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The Effects of Nitrogen Treatments, Cultivars and Harvest Stages on Stalk Yield and Sugar Content in Sweet Sorghum

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Abstract: Due to the population increase, about 1.5 million tons of sugar is needed annually in Iran. Half of this amount is provided by sugar beet and sugarcane industries and the other half is imported. These two crops are facing many problems such as: high cost of planting and harvesting, long growing season and high water requirement. Whereas, sweet sorghum is well adapted to tropical and sub-tropical regions, highly biomass production, low water and fertilizers requirements and short growing season. So obtained sugar from this plant may replace imported sugar from aboard. This study was carried out, at Isfahan University Research Station, to evaluate the effect of three nitrogen treatments, three sweet sorghum cultivars and three harvesting stages on the stalk yield and sugar content. The results showed the effect of nitrogen treatments on stalk yield, brix value and sucrose content were not significant, but the effects of cultivars and harvesting stages on the above measurements were significant. Among sweet sorghum cultivars, cv Rio had the highest stalk yield, brix value and sucrose content. These measurements were not significant for cv Vespa and IS2325. The effect of harvesting stage was significant for the stalk yield, brix value and sucrose content. Harvested plant at physiological maturity had the highest stalk yield, brix value and sucrose content and lowest at flowering stage. Based on these results, the highest stalk yield, brix value and sucrose content were obtained by planting cv Rio and harvested at physiological maturity stage.

Key words: Sweet sorghum, nitrogen treatments, cultivars, harvesting stages, stalk yield, sugar content

INTRODUCTION

Sorghum (*Sorghum bicolor* L. (Moench)), is multipurpose cereal, contains grain, forage and sweet types. Sweet sorghum mainly is planted for sugar and ethanol production (Gnansounoua *et al*., 2005). Sugar beet and sugarcane are the main sources of sugar production in the world (Pennington and Baker, 1990). In Iran planting and harvesting of both these crops are facing many problems such as: long growing season and high water and fertilizer requirements. Sweet sorghum is well adapted to sub-tropical (Rego *et al*., 2003) and temperate regions of the world. It is highly biomass production, low water requirement (Girma, 1989; Mastrorilli *et al*., 1999) and short growing season (Roman *et al*., 1998). Therefore, sweet sorghum can be replaced sugar beet and sugarcane under Iranian hot and dry climate condition (Kulkarni *et al*., 1995). Sorghum is a C4 crop and good N used efficiency (Gardner *et al*., 1994). Application of nitrogen fertilizer increase sweet sorghum stalk yield (Johnston, 2000). Galani *et al*. (1991) reported nitrogen fertilizer increase sucrose content, protein percent and growth rate in sweet sorghum. Application of nitrogen fertilizer in most cases increases brix value (Pholsen and Sornsungnoen, 2004). Quantity and quality of sugar in stem change at different growth stages, so harvesting stage is an important factor on sugar content (Parvatikar and Manjunath, 1991). Also sweet sorghum accumulates large amounts of sugar in its stems near the time of grain maturity. Sweet sorghums have 10 to 25% sugar in stalk juice, with sucrose being the predominant disaccharide (Hunter and Anderson, 1997). Nitrogen increases stalk yield and sucrose content in sweet sorghum (Leible and Kahnt, 1991; Sumantri and Lestari, 1997). Therefore, this study was designed to determine the optimum nitrogen treatment, cultivars and harvesting stages of sweet sorghum for obtaining highest stalk yield, sucrose content and brix value under Iran climatic conditions.

MATERIALS AND METHODS

This experiment was carried out at the Isfahan University Research Station, Iran. Three nitrogen treatments: 100 kg ha^{-1} urea at planting, 100 kg ha^{-1} urea at 4 leaf stage and 100 kg ha^{-1} urea at booting (f_1); 100 kg ha^{-1} urea at planting and 200 kg ha^{-1} urea at 4 leaf stage(f_2) and 300 kg ha^{-1} urea at planting (f_3), three

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sweet sorghum cultivars: Vespa (c_1), IS2325 (c_2) and Rio (c_3) and three harvesting stages: flowering (h), physiological maturity (h_2) and before chilling (h_3) were assessed in split- split plot design with three replications. Nitrogen treatments assigned to main plot, cultivars to sub-plot and harvesting stages to sub-sub plot. In May 2003, seeds were planted in furrows 10 m long and 0.5 m apart. Following establishment, plants were thinned to 10 cm apart so that the final populations were 200,000 plants/ha. Plants were harvested at each harvesting stage. Stalks were weighed after the leaves and panicles were removed, then the stalks passed through sugar mill and brix value and sucrose content of the juice were measured according to Varma (1988).

