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An agronomic practices for the improvement of sweet sorghum (*Sorghum bicolor* L. Moench) crop: A study at Gangetic plains of West Bengal

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Abstract

Sustainable bioenergy cropping systems require not only high yields but also efficient use of inputs. Sweet sorghum (*Sorghum bicolor* L. Moench) is a multipurpose crop that has great potential as a bioethanol crop. To make an appreciable profit from cultivating sweet sorghum in gangetic plains of West Bengal, different agronomic practices would be developed in general and nutrient management in particular need to be standardized. The objective of this study is to determine the response of different N:P:K doses on sweet sorghum crop in this agro climatic region. The experiment was conducted at Krishi Vigyan Kendra, Nimpith, South 24-Pgs, West Bengal in the year 2013-14. Randomized block design (RBD) was used for the experiment. The total number of treatment combinations was 18 ($N_3 \times P_2 \times K_3$) replicated thrice and total number of plots become 54. Data was collected every 30 days interval starting from 40 Days after Sowing to 130 DAS. The maximum plant height of 191.18 cm was observed in $N_3P_2K_3$ treatment at 130 DAS. The maximum Green Biomass of 25.26 t/ha was observed with $N_3P_2K_3$ treatment at 100 DAS. The maximum sugar concentration of 10.25% was observed with $N_3P_2K_3$ treatment at 100 DAS and highest sugar yield of 1816.50 kg/ha was observed with $N_3P_2K_3$ at 100 DAS. Harvesting at 130 to 140 days after sowing might be suitable for sweet sorghum for this agro climatic zone of West Bengal with $N_3P_2K_3$.

Key words: sweet sorghum, nitrogen, potassium, phosphorus, plant height, sugar percentage, biomass.

Introduction

Sweet Sorghum (*Sorghum bicolor* L. Moench) is a C4 annual grass which can produce high forage biomass yield per unit of land (Fribourg 1995, Rooney et al.2007) and ranks fifth among world cereals after wheat, rice, maize and barley (Sato et al., 2004; Khalil, 2008; Namoobe et al 2014). The crop is adapted to the arid and semi-arid tropics and dry-temperate areas of the world (Kidambi et al., 1990; Blum, 2004). The crop is grown primarily in the warm dry climates of Africa, India, Pakistan, China and the Southern United States, to be used as food and fodder (Alagarswamy and Chandra, 1998). Sorghum crop is considered a promising bio-ethanol crop that could ease the conflict over oil derived from fossil deposits. Day and Sarkar (1982) found that the sweet sorghum juice does not ferment as well as sugarcane juice and hence suggested a need for further research on fermentation of alcohol from this feedstock and for evaluation of proposed schemes and economics for fuel production from this crop. Smith and Buxton (1993) identified the factors that could affect maximum sugar yield from sweet sorghum in temperate zone locations. Added nitrogen fertilizer had little discernible effect on increasing fermentable sugar production. Subramanian et al.2005 outlined the policy and planning issues for utilization of ethanol and bio-diesel in automotive diesel engines in India taking into consideration environmental benefits, energy self-sufficiency and benefits to rural economy. The policy also measures related to implementation and barriers. Limited information is available on crop adaptability in this agro climatic region. Time of harvest is yet another factor, which indirectly influences biomass yield, quality of juice and ultimately ethanol production because of variation in climatic conditions during pre-harvesting and post-harvesting period.

The All India Coordinated Sorghum Improvement Project (AICSIP) has the national mandate for improving sorghum productivity across different sorghum growing states in India. A multi - disciplinary approach has adapted the strengthen the multi-location testing program. Knowledge based specialized tools available across disciplines were integrated so as to synergize crop improvement and management processes. Crop improvement activity aims at attaining a higher productivity, while management helps attain the potential by providing an enabling environment. Of the various inputs that improved the efficiency of a cultivar in realizing its potential, fertilizers [nitrogen (N) in particular] play a crucial role in both irrigated and rain fed environments. Two major components of uptake efficiency and utilization efficiency contributed to the variation in nitrogen use efficiency (Moll et al.1982, Onken et al.1985, Namoobe et al 2014). The first was related to the capability of location specific soil to supply the essential nutrient, while the second was related to the adaptive root related genetic trait (Eghball and Maranville, 1993).

In this particular study we have studied the issue of plant adaptability in general and efficiency of nutrient response in particular.

