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# Comparison of biomass productivity and its persistency among four perennial grasses for bioenergy feedstock production in temperate region of Japan

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## Introduction

a low-input condition (Somerville *et al.* 2010). These species generally show a low demand for nutrients in the long term because perennials translocate mineral nutrients into their roots at the end of the growing season and reutilized them in regrowing next growing season. These characteristics of perennial grasses make it possible to perform sustainable feedstock production for bioenergy and reduce CO<sub>2</sub> emissions for agreed environmental goals. Several perennial grasses have been selected as suitable bioenergy crops in the US and Europe (Lewandowski *et al.* 2003). Since it is preferred to exploit biodiversity in order to supply stable bioenergy feedstock in diverse environments including marginal areas, it is required to select bioenergy crops suited to each local environment. In temperate regions of eastern Asia, however, few studies have been conducted to evaluate perennial grasses from a standpoint of feedstock production for bioenergy in the past. The present study compared biomass productivity and its persistence among the four perennial species (*Erianthus arundinaceus*, *Pennisetum purpureum*, *Saccharum spontaneum* and *Miscanthus sinensis*), with the aim of determining which species is the most promising bioenergy crop in temperate regions of Japan.

The present study was the first report of comparison of above ground biomass yield and its persistence among several bioenergy crops in a temperate zone of eastern Asia.

## Materials and Methods

The experiment was carried out for a 5-year period in a field of Andosol soil at the NARO Kyushu Okinawa Agricultural Research Centre (NARO/KARC), Kumamoto, Japan (N 32°88', E 130°74'). Weather data during the period of the experiment was drawn from the data of Kumamoto, Japan, published on Japan Meteorological Agency (<http://www.data.jma.go.jp>). Above ground dry matter yield under two nutrient regimes was compared for the four perennial species listed in Table 2: *E. arundinaceus*, *P. purpureum*, *S. spontaneum* and *M. sinensis*. Seedlings of these species were grown from division and were transplanted on late April, 2007. In the high-nutrient treatments, fertilizer was applied at 100 kg N/ha, 100 kg P<sub>2</sub>O<sub>5</sub>/ha and 100 kg K<sub>2</sub>O/ha before transplanting. The plots were laid out in a randomized block design with two replications, whereas no fertilizer was applied in the low-

nutrient treatments. Above ground yield was manually harvested from the centre of each plot to remove an edge effect on biomass production. The plants were harvested in late December after being dried out with standing. A harvested sample was weighed for the total fresh weight and then a sub-sample (about 2.0 kg) was oven dried at 70 °C until constant weight was reached over 2 days to estimate the dry weight of the sub-sample and calculate dry matter (DM) percentages. Biomass yield (*y*) was evaluated as followed:  $y$  (t DM/ha) = (a total fresh weight) × (the dry matter percentage of a sub-sample) × (a ratio of 10,000 divided by a value of harvested area (m<sup>2</sup>)). All statistical analyses were carried out using SAS.

## Results and Discussion

There are very few published reports showing data on biomass productivity and adaptability to diverse environments for *Erianthus* spp., although the potential of *Erianthus* spp. has been recognized by sugarcane breeders and researchers (Jackson and Henry 2011). The present study showed that *E. arundinaceus* maintained the highest DM yield under both nutrient treatments in the 2nd—5th year, although the above ground biomass was relatively low in the 1st year (Table 1). *E. arundinaceus* maintained high productivity (26 t DM/ha) even in the low-nutrient treatments. The present result suggest that *E. arundinaceus* has a great advantage in producing bioenergy feedstock under a low-input management in temperate regions of Japan. The biomass yields of *P. purpureum* showed the highest biomass under both nutrient regimes in the first year. This result suggested that *P. purpureum* completed plant establishment more rapidly than *E. arundinaceus*. However, a reduction of yield was observed from the 2nd year, especially under the low-nutrient conditions. This agreed with a recent study evaluating low-input biomass production of *P. purpureum* in the coastal plain of Georgia, USA (Knoll *et al.* 2011). Ishii *et al.* (2000) estimated that the 80% of Merkeron, a strain of *P. purpureum*, overwintered when the mean daily minimum temperature in winter was 1.5°C. In the present study, the mean temperature in winter was 0.3°C, 1.0°C and 0.5°C in 2nd—4th pre-seasons, which could be a severe condition for *P. purpureum* to regrow satisfactorily in the following spring. Finally, *P. purpureum* did not survive in the 5th year. This suggested that the depression of biomass production in *P. purpureum* was partially attributed to its lower overwintering ability in addition to lack of soil

**Table 1. Biomass yield (t DM/ha) of four perennial grasses in high- and low-nutrient conditions for five years.**

Nutrient conditions	Species	1st year	2nd year	3th year	4th year	5th year
High-nutrient	<i>E. arundinaceus</i>	10.9	37.1	37.6	31.2	29.8
	<i>P. purpureum</i>	41.6	26.7	19.4	26.4	-
	<i>S. spontaneum</i>	25.1	19.3	16.5	19.8	7.5
	<i>M. sinensis</i>	10.2	20.6	26.0	23.3	19.7
Low-nutrient	<i>E. arundinaceus</i>	12.0	38.4	37.1	29.0	26.0
	<i>P. purpureum</i>	33.1	36.9	14.4	15.5	-
	<i>S. spontaneum</i>	26.2	23.9	15.2	12.0	12.3
	<i>M. sinensis</i>	9.8	18.5	19.6	22.8	11.5

nutrients. Biomass yield of *S. spontaneum* reached approximately 25 t DM/ha in the first year, irrespective of nutrient conditions. The biomass gradually decreased from the 2nd year. The reduction in the yield may be caused by low temperature in winter because the cultivar used originated from a tropical region of Java, Indonesia. *M. sinensis* required 2 years at least to accomplish plant establishment, and the yield under the low-nutrient treatment approached 22.8 t DM/ha in the 4th year, suggesting that *M. sinensis* carries a capability to produce the biomass relative sustainably with low levels of soil nutrients. *M. sinensis* originated in eastern or southeastern Asia and contains a vast amount of genetic variation in the natural population. This explains its wide distribution in both warm to cool temperate regions (Clifton-Brown et al. 2008). Therefore, *M. sinensis* will be better suited for biomass production in relatively high latitude regions of eastern Asia.

## Conclusion

The present study compared biomass productivity and its persistence among the four perennial species for five years (Table1), with the aim of determining which species is most promising bioenergy crop in temperate regions of Japan. In practice, it will be required to produce bioenergy feedstock under minimal inputs such as fertilizers or irrigation. *E. arundinaceus* showed the greatest biomass production in the temperate region of Japan and maintained yield even under the low-nutrient conditions (above 25 t DM/ha) from the 2nd year. The present study demonstrated that *E.*

*arundinaceus* is more appropriate for producing biomass feedstock in respect of its high productivity and persistency in temperate regions of eastern Asia.

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