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Effects of planting density and levels of nitrogen on growth and development of sweet sorghum [*Sorghum Bicolor* (L.) Moench] varieties

Harshlata Sahu, GS Tomar and Vikram Singh Thakur

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 growth parameters like plant height, Leaf production, Stalk diameter, Leaf area index, crop growth rate and dry matter accumulation were significantly influenced by varieties, levels of nitrogen and planting densities. Sweet sorghum variety SSV-84 registered significantly higher plant height 284.34(cm) with higher no. of leaves 12.28, recorded highest diameter 2.5 cm stalk diameter(cm), higher leaf area index 5.79, higher crop growth rate 2.24 (g plant^{-1} day^{-1})and greater dry matter accumulation 75.66 (g plant^{-1}) compared to CSV 24SS. Plant density of 11.11 plants m^{-2} have more no of leaves 12.13 per plant, higher stalk diameter 2.39 (cm) along with higher leaf area index 5.53 as well as higher Dry matter accumulation 68.15 (g plant^{-1}) in comparison to higher planting density (13.33 plants m^{-2}) but plants of higher planting density (13.33 plants m^{-2}) have higher plant height 281.93 (cm) and greater Crop growth rate 1.75 (g plant^{-1} day^{-1}) as compared to lower Plant 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 plant height 335.78 (cm), have maximum no of leaves 13.13 per plant, highest stalk diameter 3.10 (cm), highest Leaf area index 6.97, greater Crop growth rate 2.25 (g plant^{-1} day^{-1}) as well as Dry matter accumulation 80.59 (g plant^{-1}) being significantly higher than other levels of nitrogen.

Keywords: Planting density, Sweet Sorghum, levels of Nitrogen

Introduction

Sweet sorghum is a multipurpose crop. It produces food (grain from its ear head), sugary juice from its stem which can be used as table syrup or fermented to produce ethanol (fuel) and the biogases and leaves make excellent fodder for animals. There is no other crop which produces food, fuel, and fodder from the same piece of land. Sweet sorghum grows in dry conditions, tolerates heat, salt and water logging, makes it an ideal for semiarid areas where many of the world's poor live. It is typically an annual crop, but some cultivars are perennial. It is similar to grain sorghum having sugar rich stalk, almost like sugarcane, yields high biomass and fermentable sugars. 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. Sweet sorghum possesses considerable potential as an alternative crop to sugarcane. Its average grain yield 17-28 q ha-1 with a cane yields of about 35-50 t ha-1. Besides, its juice extractability is 40-50 % with a brix value of 16-19. It also yields ethanol up to 2500-4000 l ha-1. Besides having rapid growth, high sugar accumulation and biomass production potential, sweet sorghum has wider adaptability is poised to become a major constraint to agricultural production in coming years, cultivation of sugarcane and rice become difficult. Sweet sorghum can transform the available water more efficiently into dry matter than most of C4 crops and the crop is able to utilize water from as deep as 270 cm soil depth. In India sorghum is grown over an area of 2.85 million ha in kharif and 4.18 million ha in Rabi season respectively. The area under sorghum is decreasing because of its low average productivity and profitability. Sweet sorghum can be popularized as profitable crops in all the sorghum growing regions and uplands of rice growing regions in India. For sweet sorghum to become a profitable crop, agronomic practices needs to be optimized to improve productivity and profitability. Amount 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. Sweet sorghum varieties differ widely in their adaptation to various soil and climatic conditions.

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 experimental crop encountered with an optimum weather conditions throughout the growing season. The crop received 347.5 mm rainfall and maximum temperature varied from 33.4 ºC in last week of December to 25.1 ºC in First week of September, whereas, minimum temperature varies from 10.8 ºC in first week of December to 28.3 ºC in first week of September. The observation on growth characters *viz*., plant height, number of leaves, stem diameter, dry matter accumulation, LAI and CGR were recorded at 20, 40, 60 DAS and at physiological maturity. To measure the plant height five randomly marked plants in net plot area were measured in cm from soil surface to the base of the fully opened top leaf until cob emergence. Later the plant height were measured from the base of the plant to the collar of flag leaf and expressed in centimeters. Total numbers of green leaves produced per plant were counted from five randomly marked plants and their average was taken as the number of leaves per plant. The stalk diameter five randomly plants from the base, middle and top was measured, averaged and then expressed in centimeters. To calculate dry matter accumulation (g plant-1) the five randomly selected plants were uprooted carefully along with the roots. Root portion was detached and shoot portion of the plant was sun dried followed by drying in hot air oven at 60 ºC for 48 hours to record constant dry weight. The samples were weighed on an electronic digital balance and then average was worked out by dividing the summation by five to get dry matter accumulation in g plant-1. To calculate Leaf area (dm2 plant-1) and LAI lengths of all the fully opened leaf lamina per plant were measured from the base to the tip of the leaf. Breadth was taken at the widest joint of the leaf lamina. The products of leaf length and breadth were multiplied by the factor 0.79. The average leaf area per plant was expressed in cm2 per plant. Crop growth rate (CGR) was worked out by using the formula proposed by Watson and expressed as 'g' per dm2 per day

