P L A N T B R E E D I N G A N D S E E D S C I E N C E
Volume 49 2004

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PLANT RESOURCES OF *TRIARRHENA* AND *MISCANTHUS* SPECIES IN CHINA AND ITS MEANNING FOR EUROPE

ABSTRACT

The giant grasses, some speeies in *Triarrhena* and *Miscanthus,* have high potential of biomass productivity and could be used as a source of renewable raw material and energy. China is one of the most important distribution areas of these plants. An overall investigation on the high potential speeies and their geographical distribution in China is undertaken and the results are presented. *T. lutarioriparia,* ever named *Miscanthus sacchariflorus,* is an endemie speeies in China. It can grow to 6-7 m high and is being used as an important paper-making material. This species distributes in China in warm temperate regions from 28°36' North latitude to 34°49' North latitude; and from 110°41' East longitude to 121°29' East longitude. A cultivation trial shows that this species can grow over 3.5 m and over-winter safely in Braunschweig, Germany. The product quality, botanical and agronomie properties of this species are somewhat different to another hybrid species, *Miscanthus × giganteus,* the well-known species being cultivated and investigated in Europe. It is very interesting to integrate the newly introduced plant, *T. lutarioriparia* into the start materials of *Miscanthus* breeding work. There are more information about other related plants given in this paper.

Key words: biomass, *Miscanthus*, plant resources, renewable energy, *Triarrhena*

INTRODUCTION

The genus *Miscanthus* includes some high-growing species which are distributed in East Asia. A hybrid species *M. × giganteus* was introduced from Japan to Europe in about 1935 (Greef and Deuter 1993). Since 1980s this species has been intensively investigated in Europe being regarded as a potential biomass and renewable energy supplier (Greef 1996, El Bassam 1998, Jeżowski 1999, Xi 2000). Studies with biochemical methods revealed the restricted genetie diversity of *Miscanthus* species used in Europa (Greef *et al.* 1997, Deuter, Jeżowski 1997). This is an unfavourable situation for the *Miscanthus* breeding work and a long period use of these plants in Europe.

Communicated by Andrzej Anioł

Miscanthus sacchariflorus is used in Japan as a forage grass. This species name was also used for Chinese *Miscanthus* plants, including a small form in northern China and a tall form in South-East of China. The latter was the highest plant in the genus *Miscanthus.* Liou (1989) identified the small form as *Triarrhena sacchariflora* and the tall form as *T. lutarioriparia.* The tall one is used as an important raw material for paper-making industry in China.

There are more high-growing grass species in China which have high potential of biomass productivity. The present systematic positions of these plants are listed below:

Gramineae (Poaceae)
Subfam. Panicoideae
Trib. Andropogoneae
Subtrib. Saccharinae
Genus *Triarrhena* (Maxim.) Nakai 1950
1. T. lutarioriparia L. Liou 1989
2. T. sacchariflora (Maxim.) Nakai 1950
Genus *Miscanthus* Andersson 1855
3. M. sinensis Andersson 1856
4. M. floridulus (Labill.) Warb. ex K. Schum. and Lauterb.1901
5. Miscanthus × *giganteus* Greef et Deu. 1993
Subfam. Pooideae
Trib. Arundininae
Subtrib. Arundineae
Genus *Arundo* L. 1753
6. A. donax L. 1753
Genus *Phragmites* Adans 1763
7. Paustralis (Cav.) Trin. ex Steud. 1841
Genus *Neyraudia* Hook. f. 1896
8. N. reynaudiana (Kunth) Keng ex Hitchc. 1934

These plants are very interesting for biomass production or as breeding materiais in China and in Europe, but there were no information on the exact natural distribution areas of the plants listed above, with exception of the common reed *Phragmites australis* which grows almost all over the world.

An investigation on the distribution of these plants and the possibility to grow them in northem regions have been conducted. Point of main efforts are on *Triarrhena* and *Miscanthus* species.

MATERIALS AND METHODS

An expedition was undertaken for a survey on the distribution of giant grasses in China. The plants, their growing habitats and conditions were observed. The plant heights were measured and the plant material, e.g. rhizome, culm and seeds were collected when possible. Over

100 sites were observed and over 20 000 km were travelled by feet or by other means in China in 1994–1999.

The collected plant materiais were transplanted and cultivated in Yuncheng in northern China. Different methods of plantation were tried, Le. with seeds, rhizomes and pieces or culms, all of these methods are successful in *Triarrhena* species.

Photo-stereomicroscopy was used to identify the plants and their morphological and anatomical properties.

RESULTS:

1. General description and distribution of the observed giant grasses

The observed high-growing grasses are all the so-called reed-like grasses. They all have rhizomes as storage parts and therefore grow rapidly in the next spring. Some of them, *Triarrhena and Miscanthus,* are C4-plants, having a more effective photosynthetic pathway. Based on their physiological properties they have great potential of biomass production, frequently over the productivity of the trees.

