Evaluation of Four Cellulosic Energy Crops for Biomass and Ethanol Production in Georgia

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Introduction

Numerous technologies that can convert cellulosic biomass into various liquid biofuels are currently under development, making production of cellulosic biomass more attractive than ever. Miscanthus (*M.* × *giganteus*) and switchgrass (*Panicum virgatum* L.) as two dedicated cellulosic energy crops have been extensively evaluated for biomass production in Europe and the United States, respectively, both with very favorable results (Fig. 1-2). Energycane (*Sacharum spontaneum*) and napiergrass (*Pennisetum purpueum*) are another two potential, perennial cellulosic energy crops with high yield potential (Fig. 3-4). Georgia as one of the ideal states for cellulosic feedstocks production in the Southeast could play a leading role in biomass production to meet the mandate. However, truly comparative performance data of the four potential cellulosic energy crops are lacking in Georgia. Therefore, the purpose of this study was to evaluate biomass and ethanol production potential of the four cellulosic energy crops grown in Georgia as affected by irrigation and delayed harvest, and to provide comparative performance data for the four perennials.

Fig. 1. Miscanthus

Fig. 2. Switchgrass

Fig. 3. Energycane

Fig. 4. Napiergrass

Procedure

Small plot experiments were conducted under dryland and irrigation conditions at the Southeast Georgia Research and Education Center of the University of Georgia in Mid-east Georgia on a Dothan loamy sand. The experiment under each condition was laid out in a split-plot design in which four different perennial grass species corresponded to main plots, and three harvest dates (Mid-Dec., Mid-Jan., and Mid-Feb.) to subplots. In the fall of 2008, stem cuttings of L79-1002 energycane and Merkeron napiergrass, with 1 m in length, were planted 12 cm deep in rows 1.8 m apart. Miscanthus rhizomes were transplanted from the greenhouse into the main plots in rows 0.46 m apart in the spring of 2009. EG 1101 switchgrass was seeded in the greenhouse in small pots and planted similarly to miscanthus at the same time. After establishment, aboveground biomass from the four perennials was cut with a silage chopper in the central two rows of each subplot at the designated harvest date (Fig. 5). A subsample was taken from each subplot for determination of dry matter. Ethanol production was estimated by using a benchtop dilute acid pretreatment and simultaneous saccharification and fermentation procedure (Fig. 6-12). Analysis of variance was conducted using the PROC MIXED procedure in SAS. A critical P value of 0.05 was used as cutoff for testing fixed effects as well as determining differences among least-squares means.

Fig. 5. Silage chopper

Fig. 6. Ground samples

Fig. 7. Autoclave

Fig. 8. Enzymes

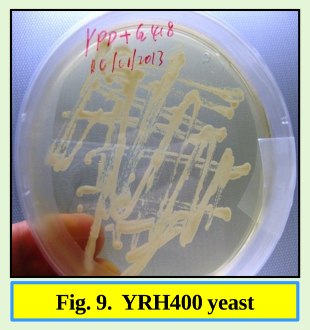

Fig. 9. YRH400 yeast

Fig. 10. Samples in a shaker

Fig. 11. GC machine

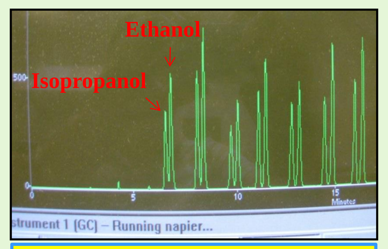

Fig. 12. Sample measurement

Results

Napiergrass and energycane provided significantly higher biomass yield as well as ethanol yield than switchgrass and miscanthus, regardless of year, irrigation and harvest treatments (Fig. 13-14). Under dryland condition, average dry biomass yields for napiergrass, energycane, switchgrass and miscanthus from the delayed harvests in Mid-February of 2013 and 2014 were 34.38, 20.31, 11.68, and 3.99 Mg ha^{-1} (15.32, 9.05, 5.21, and 1.78 tons/acre), respectively. Irrigation enhanced biomass and ethanol yields of the four energy crops, with yields of energycane and miscanthus increasing relatively higher (Fig. 15-16). Compared to harvest in December, delayed harvest in February resulted in significant reduction in biomass and ethanol yields of all four energy crops except miscanthus and switchgrass (Fig. 17-19).

