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Effect of planting density and levels of nitrogen on ethanol production of sweet sorghum (*Sorghum bicolor* [L.] Moench) varieties

Harshlata, GS Tomar and Sonal Sai

Abstract
A field experiment was conducted during rainy season, 2015 at the Research –cum-Instructional Farm, Indira Gandhi Krishi Vishwavidylaya, Raipur (Chhattisgarh) to assess the potentiality of sweet sorghum [*Sorghum bicolor* (L.) Moench] varieties under different planting densities and levels of N fertilizers. The results revealed that the juice extraction, juice extractability, juice yield, brix value and ethanol production were significantly influenced by varieties, levels of nitrogen and planting densities. Sweet sorghum variety SSV-84 registered significantly higher ethanol yield (404.10 L ha^{-1}) with higher juice extraction (27.24%), extractability (269.80 ml kg^{-1}), juice yield (6691.56 L ha^{-1} with greater brix value (16.62) compared to CSV 24SS. Plant density of 13.33 plants m-^{2} gave maximum amount of juice (7283.96 L ha^{-1}) along with higher juice extraction (28.52%), extractability (282.65 ml kg^{-1}) as well as ethanol yield (401.89 L ha^{-1}) in comparison to lower planting density. Among different levels of N fertilizers, application of nitrogen at 120 kg N ha^{-1} recorded the highest juice yield (7578.93 L ha^{-1}), juice extraction (27.09%), extractability (271.12 ml kg^{-1}), brix value (18.75 as well as ethanol yield (473.89 L ha^{-1}) being significantly higher than other levels of nitrogen.

Keywords: Sweet sorghum, bioethanol crop

Introduction
Renewable resources can contribute towards meeting energy requirements with the added advantage of greater environmental protection, especially in terms of lower CO_2 emissions (Basavaraj *et al.*, 2012) [2]. Among different crops, sweet sorghum (*Sorghum bicolor* L. Moench) is of particular interest because its biomass is used for the production of energy, fiber or paper, as well as for syrup and animal feed. It is the potential alternative sugar crop for ethanol production in India (Hunsigi *et al*., 2010) [4] the cost of its cultivation can be three times lower than that of sugarcane. Bioethanol can be produced from stem sap, while the grains are used as food. Compared to other sorghums, sweet sorghum produces less grain but contains a large amount of readily fermentable carbohydrates, require 37% less nitrogen fertilizer and 17% less irrigation water than maize and could yield more ethanol than maize during a dry year. In India sorghum is grown over an area of 2.85 million ha in kharif and 4.18 million ha in rabi season with a 3.08 million ton and 3.06 million ton production of grain in kharif and rabi season respectively.

To make sweet sorghum a sustainable and profitable crop, there is a need for standardize the best agronomic practices, apart from breeding high-yielding cultivars, which can contribute to increased yields. Among the various agronomic factors, proper crop nutrition and appropriate planting geometry are of prime importance in getting higher grain and biomass yield of better quality. Nitrogen (N) is an essential nutrient and key limiting factor in crop production of different agro-ecosystems (Prasad *et al.*, 2014) [8]. Results of investigation carried out by Sawargaonkar *et al*., (2013) [11] in ICRISAT, Hyderabad revealed that nitrogen application had significant effect on plant height, number of leaves $plant^{-1}$, sugar content, green stalk yield, juice yield, brix percent and potential ethanol yield1. In general, maintaining optimum crop geometry in terms of inter- and intra-row spacing is prerequisite for better utilization of water, nutrients and solar energy in sweet sorghum. The study conducted by Djanaguiraman and Ramesh (2013) [3] revealed that plant population of 7.2 plants m^{-2} along with nitrogen level of 120 kg N ha-1 resulted in higher millable stalk yield and brix value. Since information on these aspects is lacking under the agro-climatic conditions of Chhattisgarh, hence, the present investigation was undertaken to examine the effect of planting density and levels of nitrogen on ethanol production of sweet sorghum varieties under the Agro-climatic situations of Raipur.

Materials and methods

Experimental details

The Experiment was carried out to study the effect of planting density and levels of nitrogen on ethanol production of sweet sorghum in rainy seasons of 2014 at the Instructional Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) The experiment included two varieties (viz., V_1-SSV-84 and V_2-CSV-24SS), two planting densities (viz., P_1-111.11 plants m^{-2} with plant geometry of 50 × 15 cm and P_2- 13.33 plants m^{-2} with plant geometry of 60 × 15 cm and four levels of nitrogen (viz.,N_0-0, N_1-40, N_2-80 and N_3-120 kg N ha^{-1}) were tested in factorial split plot design assigning varieties x plant geometry in main plots and levels of nitrogen in sub plots. The soil of experimental field was clay loam (*Vertisols*) in texture with available nitrogen (201.78 kg ha^{-1}), phosphorus (14.07 ha^{-1}) and available potassium (349.31 ha^{-1}) having soil pH of 7.12. The crop was fertilized with a uniform dose of 80 kg P_2O_5, 40 kg K_2O with varied levels of nitrogen per hectare as per treatments. The experimental crop encountered with an optimum weather conditions throughout the growing season. The crop received 347.5 mm rainfall and maximum temperature varied from 33.4ºC in last week of December to 25.1ºC in First week of September, whereas, minimum temperature varies from 10.8ºC in first week of December to 28.3ºC in first week of September.

