Journal of Environmental Biology **July 2006,** 27(3) 601-605 (2006)

Effects of planting date and time of nitrogen application on yield and sugar content of sweet sorghum

A. Almodares and S.M. Mostafafi Darany
Biology Department, College of Science, University of Isfahan, Isfahan, Iran 81846-73441

(Received: 27 May, 2005 ; Accepted: 19 December, 2005)

Abstract: *This experiment was conducted at Azad University experiment station to evaluate the effects of planting date and time of nitrogen application on yield and sugar content of sweet sorghum in 2003. Four planting dates (May 4, March 19, June 3 and June 18) and three stages of nitrogen application (3-5/8 leaf stage, boot stage and soft dough stage) were assigned to the main and subplots, respectively. Plant height and diameter, fresh stalk yield, total dry weight, brix value (soluble solids), sugar content and grain yield were affected by planting date. For all the characteristics, the maximum value was obtained by the first planting date. Only stem height, diameter and total plant dry weights were affected by time of nitrogen application. In these cases, nitrogen application at (3-5/8) leaf stage was superior to others. According to the results, sweet sorghum should be planted on the beginning of May and nitrogen be applied at (3-5/8) leaf stage.*

Key words: *Sweet sorghum, Planting dates, Nitrogen application, Sugar contents.*

Introduction

Sugar beet and sugar cane are the main sources of sugar in Iran. Both of these crops are facing many problems, so the farmers are not interested in planting sugar beet, unless the government heavily subsidizes the crop. Sugarcane can be grown only in southern parts of the country; however land preparation due to the presence of salt is expensive, thus there are no private sugarcane farms in the country. More over food industries are consuming one third of total sugar. Sweet sorghum belongs to C4 crop with high photosynthetic efficiency and high productivity. It is one of the many types of cultivated sorghum which is characterized by high sugar content in juice of stem. Sorghum is genetically accustomed to hot and dry conditions, but as Smith *et al.* (1987) reported it can be cultivated world wide in temperate climates. Cowley and Smith (1972), Ferraris and Stewart (1979), and Inman-Bamber (1980) have shown that sweet sorghum is a potential source of sugar and a multipurpose industrial crop. As Ferraris and Stewart (1979) reported sweet sorghum can be processed for sugar and its components can be used for many products. Although seed yield is not a priority in sweet sorghum, but dual purpose sweet sorghum cultivars are more suitable due to the limitation of grains in the country. The advantage of planting sweet sorghum in Iran is to extract the juice form stalk during the growing season. The produced syrup (mixture of sucrose, glucose and fructose) is well accepted by food industries. The grain can be used for producing glucose during and after seed maturity. Moreover, when the plants freeze about December, the quality of the juice is reduced significantly, then the panicles can be harvested, and the grains used for glucose production. Sweet sorghum needs a long growing season and yield declines with late sowing (Broadhead, 1972). Early planting is generally making big problem for farmers because they must harvest their barley or wheat before attempting to plant corn for silage, sunflower, or sorghum. For successful crop production, the growing cycles of it should be the exact duration contained within the available growing period. Failure to match the existing conditions may results in the reduction of yield and quality. In sweet sorghum, it is important for the farmer to know the best planting dates in order to have longer periods of sweet sorghum sales. Sweet sorghum must have both high grain yield and high sugar content, in the juice of its stem in order to develop energetic crop without competition of field with other crops. Many studies about sweet sorghum have shown that yield declined as planting date was delayed but results on brix value, sucrose content and purity levels are inconclusive. According to Hipp *et al.* (1969) yields of sweet sorghum stalks increased with early planting, but brix value, sucrose content and juice purity were not affected by planting date. Similarly Cowley and Smith (1972) reported a decline of yields with late planting but did not find any correlation between planting dates, sucrose content, purity, and brix value. Maheshwari *et al.* (1974) reported a decline in yield of sweet sorghum stalks but juice quality like sucrose content, juice purity, and brix value were improved with delay in planting date. Inman-Bamber (1980) reported a rapid decline in the stalk and sucrose yield of sweet sorghum with delayed planting dates. Similarly, Ferraris and Charles- Edward (1986), Petrini *et al.* (1993) and Almodares *et al.* (1994) reported higher yields of stalks, brix value, sucrose content and purity with early planting than late planting. Generally, sweet sorghum responds well to fertilizers, especially nitrogen. In sweet sorghum it is recommended that the fertilizers should be applied during planting time, to promote the early growth of the plant. Late applications of fertilizers especially high use of nitrogen may interfere with juice quality. Ferraris and Stewart (1979) and Jackson and Arthur (1980) found that application of nitrogen