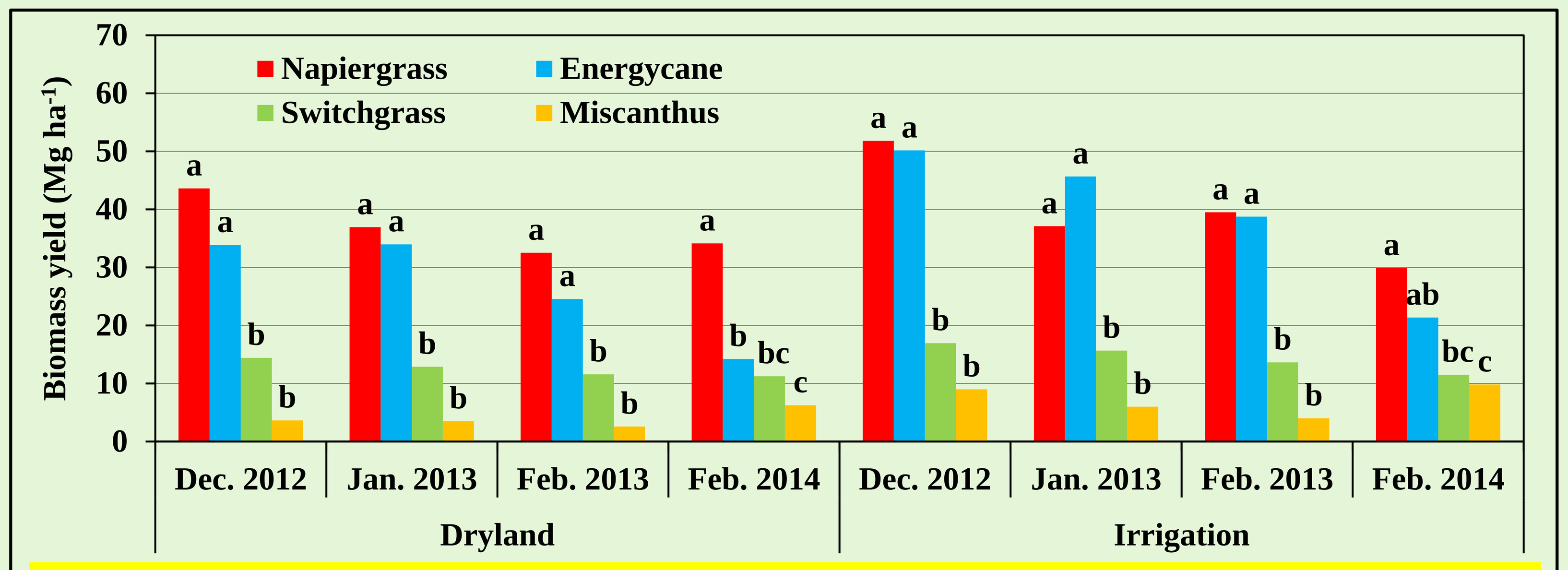

Fig. 13. Biomass yield for the four perennials across growth conditions and harvest dates in the growing seasons of 2012 and 2013. Means within each harvest date and growth condition with different letters differ (*P*<0.05).