Laboratory analysis for ethanol production

Five plants were chosen randomly from each plot for data collection during the physiological maturity stage. The leaf was stripped and cane weight was recorded. These five plants were crushed on an electrically operated two-roller cane crusher to estimate juice extractability and quality. The percent Brix was recorded using Brix hydrometer (hand refractometer (0-30^0) and corrections were made with room temperature and corrected values are expressed in degrees. Extraction per cent refers to the actual amount of juice extracted from known weight of the stripped stalk and expressed as per cent of extraction.

Extractability as an index of juiciness of stem was estimated using the formula,

Volume of juice extracted (ml)

Extractability (ml kg^{-l}) = Weight of stripped stalks (kg)

Juice yield (L ha-1) was calculated according to the equation,

Juice yield (L ha-1) = {Extractability (ml kg^{-1}) X Millable stalk yields (t ha^{-1})}

Ethanol yield was computed from total soluble solids in juice by multiply the brix reading from correction factor, given by following formula-

Ethanol yield (L ha^{-1}) = {Juice yield X Brix (%) X 0.85}/1.75

Results and discussion

Juice extraction (%) and extractability (ml kg^{-1})

The data on juice extraction and extractability presented in Table 1 showed that both these parameters were significantly influenced by variety, plant density and levels of nitrogen. The highest amount of juice (27.24%) was extracted from the millable canes (green biomass) of SSV-84 as compared to the variety CSV 24SS which consequently resulted in greater extractability of 269.80 ml kg^{-1} because of superior genetic characterstics of SSV 84 variety. The plant density of 13.33 plants m^{-2} at plant geometry of 50 x 15 cm (P_2) had more number of plants or stalks resulting higher juice extraction (28.52%) coupled with greater extractability amounting 282.65 ml kg^{-1} compared to plant density of 11.11 $plants^{-2}$ at 60 x 15 cm (P_1). In the present experiment increased juice extraction and extractability due to higher plant density may be ascribed due to more green stalk production under narrower plant geometry. The variation in juice extraction due to plant density was also reported by Mahmoud *et al.* (2013) [6], however, contrary to our results, they observed an increase in juice extraction as plant density decreased. The increasing levels of nitrogen increased the juice extraction and extractability significantly. Application of nitrogen at 120 kg N ha^{-1} recorded the highest percentage of juice extraction (27.09) and extractability (271.12 ml kg^{-1}) which differed significantly over rest of the levels of nitrogen. The results are in accordance with the findings of Almodares *et al*. (2008) who showed that application of 180 kg urea ha^{-1} significantly enhanced the juice extraction to the tune of 34 percent and similar finding was reported by Uchino *et al*. (2010) [12] who showed that juice volume, brix and sugar yield was significantly higher in 90 kg N to 150 kg N than in 0 kg N to 60 kg N.

Juice yield (L ha^{-1})

As the sweet sorghum juice is extracted from the stalk, higher the green stalk yield higher would be the amount of juice. The data pertaining to juice yield of sweet sorghum has been presented in Table 4.10. Results revealed significant differences due to different treatments in their effects on juice yield. As the sweet sorghum juice is extracted from the stalk, higher the green stalk yield would give higher amount of juice. The variety SSV 84 yielded higher juice (6691.56 L ha^{-1}) that was significantly greater than those produced by CSV-24SS (5714.20 L ha^{-1}) and amounted to be 14.6% more than CSV 24SS which might be ascribed due to the higher green biomass (stalk) yield given by variety SSV 84 in the present experiment. In contrast to our findings, Kumar *et al*. (2008) [5] reported the less juice yield from SSV 84 compared to RSSV 9, though difference between them was non-significant.

