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Giant Miscanthus: Biomass Crop for Illinois

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Traditional energy sources in Illinois include coal, oil, and nuclear power. There is presently, however, much interest in locally produced energy sources that can reduce reliance on energy that originates outside of Illinois. Wind, corn-based ethanol, and soybean-based biodiesel are all examples of locally produced alternative energy sources. Other potential Illinois energy sources are crop residues or dedicated plants, primarily perennial grasses, which are burned to produce heat and electricity or treated with enzymes to produce sugars that can then be used to produce cellulosic ethanol. Plants used in these ways may be termed biomass crops, biofuel crops, bioenergy crops, or feedstocks. One such biomass crop is the US native prairie plant, switchgrass (*Panicum virgatum* L. Poacea/Gramineae). A warm-season grass, switchgrass can grow to 1.8 m or more; produces short, scaly rhizomes; and is tolerant of a variety of soils. There are two distinct forms of switchgrass, an upland type adapted to the Northern US and a lowland type adapted to the Southern US. It is readily propagated by seed and has been the subject of much research. Moreover, it is already being used in the Midwest to produce burnable biomass and is being touted as a likely source of ethanol.

In addition to switchgrass, researchers at the University of Illinois are studying another grass, giant miscanthus (*Miscanthus* × *giganteus,* Poaceae/Graminae). Giant miscanthus has been widely studied and grown in Europe where it is being used to produce biomass to burn for heat and electricity. The potential for using giant miscanthus as an alternative energy source in Illinois appears to be great: in side-by-side studies at three Illinois locations, giant miscanthus has produced more than double the biomass of upland switchgrass per unit area.

WHAT IS GIANT MISCANTHUS?

The genus *Miscanthus* comprises a group of more than 10 grass species, most of which are native to Asia. There appears to be much interspecific hybridization within the genus; giant miscanthus is a hybrid believed to have *M. sinensis* Anderss. (a diploid species) and *M. sacchariflorus* (Maxim.) Hack (a tetraploid species) as its parents. The cross between the diploid and tetraploid produces a triploid, which is unable to produce viable seed. Though this cross occurred naturally, a similar breeding technology is used widely in the watermelon industries to produce seedless fruits; most seedless bananas are also triploid. In the US, several species and cultivars, primarily *M. sinensis* types, have been widely used as ornamentals in landscape plantings.

Giant miscanthus is a perennial warm-season (C4) grass, with a growing season in Central Illinois that begins in late April and is completed as it goes dormant following the first killing frost, usually in October. Growth each year originates from the buds on scaly rhizomes. In Central Illinois, established plants typically reach more than 2 m tall by the end of May and greater than 4 m at the end of each growing season (Fig. 1). In established giant miscanthus plantings, approximately 54 to 107 shoots per square meter are developed. The grass does not flower every year, and when flowering does occur, it takes place in late September or early October in Central Illinois. As a sterile hybrid, no viable seeds are produced.

As temperatures cool in the fall, the dark green foliage fades to buff and drops, leaving stems (and sometimes sterile flowers at their terminus). Stems are the most commercially important portions of giant miscanthus, and harvesting the dried stems takes place during winter. Harvestable stems resemble bamboo and are usually 1.3 to 2.0 cm in diameter and more than 3 m long.

PROPAGATION

Being sterile, giant miscanthus is propagated asexually, usually by dividing the rhizomes(Fig. 2), the underground storage organs. The 0.7 to 1.3 cm diameter buff-colored rhizomes have multiple nodes and are scaly and variably branched. Producing new plants using tissue culture and rooted stem cuttings has also been successful, but the resulting plants often fail to survive transplanting to field settings.

For greenhouse propagation, plant 30 to 60 g rhizomes (usually 7 to 12 cm long) in 12 cm square pots using a soil-less greenhouse mix. The pots are grown under 16-hour per day supplemental lighting, irrigated as necessary, and fertilized every two weeks using a soluble greenhouse fertilizer. These potted plants can usually be divided every 4-to-8 weeks. While much of the rhizome stock at the University of Illinois has been propagated in this manner, it is likely that propagation in the field will be more common on an industrial scale.

To propagate stock in the field, use rhizomes that are approximately 10-to-15 cm long weighing 42 to 60 g. The ideal planting time in Central Illinois is mid April through May, but with irrigation, rhizomes have successfully been planted as late as mid-July. Plant the rhizomes approximately 10 cm deep. If clumps are to be divided after one growing season, plant the rhizomes in rows 60 cm apart, but increase spacing to 75 to 90 cm apart if the clumps are to be divided following two years of growth. Under ideal conditions, one-year clumps typically yield 7 to 10 harvestable rhizomes and two-year clumps 25 or more rhizomes.