resulted in higher stem yield and sucrose content. Galani *et al.* (1991) reported that an increase in juice yield and no response in juice brix resulted in an experiment with increasing N rates. Cowley and Smith (1972) did not find any correlation between nitrogen levels and sucrose content and purity. Timing of nitrogen application may have detrimental effects on juice quality. Freeman *et al.* (1973) reported that late application of fertilizer, especially nitrogen, should be avoided as this interferes with juice quality. Although seed yield is not a priority in sweet sorghum, some sweet sorghum cultivars displayed high potential for seed production and compared well with grain sorghum. Hesker (1966) reported that sweet sorghum is an excellent producer of grain. The purpose of this research was to find the effects of planting date and stage of nitrogen application on biomass, sugar content of stalk, and grain characteristics.

Materials and Methods

The experiment was conducted at the Azad University Experiment Station on a clay soil in 2003. Four planting dates, May 4, May 19, June 3, and June 18 and three stages of nitrogen applications, 3-5/8 leaf, boot, and soft dough stages were assessed in a split plot design with four replications. The planting dates were assigned to the main plots and stages of nitrogen application to the sub-plots. Each subplot consisted of 6 rows, 10 m long and 0.50 m apart. The within-the-row spacing was 0.10 m. 200 kg/ha diammonium phosphate was broadcast and disked into the soil before planting. Sweet sorghum cultivar Soave was planted according to the above dates. 200 kg/ha urea was applied to the mentioned growth stages. Plots were irrigated as needed. Plants were harvested at 3-5/8 leaf stage, flowering, hard dough stage, and physiological maturity. In each stage the height and diameter of stalk, total fresh stalk weight, total dry weight, soluble solids (brix value) and sugar yield were measured. The sugar yield was calculated as,

Sugar yield/ha = the percentage of the fresh stalk X the fresh weight of stalk. The percentage of sugar in fresh stalk (on weight basis) was calculated as, 0.1516 + 0.8746(brix value). At physiological maturity grain yield and its component (No. of grain per ear, 100 gr. grain weight, ear length, biological yield and harvest index were measured.

Results and Discussion

Table 1 shows the effects of planting date and stage of nitrogen application on the height of stem at 3-5/8 leaf, flowering, and hard dough stages. The stalks were shorter at early planting. This is contrary to Balole (2001) finding that early planting (October planting) resulted in taller main stems than late plantings (November and December plantings). After flowering the reproductive sink, becomes extremely strong, which limits the assimilates portioned for additional leaf, stem, and root growth. Sweet sorghum is a short photoperiod sensitive plant. According to Balole (2001) physiological mechanisms in plants are capable of sensing differences in day length. Under most field conditions, late planting is associated with a reduction in number of days to panicle initiation and flowering, which may effect temperature and photoperiod (Pauli *et al.*, 1964; Caddel and Weibel, 1971). For the first three planting dates, the growing season from planting to flowering was long and the assimilates were used for vegetative growth such as height and stem diameter of stem. For the last planting date the growing season was short and there was not much time for vegetative growth, therefore the height of stem for last planting date was thin and short (168 cm height and 1.12 cm diameter in the last planting date compared to 203 cm height and 1.37 cm diameter in the first planting date). (Table 1 and 2). Except for 3-5/8 leaf stage, the time of nitrogen application did not affect the height. When nitrogen was applied at 3-5/8 leaf stage, the plants were taller at 3-5/8 leaf stage than at other stages. This indicates that the effect of nitrogen on

Table – 1: Mean comparisons[1] among planting dates and stages of nitrogen application for stem height at different growth stages.