Plant density had significant effect on juice yield of sweet sorghum. The maximum amount of juice (7283.96 L ha^{-1}) was extracted from the plants seeded in narrow spacing of 50 x 15 cm with plant density of 13.33 plants m^{-2} (P_2), while minimum amount (5903.21 L ha^{-1}) were produced by the plants seeded at 60 x 15 cm with plant density of 11.11 plants m^{-2} (P_1). This increase came out to be 18.95% greater than that of P_1 plant density. As maximum green biomass (stalk) yield were obtained from plant density of 13.33 plants m^{-2} which might be responsible for greater juice yield in that particular treatments. Similar observations were also made by Mahmoud *et al*. (2013) [6] who reported that higher plant density resulted in higher yield of stalks and consequently the final juice (syrup) yield which is also evidenced in Table 4.9 of preceding section. Contrary to these results, Djanaguiraman and Ramesh (2013) [3] reported that high density decreased the juice yield compared to low plant density at Coimbatore and similar results was reported by Wortmann *et al*. that juice content is more in wider spacing as compare to narrower spacing.

The juice yield also varied significantly due to levels of nitrogen. There was progressive increase in juice yield with the successive levels of nitrogen. Application of nitrogen at 120 kg N ha^{-1} recorded the maximum amount of juice (7578.93 l ha^{-1}) which was significantly higher over other levels of nitrogen. The lowest amount of juice was obtained with no nitrogen treatment. Without nitrogen application (N_0), an extent of increase in juice production was to the tune of 39.76, 27.94 and 18.66 percent due to 120, 80 and 40 kg N ha^{-1}, respectively. Other researchers (Kumar *et al*. 2008; Miri and Rana, 2014) [5, 7] also reported their results similar to our findings. However, highest stover yield of pearlmillet was recorded with 90 kg N ha^{-1} (Prasad *et al*. 2014) [8].

Brix percent

The brix percent in juice (Table 1 and Fig.1) exhibited significant effect due to variety, plant density and levels of nitrogen. Variety SSV-84 gave significantly superior brix values (16.62) compared to CSV-24SS. An extent of increase in brix of juice was to the tune of 5.53 percent in SSV 84 over CSV 24SS variety. Similarly, Kumar *et al*. (2008) [5] also found 34% higher brix count in SSV 84 as compared to RSSV 9. Furthermore, plant density of 11.11 plants m^{-2} at plant geometry of 60 x 15 cm at resulted in significantly higher brix (16.83) which was worked out to be 7.17 percent more than those noticed (15.41%) in closer plant geometry of 50 x 15 cm having 13.33 plants m^{-2}. Similar to these results, Djanaguiraman and Ramesh (2013) [3] also revealed that plant population of 7.2 plants m^{-2} resulted in higher brix value compared to plant density of 21.7 and 10.9 plants m^{-2}.

The brix of the juice were significantly influenced by levels of nitrogen over control. Among different levels of nitrogen, the highest brix content (18.75%) was recorded when crop were fertilized at 120 kg ha^{-1} which was significantly superior over control (15.17%) but remained on par with N_2 level of nitrogen. The value of brix increased to the tune of 19.09, 13.31 and 7.64 due to N_3, N_2 and N_1 levels of nitrogen over N_0 (control) treatments. The higher content of brix might be due to more availability of nitrogen from soil and fertilizers which improved the metabolic activity during physiological maturity stage might have triggered the process related to quality parameters. Though Miri and Rana (2014) [7] also reported increased brix reading up to 100 kg N ha^{-1} but found decreasing trend in brix beyond 100 kg N ha^{-1}.

Potential ethanol yield (L ha^{-1})

Conversion efficiency of sweet sorghum juice to ethanol is related to both juice yield and sucrose content in the juice, which in turn is indicated by the brix reading. It is evident from the data presented in Table 1.that ethanol yield was significantly influenced by various treatments under study. Crop variety differed significantly in terms of ethanol production. The variety SSV-84 (V1) produced significantly higher amount of ethanol (404.10 l ha^{-1}) which worked out to be 6.45 percent more than CSV-24SS (V2). Miri and Rana (2014) [7] also found significant differences in estimated ethanol yield due to varieties and reported that CSH 22 SS produced greater estimated ethanol yield than RSSV 9 and SSV 84, which was the natural corollary of stripped stalk weight of sweet sorghum varieties. In contrast to our findings, Rao *et al*. (2013) [9] reported that the among the test OPVs, SPSSV 15 (15%) SPSSV 20 (23%) and SPSSV 27 (14%) were superior for bio-ethanol yields than the best check SSV 84. Plant density of 13.33 plants m^{-2} at 50 x 15 cm planting geometry (P_2) produced the higher amount of ethanol (401.89 l ha^{-1}) compared to that obtained by the plants density of 11.11 plants m^{-2} seeded at 60 x 15 cm spacing (P_1) because of more number of plants resulting more juice yield and ethanol yield Thus closer plant geometry enhanced the ethanol production to the tune of 4.33 percent over wider plant geometry. Contrary to these results Djanaguiraman and Ramesh (2013) [3] found higher brix values at lower plant densities.