1.1 Triarrhena lutarioriparia

Under the generally used name *Miscanthus sacchariflorus* (Maxim.) Benth. are many different variants which can be sorted into two groups: one consists of tall-growing plants and the other of smaller-growing plants. The two groups are different not only in their sizes, but also in some other morphological characteristics. They have different distribution ranges due to their adaptability to different climatic and geographical conditions. Recently, they are classified as 2 species (Liou 1989):

Triarrhena lutarioriparia L. Liou

Triarrhena sacchariflora (Maxim.) Nakai

The common characteristics of *T. lutarioriparia*:

A perennial plant growing in warm temperate regions, with long creeping rhizome covered with scale-like sheath-blades. Culms 2-7.5 m tall, 0.8-3.5 cm in diameter near base; culm hollow or partly pith-tilled and partly hollow; with or without wax powder on surface, with or without branches; erect or lodging-easy; making an extensive colony. Leaf-blade long, 90-100 cm × 1.5-4 cm; with scabrous margins; glaucous underneath; ligules consist of a tringe of minute hairs (cilia); auricles present or not; leat-sheath with or without hairs. Panicle consists of numerous, subdigitally arranged racemes on short main axis, racemes 20-35 cm long, somewhat pendulous. Central axis of the panicle shorter than racemes, i.e. shorter than ″ of the whole panicle. Spikelet paired, one short- and one long-pedicellate, both alike, 4-6mm long, bearded at base with white hairs, which are far longer than the spikelet. Glumes sub-equal, faintly 3-nerved, lower glume as long as spikelet and sparsely hairy on edge, upper glume shorter. Up-

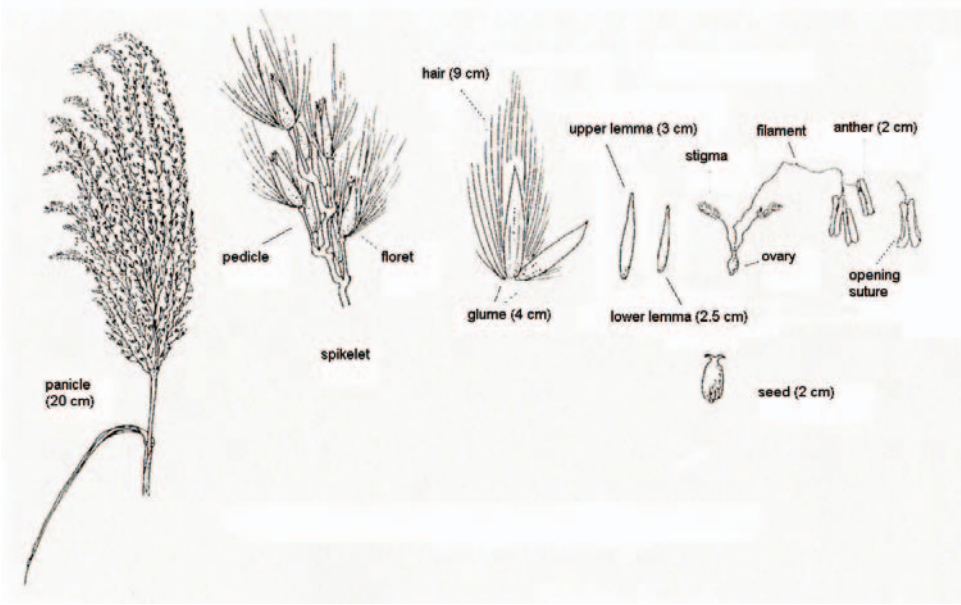

Fig. 1 Inflorescence of *Triarrhena lutarioriparia*

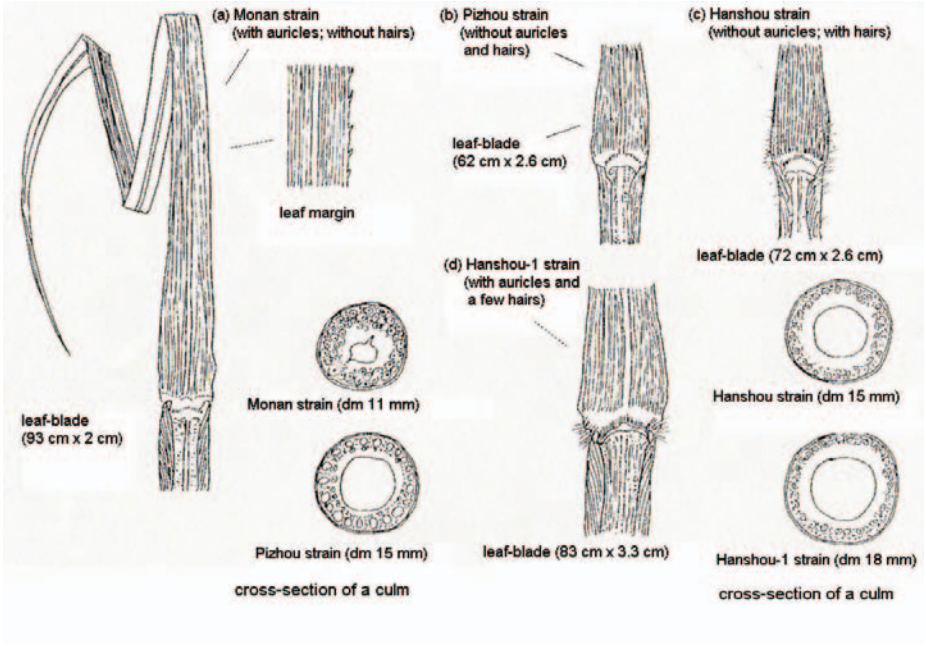

Fig. 2 Leaf-blade and culm of *Triarrhena lutarioriparia*

per lemma awnless, lower lemma shorter and nerveless. Anthers 2 mm long. Seed about 2 mm tong, dark brown (Figs 1-3).

