

Distribution: Korea, Japan, China

Remark: Until now, this taxon has been recorded in Korean flora as Daknamu (Lee, 1996; Lee, 2003), however this has not used for making Korean traditional paper Hanji. The Korean name of B. × hanjiana M. Kim is changed into Daknamu instead of Kkujiaknamu. Therefore, Korean name for B. kazinoki is also changed into Aegidaknamu instead of Daknamu.


4) B. kazinoki for. koreana M. Kim for. nov. Fig. 1-F, G.


Korean name: Gageo-Aegidaknamu 가게에기담나무

English name: Gageo Paper Mulberry

Forma affinis B. kazinoki, sed differt a forma dioecia.
This form look like B. kazinoki, but it has a dioecious plants.

Distribution: Is. Gageo in Korea

Remark: B. kazinoki for. koreana M. Kim having a dioecious plants found in Is. Gageo, is distinguish from the species of B. kazinoki having a monoecious plants.

Key to Broussonetia x hanjiama and its closely related taxa.

1. Trees or Shrubs.
2. Plant dioecious. Stamine inflorescence cylindrical. Petiole and stipule more than 1 cm diameter.
3. Petiole 3-4 cm long. Stipules 1.6-2.0 cm long. Pistilate inflorescence more than 1 cm diameter. Stamine inflorescence 5-7 cm long ............. B. papryfera
3. Petiole 1-2 cm long. Stipules 1.1-1.5 cm long. Pistilate inflorescence less than 1 cm diameter. Stamine inflorescence 2-3 cm long ............. B. x hanjiama
2. Plant monoecious. Stamine inflorescence globose. Petiole and stipule less than 1 cm long .... B. kazinoki
1. Climbing woody plants .............. B. kaempferi

Discussion

This is a review of the Korean Broussonetia species based on morphological features. It was reconfirmed that a hybrid species, B. x hanjiama M. Kim is originated from the natural hybridization between B. papryfera (L.) L’Her. ex Vent. and B. kazinoki Siebold. This hybrid has been used for making Korean traditional paper, Hanji (Kim et al., 1992). Broussonetia x hanjiama did not show variable forms comparing with those of Ilex x wandoensis C. F. Miller & M. Kim (Miller and Kim, 2002).

Is. Gageo is located in the most southwestern Korea, and has well preserved natural forests composing with Castanopsis cuspidata var. sieboldii, Quercus acuta, Dendropanax morifolia, Ilex integra, Daphniphyllum macropodum, etc. Broussonetia x hanjiama grows with a dominant species, Machilus thunbergii, in canopy layer, and in the shrubbery zone with Mollotus japonicus, Euscaphis japonica, Callicarpa japonicoa in this island. This species has been cultivated around human habitation, its natural habitats, however, has been unknown till now. This study found that, even though Is. Gageo is a small size, this is the only island having all three Korean species of Broussonetia: male and female plants of B. papryfera, male and female plants of B. x hanjiama, monoecious plants of B. kazinoki, dioecious plants of B. kazinoki for. koreana.

The name of B. kazinoki x B. papryfera was not validly published under the rules of the International Code of Botanical Nomenclature. This study found its natural habitats from Is. Gageo in jeonnam, Korea. Thus, we describe a hybrid, B. x hanjiama M. Kim of Broussonetia, as a new taxon. This species has been used for making traditional paper Hanji in Korea. Its Korean name is also changed into Daknamu instead of Kkujiaknamu (Kim et al., 1992). Female plants of this taxon have been cultivating in most region of Japan including Kyoto for making traditional paper, Kozo-shi. Because B. kazinoki has not cultivated for making Korean traditional papers Hanji (Lee, 1996; Lee, 2003), its name should be changed into Aegidaknamu instead of Daknamu.

Some plants of B. kazinoki found in Is. Gageodo is named as B. kazinoki for. koreana M. Kim, because these has the same morphological features as those of B. kazinoki except for the feature of sexual organ, dioecious. This female plant is cultivating in some region of Japan for making traditional paper, Kozo-shi.

Although all Korean Broussonetia species (Moraceae) has been reviewed based on morphological characters in this study, we believe that diverse approaches including molecular systematics using DNA sequences are required to get a better taxonomic understanding of them.

Acknowledgement

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Literature Cited