Materials and Methods

The research experiment was conducted in 2015-2016 at Krishi Vigyan Kendra (KVK) Sri Ramkrishna Mission Ashram, Nimpith, South 24-Pgs (75 Km away from

Kolkata) and Soil texture of Nimpith is mainly clay loam, alluvial coastal saline and organic carbon and phosphate content is mainly Medium to high type, potash content mainly medium to high and pH range between 6.4 to 7.6.

The experiment was arranged as a randomized block design (3×2×3) where total treatment combinations are eighteen (18) with three (3) replications and each plot measuring (4m×3m). To study the effect of fertilizer in sorghum growth, three levels of Nitrogen {0 (N1), 50 (N2) and 100 (N3) Kg/ha} were applied as urea (46% N). Two levels of Phosphorous {0 (P1), 60 (P2) Kg/ha} were applied as single super phosphate (16% P) and three levels of potassium {0 (K_1), 60 (K_2), 80 (K_3) Kg/ha} wear applied as Muriate of potash (60% K). All fertilizers were be applied as basal dose accept nitrogen. Half of the nitrogen was applied as basal and another half as top dressing at 30 days after Sowing. All the data was statistically analyzed using Analysis of Variance technique as described by Gomez and Gomez (1984).

Row to Row 45 cm and Plant to Plant 15 cm spacing were maintained. Plot Size 12 Sq. m (4m×3m), Plant Population 96 /Plot (12×8). Sweet sorghum varieties were namely Madhura was supplied from Dry land cereals Research Programme, ICRISAT (International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh). Data was collected every 30 days interval starting from 40 DAS (Days After Sowing) up to 130 DAS so, the research experiment started from 14/06/2015 to 22/10/2015. Randomly ten selected plant were collected from each treatment for plant heights, green bio mass, sugar concentration, sugar yield from four different harvests. Plant height/stalk length (cm):Height of the primary shoot was measured from the ground level to the base of the youngest fully opened leaf until ear head emergence, after which plant height was measured from the base of the plant to the tip of the ear head and expressed in centimeters. Green Bio-mass:Total weight of ten randomly selected plants in each treatment and expressed as the average bio-mass yield (t/ha). Sugar concentration (%) Brix is the percentage of solids in the sample. Juice brix values were recorded by using hand refractometer ($0\text{-}30^0$) and correction was made with room temperature and corrected values were expressed in percentage. Sugar Yield (Kg/ha):Sugar yield:Calculated sugar yield per hectare was worked out using the formula and expressed in terms of ton per hectare(Reddi 2006).

***Calculated sugar yield (t/ha)*:**= {S-0.4 (B-S)} × F × Y/100

B and S = Brix & pol per cent, respectively of the juice sample extracted. F = Value of the factor depending on the fibre percentage of the sample. Y = weight of the stripped stalk (t/ha).

Results and Discussion

Effect on plant height (cm):

The effect of plant height on individual doses of nitrogen, potassium, and phosphorous were showed significantly different from each other (Table-1). In case of nitrogen N3 (100 kg/ha) gave highest data (186.37 cm) at 130 DAS this result indicate that increase of nitrogen application plant height will be increase similar results was found Salvatore et al. (2012) and they also proposed that yield was less sensitive to N level. In case of potassium K3 (80 kg/ha) height length (175.61 cm) at 130 DAS and in case of phosphorous P2 (60 kg/ha) give highest length (175.22 cm) at 130 DAS. This result indicate that Nitrogen uptake was improved with P and K application but the difference between these two was non significant similar results was found Abida Akram et al(2007). In case of Interaction effects between nitrogen, potassium and phosphorous N3P2K3 (100:60:80) gave highest length (191.18 cm) at 130 DAS similar results was found Kushwaha et al (2014) have recommended that 80:40:40 kg ha-1 of NPK recorded highest plant height (212.07 cm). Interaction effects of nitrogen, potassium, phosphorous were significantly different at 40 DAS, 70 DAS and 100 DAS, among the interaction data at 40 DAS of plant height N3P2K3 (100:60:80) gave highest length (74.42 cm) and Similar result found at 70 DAS where N3P2K3 (100:60:80) give highest lenght (154.88 cm) and Similar result found at 100 DAS where N4P2K4 (100:60:80) give highest lenght (186.25 cm)

Effect on green biomass (ton/ha):