Treatment	Stems height (cm)		
	3-5/8 leaf	Flowering	Hard dough
Planting date			
May 4	9.4c	194.2a	203.1a
May 19	12.6b	193.7a	195.1a
June 3	12.8b	188.5a	194.5a
June 18	14.7a	165.7b	168.0b
Stages of nitrogen application			
3-5/8 leaves	13.7a	186.3	189.2
Booting	11.9b	186.0	190.2
Soft dough	11.6b	185.9	189.3

[1] Means comparisons were made using Duncan's multiple range test. Means with the same letter are not significantly different at 5% level.

Table – 2: Mean comparisons[1] among planting dates and stages of nitrogen application for stem diameter at different growth stages.

Treatment	Stem diameter (cm)	
	Flowering	Hard dough
Planting date		
May 4	1.23	1.37a
May 19	1.30	1.22b
June 3	1.17	1.16bc
June 18	1.1.7	1.12c
Stages of nitrogen application		
3-5 /8leaves	1.29a	1.28a
Booting	1.20a	1.19b
Soft dough	1.16b	1.18b

Means comparisons were made using Duncan's multiple range test. Means with the same letter are not significantly different at 5% level.

Table – 3: Mean comparisons[1] among planting dates and stages of nitrogen application for fresh stalk yield at different growth stages.

Treatment	Fresh stalk weight (kg/ha)	
	Hard dough	Physiological maturity
Planting date		
May 4	43750a	43000a
May 19	38000a	32170b
June 3	29420b	28080bc
June 18	26750b	24550c
Stages of nitrogen application		
3-5/8 leaves	36087	35250
Booting	34787	31187
Soft dough	32558	31062

Means comparisons were made using Duncan's multiple range test. Means with the same letter are not significantly different at 5% level.

plants is short. No matter when nitrogen was applied, it did not affect the height of plant which is normally harvested after flowering. Seed planted early produced thicker stems (1.23 cm) (Table 2). As planting date was delayed, the stems became thinner (1.17cm). At hard dough stage, stem diameter was the highest for the first planting date (May 4) and the lowest for the last planting date (June 18). The effect of planting date on stem diameter was not shown until the late stage of plant growth (hard dough). Balole (2001) found that planting date did not affect the main stem thickness but he mentioned that early planting improves main stem size through increasing main stem height. Early nitrogen application increased stem diameter both at flowering and hard dough stages. Late application of nitrogen did not increase stem diameter. To have thick and tall stems, it is better to plant soon and applies nitrogen at the plant's vegetative growth stage (3-5/8 leaf stage). At physiological maturity, the highest fresh stalks yields were observed in the May 4 planting (Table 3). The fresh stalk yields were significantly decreased as delayed in planting dates. Stem height and stem diameter were the highest for May 4 planting and the lowest for the June 18 planting (Tables 1 and 2). According to Hipp *et al.* (1969) and Broadhead (1972), yields of sweet sorghum stalks increases with early planting. Similar results have been reported by Inman-Bamber (1980), Ferraris(1988) and Almodares *et al.* (1994) indicating that early planting causes in higher stem yield, more tiller and taller main stems than late planting. Similarly Cowley and Smith (1972), Maheshwari *et al.* (1974) and Inman- Bamber (1980) reported a decline in yields of stalk with late planting. Sweet sorghum needs a long growing season and the yield declines with late sowing (Broadhead, 1972). Balole (2001) reported that high stem yields in early planting is associated with an increase in the growing period from emergence to panicle initation and boot stage; and increase tiller number and stem height. Fresh stalk weights were not significantly different at different stages of nitrogen application. 36087, 34787 and 32558 kg/ha for 3-5/8 leaf, booting and soft dough stages, respectively (Table 3). These results are consistent with Almodares *et al.* (1996) findings that time of nitrogen application (tillering or booting) and amounts of nitrogen levels (100,200 and 300 kg/ha urea) did not increase the stalk yield of sweet sorghum cultivars. Similarly, Balola (2001) found that comparing to unfertilized control, nitrogen applications increased stalk yields but there were no differences between time of nitrogen application (40 days after emergence and booting) and amounts of nitrogen application (60 and 120 kg N/ha). However, the results are in contradict with the findings of Broadhead *et al.* (1963), and Jackson and Arthur (1980) who reported increase stem dry mass, with nitrogen increasing. Table 4 shows that total plant dry weights were significantly higher in the first two early planting dates than others. …These results are consistent with the findings of Inman-Bamer (1980) and Ferraris (1988) who reported increase stem dry mass, with early planting, compared to late plantings. They attributed the decrease in dry mass with late planting to reduction of the growth period of sweet sorghum.The results indicate that early planting improves brix value (Table 5).

