Lewandowski, I., J. M. O. Scurlock, E. Lindvall, and M. Christou. 2003. The development and current status of perennial rhizomatous grasses as energy crops in the US and Europe. Biomass & Bioenergy 25:335–361.

Abstract:
Perennial grasses display many beneficial attributes as energy crops, and there has been increasing interest in their use in the US and Europe since the mid-1980s. In the US, the Herbaceous Energy Crops Research Program (HECP), funded by the US Department of Energy (DOE), was established in 1984. After evaluating 35 potential herbaceous crops of which 18 were perennial grasses it was concluded that switchgrass (*Panicum virgatum*) was the native perennial grass which showed the greatest potential. In 1991, the DOE's Bioenergy Feedstock Development Program (BFDP), which evolved from the HECP, decided to focus research on a "model" crop system and to concentrate research resources on switchgrass, in order to rapidly attain its maximal output as a biomass crop. In Europe, about 20 perennial grasses have been tested and four perennial rhizomatous grasses (PRG), namely miscanthus (*Miscanthus* spp.), reed canarygrass (*Phalaris arundinacea*), giant reed (*Arundo donax*) and switchgrass (*Panicum virgatum*) were chosen for more extensive research programs. Reed canarygrass and giant reed are grasses with the C_3 photosynthetic pathway, and are native to Europe, Miscanthus, which originated in Southeast Asia, and switchgrass, native to North America, are both C_4 grasses. These four grasses differ in their ecological/climatic demands, their yield potentials, biomass characteristics and crop management requirements. Efficient production of bioenergy from such perennial grasses requires the choice of the most appropriate grass species for the given ecological/climatic conditions. In temperate and warm regions, C_4 grasses outyield C_3 grasses due to their more efficient photosynthetic pathway. However, the further north perennial grasses are planted, the more likely cool season grasses are to yield more than warm season grasses. Low winter temperatures and short vegetation periods are major limits to the growth of C_4 grasses in northern Europe. With increasing temperatures towards central and southern Europe, the productivity of C_4 grasses and therefore their biomass yields and competitiveness increase.

Since breeding of and research on perennial rhizomatous grasses (PRG) is comparatively recent, there is still a significant need for further development. Some of the given limitations, like insufficient biomass quality or the need for adaptation to certain ecological/climatic zones, may be overcome by breeding varieties especially for biomass production. Furthermore, sure and cost-effective establishment methods for some of the grasses, and effective crop production and harvest methods, have yet to be developed.

This review summarizes the experience with selecting perennial grasses for bioenergy production in both the US and Europe, and gives an overview of the characteristics and requirements of the four most investigated perennial rhizomatous grasses: switchgrass, Miscanthus, reed canary grass, and giant reed.

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