The results showed the effect of green biomass on individual doses of nitrogen, potassium, and phosphorous were significantly different from each other (Table-2). In case of nitrogen N3 (100 kg/ha) gave highest data (25.10 t/ha) at 100 DAS. This result indicate that increasing nitrogen application helps to sweet sorghum yield production similar results was found Mengel and Kirkby (2001), they mentioned that corn and sorghum yield would have dropped by 41% and 19%, respectively, without nitrogen fertilizer application. In case of potassium K3 (80 kg/ha) gave highest data (24.81 t/ha) at 100 DAS, which is similarly observed by Sharma and Kumari (1996) that with increase in K fertilizer application, sweet sorghum grows better and in case of Phosphorous (60 kg/ha) gave highest data (24.81 t/ha) at 100 DAS This result indicate Phosphorus(60 kg/ha) gave significantly higher yield as compared to that with potassium(80 kg/ha) similar result found by Abida Akram et al(2007). Interaction effects of nitrogen, potassium, phosphorous were significantly different at 40 DAS, 70 DAS and 130 DAS, among the interaction data at 40 DAS of plant green biomass N3P2K3 (100:60:80) gave highest yield (14.37 t/ha) and Similar result found at 70 DAS where N3P2K3 (100:60:80) give highest yield (19.11 t/ha) and Similar result found at 130 DAS where N3P2K3 (100:60:80) give highest yield (24.43 t/ha) where the highest green biomass(t/ha) yield found of 100 DAS (25.26 t/ha) at N3P2K3 (100:60:80) treatment combination.

Effect on sugar percentage (%):

The results showed the effect of sugar percentage (%) on individual doses of nitrogen, potassium, and phosphorous were significantly different from each other (Table-3). In case of nitrogen N3 (100 kg/ha) gave sugar percentage (10.05 %) at 100 DAS. This result indicate that increasing nitrogen application helps to improved sweet sorghum sugar percentage but Ramadan (2003) found that increasing nitrogen rate up to 100 kg/fed markedly increased stalk diameter, stalk length, LA and reducing sugar as well as stalk yield and syrup yield, while increasing nitrogen rate upto 120 kg/fed decreased sucrose, Brix and purity percentages. In case of potassium K3 (80 kg/ha) gave highest sugar percentage (9.40 %) at 100 DAS but Barik and Roy (2015) was found that applying potassium 90 kg/ha gave highest data 8.99% in sugar percentage so we can indicate that increasing potassium application is not helpful to improved sweet sorghum sugar percentage. in case of phosphorous P2 (60 kg/ha) give highest sugar percentage (9.36 %) at 100 DAS similar results was found by Barik and Roy (2015). Interaction effects of nitrogen, potassium, phosphorous were significantly different at 40 DAS, 70 DAS and 130 DAS, among the interaction data at 40 DAS of plant sugar percentage N3P2K3 (100:60:80) gave highest percentage (6.03 %) and Similar result found at 70 DAS where N3P2K3 (100:60:80) give highest sugar percentage (8.29 %) and Similar result found at 130 DAS where N3P2K3 (100:60:80) give highest sugar percentage (10.11 %) where the highest sugar percentage (%) found of 100 DAS (10.25 %) at N3P2K3 (100:60:80) treatment combination.

Effect on sugar yield (kg/ha):

The results showed the effect of sugar yield (kg/ha) on individual doses of nitrogen, potassium, and phosphorous were significantly different from each other (Table-4). In case of nitrogen N3 (100 kg/ha) gave highest sugar yield (1770.20 kg/ha) at 100 DAS. In case of potassium K3 (80 kg/ha) gave highest sugar yield (1638.01 kg/ha) at 100 DAS and in case of phosphorous P2 (60 kg/ha) give highest sugar yield (1631.64 kg/ha) at 100 DAS This result indicate that increasing fertilizer doses can helps to increase biomass content for this cause indirectly its help to increases sugar yield. Interaction effects of nitrogen, potassium, phosphorous were significantly different at 40 DAS, 70 DAS and 130 DAS, among the interaction data at 40 DAS of plant sugar yield N3P2K3 (100:60:80) gave highest yield (607.86 kg/ha) and Similar result found at 70 DAS where N3P2K3 (100:60:80) give highest sugar yield (1111.80 kg/ha) and Similar result found at 130 DAS where N3P2K3 (100:60:80) give highest sugar yield (1733.28 kg/ha) where the highest sugar yield (kg/ha) found of 100 DAS (1816.50 kg/ha) at N3P2K3 (100:60:80) treatment combination.