The flowering and seed-ripening time is from September to November.

Differences between *T./utarioriparia* and *T.sacchariflora:*

**T. lutarioriparia:* Plant height usually over 2 m. Culm diameter

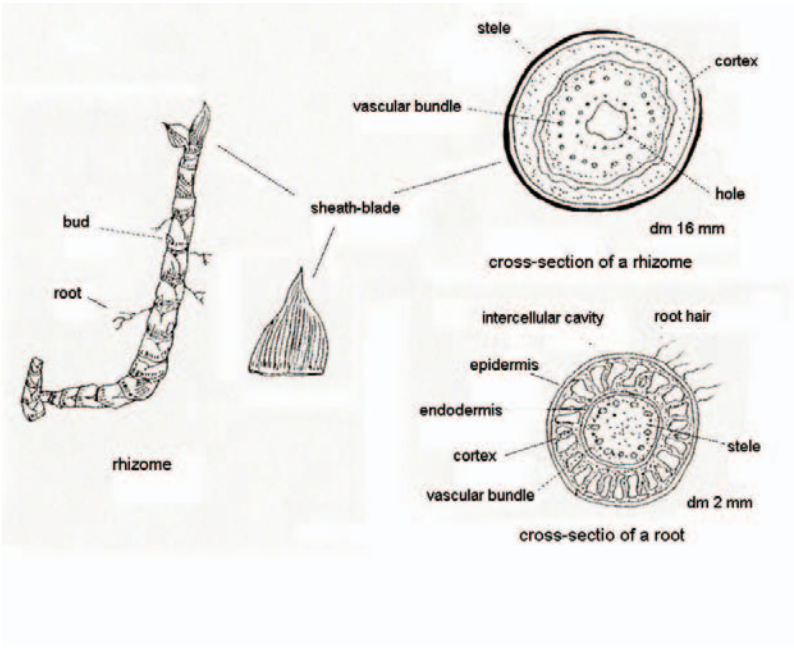

Fig. 3 Rhizome and root of *Triarrhena lutarioriparia*

usually over 0.8 cm. Without hairs in the axiles of the branches (rachises) on the panicle. Grows on lowland in warm temperate regions.

**T. sacchariflora:* Plant height usually under 2 m. Culm diameter always under 0.5 cm. With hairs in the axiles of the branches (rachises) on the panicle. Grows on hillsides or field-sides in temperate to cold temperate regions.

Distribution of *T. lutarioriparia* in China:

The results of the investigation show that *T. lutarioriparia* distributes in China in a range from 28°36’ N lat. (Yiyang) to 34°49’ N lat. (Pinglu); and from 110°41’ E long. (Ruicheng) to 121°29’ E long. (Shanghai). The most bountitul natural vegetations are in the lake-island regions along the Yangtze River (Dongting Lake and Poyang Lake).

T.sacchariflora has a northem and larger distribution range: from 30°42' N lat. (Gaohebu) to 41°48' N lat. (Shenyang); and from 110°27’ E long. (Ruicheng) to 123°25’ E long. (Shenyang). According to the literature

it distributes widely towards North-East, including all of northern-eastern China, Korea, a part of Siberia and Japan (Liou 1989).

1.2 Miscanthus sinensis

This species shares the geographical distribution in the North with *T. sacchariflora* and in the south with *M. floridulus.* It is easily distinguished from *T. sacchariflora* with their awns on spikelets, but in the south it is sometimes confused with *M. floridulus,* because there are trequently transition torms between these species, perhaps arising from natural crossing. *M. floridulus* distributes more widely towards the South, from warm temperate to subtropical regions. The question of how to make a decision in identifying these two species will be discussed after the description *ot M. floridulus.*

