BIOMASS PRODUCTION AND ETHANOL POTENTIAL FROM SWEET SORGHUM IN CROATIA

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Abstract: Sorghum has been identified as a preferred biomass crop for fermentation into methanol and ethanol fuel. The adaptation of sorghum to sub-humid and semiarid climates has extended sorghum production into larger regions than other warm-cereal grains. Sorghum can produce approximately 30 dry tons/ha per year of biomass on low quality soils with low inputs of fertilizer and limited water per dry ton of crop, half of that required by sugar beet and third of the requirement for sugar cane or corn. The foreseen results were to test different Sweet Sorghum genotypes to their aptitudes to produce biomass and ethanol production in the climatic conditions of Croatia. The Sweet Sorgum hybrid proved to be very valuable and well adapted to the conditions of Croatia, outlined by high productivity of biomass and ethanol production.

Keywords: sweet sorghum, cultivar, biomass, ethanol, energy

Introduction

The genus *Sorghum* is characterized by a vastly diverse germ plasm in terms of phenotypic and morphological traits. Many of these have been exploited to give genotypes suitable for grain and forage production, as well as, alternative uses, such as energy, pulp for paper, food products, high grade chemicals and building products (Duncan et al., 1991). Quality parameters of wheat bioethanol versus bread is recently studied (Szakal et al. 2007), but much of the work related to non-food agricultural production of sorghum has been conducted on sweet sorghum, because of the increased interest in sugar crops as potential renewable resources that can be converted into ethanol. It also has a shorter growing season than sugarcane, and is therefore suitable to be grown in geographical areas with a temperate climate. It also has rapid rates of growth. In several studies, sweet types have been evaluated for fermentable sugar production and theoretical ethanol yields (Smith et al., 1987; Copani et al., 1989; Belletti et al., 1991), for the relationships between agronomic practices and yield (Broadhead and Freeman, 1980, Németh, T. and Izsáki, Z., 2005) and among growth parameters (Shih et al., 1981; Ferraris and Charles-Edwards, 1986a; Tarantino et al., 1992), for the pattern of soluble carbohydrates accumulation (McBee and Miller, 1982; Ferraris and Charles-Edwards, 1986b; Petrini et al., 1993), and for relevant physiological aspects of this metabolic process (Vietor and Miller, 1990; Tarpley et al., 1994). Unlike sweet genotypes, nonsweet, and especially those characterized by stalk storage organ with high fiber content, have had little attention, so far. A comparative analysis of the growth and yield performances of five late maturing and productive sweet and fiber sorghums has been conducted, with the perspective of their introduction in temperate Croatia climate areas as competitive multiproduct crops. Biomass production of energetic purpose has a number of benefits for environment (Szakal et al. 2007) and for wellfare of family farms as well (Nagyne Demeter et al. 2007, Sipos et al. 2007).

The objectives of this study were to evaluate the productivity of a group of sweet sorghum cultivars of varying maturity and morphology, to determine sugar accumulation patterns in the cultivars, to examine cultivar growth patterns, and to evaluate sweet sorghum as an energy crop by producing ethanol from the cultivars processed as silage.

Material and methods

A 3 year field experiment was conducted in northwest Croatia at the Faculty of Agriculture University of Zagreb experimental field during 2004-2006, and a randomised complete block design in a split-plot arrangement was used. Prior to establishment of the sweet sorghum plots, fields were in the soybean year of an oat-corn-soybean rotation. Experimental plots were chisel-plowed in the fall. The seedbed was prepared in the spring with a field cultivator and a harrow in one pass. The sowing density was 150 000 plants per hectare, space between rows was 0.70 m and the between plant spacing was 0.095 m, and the depth was of 3 cm. The sowing time was the 29 th April in 2004, 1th May in 2005 and the 5th May in 2006. A summary of production treatments involved: fertilisation before plowing (48 N ha^{-1}, 156 kg P ha^{-1}, 156 kg K ha^{-1}), plowing at 30 cm, granular topdressing 2 x 54 kg N ha^{-1}. Prior to sorghum planting, production in this area is primarily devoted to livestock. The average frost-free season at this location was 165 days. Five cultivars of *Sorghum bicolor* (L.) Moench, were selected to include a wide range of maturities, morphologies, and breeding histories. The cultivars, were Grazer N, Keller, Wray, Sugar Drip and Rio. Developed at various locations, several of these are dual-purpose forage and syrup cultivars. Dry matter yield and ethanol production were studied.
Laboratory methods and statistical analysis: Dried or frozen plant samples were analyzed for sugars. A main stalk subsample was frozen at – 20°C and used for the determination of fermentable carbohydrates (glucose, fructose and sucrose) and a second stalk was sampled and dried to constant weight at 60°C and ground (size 1 mm) for chemical anlysis. After filtration, the level of soluble carbohydrates was determined enzymatically (Anon, 1984). Reducing sugars consisting of glucose and fructose along with a nonreducing sugar, sucrose, were determined calorimetrically. Sugar concentrations of samples were then calculated, along with percentages and determination of sugar yields on the basis of land area.
Fermented silage samples were analyzed for residual sugar, and high pressure liquid chromatography was used to analyze ethanol and volatile fatty acid concentrations. Potential ethanol production was calculated using the total sugar yields for the two cultivar replications that were fermented. The General Linear Model procedure and Analysis of Variance procedure (SAS) were used to determine the statistical significance of cultivar, year and potential of ethanol production.

