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AGRONOMY

Response of Various Yield of Sweet Sorghum Crop (*Sorghum bicolour* L. Moench) to Different Levels of Fertilizer in Lateritic Soil of Birbhum, West Bengal

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ABSTRACT

Strategic management and efficient application of inputs are the primary demands for sustainable, healthy and promising bio energy cropping system. Sweet sorghum (*Sorghum bicolor* L. Moench) is identified as an industrial crop by virtue of accumulation of fermentable sugars in stem and the stalk syrup is an enriched source of bio ethanol. To make an increasing profit from cultivation of sweet sorghum in Gangetic plains of West Bengal, several agronomic practices have been proposed both in general parameters and nutrient management. This plot experiment was conducted in open pollinated field condition to evaluate the response of different N, K and P doses on growth and sugar yield of sweet sorghum in this agro climatic zone. The experiment was conducted at Visva Bharati Agriculture Farm, Birbhum during 2017 in a randomized block design (RBD) having three replications. The total number of treatment combinations were 18 (3N×2P×3K) with a total of 54 plots. Data were collected on every 30 days interval starting from 40 Days after Sowing (DAS) to 130 DAS. The results revealed that maximum plant height of 192.19 cm was observed in N3P2K2 treatment at 130 DAS. The maximum Green Biomass of 26.47 t/ha was observed with N3P1K3 treatment at 100 DAS. The maximum sugar concentration of 9.34% was observed with N3P2K3 treatment at 100 DAS and the highest sugar yield of 1717.62 kg/ha with the same ratio of fertilizer treatment. All the values of parameters statistically evaluated to identify the cost-effective status as well as the significance of the study.

Highlights

- Effect of combined doses of fertilizers corresponding to the outcome of growth parameters and sugar yield was the major focus of this lateritic study.

Keywords: Sweet Sorghum, Nitrogen, Plant Height, Sugar Yield, Ethanol, Sugar Concentration.

Sorghum bicolor (L) has been proven to be a huge scale energy crop with the virtues of its stalk containing high fermentable carbohydrates and facilitating cultivation in nearly all temperatures and tropical climatic zones (Sree *et al.* 1999). It has also high drought resistant capacity because of its quality to remain dormant during dry climate for a long time (Woods 2000). United States has assessed according to the widespread agronomic judgement and admitted that sorghum has wide adaptability and remarkable production potential (Smith *et al.* 1987; Smith & Buxton 1993).

Many reports have already evaluated different varieties of this crop for fermentable sugar production and ethanol yields with theoretical calculation (Smith *et al.* 1987; Copani *et al.* 1989; Belletti *et al.* 1991). Chemical compositions of sweet sorghum and their potential and proportional relationships with alcohol production have been estimated by Smith *et al.* (1987), Smith & Buxton (1993), Billa *et al.* (1997), Dolciotti *et al.* (1998), Zhao *et al.* (2009) and many others. Optimum balancing of exogenous nutrient input is necessary for good yield of sorghum plant. A significant effect of potassium (K) on Sorghum growth was analysed by Sharma and Ramna (1993). In water stress condition potassium interferes and effect the modulation of sorghum generally the physiology parameters (Sharma and Kumari 1996). Tisdale *et al.* (1985) justified and admitted the quality and yield of beneficial fruits, forage, vegetable and grain. Crops show improvement when they have sufficient P nutrition. Phosphorus application on low P soils turned into higher yield and superior crop quality was reported by Cisar *et al.* (1992). A report also says that crop sustains better condition and production with applied P than to residual P in soil (Singaram and Kothandaraman 1994).

Although sorghum [*Sorghum bicolor* (L) Moench] belongs to C4 crop, it uses nitrogen (N) and water more efficiently than most C3 crops (Anten *et al.* 1995; Young and Long, 2000). It is a crop with good nitrogen use efficiency or NEU (Gardner *et al.* 1994) but with inappropriate N fertilization that restricts yield. Depending upon soil fertility, a dose of 45 to 224 kg N ha-1 is often applied for production of this crop (Zhao *et al.* 2005). However, high N fertilization should be controlled since excessive N may inhibit crop growth as well as ethanol yield (Wiedenfeld 1984). Considerably increasing production costs and reducing energy efficiency due to the account for N fertilization up to 50% of the total energy intake in arable crops was reported by Kuesters and Lammel (1999). Nevertheless, the N application timings also have a higher effect on plant growth rate (Tsialtas and Maslaris 2005) and yield (Almodares and Darany 2006) than the total amount of N applied. Different studies stated that mismanagement of N, such as over N application, can result in contamination of groundwater (Jaynes *et al.* 2001) and wrong N supply and plant N status considerably affect and harm sorghum leaf area index (Locke and Hons, 1988) as well as canopy radiation use efficiency (Muchow and Sinclair 1994) and soil pH balance for the crop (Munck 1958). As a consequent the proton release can acidify the root vicinity (Marschner and Römheld 1983; Schaller and Fischer 1985).