Table 1: Plant Height (cm) At Various Growth Stages of Sweet Sorghum by Different Fertilizer Doses

TREATMENT	PLANT HIGHT			
	40 DAS	70 DAS	100 DAS	130DAS
NITROGEN				
N1	46.69	126.39	151.35	156.28
N2	58.46	139.88	171.70	176.79
N3	66.84	148.55	181.38	186.37
SE	0.43	0.42	0.31	0.30
LSD	0.87	0.86	0.63	0.61
POTASSIUM				
K1	54.00	135.65	165.58	170.57
K2	57.51	138.26	168.28	173.26
K3	60.49	140.90	170.57	175.61
SE	0.43	0.42	0.31	0.30
LSD	0.87	0.86	0.63	0.61

PHOSPHORUS				
P1	54.48	136.17	166.10	171.07
P2	60.18	140.37	170.18	175.22
SE	0.35	0.35	0.25	0.24
LSD	0.71	0.70	0.52	0.50
INTERACTION				
N1P1K1	40.60	122.32	147.26	151.81
N1P1K2	44.24	122.92	149.13	154.06
N1P1K3	46.31	126.27	152.60	157.55
N2P1K1	52.49	135.30	165.86	171.12
N2P1K2	56.04	138.60	170.49	175.49
N2P1K3	58.00	140.37	172.21	177.24
N3P1K1	61.82	143.78	177.20	182.20
N3P1K2	63.17	147.83	178.98	183.98
N3P1K3	67.65	148.13	181.20	186.20
N1P2K1	46.43	125.86	150.11	155.24
N1P2K2	50.08	128.50	153.93	158.94
N1P2K3	52.46	132.46	155.05	160.05
N2P2K1	58.99	140.13	171.73	176.73
N2P2K2	61.18	141.54	173.82	178.75
N2P2K3	64.08	143.32	176.10	181.40
N3P2K1	63.64	146.51	181.31	186.31
N3P2K2	70.36	150.15	183.35	188.33
N3P2K3	74.42	154.88	186.25	191.18
SE	1.05	1.04	0.76	0.73
LSD	2.13	2.11	1.55	1.49

Table 2: Green Biomass (t/ha) At Various Growth Stages Of Sweet Sorghum By Different Fertilizer Doses

TREATMENT	PLANT GREEN BIOMASS			
	40 DAS	70 DAS	100 DAS	130DAS
NITROGEN				
N1	13.40	18.26	24.32	23.49
N2	13.69	18.54	24.76	23.87
N3	14.08	18.90	25.10	24.26
SE	0.008	0.008	0.009	0.007
LSD	0.016	0.016	0.018	0.015
POTASSIUM				
K1	13.60	18.48	24.63	23.77
K2	13.74	18.57	24.74	23.88
K3	13.84	18.65	24.81	23.97
SE	0.008	0.008	0.009	0.007
LSD	0.016	0.016	0.018	0.015

PHOSPHORUS				
P1	13.65	18.46	24.64	23.82
P2	13.80	18.67	24.81	23.93
SE	0.007	0.007	0.007	0.006
LSD	0.013	0.013	0.015	0.012
INTERACTION				
N1P1K1	13.24	18.13	24.17	23.32
N1P1K2	13.40	18.18	24.23	23.44
N1P1K3	13.46	18.25	24.31	23.5
N2P1K1	13.55	18.35	24.55	23.73
N2P1K2	13.62	18.44	24.68	23.81
N2P1K3	13.70	18.50	24.75	23.92
N3P1K1	13.87	18.65	24.90	24.09
N3P1K2	13.95	18.76	25.04	24.23
N3P1K3	14.09	18.84	25.10	24.32
N1P2K1	13.31	18.20	24.30	23.49
N1P2K2	13.49	18.31	24.41	23.54
N1P2K3	13.53	18.46	24.49	23.64
N2P2K1	13.64	18.56	24.72	23.86
N2P2K2	13.75	18.64	24.89	23.93
N2P2K3	13.87	18.72	24.96	23.98
N3P2K1	13.98	18.96	25.12	24.15
N3P2K2	14.25	19.06	25.18	24.35
N3P2K3	14.37	19.11	25.26	24.43
SE	0.020	0.020	0.022	0.018
LSD	0.040	0.040	0.044	0.036

Table 3: Sugar percentage (%) At Various Growth Stages Of Sweet Sorghum By Different Fertilizer Doses

TREATMENT	SUGAR PERCENTAGE			
	40 DAS	70 DAS	100 DAS	130DAS
NITROGEN				
N1	3.53	6.64	8.60	8.32
N2	5.02	7.62	9.24	9.00
N3	5.81	8.05	10.05	9.76
SE	0.0081	0.0087	0.0070	0.0088
LSD	0.0164	0.0177	0.0143	0.0179
POTASSIUM				
K1	4.65	7.33	9.18	8.90
K2	4.81	7.46	9.31	9.02
K3	4.90	7.53	9.40	9.17
SE	0.0081	0.0087	0.0070	0.0088
LSD	0.0164	0.0177	0.0143	0.0179