The common characteristics of *M. sinensis:*

A perennial grass growing on hillsides- and field-sides in temperate

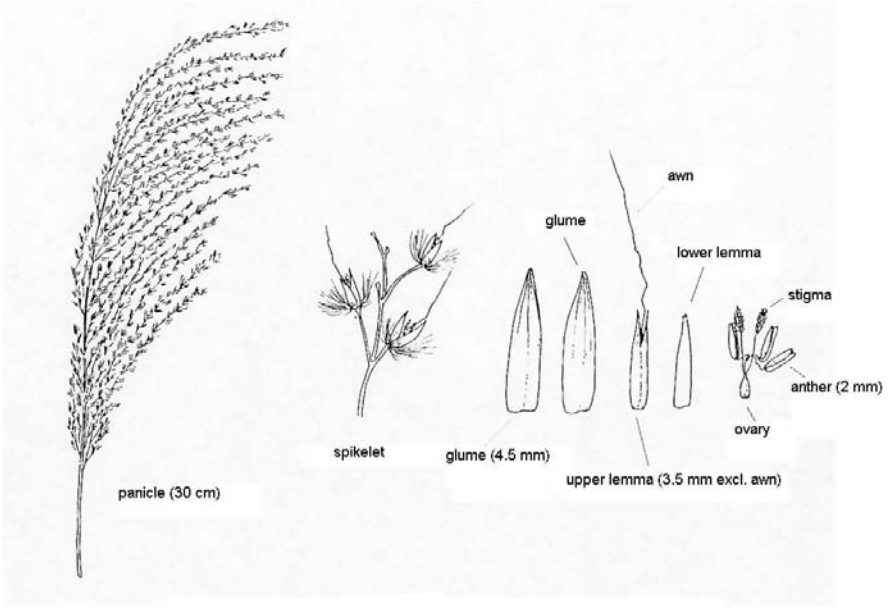

Fig. 4 Inflorescence of *Miscanthus sinensis*

regions, with short rhizomes. Culms densely tufted, erect or half-erect, 0.5-3.3 m tall, 3-7 mm in diameter near base. Leaf-blades long, 20-70 cm × 0.6-1.2 cm, with very rough margins; midrib white. Ligules conspicuous, short ciliate on upper margin. Panicle has 10-25 racemes which are 10-30 cm long, slightly noding; central axis shorter than racemes, i.e. shorter than 1/2 of the whole panicle. Spikelets paired, one short-and one long-pedicellate; both alike, 4-7 mm long,

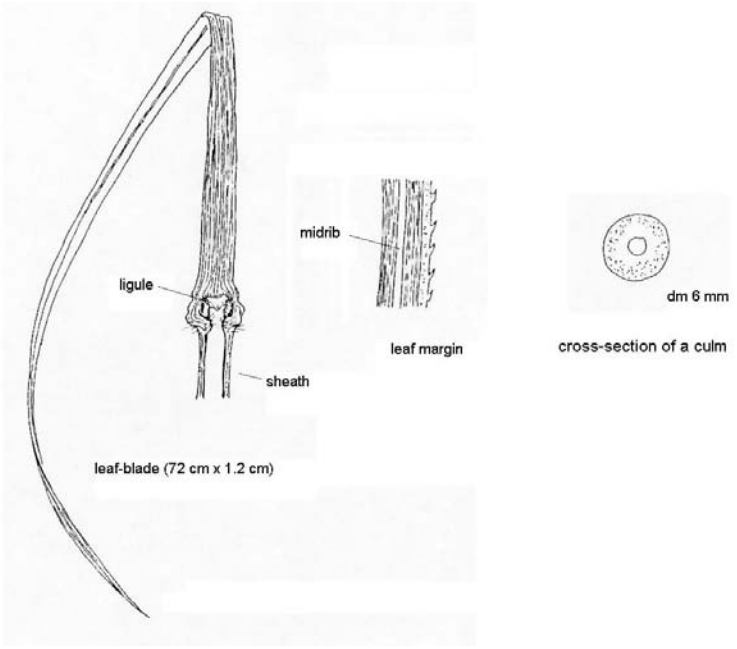

Fig. 5 Leaf-blade and culm of Miscanthus sinensis

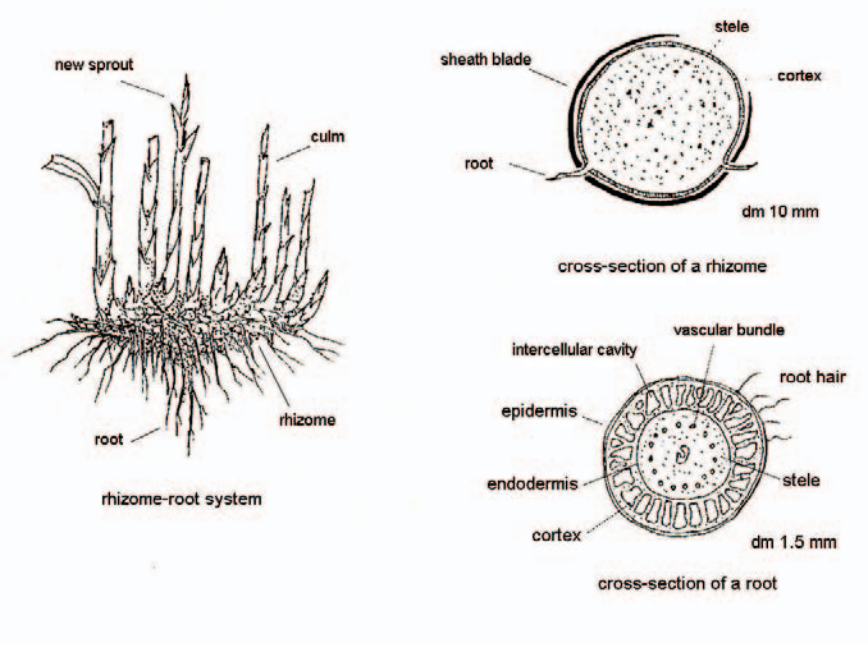

Fig. 6 Rhizome and root of *Miscanthus sinensis*

bearded at base with white hairs, which are as long as the spikelet. Glumes equal, as long as the spikelet; the upper 3-nerved, the lower 1-nerved. Upper lemma deeply bifid, awned between the teeth, awn 8-10 mm long, exserted, geniculate. Lower lemma membranous, hyalin. Anthers 2 mm long. Seed purplish brown or dark brown (Figs 4-6).