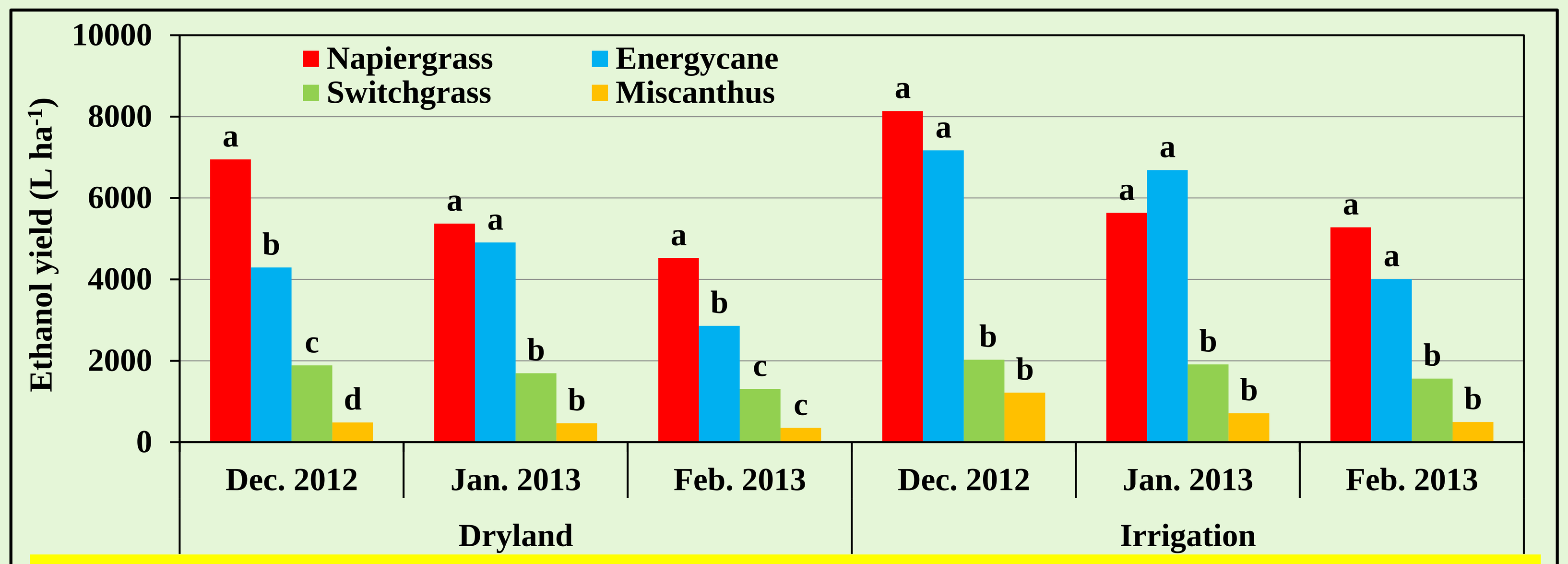

Fig. 14. Ethanol yield for the four perennials across growth conditions and harvest dates in the 2012 growing season. Means within each harvest date and growth condition with different letters differ (*P*<0.05).