Table – 4: Mean comparisons[1] among planting dates and stages of nitrogen application for total dry weight at different growth stages.

Treatment	Total dry weight (g/m²)			
	3-5/8 leaf	Flowering	Hard dough	Physiological maturity
Planting date				
May 4	26.8	1413.0a	2281.2a	2085.0a
May 19	38.5	1389.3a	1885.6b	1870.2a
June 3	38.4	1123.3b	1494.8c	1482.1b
June 18	39.8	972.7b	1198.1c	1126.9b
Stages of nitrogen application				
3-5/8 leaves	44.8a	1338.5a	1811.8	1938.5a
Booting	30.9b	1175.3b	1651.7	1549.4b
Soft dough	31.9b	1159.8b	1680.7	1577.0b

Means comparisons were made using Duncan's multiple rang test. Means with the same letter are not significantly different at 5% level.

Table – 5: Mean comparisons[1] among planting dates and stages of nitrogen application for brix value and sugar yield at physiological maturity stage stages.

Treatment	Brix value (%)	Sugar yield (kg/ha)
Planting date		
May 4	19.58a	7436.6a
May 19	18.66ab	5191.4b
June 3	18.25bc	4643.6bc
June 19	17.50c	4127.8c
Stages of nitrogen application		
3-5/8 leaves	18.18	5713
Booting	18.87	5226
Soft dough	18.43	5110

Means comparisons were made using Duncan's multiple range test. Means with the same letter are not significantly different at 5% level.

Table – 6: Mean comparisons[1] among planting dates and stages of nitrogen application for the characteristics measured at different growth stages.

Treatment	Grain yield kg/ha	Grain in ear No.	100 grain weight g	Ear length cm	Biological yield g/m^2	Harvest index
Planting date						
May 4	68996.2a	1732.5a	2.0a	18.5a	2085.5a	34.3a
May 19	7320.0a	1788.0a	2.0a	18.5a	1930.7a	40.4a
June 3	4685.2b	1306.5b	1.8b	18.2a	1610.1b	37.1a
June 18	3102.0c	1131.7b	1.4c	17.1b	1126.9b	21.8b
Stages of nitrogen application						
3-5/8 leaves	5370.9	1435.2	1.8ab	18.1	1938.4a	28.3
Booting	5666.1	1480.5	1.9a	18.0	1549.4b	36.4
Soft dough	5465.2	1553.1	1.7b	18.1	1577.0b	35.4

Means comparisons were made using Duncan's multiple range test. Means with the same letter are not significantly different at 5% level.

