International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(1): 2098-2101

Received: 25-11-2017
Accepted: 27-12-2017

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# Effect of planting density and levels of nitrogen on yield and yield attributes of sweet Sorghum (*Sorghum bicolor* [L.] Moench) Varieties

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**Abstract**
The experiment was conducted in the research farm of 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 yield and yield attributes were significantly influenced by varieties, levels of nitrogen and planting densities. Sweet sorghum variety SSV-84 registered significantly higher grain yield (16.64 q $ha^{-1}$) with higher yield attributes, green biomass yield (24.80 t $ha^{-1}$) and dry biomass yield (5.93t $ha^{-1}$) compared to CSV 24SS but Harvest Index is higher in CSV 24SS. Plant density of 13.33 plants m-$^{2}$ gave higher grain yield (18.33 q $ha^{-1}$) with higher green biomass yield (25.77 t $ha^{-1}$) and dry biomass yield (6.15 t $ha^{-1}$) in comparison to lower planting density but yield attributes viz., No of grain/cob(1421.20), test weight (23.40 g), grain yield $plant^{-1}$(19.97 g) and Harvest index (19.38) is higher in planting density of 11.11 plants $m^{-2.}$. Among different levels of N fertilizers, application of nitrogen at 120 kg N $ha^{-1}$ recorded the highest grain yield (20.13 q $ha^{-1}$) with higher yield attributes, green biomass yield (27.94 t $ha^{-1}$) and dry biomass yield (6.70 t $ha^{-1}$) are significantly higher than other levels of nitrogen but Harvest index is recorded highest in control plot for Nitrogen.

**Keywords:** Bio-ethanol crop, nitrogen levels, varieties, Sweet sorghum

## 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). Among different crops, sweet sorghum (*Sorghum bicolor* L. Moench) is of particular interest because its seeds can be use as food, biomass is used for the production of energy, fiber or paper, as well as for syrup and animal feed. 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. 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). 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) revealed that plant population of 7.2 plants $m^{-2}$ along with nitrogen level of 120 kg N ha-1 resulted in higher Grain and millable stalk yield. 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

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 observation on yield and yield attributes viz., cob length, no of grains per cob test weight, the cobs from the five randomly selected plants for taking growth observations at the time of physiological maturity were used and the following observation. To observe length of cob the length from peduncle to tip of the cobs was recorded and expressed in cm. All matured cobs of five tagged plants from each plot were picked up and their grains were counted and it was averaged by seeds of five tagged plants to get mean number of grains $plant^{-1}$. To record test weight thousand grains from the produce of each net plot were counted randomly then weight was recorded in gram accurately. The cobs of five randomly selected plants from net plot were oven dried, threshed and the mean weight of grains were recorded and expressed as grain yield g $plant^{-1}$. For Grain yield plants from each net plot were harvested at physiological maturity and cobs were separated, air dried, threshed, cleaned and weighed. Grain yield $ha^{-1}$ was worked out in kg $ha^{-1}$ with appropriate multiplication factor. Green biomass yield and dry biomass yield was recorded by standardized procedures.