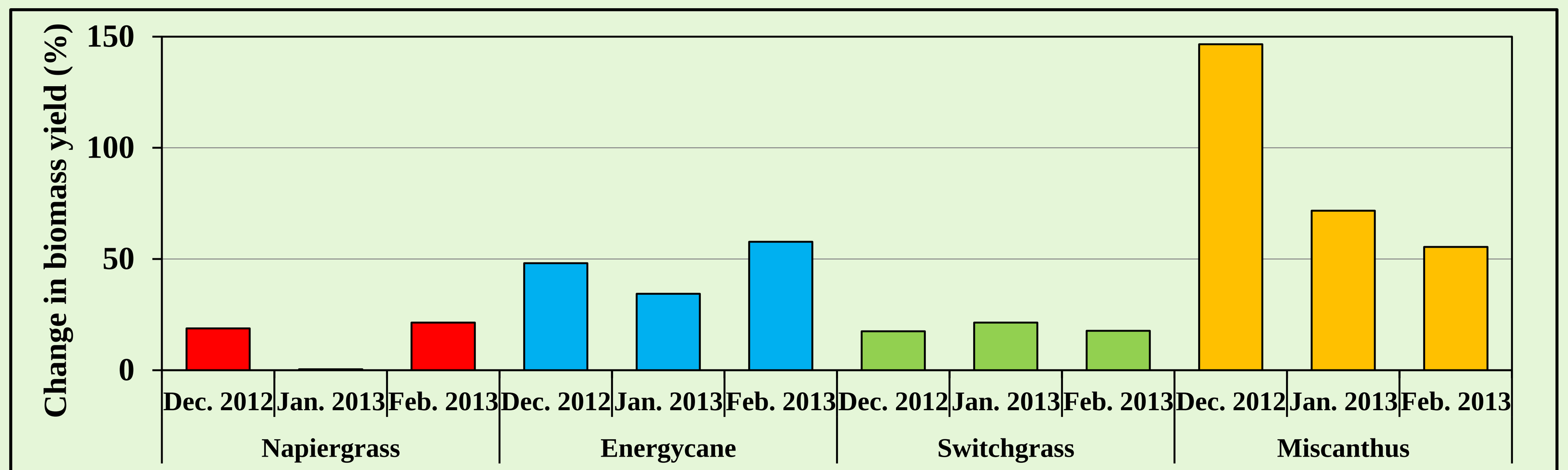

Fig. 15. Effect of irrigation on the four perennials for biomass production across harvest dates.

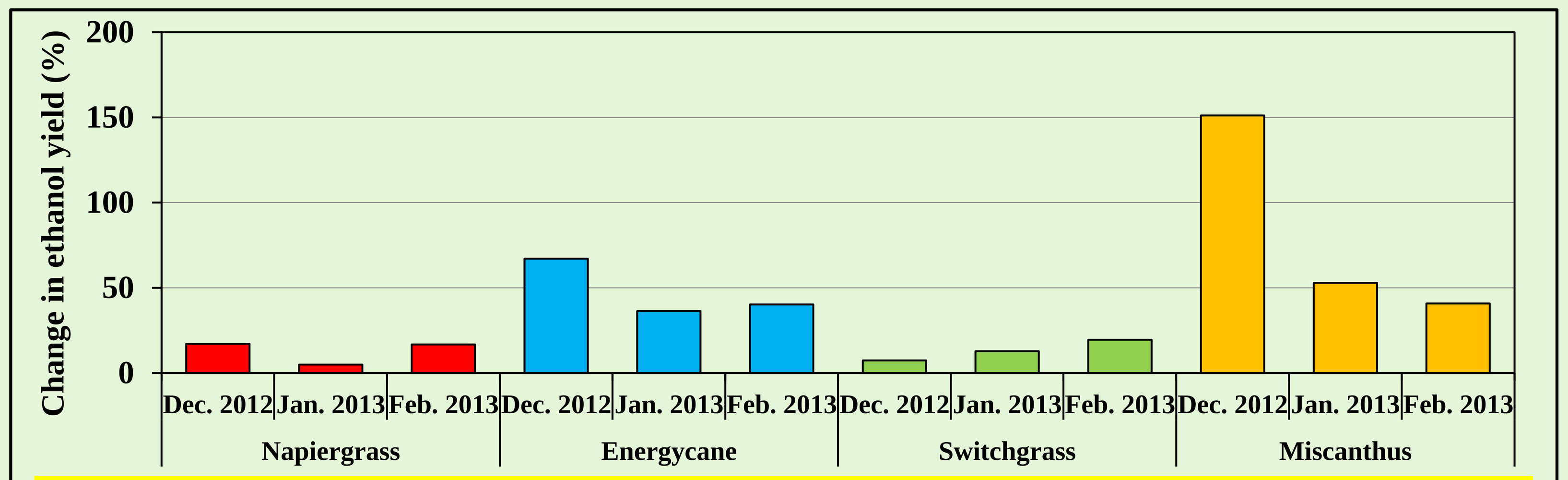

Fig. 16. Effect of irrigation on the four perennials for ethanol production across harvest dates.

Table 1. Ethanol conversion rate of napiergrass, energycane, switchgrass and miscanthus under dryland and irrigation conditions as influenced by harvest date.