$$CGR = \frac{(W2-W1)}{(t_2-t_1)\,P}$$

Where, (W2-W1) = Dry matter production per plant (g) at time t_2 and t_1, respectively.

P= Ground area covered by plant (dm^2)

Results and Discussion

Data on plant height did not differ significantly at 20 DAS, but differed the Sweet sorghum variety SSV-84 resulted in significantly higher plant height measuring 75.43, 189.28 and 284.34 cm at 40, 60 DAS and at physiological maturity stages, respectively as compared to variety CSV-2455. The significant difference among genotypes for plant height has also been observed by Reddy *et al*. (2008) at ICRISAT, Patancheru (AP). Plant density of 50 x 15 cm at 13.33 plants m2 (P2) showed markedly higher plant height of 76.26, 190.85 and 281.93 cm at 40, 60 DAS and at physiological maturity respectively as compared to wider plant geometry at 11.11 plants m2 (P1). These results are in line with the findings of Verma and Tomar (2010) [19]. The sweet sorghum plants were consistently taller in plots fertilized with 120 kg N ha-1 and recorded maximum plant height of 79.66, 198.79 and 335.78 cm at 40 and 60 DAS as well as at physiological maturity stages, respectively compared to all other levels of N. The plant height declined significantly with decreased levels of N and shortest plants were produced under control (N0) treatment. Similar results have been also reported by Djanaguiraman and Ramesh (2013) [5]. Variety SSV-84 bore maximum number of leaves *viz*., 5.09, 6.37, 11.14 and 12.28 per plant at 20, 40 and 60 DAS as well as at physiological maturity stages respectively, but differed significantly only at 60 DAS and at physiological maturity stages over CSV-24SS (V2). The number of leaves per plant did not varied significantly during initial period of plant growth (20-60 DAS) due to variation in plant density but later at physiological maturity stage, plant density of 60 cm x 15 cm at 11.11 plants ha-1 (P1) recorded significantly more number of leaves (12.13 per plant) compared to those observed at 13.33 plants-2 (P2). The maximum number of leaves *viz*., 5.70, 7.32, 12.45 and 13.13 per plant at 20, 40, 60 DAS as well as at physiological maturity stages respectively, was produced by the plants fertilized with highest level of nitrogen (120 kg ha-1) which were significantly higher over lower levels of nitrogen application. Plant devoid of nitrogen fertilizer (N0) produced significantly lesser number of leaves per plant in all the stages of plant growth. Stalk diameter remained unaffected at 20 DAS due to different treatments under study. Variety SSV-84 recorded significantly highest diameter of 2.40 and 2.50 cm at 60 DAS and at physiological maturity stages compared to Variety CSV-24SS but both the varieties remained statistically on par with regards to their stem diameter recorded at 40 DAS. Average stalk diameter was thicker in plots planted at 11.11 plants m-2 (P1) than those planted at 13.33 plants m2. Plant spaced with 60 x 15 cm at 11.11 plants m-2 resulted in significantly greater stalk diameter of 1.98, 2.28 and 2.39 cm at 40, 60 DAS and at physiological maturity stages, respectively compared to narrow spacing of 50 x 15 cm at 13.33 plants-2 (P2). Increasing plant density significantly decreased stalk diameter. Reason of stem diameter reduction at high densities can be linked to a reduction of assimilate allocation and more intra-plant competition for light and mineral nutrients. The results were in conformation with the studies made by Zand and Shakiba (2013) [20]. Among different levels of N application, plants attained maximum thickness (*viz*.1.21, 2.31, 2.99 and 3.11 cm at 20, 40, 60 DAS and at physiological maturity stages respectively) when fertilized with 120 kg N ha-1, but significant difference occurred during later part of the growth stages. The control treatment (N0) resulted in plants having smaller stem diameters which was significantly lower than those found under different levels of N application. The obtained results insure the importance of N in stimulating and enhancing the photosynthetic and metabolic activities of plants which reflected on the increase in the vegetative growth of sweet sorghum. The results are in harmony with those reported by Mahmoud *et al*. (2013) [22]. Interaction between different treatments could not affect stem diameter significantly across the different stages of crop growth. Days to 50 % flowering was significantly affected due to varieties, plant density and levels of nitrogen. The dates of flowering were significantly delayed in variety CSV-24SS compared to SSV-84 which flowered earlier than CSV-24SS. Plant density also affects the time to 50 % flowering. This could be related to the supportive effects of more available fertilizers to lower number of plants per unit area which permitted building of more vigorous growth that resulted in higher number of days for flowering. Similarly, Zand and Shakib (2013) [20] also reported that as plant density increased