**Results and Discussion**

Results showed that cob length recorded by SSV-84 (17.31 cm) was significantly superior over CSV-2455 (15.90 cm). Sweet sorghum seeded at a wider plant geometry of 60 x 15 cm at 11.11 plants $m^{-2}$ ($P_1$) produced longer cobs (16.47 cm) significantly superior to those obtained from the crop grew in closer spacing of 50 x 15 cm ($P_2$) at 13.33 plants $m^{-2}$. Increasing intra and inter plant competition for space, light, water and nutrients, which are induced at high densities decreased the length of cobs in sweet sorghum. The results are in line with the findings of Thakur *et al*. (2009) who reported that plant density of 1.11 lakhs plants $ha^{-1}$ gave maximum yield attributing characters compared to higher plant densities. It is also clear from the data that increasing levels of nitrogen significantly increased the length of cobs. Maximum length of cob (18.60 cm) was recorded when crop was supplied with 120 kg N ha-$^{1}$ ($N_3$) while shorter cobs (15.08 cm) was produced by the crop not fertilizer with N ($N_0$) and differences between them was markedly significant.The variety SSV-84 registered maximum number of grains (1284.42 $earhead^{-1}$) which was significantly greater than those produced (1112.34 $cob^{-1}$) by CSV-24SS with a margin of 13.4 percent. The variation in the number of grains per panicle were also reported by Namoobe *et al*. (2014). The competition for radiation and nutrients at higher densities makes the plants to spend more energy and assimilates for increasing their heights by increasing inter nodal length. Thus, less assimilates are supplied to physiological sinks in panicle which at the end, results in embryo abortion and the loss of grain number per panicle (Mousavi *et al*., 2012) [9]. Application of nitrogen at 120 kg N $ha^{-1}$ proved significantly superior with maximum number of grains (1613.92 $cob^{-1}$) with a handsome margin of 43.61, 31.88 and 27.49 per cent over control, 40 and 80 kg N $ha^{-1}$, respectively. However, number of grains produced by control treatment remained on par with those produced at $N_1$ and $N_2$ levels of nitrogen application. The difference in grains per ear head due to two and three way interaction failed to reach up to level of significance. The variety SSV-84 attains maximum 1000-grain weight (23.95 g) which was proved to be significantly superior over CSV-24SS which registered lesser 1000-grain weight (22.14 g). As regards to effect of plant density on test weight, sweet sorghum seeded with wider plant geometry of 60 x 15 cm at plant density of 11.11 plants $m^{-2}$ recorded significantly higher 1000-grain weight (23.40 g) than those given by closer spacing with plant density of 13.33 $plants^{-2}$. An increasing intra and inter plant competition for water and nutrients, which are induced at high densities resulted in decreased 1000 grains weight of sorghum. Mousavi *et al*. (2012) [9] was also expressed that increased plant density resulted in significant loss of 1000-grain weight of grain sorghum. Increasing levels of nitrogen increased the 1000 grain weight significantly up to the maximum dose of nitrogen. The decrease in N level resulted in the loss of 1000 grain weight so that the highest test weight (25.42 g) was obtained at N fertilization level of 120 Kg $ha^{-1}$ ($N_3$) and the significantly lowest one (20.88 g) at no-N treatment (N0). The reason for 17.86% loss of 1000-grain weight under no-N application was that N provides more appropriate nutritional conditions for grain during grain filling period by providing suitable conditions for plant cover formation and the increase the assimilates whereby it enhanced the 1000-grain weight. The results showed that grain yield per plant recorded by SSV-84 (19.29 g $plant^{-1}$) were significantly higher over CSV-24SS (18.04 g $plant^{-1}$). These results are in line with those reported by Reddi and Janawade (2006) [15]. Plant density of 11.11 plants $m^{-2}$ with planting geometry of 60 cm x 15 cm ($P_1$) resulted in significantly higher individual plant grain yield (19.97 g $plant^{-1}$) compared to the individual grain yield (18.05 g $plant^{-1}$) obtained from plant density of 13.33 plants $m^{-2}$ at closer plant geometry of 50 x 15 cm($P^2$). As the plant density increased, the individual plant grain yield was decreased, so that the individual plant grain yield was 9.33% higher under the density of 11.11 plants $m^{-2}$ than under the density of 13.33 plants $m^{-2}$. Low grain yield at high plant density was probably due to increased inter plant competition over the uptake of nutrient, water as well as decrease in individual plant leaf area. The individual plant grain yield was markedly increased by levels of N application so that the highest grain yield of 20.7 g $plant^{-1}$ under the application of 120 Kg N $ha^{-1}$ and the lowest one of 17.58 g $plant^{-1}$ under no-N fertilization. Other levels of N also proved to be better than the plots devoid of N fertilizers ($N_0$). The 15.1% loss of grain yield without N fertilization compared to N level of 120 kg $ha^{-1}$ can be related to the fact that N deficiency at either growth stage disrupts the synthesis of assimilates, consequently results in the loss of floret number per panicle and 1000 grain weight which is followed by the loss of yield. In other words increase in grain yield induced by the increase in N fertilization level is associated with the generation of strong sinks, i.e. more number of grains and the activity of source, i.e. higher leaf area index and duration. The interaction of variety, crop geometry and levels of nitrogen did not influenced the grain yield per plant significantly. It is evident from the data given in Table that grain yield of sweet sorghum influenced significantly due to variety, crop geometry and levels of nitrogen. Crop variety SSV-84 produced the maximum grain yield of 16.64 q $ha^{-1}$ which was significantly higher than CSV-24SS by a narrow margin of 3.91 per cent. The higher grain yield in SSV 84 was partly attributed to improvement in yield parameters and partly by good agronomic management. Increase in grain yield was therefore, due to significant increase in cob length, grain number per cob and grain yield per plant. Moreover, the potentiality of sweet sorghum genotypes is not only controlled by the environment where it is grown and the input management but, also by the inherent genetic make-up of the plant. The plant density provides the best chance to produce the more dry matter and grain yield per unit area. Hence, plant density exhibited significant effects on grain yield. In this study also, sweet sorghum planted with narrow spacing of 50 cm x 15 cm with a plant density of 13.33 plants $m^{-2}$ ($P_2$) produced significantly higher grain yield (18.33 q $ha^{-1}$) which was significantly greater than those obtained under wider crop geometry at plant density of 11.11 plants $m^{-2}$ ($P_1$). Similar results are reported by Desai *et al (*2012) [20] they recorded maximum values of growth and yield parameters in closer spacing (30x30). In other words there was increase in grain yield by 21.9 percent in closer plant geometry ($P_2$) than the wider plant geometry. It may be worth mentioning here that the reduction in yield attributes in terms of number of grains cob-1, length of cobs, 1000 grain weight and grain yield per plant of sweet sorghum accompanying higher plant density was compensated by higher grain yield of sweet sorghum in the present investigation. Snider *et al*. (2012) [10] was also of the view that narrow row spacing provides the maximum yield benefit by significantly increasing stem density. The individual plant grain yield was markedly increased by levels of N application so that the highest grain yield of 20.7 g $plant^{-1}$ under the application of 120 Kg N $ha^{-1}$ and the lowest one of 17.58 g $plant^{-1}$ under no-N fertilization. The 15.1% loss of grain yield without N fertilization compared to N level of 120 kg $ha^{-1}$ can be related to the fact that N deficiency at either growth stage disrupts the synthesis of assimilates, consequently results in the loss of floret number per panicle and 1000 grain weight which is followed by the loss of yield. In other words increase in grain yield induced by the increase in N fertilization level is associated with the generation of strong sinks, i.e. more number of grains and the activity of source, i.e. higher leaf area index and duration. These results are in accordance with the observations of Mousaavi *et al*. (2012) [9] and Sujathamma *et al*. (2015) [13]. The green biomass yield is very important and green stalk is considered as the economic yield of sweet sorghum. The green biomass (stalk yield) was also significantly affected due to variety. The green biomass obtained from variety SSV-84 was significantly higher (24.80 t ha-1) compared to CSV-24SS (23.60 t $ha^{-1}$). Thus the magnitude of increase in green biomass was 4.8 percent in SSV-84 over CSV-24SS. However, results of experiment conducted by Miri and Rana (2014) [8] found significantly higher biological yield of 24.64 t $ha^{-1}$ from CSH 22 SS than those of RSSV 9 and SSV 84 at New Delhi.