Growth condition	Harvest date	Ethanol conversion rate (mg g^{-1} grass)			
		Grass species			
		Napiergrass	Energycane	Switchgrass	Miscanthus
Dryland	Dec. 2012	126	100	104	102
	Jan. 2013	115	114	105	105
	Feb. 2013	110	91	89	105
Irrigation	Dec. 2012	124	114	94	109
	Jan. 2013	121	114	96	95
	Feb. 2013	107	102	78	99

Fig. 17. Leaf drop of napiergrass over winter

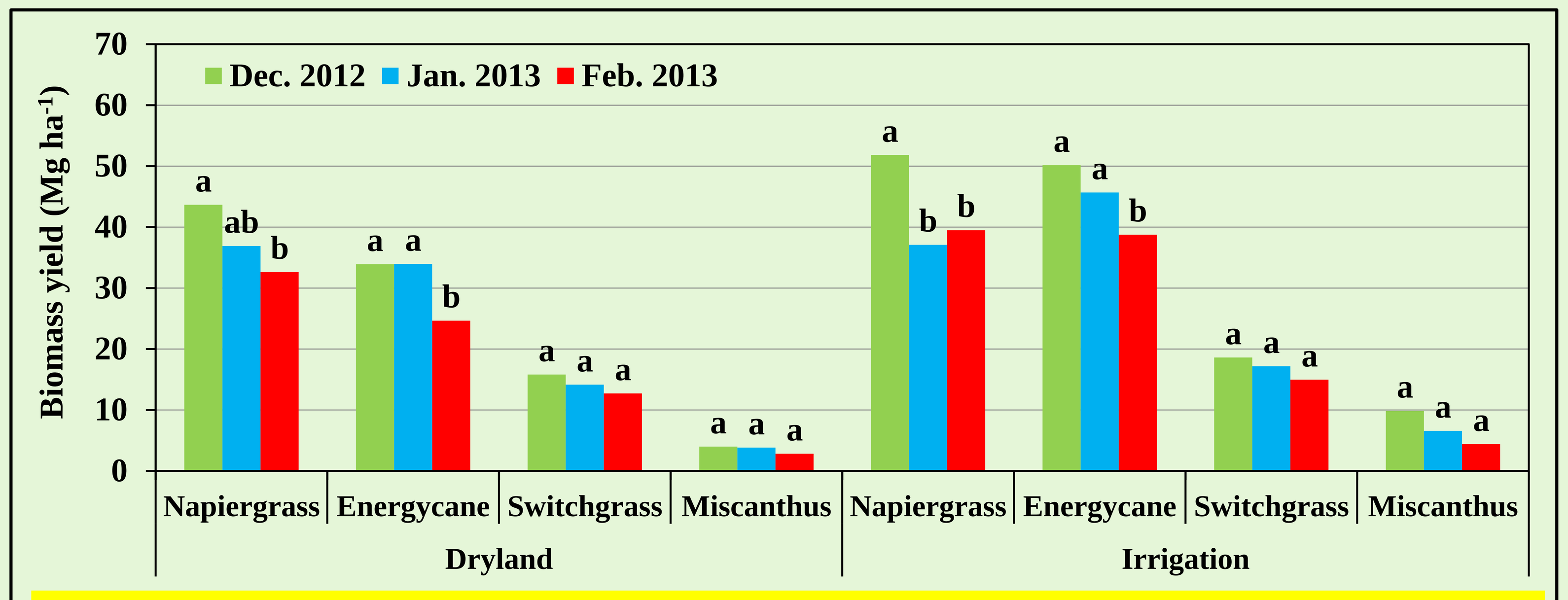

Fig. 18. Effect of harvest date on the four perennials for biomass production under dryland and irrigation conditions. Means within each perennial energy crop and growth condition with different letters differ (*P*<0.05).