RESULTS AND DISCUSSION

Table 1 shows analysis of variance for nitrogen treatments, sweet sorghum cultivars and harvesting stages on stalk yield, birx value and sucrose content. The results showed that effect of nitrogen treatments on stalk yield, brix value and sucrose content were not significant. Many reports show that application of nitrogen increases stalk yield (Mohammed and Hamed, 1988; Balasubramanian and Ramamoorthy, 1996; Johnston, 2000; Ayub *et al*., 2002). Present results are disagreement with the above reports because the nature of our nitrogen treatments were included both amount and date of nitrogen application. The effect of cultivars on the above measurements was significant at 1% level (Table 1). Cv Rio had the highest stalk yield (62.85 t ha^{-1}), birx value (17.10%) and sucrose content (11.53%), (Table 2). High stalk yield of cv Rio may be due to its long and thick stem. El-Bassam *et al.* (1987) found similar results. Also Belletti *et al.* (1991) compared 39 sweet sorghum cultivars and reported cv Rio among those cultivars had the highest stalk yield. Brix value of cv Rio was higher than other sweet sorghum cultivars probably due to the genotypic differences exist among them as reported by Galani *et al.* (1991). Stalk yield of IS 2325 was higher than cv Vespa but their brix value and sucrose content were not significant (Table 2). Cv Rio had the highest sucrose content (11.53%) among sweet sorghum cultivars and this is because of its highest brix value. The effect of harvesting stage on stalk yield, brix value and sucrose content were significant at 1% level (Table 1). Stalk yield was highest at physiological maturity (51.89 t ha^{-1}) and lowest at flowering (43.83 t ha^{-1}) (Table 3). These could be due to the growth and development of stalk which was completed at physiological maturity. Zanini (1990) reported stalk yield increases and was highest at physiological maturity. Before chilling stage stalk yield was reduce because of stalk moisture reduction. Brix value was higher at physiological maturity and before chilling (15.97%) than flowering (13.44%). Choudhari (1990) studied the effect of harvesting stages on stalk juice and brix value and found the amount of brix value was lowest at flowering stage. Galani *et al.* (1991) found brix value increases from flowering to physiological maturity stage. Sucrose content was highest (10.8%) at physiological maturity and lowest (6.07%) at flowering (Table 3). In sweet sorghum assimilate does not mobilize from stem to the grain so that sucrose content increases at physiological maturity (Pennington and Baker, 1990). Ferraris (1986) reported that Sucrose and soluble solids concentration and yields in stems were highest at or near grain maturity. Low sucrose content at flowering stage could be due to high acid invertase enzyme at that stage. At physiological maturity, the acidic invertase content decreases whilst natural invertase increases. As a result sucrose content may be increased at this stage (Lingle and Dunlap, 1987). The interaction between nitrogen treatments and harvesting stages on brix value was significant at 1 percent level (Table 1). Figure 1 shows the interaction between nitrogen treatments and harvesting stages on brix value. The brix value was higher at both physiological maturity and before chilling than flowering stage regardless of nitrogen treatments. The interaction

Table 1: Mean squares of stalk yield, brix and sucrose

Treatments	df	Stalk yield	Brix	Sucrose
Replication	2	58.09	2.23	7.84
Nitrogen treatments (F)	2	10.25	7.37	2.13
Error a	4	4.30	1.88	1.35
Cultivars (C)	2	6323.47**	70.66**	190.74**
F*C	4	5.05	2.24	0.5
Error b	12	8.92	0.98	1.71
Harvesting (H)	2	455.91**	67.18**	151.29**
F*H	4	7.86	3.68**	1.64
C*H	4	81.61**	14.68**	29.41**
F*C*H	8	6.86	1.76	3.64
Error c	36	11.06	0.91	1.80

** Significant at 1% level

Table 2: Mean comparisons* among sweet sorghum cultivars for stalk yield, brix and sucrose content

Cultivars	Stalk yield (t ha^{-1})	Brix (%)	Sucrose (%)
Vespa	32.35c	14.48b	7.38b
IS2325	49.77b	14.15b	6.57b
Rio	62.85a	17.10a	11.53a

* Values within one column followed by the same letter(s) are not significantly different at p<0.05

Table 3: Mean comparisons* among sweet sorghum cultivars for harvesting stages

Harvesting stages	Stalk yield (t ha^{-1})	Brix (%)	Sucrose (%)
Flowering	43.83c	13.44b	6.07c
Physiological maturity	51.89a	15.59a	10.8a
Before chilling	49.25b	16.35a	8.61b

* Values within one column followed by the same letter(s) are not significantly different at p<0.05