days to 50% flowering decreased. Days to 50% flowering differed significantly with increase in nitrogen levels. Application of nitrogen at 120 kg N ha-1 (N3) reduced the number of days required for 50 % flowering (6 days) compared to crop grew without N fertilizer (N0). These results are fully in line with the recent findings of Sujathamma *et al*. (2015) [23] who reported that nitrogen decreased the interval form seeding to flowering. The varieties influenced LAI of sweet sorghum significantly at 60 DAS and at physiological maturity. Variety SSV-84 (V1) recorded maximum LAI of 4.36 and 5.79 at 60 DAS and at physiological maturity stages respectively, which was significantly higher over those recorded in CSV-24SS (V2). The LAI did not varied significantly due to varieties during early part of crop growth. The variation in plant density caused prominent variation in LAI at 40, 60 DAS and also at physiological maturity stages of crop growth. The maximum LAI of 3.63, 5.80 and 5.53 was recorded at 40,60 DAS and at physiological maturity stages respectively, when crop was seeded at 60 x 15 cm spacing a t 11.11 plants m-2 (P1) and these values stand significantly higher over those observed under the treatment of narrow spacing (P2). Such effect might be due to interplant competition for light and mineral nutrients. The differences in leaf area index of sweet sorghum due to different levels of N application were found significant across all the stages of crop growth. Application of N at 120 kg ha-1 attain maximum LAI of 1.34, 4.76, 6.20 and 6.97 at respective stages of crop growth as compare to lower levels of N fertilization. Sweet sorghum grew without N fertilizer (N0) registered significantly minimum values of LAI during all the stages of crop growth compared to those recorded under different levels of N. Increased LAI may be due to the fact that addition of nitrogen in this investigation increased the number of leaves and total leaf area per plant due to the effect on enlargement of leaves cell. Crop growth rate and the periodic data pertaining to crop growth rate (CGR) of sweet sorghum recorded at 20-40, 40-60 and 60-90 DAS were tabulated and subjected to statistical analysis. Irrespective of the treatments, the crop growth rate declined at 40-60 DAS. It is very imperative to note from the data that crop growth rate did not differ significantly due to variety during initial period of growth (20-60 DAS) but later on at 60-90 DAS it varied significantly. The CGR of SSV-84 (V1) reached to maximum (2.24 g plant-1 day-1) at 60-90 DAS which was significantly higher than that determined in CSV-24SS (V2). The crop growth rate throughout the crop growth period remained unaffected due to variation in plant density. Nitrogen levels brought significantly positive differences in crop growth rates at 20-40 DAS and 60-90 DAS but decreasing trends of CGR was determined with the increasing levels of nitrogen at 40-60 DAS. The CGR reached maximum (1.18 and 2.25 g day-1 during 20-40 and 60-90 DAS, respectively) when plants were fertilized with 120 kg N ha-1(N3) which were significantly superior over lower levels of nitrogen application. The CGR declined significantly when sweet sorghum was not fertilized with nitrogen (N0) in comparison to different doses of nitrogen treatments. On the other hand the CGR reduced to minimum at 40-60 DAS due to 120 kg N ha-1. These results are in accordance with the findings of Meena and Meena (2012) [9] who reported that crop growth rate showed an increasing trend with successive increase in levels of nitrogen from 0 to 120 kg ha-1. Dry matter accumulation increased with advancement in the age of crop, which recorded highest value at physiological maturity. The effect of variety on dry weight per plant was not significant during initial stages (20-60 DAS) of crop but showed significant variation at physiological stage. At this stage, the maximum amount of dry matter (75.66 g plant-1) was accumulated by SSV-84 (V1) which was 26.25 % higher than those given by CSV-24SS (V2). Dry matter accumulation was significantly higher at plant geometry of 60 x 15 cm at plant density of 11.11 plants m-2 (P1) which may worked out to be greater by 1.77, 2.55, 0.86 and 0.71 g plant-1 at 20, 40, 60 DAS and at physiological maturity stage, respectively than that found in narrow plant geometry of 50 x 15 cm with plant density of 13.33 plants m-2 (P2). Increasing levels of nitrogen recorded significantly higher dry matter accumulation over its lower doses at all the stages of crop growth. Application of 120 kg N ha-1 registered the maximum dry matter accumulation of 7.57, 31.16, 35.56 and 80.59 g plant-1 at 20,40,60 DAS and at physiological maturity respectively which was significantly higher than those recorded with lower levels of N. The rapid increase in drymatter accumulation in response to levels of nitrogen is consistent with work on sweet sorghum in other environments (Singh *et al*., 2014) [18].