The flowering and seed-ripening time is from July to December.

Distribution of *M. sinensis* in China:

According to this study, *M. sinensis* distributes in a range from 22°48' N lat. (Nanning) to 33°55' N lat. (Fengxian); and from 103°19' E long. (Emei) to 120°06' E long. (Huzhou). This plant arises only in habitats under 1800 m altitude, mostly under 1000 m altitude.

In South-West of China the general altitude is high and there are some other species with smaller sizes distributed, i.e. *Diandranthus* species, e.g. *D. brevipilus* and *D. nepalensis* which were also called *Miscanthus* species earlier.

In the literature it is stated that *M. sinensis* has a very large range of distribution in East Asia, far North through northern-eastern China to Siberia, this has now been proved incorrect. The dominant populations of this species are mainly found in Mid-South of China, in warm temperate regions.

1.3 Miscanthus floridulus

This is a wide-spreading species and generally dominant in its habitats, more robust than *M. sinensis.* According to this investigation two forms can be subdivided inside this species. One is the normal form growing on hillsides or field-sides with erect or half-erect culms. The other form is that mainly growing on field-sides or roadsides, with erect and densely clustered culms, more robust than the normal form and therefore easy to identify. This form has limited distribution and is usually used as a hedge plant. So it is named here as the hedge form.

The common characteristics of *M. floridulus:*

A robust perennial plant growing at lower altitudes in subtropical to warm temperate regions, with thick and short rhizomes. Culms pith-filed, 2.0-4.1 m tall, 8-10 mm in diameter near base, densely tufted in large clumps. With wax powder on culm surface and the base of leaf-blade. Leaf-blade long, 30-100 cm × 1.5-3.5 cm, with very rough margins and white midrib, glabrous except for basal tomentose portion. The sharp teeth on leaf-margins arranged normally forward, but sometimes backward (in hedge form). Ligules tall, short fimbriate on upper margins. Radical leaves usually pass the winter keeping green. Panicle has numerous racemes which are 10-20 cm long, evidently shorter than the central axis, i.e. the central axis is relatively

thick and longer than $^{2}/_{3}$ of the whole panide. Spikelets paired, one short- and one long- pedicellate, 3-4 mm long, bearded at base with white hairs, which somewhat longer than the spikelet. Glumes alike, as long as spikelet, glabrous or short hairy on back. Upper lemma deeply bitid, awned from the sinus, awn 8-10 mm long. Lower lemma hyalin. Anthers 2 mm long. Seed brown (Figs 7-9).

The flowering and seed-ripening time is from May to October.

The normal form flowers earlier while the hedge form later.

The whole plant looks blue-green, evergreen except for the panicle-building culms, during the year in warmer regions.

There are mainly 4 points to differentiate *M. sinensis* and *M. floridulus:*

1) The central axis of the panicle is longer than $^{2}/_{3}$ of the whole panicle in *M. floridulus,* while that is shorter than ″ of the whole panicle in *M.sinensis.*
2) The leaf-blade has a more hairy and waxy surface at base in *M. floridulus* than in *M. sinensis.*
3) The flowering time of *M. floridulus* is generally earlier than that of *M. sinensis.*
4) In winter *M. sinensis* will dry out, while *M. floridulus* is an evergreen plant.