PHOSPHORUS				
P1	4.59	7.26	9.23	8.87
P2	4.98	7.61	9.36	9.18
SE	0.0066	0.0071	0.0057	0.0072
LSD	0.0134	0.0144	0.0117	0.0146
INTERACTION				
N1P1K1	3.17	6.36	8.42	8.11
N1P1K2	3.21	6.52	8.53	8.23
N1P1K3	3.23	6.60	8.63	8.33
N2P1K1	4.74	7.29	9.11	8.76
N2P1K2	4.90	7.46	9.23	8.91
N2P1K3	5.02	7.50	9.30	9.03
N3P1K1	5.44	7.74	9.87	9.34
N3P1K2	5.74	7.90	9.94	9.43
N3P1K3	5.87	8.01	10.05	9.73
N1P2K1	3.74	6.76	8.63	8.31
N1P2K2	3.87	6.78	8.68	8.41
N1P2K3	3.93	6.81	8.73	8.55
N2P2K1	5.02	7.71	9.03	8.94
N2P2K2	5.15	7.83	9.32	9.12
N2P2K3	5.31	7.93	9.44	9.25
N3P2K1	5.80	8.11	10.04	9.95
N3P2K2	5.98	8.23	10.15	10.01
N3P2K3	6.03	8.29	10.25	10.11
SE	0.0198	0.0213	0.0172	0.0216
LSD	0.0402	0.0433	0.0350	0.0438

Table 4: Sugar Yield (kg/ha) At Various Growth Stages of Sweet Sorghum by Different Fertilizer Doses

TREATMENT	SUGAR YIELD			
	40 DAS	70 DAS	100 DAS	130DAS
NITROGEN				
N1	331.77	850.55	1468.14	1371.61
N2	482.68	991.45	1604.72	1507.53
N3	574.45	1067.13	1770.20	1661.97
SE	0.57	0.88	0.92	1.09
LSD	1.17	1.78	1.86	2.21
POTASSIUM				
K1	445.56	951.07	1588.30	1485.93
K2	465.69	972.33	1616.75	1512.42
K3	477.66	985.73	1638.01	1542.76
SE	0.57	0.88	0.92	1.09
LSD	1.17	1.78	1.86	2.21

PHOSPHORUS				
P1	441.57	941.72	1597.07	1484.21
P2	484.36	997.71	1631.64	1543.19
SE	0.47	0.72	0.75	0.89
LSD	0.95	1.45	1.52	1.80
INTERACTION				
N1P1K1	294.19	808.66	1428.36	1327.23
N1P1K2	302.21	831.87	1449.67	1353.06
N1P1K3	305.30	845.59	1471.88	1373.76
N2P1K1	450.35	938.81	1568.72	1458.40
N2P1K2	468.40	965.67	1597.81	1488.02
N2P1K3	482.25	974.18	1615.66	1515.39
N3P1K1	529.56	1012.25	1725.27	1578.43
N3P1K2	561.71	1040.16	1745.87	1603.81
N3P1K3	580.20	1058.26	1770.36	1659.83
N1P2K1	349.29	863.44	1471.47	1368.94
N1P2K2	366.55	871.07	1487.27	1388.76
N1P2K3	373.10	882.68	1500.17	1417.89
N2P2K1	480.89	1003.90	1565.71	1496.17
N2P2K2	496.99	1024.29	1626.91	1530.79
N2P2K3	517.23	1041.89	1653.53	1556.42
N3P2K1	569.08	1079.38	1770.25	1686.40
N3P2K2	598.26	1100.93	1792.97	1710.05
N3P2K3	607.87	1111.80	1816.50	1733.28
SE	1.41	2.15	2.24	2.66
LSD	2.86	4.36	4.56	5.40

Conclusion

To make sweet sorghum a sustainable and profitable crop, there is a need for standardization of agronomic practice, apart from breeding high-yielding cultivars, which can contribute to increased yields resulting in higher returns to farmers. In West Bengal unfortunately no scientific data are available on sweet sorghum crop though this crop has the potential to give an excellent yield comparable to other states of our country. Application of fertilizers has a direct impact on crop productivity. Nitrogen (N) is one of the major nutrients that supports crop growth and is the most responsive nutrient required by sorghum. Most of the sorghum growing soils in India are deficient in Nitrogen (N), thus nitrogen fertilization has become a significant constraint in sorghum cultivation. Varied responses have been observed when this nutrient was supplied to sweet sorghum either alone or in combination with other major nutrients.

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