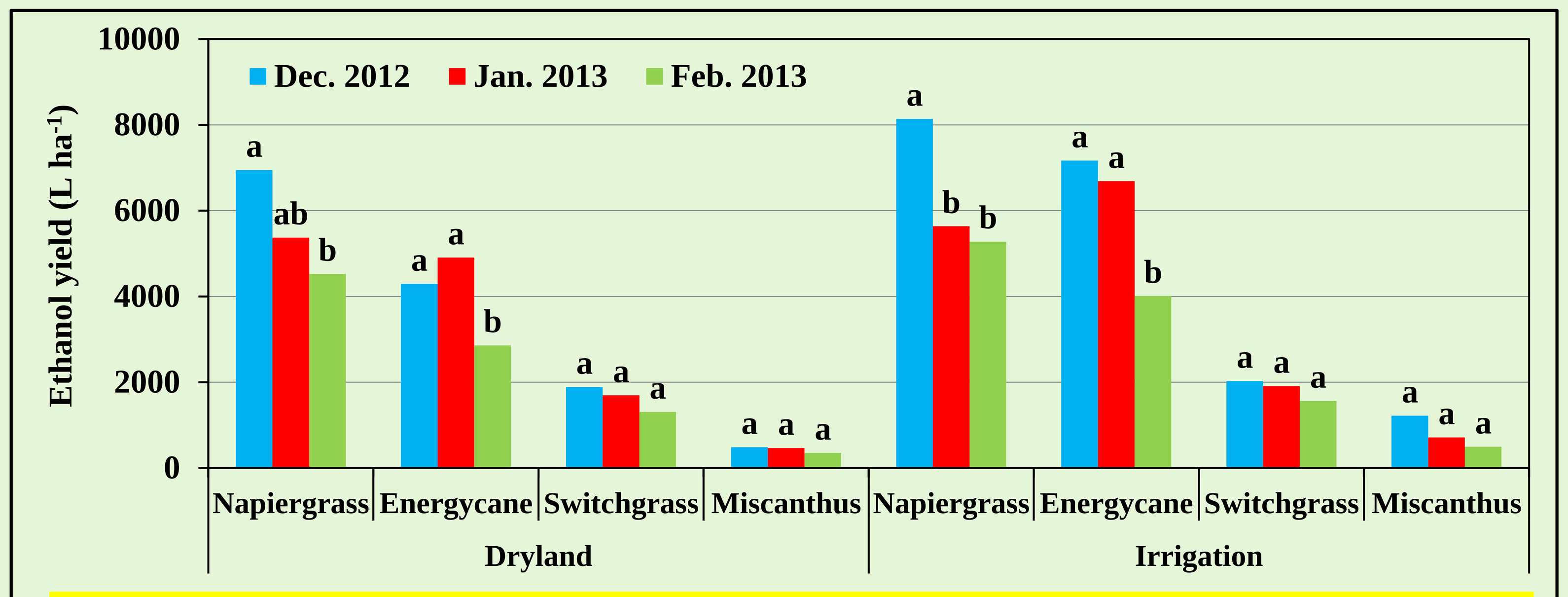

Fig. 19. Effect of harvest date on the four perennials for ethanol production under dryland and irrigation conditions. Means within each perennial energy crop and growth condition with different letters differ (*P*<0.05)

Conclusions

1) Napiergrass and energycane provided much higher biomass yield (20-40 Mg ha^{-1}) as well as ethanol yield (3000-8000 L ha^{-1}) than switchgrass and miscanthus (3-20 Mg ha^{-1}; 300-3000 L ha^{-1}) under similar conditions;
2) Napiergrass and switchgrass appear to be more drought-tolerant than energycane and miscanthus;
3) Delaying harvest in Mid-February slightly reduced fermentability of all four cellulosic energy crops (Table 1), most likely due to loss of fermentable free sugars;
4) Delaying harvest in Mid-February resulted in significant reduction in biomass and ethanol yields of napiergrass and energycane;
5) In this study, napiergrass and energycane showed high potential for biomass feedstock and ethanol production in Georgia.

Acknowledgments

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