In this study a fertilizer dosimetry with nitrogen and potassium is combined in a variable manner and applied on sweet sorghum in open pollinated suitable climatic condition and the proper yield efficiency is standardized by collecting data in parameters such as its plant height, sugar content, sugar percentage and fresh green biomass, etc with a repeated method.

MATERIALS AND METHODS

Selection of Field Area

The research experiment was undertaken in 2017 at Visva Bharati Agriculture Farm, Bolpur, Birbhum (175 Km away from Kolkata). Soil texture of Birbhum is mainly old alluvial and red laterite. The organic carbon is medium and phosphate as well as the potash content is low type, and pH ranges between 6.5 and 7.5 (neutral).

Sorghum Cultivar

Sweet sorghum variety SSV-84 was collected from Indian Institute of Millets Research (IIMR) Rajendranagar (Hyderabad, Telangana, India).

Block Design

The experiment was arranged in a random way by designing blocks (3×2×3) where total treatment combinations were eighteen (18) with three (3) replications and each plot measuring (4m×3m). Row to Row 45 cm and Plant to Plant 15 cm spacing were maintained. Plot Size 12 Sq. m (4m×3m) with Plant Population 96 /Plot (12×8) were designed.

Doses of Fertilizers

To study the influence of different levels of N,K and P on the growth and quality parameters of sweet sorghum three doses of Nitrogen {0 (N1), 60 (N2) and 120 (N3) Kg/ha} were applied by mean of urea (46% N). Three levels of potassium {0 (K1), 60 (K2), 80 (K3) Kg/ha} were applied as Muriate of potash (60% K). Two levels of Phosphorous {0 (P1), 60 (P2) Kg/ha} were applied as single super phosphate (16% P). All fertilizers were applied as basal dose accept for nitrogen. Half of the nitrogen was applied as basal and another half as top dressing at the 30th day after sowing (DAS).

Measurements

Data was collected at every 30 days interval starting from 40 DAS (Days After Sowing) up to 130 DAS as the research experiment started from 07/06/2017 to 15/10/2017. Randomly ten selected plant were collected from each treatment for measuring its plant heights, green bio mass, sugar concentration, and 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 was 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- 300) 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. All doses were applied in combinations ratio and results were judged with respect to the control of each doses.

Statistical Analysis

All the data was statistically analyzed using Analysis of Variance technique as described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Effect on plant height (cm)

The effect for individual doses of nitrogen, potassium and phosphorus on plant height were significantly different from each other (Table 1). In case of nitrogen, N3 (120 kg/ha) gave the highest data (175.46 cm) at 130 DAS. This result indicates that increase of nitrogen application caused increase of plant height, which follows similar results as that of Salvatore *et al.* (2012) but they also proposed that yield was less sensitive to N level. In case of potassium K3 (80 kg/ha) the highest length was 171.35 cm at 130 DAS. On the other hand, dose of phosphorus P2 (60 Kg/ha) showed better plant height rather than null application of phosphorus fertiliser. In case of combined and interaction effects between nitrogen, phosphorus and potassium N3P2K2 gave the highest length (192.19 cm). Although N3P2K2 combination shows the highest result, if the LSD value is subtracted from the highest value the resultant covers a broad range, which indicates that lower doses also equally carry the same impact and should be cost effective rather than the particular higher dose.