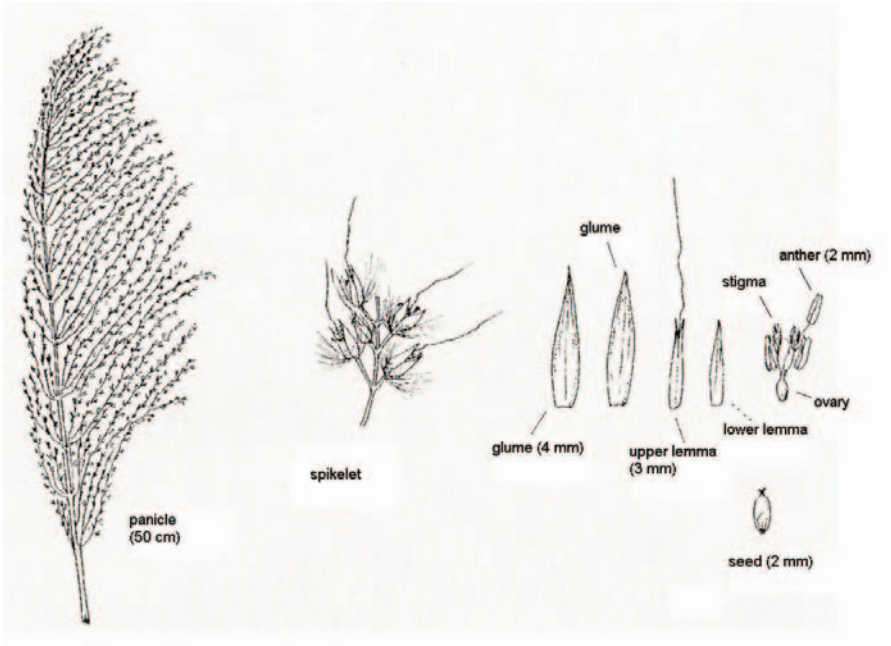

Fig. 7 Inflorescence of *Miscanthus floridulus*

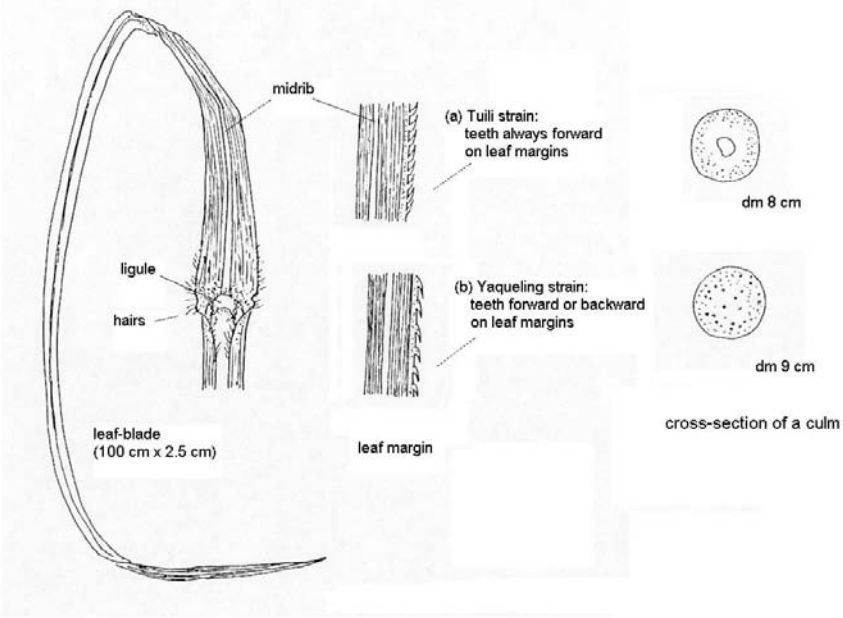

Fig. 8 Leaf-blade and culm of *Miscanthus floridulus*

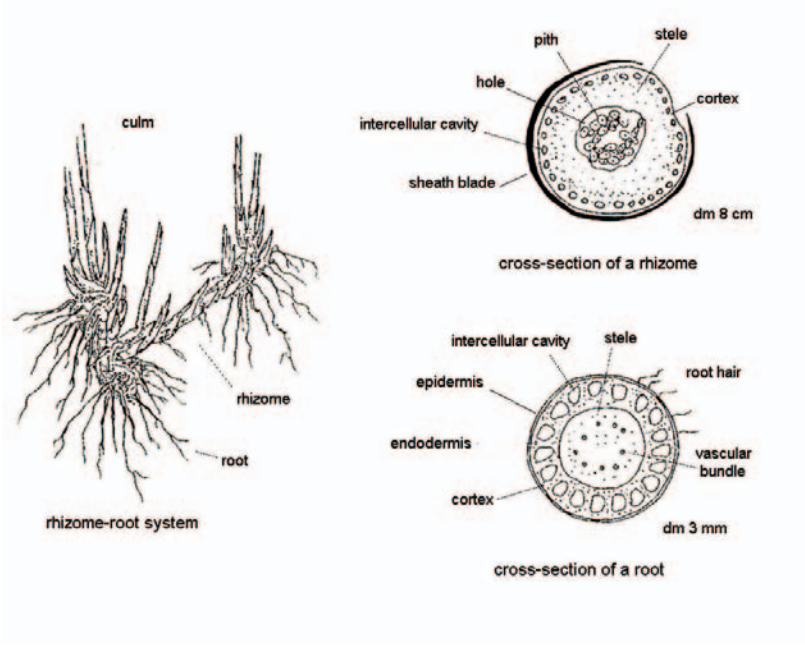

Fig. 9 Rhizome and root of *Miscanthus floridulus*

Distribution of *M. floridulus* in China:

The species *M. floridulus* distributes in a range from 19°14' N lat. (Qionghai) to 31°46' N lat. (Sanshipu); and from 107°39' E long. (Yaozhai) to 120°06' E long. (Huzhou).

The hedge form of this species distributes mainly in Hubei Province, from 30°05' N lat. (Shanpo) to 30°50' N lat. (Dangyang) and from 111°17' E long (Yichang) to 114°20' E long (Shanpo).

1.4 Miscanthus × giganteus Greef et Deu.

This species was introduced from Japan to Denmark in 1935 and distributed to some European countries towards the end of 1970s *(*Greef and Deuter 1993). In recent years it attracted more attention by European researchers with its potential of high biomass production and possibility to be used as a source of renewabie energy and raw material. But its exact taxonomic position had not been examined in detail for a long time, and called *Miscanthus sinensis giganteus,* until Greef and Deuter (1993) conducted the syntaxonomy and nominated it as *Miscanthus × giganteus* Greef et Deu., placed it in genus *Miscanthus,* section *Triarrhena.*

It was thought interesting that this species was ever called China Reed *(Miscanthus sinensis)* in Europe, but it was uncertain whether it really appears in China or not. To get more information and as a comparison this species was also included in this work.