Results and discussions

The number of days to anthesis (full blossom) for the 5 cultivars grown in Croatia provides an indication of relative maturity, although cultivars differed in rates of seed head development during the post-anthesis development period. Maturation was linked to other yield characteristics. Tabe 1 shows how the cultivar varied in dry matter production and ethanol potential production during the 3 season (2004-2006).

Dry matter production: Cultivar Wray had the highest percentage of dry matter at single harvest in all 3 years (31,80 t ha^{-1}), and as well yielded the most dry matter over all 3 years (average of 30,08 t ha^{-1}). Yield characteristics differed among years, due to climatic differences in years, but the relative rank order of the cultivars remained rather consistent. Two cultivars, Grazer N and Rio, had the least dry matter yield of the cultivars. Three other cultivars, Keller, Sugar Drip and Wray stand out from all others as high yielded. Mean dry matter yields in 2004, 2005, and 2006 were 26,67, 29,31, and 28,55 tons per hectare, respectively. The least dry matter yield was 24,69 t ha^{-1} from Keller in 2004, while the least mean dry matter yield also achived Keller (27,33 t ha^{-1}).
Ethanol production: Cultivar Wray had the highest ethanol production at single harvest in all 3 years (3339 l ha^{-1}), and as well yielded the most ethanol over all 3 years (average of 3159 l ha^{-1}). Ethanol production differed among cultivars, years, due to climatic conditions in different years, but the relative rank order of the cultivars remained rather consistent. Two cultivars, Grazer N and Rio, had the least mean ethanol production of the cultivars, 2447 and 2633 l ha^{-1} respectively. Three other cultivars, Keller, Sugar Drip and Wray stand out from all others as high ethanol potential cultivars. Mean ethanol production in 2004, 2005, and 2006 were 2731, 2923, and 2887 l ha^{-1}, respectively. The least ethanol production was 2280 l ha^{-1} from Rio in 2004, and the least mean ethanol production also achived Rio (2447 l ha^{-1}).

Table 1. Average of yield trials for five sweet sorghum cultivars grown for three years (2004-2006)

Cultivar	Dry matter (t ha^{-1})				Ethanol production (l ha^{-1})			
	Year			Average	Year			Average
	2004	2005	2006		2004	2005	2006	
Grazer N	29,50	31,35	25,80	28,88	2670	2850	2380	2633
Keller	24,69	27,91	29,40	27,33	2590	2950	3160	2900
Wray	27,55	30,90	31,80	30,08	2893	3245	3339	3159
Sugar Drip	30,30	26,90	28,25	28,48	3220	2960	3108	3096
Rio	26,30	29,50	27,50	27,77	2280	2610	2450	2447
Average	26,67	29,31	28,55		2731	2923	2887	
LSD 0,05				1,20				70
LSD0,05 †				1,05				55
LSD0,05 ‡				2,40				125

† values for comparing means within year ‡ values for comparing means across year

Conclusions:

Results of this research suggest that climate can affect biomass production of cultivars, due to cultivars' differences in temperature sensitivity and photoperiod, and the fact that temperature initiates a photoperiod response of reproductive growth. These data helped describe how sweet sorghum cultivars vary in DM and ethanol production during the different climatic seasons, and describe potential of some hybrid cultivars for similar agoecological conditions in Croatia and Europe.

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