Table 1: Plant height (cm) at various growth stages of sweet sorghum under different fertilizer doses

Treatment	Plant height			
	40 DAS	**70 DAS**	**100 DAS**	**130DAS**
		Nitrogen		
N1	58.78	120.85	147.44	160.84
N2	67.98	129.79	156.64	170.04
N3	73.4	136.57	162.06	175.46
SE	6.97	0.72	0.76	1.68
LSD	1.42	1.46	1.55	3.42
		Potassium		
K1	64.29	126.64	152.95	166.35
K2	66.58	128.93	155.24	168.64
K3	69.29	131.64	157.95	171.35
SE	6.97	0.72	0.76	1.68
LSD	1.42	1.46	1.55	3.42
		Phosphorus		
P1	61.05	126.64	151.95	166.6
P2	72.39	152.95	166.48	181.9
SE	5.7	0.59	0.62	1.37
LSD	1.16	1.19	1.27	2.79
		Interaction		
N1P1K1	53.07	114.31	141.89	154.38
N1P1K2	54.37	115.61	144.19	155.68
N1P1K3	55.11	116.34	144.92	153.08
N2P1K1	57.96	118.37	147.66	161.11
N2P1K2	61.5	121.91	150.86	164.65
N2P1K3	63.8	124.21	156.5	166.95
N3P1K1	66.55	129.2	159.22	180.54
N3P1K2	66.25	128.89	158.91	173.56
N3P1K3	70.79	133.43	163.45	189.43
N1P2K1	58.03	120.94	151.19	164.89
N1P2K2	63.02	125.92	156.17	169.87
N1P2K3	69.06	131.97	162.22	174.85

N2P2K1	71.89	135.11	165.95	187.76
N2P2K2	75.42	138.63	169.48	183.95
N2P2K3	77.32	140.53	171.38	185.85
N3P2K1	78.21	141.91	173.24	188.14
N3P2K2	78.93	142.63	173.96	192.19
N3P2K3	79.66	143.35	174.69	189.58
SE	1.71	1.76	1.33	4.18
LSD	3.47	3.57	2.69	8.37

Effect on green biomass (ton/ha)

The results showed the effect of green biomass on individual doses of nitrogen, potassium, and cultivars were significantly different from each other (Table 2). In case of nitrogen, N3 (120 kg/ha) gave the highest data (26.47 t/ha) at 100 DAS. This result indicate that increasing nitrogen application helps sweet sorghum yield production as similar to the results of Mengel and Kirkby (2001), who 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 (26.18 t/ha) at 100 DAS, which was similarly observed by Sharma and Kumari (1996) about the increase in K fertilizer application. On the other hand phosphorus dose P2 (60 kg/ha) on sweet sorghum did not show any drastic change in green biomass. However, the highest green biomass (t/ha) yield was found on 100 DAS (26.63 t/ha) at N3P2K3 treatment combination.

Table 2: Green biomass (t/ha) at various growth stages of sweet sorghum by different fertilizer doses

Treatment	Green biomass			
	40 DAS	70 DAS	100 DAS	130DAS
		Nitrogen		
N1	14.75	19.14	25.69	24.54
N2	15.04	19.42	26.13	24.92
N3	15.43	19.78	26.47	25.37
SE	0.0081	0.0081	0.0089	0.0073
LSD	0.0164	0.0165	0.0181	0.0149
		Potassium		
K1	14.95	19.36	26	24.82
K2	15.09	19.45	26.11	24.93
K3	15.19	19.53	26.18	25.08
SE	0.0081	0.0081	0.0089	0.0073
LSD	0.0164	0.0165	0.0181	0.0149
		Phosphorus		
P1	15	19.34	26.01	24.73
P2	15.15	19.55	26.18	25.16
SE	0.0066	0.0066	0.0073	0.006
LSD	0.0134	0.0134	0.0148	0.0121
		Interaction		
N1P1K1	14.59	19.01	25.54	24.19
N1P1K2	14.75	19.06	25.6	24.31
N1P1K3	14.81	19.13	25.68	24.37
N2P1K1	14.9	19.23	25.92	24.6
N2P1K2	14.97	19.32	26.05	24.68
N2P1K3	15.05	19.38	26.12	24.79
N3P1K1	15.22	19.53	26.27	24.96
N3P1K2	15.3	19.64	26.41	25.1
N3P1K3	15.44	19.72	26.47	25.55
N1P2K1	14.66	19.08	25.67	24.72
N1P2K2	14.84	19.19	25.78	24.77
N1P2K3	14.88	19.34	25.86	24.87
N2P2K1	14.99	19.44	26.09	25.09
N2P2K2	15.1	19.52	26.26	25.16
N2P2K3	15.22	19.6	26.33	25.21
N3P2K1	15.33	19.84	26.49	25.38
N3P2K2	15.6	19.94	26.55	25.58
N3P2K3	15.72	19.99	26.63	25.66
SE	0.0198	0.0198	0.0218	0.0179
LSD	0.0402	0.0402	0.0443	0.0364

Although N3P2K3 combination shows the highest result, the LSD value is subtracted from the highest value and the resultant covers a broad range, which indicates that lower doses also equally carry the same impact and should be cost effective rather than the particular higher dose. Green biomass shows an independent result from the dose that is effective for plant height.