The highest brix value obtained with the first planting date and the least got at the last planting. The effect of planting dates on sugar yield follows the same pattern as brix value. The studies on the effect of planting date on brix value, sucrose content, and purity levels are inconclusive. Ferraris and Charles Edwards (1986), Petrini *et al.* (1993) and Almodares *et al.* (1994) found that early planting improves juice quality. Howere Balole (2001) reported that early planting did not improve juice quality. He also indicated that brix value was not affected by planting date. Hipp *et al.* (1969) reported that brix value, sucrose content and juice purity were not affected by planting date. Similarly Cowley and Smith (1972) did not find any correlation between planting dates, sucrose content, purity, and brix value. In the other hand Maheshwari *et al.* (1974) shown that juice quality like sucrose content, juice purity and brix value were improved with delay of planting date. Balole (2001) mentioned that the difference in stem moisture content might explain the poor juice quality. High moisture content in the stem may tend to dilute concentration of sucrose, lowering of pol percentage, brix value, and juice purity. Due to the hot and dry climatic condition sweet sorghum plants were irrigated through out the growing season, therefore the stem moisture content was nearly constant during the growing seaso. Almodares *et al.* (1994) found that early planting significantly increases brix value. Under the most field conditions, late planting is associated with a reduction in number of days to panicle initiation and there is more assimilate in longer growing season which increases not only brix value but also the grain yield (see later). Balole (2001) concluded that early planting increased stalk yields through increased number of tiller and main stem height, but reduced juice quality, so there is a negative relationship between stem yield and juice quality. The results of different studies show that there is positive relationship between stalk yield and juice quality (brix value). Both stalk yields and brix value were higher at first two planting dates than the last ones. No differences in brix value occurred as result of nitrogen treatment (Balole 2001; Galani *et al.*, 1991). It is recommended that fertilizers were applied during planting to promote early growth. Freeman *et al.* (1973) reported that for syrup production late application of fertilizer, especially nitrogen should be avoided as this interferes with juice quality. Sugar yield was the highest with May 4 planting (Table 5) and decreased as planting was delayed. Since sugar yield is calculated as: fresh

stalk yield X brix value, and both of these decreases due to late planting, thus the highest sugar production is obtained by early planting. Early planting is often recommended, since sucrose production tends to decline with delay in sowing (Maheshwari *et al.* 1974); Inman- Bamber 1980 and Ferraris and Charles- Edwards, 1986). The results show that brix value and sugar yield were silmilar by the stage of nitrogen application. Balole (2001) reported that sucrose content was increased by nitrogen fertilizer. Galanie *et al.*, (1991) reported that an increase in juice yield but no response in juice brix value, results from increasing the nitrogen fertilization. These results are in contradict with the findings of Freeman *et al.* (1973) who found that late application of fertilizers, especially nitrogen, has a negative effect on juice quality. In addition to stalk, seed is needed for glucose production. The results show that early planting significantly increases grain yield, number of grain per ear, 100 grain weight, ear length, biological yield and harvest index (Table 6). Stickler *et al.* (1961) showed that early planting in grain sorghum, increased grain yields through increased tillering and number of heads per unit area. Stage of nitrogen application had no significant effect on any of the measurements except for biological yield, which was higher when nitrogen was applied at 3-5 leaf stage than other stages. Utzurrum *et al.* (1998) reported that under water-limiting conditions, late nitrogen application is effective in increasing grain yield. The results indicate that to have the highest stalk, sugar yield and grain, sweet sorghum should be planted around mid May and nitrogen applied at 3- 5/8 leaf stage.

Acknowledgments

I would like to acknowledge the assistance provided by Miss H. Shirian to correct the manuscript.

References

Almodares, A., A. Aghamiri and A. Sepahi: Effects of the amount and time of nitrogen fertilization on carbohydrate contents of three sweet sorghum cultivars. *Ann. plant physiol.,* **10,** 56-60 (1996).

Almodares, A., A. Sepahi, H. Dalilotojjary and R. Ghavimi: Effect of phonological stages on biomass and carbohydrate contents of sweet sorghum cultivars. *Ann. plant physiol.,* **8,** 42-48 (1994a).

Balole, T. V.: Strategies to improve yield and quality of sweet sorghum as a cash crop for small scale farmers in Bostwana. Phd Thesis, Dept. of plant production and soil science, University of Pretoria, p.128 ,(2001).

Broadhead, D.M.: Effect of planting date and maturity of Rio sweet sorghum. *Agron. J.,* **64,** 389-390 (1972).