The characteristics of *Miscantheus × giganteus*
(According to Greef and Deuter 1993, slightly moditied):

A triploid perennial plant, with thick and stout rhizome. Culm 2.5-3.5 m long, node without hairs, root promodia and aerial branches at lower nodes sometimes observed. Leaf-blades linear, >50 × 3.0 cm, ligule truncate with hairs (2-3 mm). Inflorescence 30 cm long, rachis of panicle 15 cm long. Spikelet 4-6 mm long, longest pedicel 4 mm long. Three anthers, 2 mm long. Callus hairs about 2 times long as the spikelet. First glume 5-6 mm long, 1.5-2 mm wide, faintly 2-nerved, with hairs on back, 3-6 mm long. Second glume 4-5 mm long, 1.5-2 mm wide, 3-nerved, with hairs on back, hairs shorter than on the first glume. Upper lemma not awned, 3-3.5 mm long, <1 mm wide, nerveless, filiate haired at edge. Lower lemma 3-3.5 mm long, 3-nerved, sometimes the fertile lemma longer than 3.5 mm with an additional soft awn which more than 1 mm long. Palea present, 1 mm long. Lodicule present. No seed (Figs 10-12).

The flowering time is between September and November.

Distribution of *Miscantheus × giganteus:*

This species is cultivated for research in a number of in stitutions in Europe. The natural vegetation in its original area, perhaps in Japan, has not been determined. According to the observation of this study, it