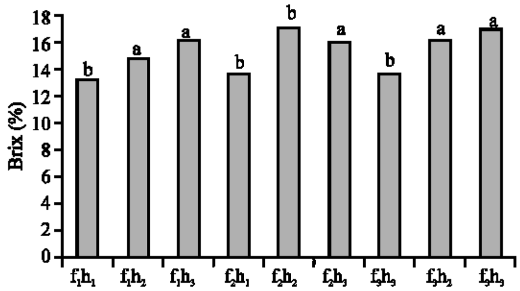

Fig. 1: Interaction between levels of nitrogen treatments (f_1, f_2, f_3) and harvesting stages (h_1, h_2, h_3) on brix value, f_1: 100 kg ha^{-1} urea at planting, 100 kg ha^{-1} urea at 4 leaf stage and 100 kg ha^{-1} urea at booting f_2: Represents 100 kg ha^{-1} urea at planting and 200 kg ha^{-1} urea at 4 leaf stage f_3: 300 kg ha^{-1} urea at planting h_1: Flowering h_2: physiological maturity h_3: Before chilling

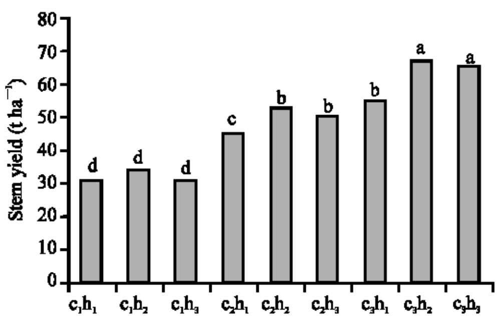

Fig. 2: Interaction between cultivars (c_1, c_2, c_3) and harvesting stages (h_1, h_2, h_3) on stalk yield h_1: flowering h_2: physiological maturity h_3: before chilling c_1: Vespa c_2: IS2325 c_3: Rio

between cultivars and harvesting stages on stalk yield, brix value and sucrose content was significant at 1% level (Table 1). Cv Rio had the highest stalk yield at both physiological maturity and before chilling (67.69 and 65.99 t ha^{-1}, respectively) whilst cv Vespa regardless of harvesting stages had the lowest stalk yield (Fig. 2). The stalk yield of IS 2325 at both physiological maturity and chilling stages were higher than flowering stage. A delay in harvesting stage after flowering increases cv Rio and IS2325 stalk yields (Fig. 2). The mean of cv Rio and IS 2325 stalk yields between two harvesting stages of physiological maturity and before chilling was not significant (Fig. 2). So cv Rio had the highest stalk yield when harvested at physiological maturity and before chilling stage. Brix value of cv Vespa and IS 2325 were lowest at flowering stage and increased as plant matured (Fig. 3). Before chilling stage, cv Vespa had higher brix value than IS 2325. The results show that the highest brix

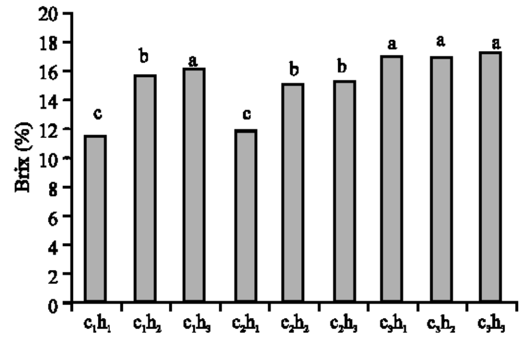

Fig. 3: Interaction between cultivars (c_1, c_2, c_3) and harvesting stages (h_1, h_2, h_3) on brix value c_1: Vespa c_2: IS2325 c_3: Rio h_1: flowering h_2: physiological maturity h_3: before chilling

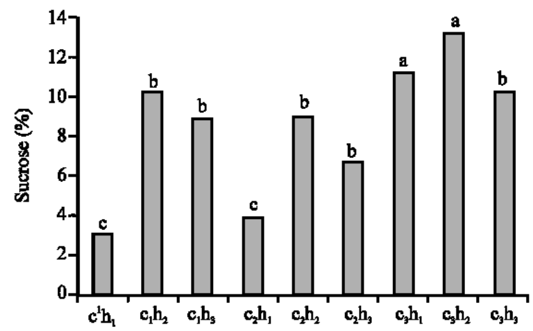

Fig. 4: Interaction between cultivar (c_1, c_2, c_3) and harvesting stages (h_1, h_2, h_3) on sucrose percent h_1: flowering h_2: physiological maturity h_3: before chilling c_1: Vespa c_2: IS2325 c_3: Rio

value of sweet sorghum cultivars was obtained at physiological maturity and before chilling stages. Cv Rio had the higher sucrose content at physiological maturity than other sweet sorghum cultivars (Fig. 4). The amount of neutral invertase enzyme in Rio was higher than other cultivars (Tarpley *et al.*, 1994). Based on these results to obtain the highest stalk yield, brix value and sucrose content, it is recommended to plant Rio and harvested at physiological maturity.

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