To optimize propagation success, irrigation should be available to supplement precipitation during dry periods and weeds should be controlled. University of Illinois studies have shown that giant miscanthus tolerates application of several pre-emergence and postemergence herbicides used to control annual grassy and broadleaf weeds (Table 1).

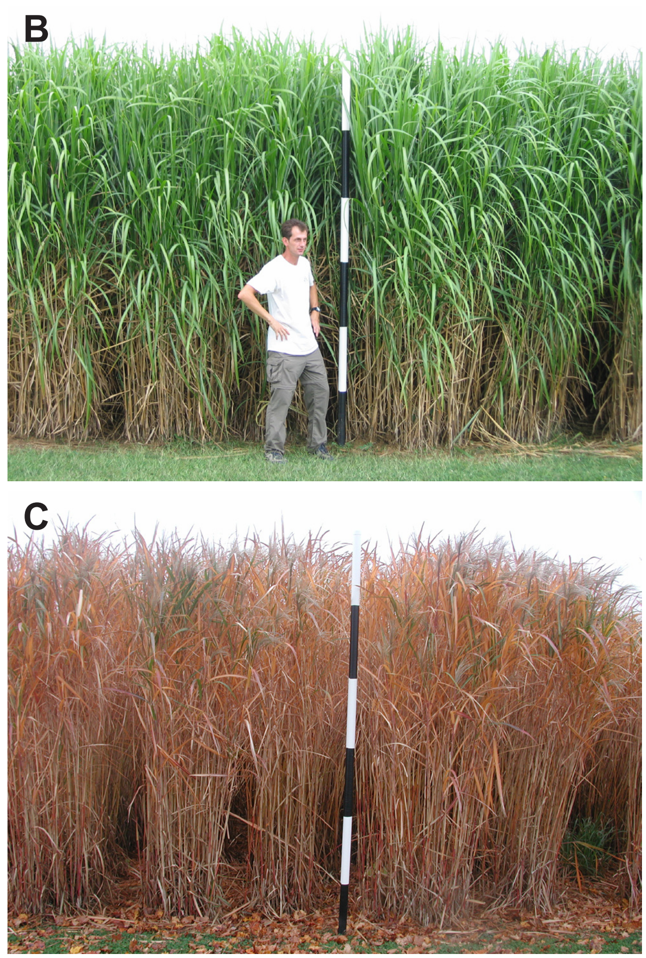

Fig. 1. Giant miscanthus growing in Central Illinois (A) April 30, (B) August 24, and (C) November 5.

Fig. 2. *Miscanthus* × *giganteus* rhizome.

GROWING CONDITIONS REQUIRED

Giant miscanthus has successfully been established and survived in northern, central, and southern Illinois sites ranging from DeKalb to Dixon Springs. Adequate water is necessary for successful establishment, as well as to optimize production. While it will not withstand continuously waterlogged soils, yield usually increases as more water is available to the crop. Normally, the summer rains and humidity in Illinois, along with the State's moisture-retentive soils, are adequate to produce high yields.

Giant miscanthus is a very cold-tolerant warm-season grass. Not only is it able to develop leaves that can photosynthesize at temperatures as low as 10°C, but stands at the University of Illinois in Urbana, planted nearly 20 years ago, have survived winters with periods below –23°C without loss.

In Illinois trials at seven sites, establishment was slowest at the two least fertile sites. Maximum yields should be obtained within three years on fertile soils, but may require 4-to-5 years on poor soils. Following establishment, giant miscanthus appears to be remarkably efficient at capturing and retaining nitrogen; in European trials, there was no significant effect of nitrogen fertilization on yield. Yield reductions were not observed even at sites where no nitrogen had been applied. Anecdotally, an ornamental planting in Central Illinois has grown 18 years without being fertilized and continues to reach 3.6 to 4.2 m and produce numerous stems. Obviously, more fertility research in Illinois is needed and is ongoing so that yields can be optimized through proper fertilization.