The potential ethanol yield of sweet sorghum was significantly influenced by different levels of nitrogen. The highest amount of ethanol (473.89 l ha^{-1}) were produced at 120 kg N ha-1 (N_3) which stand significantly superior over rest of the levels of nitrogen. The lowest amount of ethanol (379.55 L ha^{-1}) was given by control (N_0) treatments. The magnitude of an increase in ethanol production was to the tune of 16, 12 and 7 percent due to N_3, N_2 and N_1 levels of nitrogen over control (N_0) treatments. An increase in ethanol yield relative to nitrogen fertilizer was primarily due to increase in green biomass, juice yield and sugar concentration (brix). These results are in agreement with Ratnavati *et al* (2010) [10].

Table 1: Juice extraction, juice yield, brix and ethanol yield of sweet sorghum as influenced by variety, planting density and levels of nitrogen

Treatments	Juice extraction %	Extractability (ml kg^{-1})	Juice Yield (L ha^{-1})	Brix (%)	Ethanol yield (L ha^{-1})
Variety					
V_1: SSV-84	27.24	269.80	6691.56	16.62	404.10
V_2: CSV-24SS	25.11	242.11	5714.20	15.70	350.93
SEm±	0.21	1.23	197.18	0.20	7.77
CD (P=0.05)	0.58	5.75	597.02	0.64	22.43
Plant density					
P_1: 60 X 15 cm (11.11 plants m^{-2})	26.67	260.77	5903.21	16.83	373.14
P_2: 50 X 15 cm (13.33 plants m^{-2})	28.52	282.65	7283.96	15.41	401.89
SEm±	0.25	0.59	222	0.19	6.21
CD (P=0.05)	0.71	1.78	689	0.58	19.30
Levels of Nitrogen					
N_0 : Control	21.22	222.76	4565.00	15.17	379.55
N_1 : 40 kg ha^{-1}	24.19	242.54	5612.34	16.33	393.31
N_2 : 80 kg ha^{-1}	25.76	250.80	6335.20	17.50	434.33
N_3 : 120 kg ha^{-1}	27.09	271.12	7578.93	18.75	473.89
SEm±	0.85	2.90	110.2	0.42	7.0
CD (P=0.05)	2.49	8.88	351.5	1.30	20.22

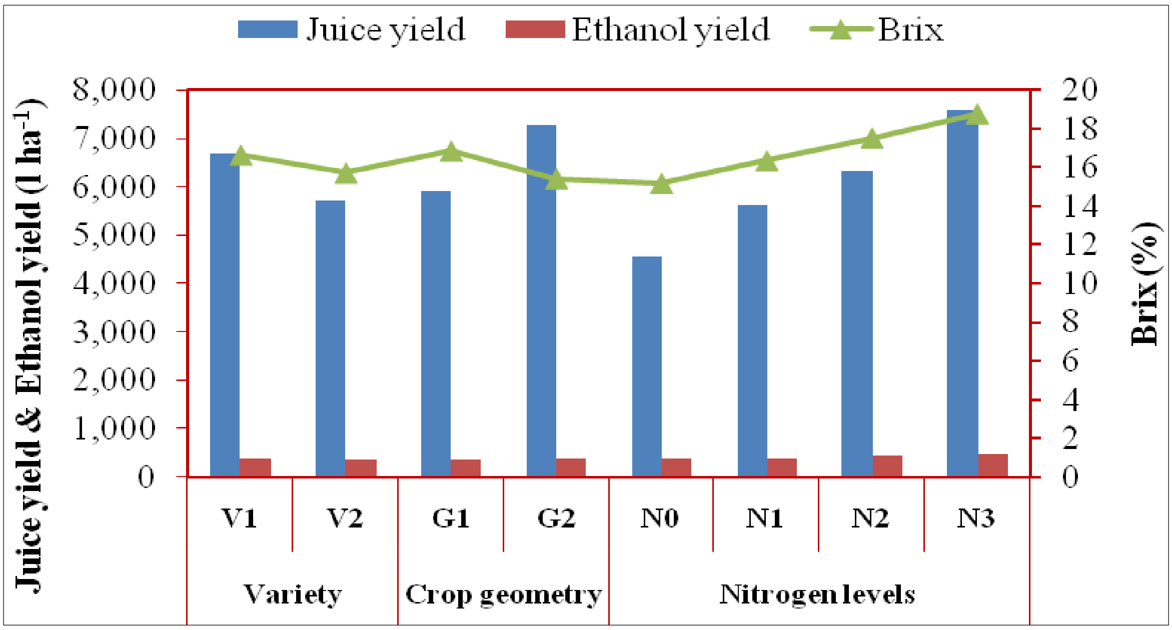

Fig 1: Juice yield, ethanol yield and Brix (%) of sweet sorghum as influenced by variety, planting density and levels of nitrogen

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