The plant density of 13.33 plants $m^{-2}$ with plant geometry of 50 x 15 cm produced significantly highest quantity of green biomass (25.77 t $ha^{-1}$) than that given (22.64 t $ha^{-1}$) by plant density of 11.11 $plants^{-2}$ having wider plant geometry of 60 x15 cm by a magnitude of 3.13 t $ha^{-1}$ having 12.14 percent. These results conforms the findings of Mahmoud *et al*. (2013) [18] and Madani *et al*. (2014) who had also reported the highest fresh stalk yield at the highest plant density. It is worth mentioning here that the reduction in growth traits in terms of number of leaves $plant^{-1}$, leaf area index, stalk diameter and dry matter accumulation per plant accompanying higher plant density was compensated by higher yield of green biomass (stalk).Significantly maximum green biomass yield (27.94 t $ha^{-1}$) being recorded at the highest level of nitrogen application ($N_3$). The crop fertilized with 120, 80 and 40 kg N $ha^{-1}$ recorded significantly more green biomass than control ($N_0$) treatment by the margin of 7.45, 4.77 and 2.65 t $ha^{-1}$ having 26.66,18.88 and 11.45 percent respectively. Increased green biomass yield due to N application could be ascribed to increased plant height, leaf production, leaf area and dry matter accumulation per unit area with N fertilization. The highest dry matter yield (5.93 t $ha^{-1}$) was achieved by variety SSV-84 ($V_1$) which was significantly greater than those produced (5.55 t $ha^{-1}$) by CSV-24SS ($V_2$). Variety $V_1$ gave 6.4 percent higher dry biomass yield over $V_2$. Similar variations in dry biomass yield of sweet sorghum due to varieties were also reported by Miri and Rana (2014) [8]. The dry biomass production was significantly higher (6.15 t $ha^{-1}$) at plant density of 13.33 plants $m^{-2}$ with plant geometry of 50 x 15 ($P_2$) than that obtained (5.33 t $ha^{-1}$) through plant density of 11.11 plants $m^{-2}$ at wider plant geometry of 60 x 15 cm ($P_1$). The magnitude of increase in dry biomass production worked out to be 13.33 in $P_2$ over $P_1$ treatments. Thus, results indicated that dry biomass yield of sweet sorghum decreased as inter-row spacing was increased. The dry biomass yield increased significantly with successive increase in nitrogen levels up to 120 kg N $ha^{-1}$. The highest dry biomass yield (6.70 t $ha^{-1}$) occurred at 120 kg N $ha^{-1}$ which was significantly greater than other levels of nitrogen. These results are well supported by Miri and Rana (2014) [8] who reported that application of 100 kg N $ha^{-1}$ caused 50% increase in fodder yield of sweet sorghum. Though, the harvest index of sweet sorghum differed significantly due to variety and levels of nitrogen. The maximum values of 18.38 were noticed in variety CSV 24 SS which was significantly higher compared to SSV 84. The lowest plant density (11.11 $plants^{-2}$) established at a plant geometry of 60 x 15 cm resulted in highest harvest index of 19.38 compared to other plant density. Compared to without nitrogen treatments, decreasing trends in HI was recorded with increased levels of N application.