Giant miscanthus plantings are occasionally started using potted plants produced in greenhouses or by planting rhizomes. When using potted plants, remove the plants from the greenhouse in mid April to mid May and place the pots in a protected outdoor area for a week to harden. After hardening, plant using a spacing of 0.9 m between rows and 0.9 m between plants in the rows (approximately 11,984 plants per ha). Field plant at the same depth as the grass was growing in the pots. Water the plants following planting and continue to water through the first growing season as necessary to ensure establishment. Control weeds as necessary during the first growing season mechanically or by applying herbicides (Table 1).

At the University of Illinois, unfertilized demonstration plots of potted giant miscanthus planted in May 2004 required no weed control after the planting season, developed a closed cover by the end of the second growing season, and were at least 3 m tall by the end of the third growing season.

More commonly, large plantings of giant miscanthus are established using rhizomes. Healthy rhizomes should be relatively free of soil and weigh approximately 28 to 56 g and measure approximately 10 to 15 cm long. They should also be firm, not shriveled, and without apparent disease or harvest damage. Based on University of Illinois findings, plant the rhizomes approximately 10 cm deep into a fine seed bed in spring as soon as soils are workable. As with potted plants, plant rhizomes using a spacing of 0.9 m between rows and 0.9 between plants in the rows (approximately 11,984 rhizomes per ha), and control weeds as necessary during the first growing season mechanically or by applying herbicides (Table 1). Expect that not all rhizomes will sprout and field skips will require re-planting in years two or three.

Table 1. Preemergence and postemergence herbicide combinations safely applied to giant miscanthus in 2006 in Urbana, Illinois.

Herbicide combination treatments
Pendimethalin + 2,4-D ester
Pendimethalin + dicamba
Pendimethalin/atrazine + 2,4-D ester
Pendimethalin/atrazine + dicamba
S-metolachlor + 2,4-D ester
S-metolachlor + dicamba
S-metolachlor/atrazine + 2,4-D ester
S-metolachlor/atrazine + dicamba

Presently in the US, there are no commercially available mechanical planters or harvesters specifically designed to work with giant miscanthus rhizomes. In Europe, potato planters and harvesters have been successfully modified for giant miscanthus rhizomes. In addition, a British company (www.bical.net/) has developed a mechanical planter specifically for giant miscanthus rhizomes. Stems have been harvested using hay cutters and balers. In some cases, the stems are chopped at harvest, while they are baled for storage in other settings (Fig. 3).

Illinois yields have varied depending on the crop age and the weather during the growing season. At three Illinois sites in replicated studies, the end-of-season biomass yields of unfertilized giant miscanthus planted in 2002 averaged over the 2004, 2005, and 2006 growing seasons were 23.7 tonnes (t)/ha in Northern Illinois, 37.5 t/ha in Central Illinois, and 44.0 t/ha in Southern Illinois. In the same three-year period, yields for unfertilized upland switchgrass, 'Cave in Rock', seeded in 2002 were 6.2 t/ha in Northern Illinois, 14.8t/ha in Central Illinois, and 7.7 t/ha in Southern Illinois. A separate demonstration in Urbana yielded approximately 40.0 t/ha of dry giant miscanthus biomass in 2006 at the end of the third growing season. Obviously, giant miscanthus is a crop worthy of continued investigation! However, the decision to grow giant miscanthus or any other biomass crop should be made after careful deliberation. At present, there are no markets in Illinois for giant miscanthus, but as the US pushes for more domestic energy production, biomass markets will no doubt develop and giant miscanthus will be one of several viable options for Illinois growers.

In conclusion, giant miscanthus produced more than twice the biomass of switchgrass at all sample locations in all years ($P<0.001$). Peak biomass occurred in the August to October period in both crops. Mature stands of *Miscanthus* averaged 48.3±2.3 TDM/ha over the three locations in 2004, whereas switchgrass produced 15.3±2.8 TDM/ha. In 2005, yields were moderated by low rainfall across the state and were 33.3±2.3 TDM/ha and 7.9±2.3 TDM/ha for *Miscanthus* and switchgrass, respectively. The average efficiency of conversion of visible solar radiation into biomass by *Miscanthus* was 3.1%. Illinois is the eighth largest consumer of gasoline in the US combusting 1.34 EJ in 2002 equal to 0.4% of visible solar energy receipt in the state. *Miscanthus*, at the average efficiency of 3.1% could, therefore, replace 30% of petroleum using 7.7% of Illinois land, assuming that 50% of biomass energy is lost in conversion to ethanol. This area appears viable than the more than 20% of the state that would be required to achieve the same with switchgrass.

Fig. 3. Cutting, chopping, and baling *Miscanthus* × *giganteus* in late winter.