Broadhead, D.M., I.E. Stokes and K.C. Freeman: Sorgo spacing experiments in Mississippi. *Agron. J.,* **55,** 164-166 (1963).

Caddel, J.L. and D.E. Weibel: Effect of photoperiod and temperature on development of sorghum. *Agron.J.,* **63,** 799-803 (1971).

Cowley, W.R. and R.A. Smith: Sweet sorghum as a potential sugar crop in south Texas. *Proc. Int. Soc. Sug. Cane Technol.,* **14,** 628-633 (1972).

Ferraris, R.: Sweet sorghum: Agronomic evaluation and potential application for Australian Agro- Industry, CSIRO Division of Tropical Crops and Pastures. Report No. 5(1988).

Ferraris, R., and D. A. Charles-Edwards: A comparative analysis of the growth of sweet and forage sorghum crops. 11 Accumulation of soluble carbohydrate and nitrogen. *Aust. J. Agric. Res.,* **37,** 513-522 (1986).

Ferraris, R. and G.A. Stewart: New options for sweet sorghum. *J.Aus.Inst. Agric. Sci.* **45,** 156-164 (1979).

Freeman, K.C., D.M. Broadhead and N. Zummo: Culture of sweet sorghum for syrup production. *Agric. Res.Serv.Agric.* Handbook., No. 441, U.S. Dept. Agric, Washington D.C. (1973).

Galani, N.N., M.H. Lomte and S.D. Choudhari: Juice yield and brix value as affected by genotype, plant density and nitrogen levels in high energy sorghum. *Bharatuya*, **16**, 23-24 (1991).

Hipp, B-W., W.R. Cowley, C.J. Gerard and A.B. Smiti: Influence of solar radiation and date of planting on yield of sweet sorghum.*Crop Sci.* **10,** 91-92 (1969).

Hesker, P.: General botany. In:"Sorghum" handbook. Publ. No.2 pp 2.1-2.3 Old. Dep. Primary Ind.Brisbane. (1966).

Inman- Bamber, N.G.: An evaluation of sweet sorghum as a sugar crop in the Midlands Mistbelt. S.A. Sugar J. 64, 419 (1980).

Jackson, D.R. and M.F. Arthur: Alcohol crop for the U.S. Gasohol USA. 2, 26-33 (1980).

Maheshwari, B.K., J. Prasad, G.B. Singh and R.K. Sharma: Studies of sweet sorghum in India- 11 Effect of date of sowing and stage of harvest on yield and quality of sweet sorghum. 40th Proceedings of the S.T.A. of Indian. (1974).

Pauli, A.W., F.C. Stickler and J.R. Lawless: Development phases of grain sorghum (Sorghum vulgare Pers.) as influenced by variety, location and planting. *Crop Sci.,* **4,** 10-13 (1964).

Petrini, C., A. Belletti and F. Salamin: Accumulation and distribution of dry matter and soluble carbohydrates in two sweet sorghum cultivars; influence of sowing date and harvesting time. *Eur.J. Agron.,* **2,** 185-192 (1993).

Smith, G.A., M.O. Gagby, R.T. Lewellen, D.L. Doney, P.H. Moore, F.J. Hills, L.G. Campbell, G.J. Hogaboan, G.E. Cone and K. Freeman: Evaluation of sweet sorghum for fermentable sugar production potential. *Crop Sci.,* **27,** 788-793 (1987).

Stickler, F.C, A.W. Pauli, H.H. Lande, H.D. Wilkins and J.L. Mingis: Row width, plant population studies with grain sorghum at Manhattan, Kansas. *Crop Sci.*, **1,** 297-300 (1961).

Utzurrum, J.R., S. Fukai and M.A. Foale: Effect of late application on growth and nitrogen balance of two cultivars of water-stressed grain sorghum. *Aust.J.Agric.Res.,* **49,** 687-694 (1998).

Correspondence to:
Dr. A. Almodares
Biology Department College of Science,
University of Isfahan, Isfahan, Iran 81846-73441
E-mail: aalmodares@yahoo.com