**Table 1:** Yield and yield attributes of sweet sorghum varieties as influenced by planting density and levels of nitrogen

| Treatments | Cob length(cm) | No of grain/cob | Test weight | Grain yield $plant^{-1}$ | Grain Yield (q/ha) | Green biomass yield (t/ha) | Dry biomass yield(t/ha) | Harvest index |
|---|---|---|---|---|---|---|---|---|
| **Variety** | | | | | | | | |
| V1: SSV-84 | 17.31 | 1284.42 | 23.95 | 19.29 | 16.64 | 24.80 | 5.93 | 17.29 |
| V2: CSV-2455 | 15.90 | 1112.34 | 22.14 | 18.04 | 15.99 | 23.60 | 5.55 | 18.38 |
| SEm± | 0.21 | 24 | 0.40 | 0.14 | 0.21 | 0.11 | 0.04 | 0.01 |
| CD (P=0.05) | 0.50 | 735 | 1.11 | 0.40 | 0.59 | 0.68 | 0.25 | 0.07 |
| Planting density | | | | | | | | |
| P1: 60 cm X 15 cm | 16.47 | 1421.20 | 23.40 | 19.97 | 14.30 | 22.64 | 5.33 | 19.38 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| P2: 50 cm X 15 cm | 15.07 | 975.54 | 22.01 | 18.05 | 18.33 | 25.77 | 6.15 | 16.58 |
| SEm± | 0.23 | 35.73 | 0.24 | 0.163 | 0.37 | 0.58 | 0.15 | 0.04 |
| CD (P=0.05) | 0.71 | 113.3 | 0.68 | 0.639 | 1.49 | 2.30 | 0.61 | 0.18 |
| Levels of nitrogen | | | | | | | | |
| N0 : Control | 15.08 | 910.08 | 20.88 | 17.58 | 12.84 | 20.49 | 4.78 | 21.08 |
| N1 : 40 kg $ha^{-1}$ | 15.70 | 1099.37 | 22.17 | 18.42 | 14.88 | 23.14 | 5.50 | 18.33 |
| N2 : 80 kg $ha^{-1}$ | 17.86 | 1170.17 | 23.71 | 19.36 | 17.43 | 25.26 | 5.97 | 16.87 |
| N3 : $120ha^{-1}$ | 18.60 | 1613.92 | 25.42 | 20.70 | 20.13 | 27.94 | 6.70 | 15.87 |
| SEm± | 0.21 | 104.68 | 0.228 | 0.19 | 0.19 | 0.23 | 0.06 | 0.31 |
| CD (P=0.05) | 0.64 | 309.11 | 0.667 | 0.56 | 0.56 | 0.69 | 0.18 | 1.00 |

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