Table 1: Plant height (cm), No of leaf, LAI at various growth stages of Sweet sorghum as influenced by variety, planting density and levels of nitrogen

Treatments	Plant height (cm) at various growth stages				No. of leaf at various growth stages				Stalk diameter at various growth stages (cm)			
	20 DAS	40 DAS	60 DAS	APM*	20 DAS	40 DAS	60 DAS	APM*	20 DAS	40 DAS	60 DAS	APM*
Variety												
V1 : SSV84	26.90	75.43	189.28	284.34	5.09	6.37	11.14	12.28	0.90	1.98	2.40	2.50
V2 : CSV24SS	27.39	72.78	184.04	272.30	4.88	6.02	10.13	11.40	0.96	1.88	2.21	2.34
SEm±	0.60	0.95	0.632	1.87	0.12	0.17	0.02	0.08	0.10	0.04	0.02	0.02
CD (P=0.05)	NS	2.81	1.89	4.88	NS	NS	0.14	0.23	NS	0.12	0.07	0.06
Planting density												
P_1:60X15cm	27.44	71.95	182.47	274.71	5.06	6.43	11.04	12.28	0.87	1.98	2.28	2.39
P_2:50X15 cm	26.85	76.26	190.85	281.93	4.91	5.96	10.42	10.95	0.99	1.76	2.11	2.21
SEm±	0.48	1.82	1.04	2.13	0.04	0.205	0.453	0.291	0.02	0.05	0.04	0.03
CD (P=0.05)	NS	5.48	3.05	5.95	NS	NS	NS	1.14	NS	0.11	0.13	0.08
Levels of Nitrogen												

N0 : Control	25.60	68.99	175.80	218.14	4.04	5.03	8.80	10.19	0.66	1.44	1.76	1.90
N1 : 40 kg ha-1	26.69	72.06	182.08	260.61	4.78	5.69	10.43	10.75	0.89	1.82	2.21	2.40
N2 : 80 kg ha-1	27.60	75.70	189.96	278.76	5.43	6.75	11.22	12.09	0.99	2.04	2.45	2.76
N3 : 120 kg ha-1	27.69	79.66	198.79	335.78	5.70	7.32	12.45	13.13	1.21	2.31	2.99	3.10
SEm±	0.46	0.510	1.02	3.78	0.07	0.16	0.15	0.13	0.036	0.04	0.06	0.05
CD (P=0.05)	NS	1.49	2.96	11.02	0.22	0.47	0.44	0.40	NS	0.11	0.20	0.16

*APM = At physiological maturity, P_1 = 60 X 15 cm (11.11 plants m^{-2}), P_2 = 50 X 15 cm (13.33 plants m^{-2})

Table 2: LAI, Crop growth rate (g $plant^{-1}$ day^{-1}), Dry matter accumulation (g $plant^{-1}$) at various growth stages of Sweet sorghum as influenced by variety, planting density and levels of nitrogen