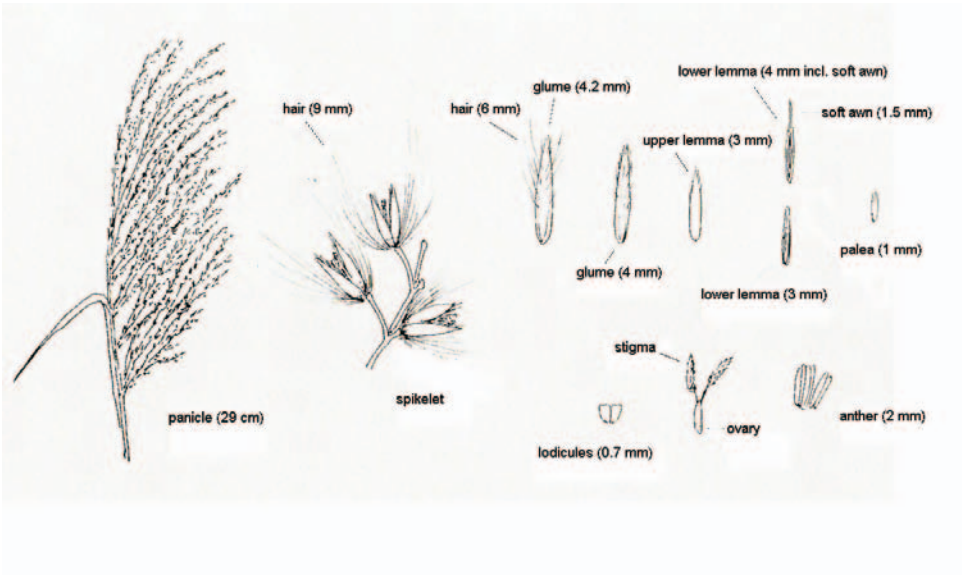

Fig. 10 Inflorescence of *Miscanthus* × *giganteus*

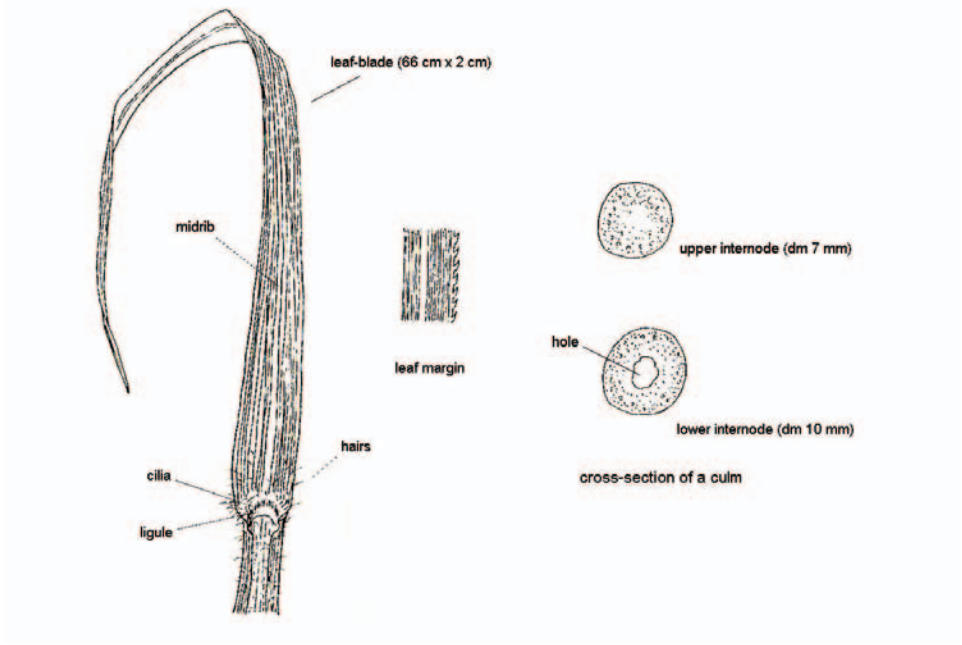

Fig. 11 Leaf-blade and culm of *Miscanthus* × *giganteus*

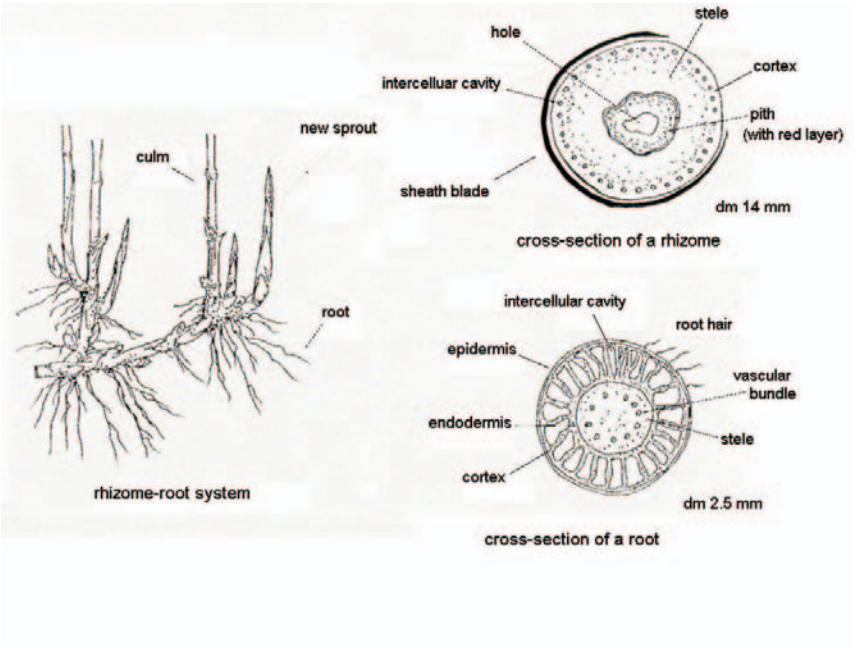

Fig. 12 Rhizome and root of *Miscanthus* × *giganteus*

does not appear in China. There are only some populations of *T. lutarioriparia,* with a form similar to *Miscanthus* × *giganteus,* Le. culm without branches, and they could be found in East of China (Jiangsu Province).

2. The height in natural vegetation and yield in cultivation of some giant grasses

The giant grasses have high potential of biamass productivity. A main characteristic of these grasses is their unusual high-growing appearances. In this investigation some measurement are taken on the observed plants (Table 1).

Table 1

The maximai height in natural vegetation and the yield in cultivation of some giant grasses

Species/Form	Max. height [m]*	Site of observation	Biomass yield in cultivation [t × ha × year]
T. lutarioriparia	>4.5	Hanshou- Yanwanghu	22.5 - 41.1 *
	3.5	Pizhou, Monan	
M. sinensis	3.32	Mengdonghe	-
	2.5	Yichang-Haiyun, Cili	
M. floridulus	3.26	Nanning- Tunli	-
	3.48	Sanjiang	
	3.50	Yaqueling	
	4.10	Wuchang-Dahualing	
Miscanthus × giganteus	3.5**	Germany	26.2 ***

*air-dried mater, see Liou 1989. **Schwarz *et al.* 1995. ***in Braunschweig, see El Bassam 1996

DISCUSSION

The giant grasses are worth attention both in their ecological and economical aspects. They grow in different places and conditions, frequently as a dominant component of the vegetation, covering and holding the soil firmly, offering habitats for many creatures, thus enriching the bio-diversity.

At the same time, these plants could be used for various purposes, namely, as industrial raw materials in ligno-cellulose production for paper-making etc. and as a sort of energy supplier, especially when they are integrated into a sustainable agriculture system and grown as industry crops.

The high biomass productivity of the giant grasses, which could be higher than that of the trees, is the basis of growing these plants for renewable raw material and energy supply. At the same time, the use of giant grasses does not disturb the vegetation and the landscape because they are perennial and regrow annually. The use of giant grasses saves the fossil energy and forest resources and benefit our environment.

To grow and to use the giant grasses sufficient varieties for different conditions and regions are necessary. A collection of the natural plant resources and thereupon a breeding work serve for this purpose. Presently in Europe are only limited diversity of *Miscanthus* plants available (Greef *et al.* 1997). To integrate the Chinese *Triarrhena* and *Miscanthus* materiais into the European *Miscanthus* breeding work is meaningful.

At present situation and for the existed natural plant materials, the following suggestions could be made for the practical use of the giant grasses:

* In southem China the giant grasses are to be cultivated in marginal lands, which still lack permanent vegetation. The first recommendable species is *Triarrhena lutarioriparia,* which could be propagated and established with seeds.
* In northern China, on the Loess Plateau, where the climate is relatively dry, *Triarrhena lutarioriparia* could also be cultivated, better with the culm propagation method.
* In Europe the first choice is *Miscanthus* × *giganteus* as a suitable species for growing giant grasses. More genotypes of giant grasses should be introduced for breeding work and for effective use for different purposes.

CONCLUSIONS

1. A great variability in gene pool of described giant grasses makes possibility to select genotypes suitable for European climate conditions.
2. The giant grasses are useful both for land conservation, against soil erosion, and for renewable raw supply. To protect and to grow these plants would benefit our environment.

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