Treatments	LAI at various growth stages				Crop growth rate (g $plant^{-1}$ day^{-1}) at various growth stages			Dry matter accumulation (g $plant^{-1}$) at various growth stages			
	20 DAS	40 DAS	60 DAS	APM*	20-40 DAS	40-60 DAS	60-90 DAS	20 DAS	40 DAS	60 DAS	APM*
Variety											
V1 : SSV84	1.01	3.39	4.36	5.79	0.93	0.33	2.24	6.11	24.76	31.27	75.66
V2 : CSV24SS	1.05	3.21	4.16	5.18	0.96	0.47	1.24	6.59	25.77	32.22	59.93
SEm±	0.07	0.10	0.04	0.08	0.02	0.04	0.05	0.15	0.29	1.15	0.42
CD (P=0.05)	NS	NS	0.13	0.21	NS	NS	0.32	NS	NS	NS	2.57
Planting density											
P1:60X15cm	1.14	3.63	5.80	5.53	0.95	0.45	1.73	6.73	26.54	33.62	68.15
P2:50X15 cm	0.93	2.97	4.52	5.45	0.94	0.35	1.75	4.96	23.99	32.76	67.44
SEm±	0.05	0.13	0.33	0.29	0.02	0.03	0.05	0.236	0.378	0.21	1.178
CD (P=0.05)	NS	0.51	1.03	0.87	NS	NS	NS	0.927	1.483	0.64	4.623
Levels of Nitrogen											
N0 : Control	0.76	2.25	4.03	5.11	0.70	0.58	0.90	5.13	19.10	30.76	48.91
N1 : 40 kg ha-1	0.92	2.87	5.96	5.35	0.89	0.45	1.74	5.87	23.69	32.63	66.77
N2 : 80 kg ha-1	1.11	3.33	6.15	6.24	1.01	0.35	2.05	6.83	27.09	34.01	74.92
N3 : 120 kg ha-1	1.34	4.76	6.20	6.97	1.18	0.22	2.25	7.57	31.16	35.56	80.59
SEm±	0.04	0.15	0.20	0.23	0.02	0.02	2.25	0.128	0.475	0.292	0.930
CD (P=0.05)	0.12	0.44	0.59	0.68	0.07	0.05	0.14	0.373	1.388	0.853	2.716

*APM = At physiological maturity, P1 = 60 X 15 cm (11.11 plants m^{-2}), P2 = 50 X 15 cm (13.33 plants m^{-2})

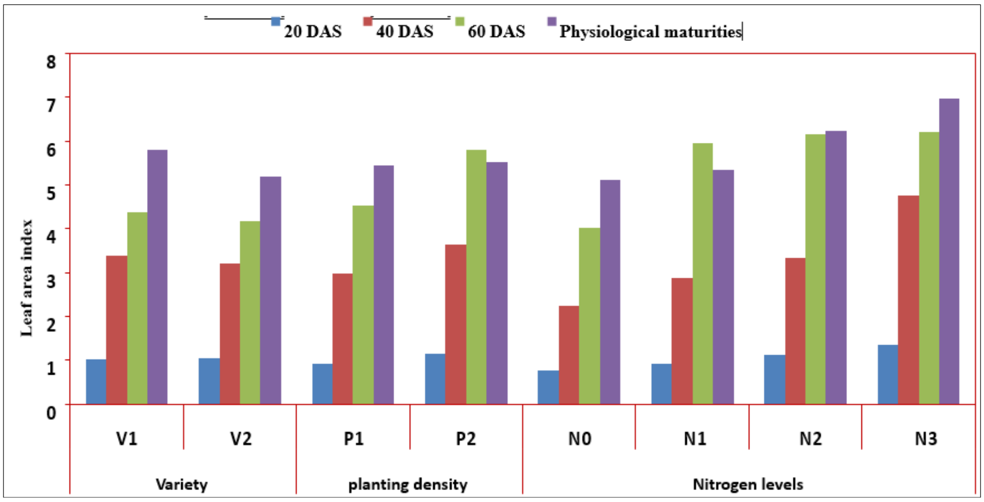

Fig 1: Leaf area index at various growth stages of sweet sorghum varieties as influenced by planting density and levels of nitrogen

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