Effect on sugar percentage (%)

The results showed that the effect of sugar percentage (%) on individual doses of nitrogen, potassium, and phosphorus were significantly different from each other (Table 3). In case of nitrogen, N3 (120 kg/ha) gave sugar percentage (9.11%) at 130 DAS. This result indicate that increasing nitrogen application helps to improve sweet sorghums' 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 up to 120 kg/fed decreased sucrose, Brix and purity percentages. In case of potassium, K3 (80 kg/ha) gave the highest sugar percentage (8.2%) at 130 DAS but Barik and Roy (2015) found that applying potassium 90 kg/ha gave the highest sugar percentage (8.9%), thereby indicating that increasing potassium application is not much significantly helpful to improve sweet sorghums' sugar percentage. On the other hand phosphorus P2 (60kg/ha) of sweet sorghum show highest sugar percentage (8.28%). In case of Interaction effects between nitrogen, potassium and phosphorus, the treatment combination N3P2K3 gave the highest sugar percentage (9.34%) that was found at 100 DAS.

Table 3: Sugar percentage (%) at various growth stages of sweet sorghum by different fertilizer doses

Treatment	Sugar percentage			
	40 DAS	**70 DAS**	**100 DAS**	**130 DAS**
		Nitrogen		
N1	4.53	6.35	6.64	6.79
N2	6.02	7.85	8.17	8.3
N3	6.81	8.65	8.96	9.11
SE	0.0081	0.0095	0.0207	0.0229
LSD	0.0164	0.0193	0.0421	0.0466
		Potassium		
K1	5.65	7.48	7.78	7.92
K2	5.81	7.64	7.94	8.08
K3	5.9	7.73	8.05	8.2
SE	0.0081	0.0095	0.0207	0.0229
LSD	0.0164	0.0177	0.0421	0.0466
		Phosphorus		
P1	5.59	7.41	7.7	7.85
P2	5.89	7.82	8.15	8.28
SE	0.0066	0.0078	0.0169	0.0187
LSD	0.0139	0.0158	0.0344	0.038
		Interaction		
N1P1K1	4.17	5.99	6.26	6.38
N1P1K2	4.21	6.03	6.31	6.43
N1P1K3	4.23	6.05	6.33	6.58
N2P1K1	5.74	7.55	7.84	7.98
N2P1K2	5.9	7.71	8	8.14
N2P1K3	6.02	7.83	8.12	8.26
N3P1K1	6.44	8.28	8.57	8.72
N3P1K2	6.74	8.58	8.87	9.02
N3P1K3	6.87	8.71	9	9.15
N1P2K1	4.74	6.58	6.88	7.01
N1P2K2	4.87	6.71	7.01	7.15
N1P2K3	4.93	6.77	7.07	7.2
N2P2K1	6.02	7.86	8.17	8.32
N2P2K2	6.15	7.99	8.3	8.45
N2P2K3	6.31	8.15	8.59	8.78
N3P2K1	6.8	8.64	8.96	9.11
N3P2K2	6.98	8.83	9.15	9.31
N3P2K3	7.03	8.87	9.19	9.34
SE	0.0198	0.0233	0.0508	0.0561
LSD	0.041	0.0475	0.1032	0.1141

Although N3P2K2 combination shows the highest sugar percentage, the LSD value is subtracted from the highest value and the resultant covers a broad range which indicates that lower doses also equally have the same impact and should be cost- effective rather than the particular higher dose. The effective dose may support the combined dose for green biomass but oppose the best combination fertilizer ratio for plant height and also the time period of both the previous parameters.

Effect on sugar yield (kg/ha)

The results showed that the effect of sugar yield (kg/ha) on individual doses of nitrogen, potassium, and phosphorous were significantly different from each other (Table 4).

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**	**130 DAS**
		Nitrogen		
N1	468.7	853.45	1197.53	1170.35
N2	635.8	1069.6	1498.17	1455.23
N3	737.79	1200.53	1664.12	1622.07
SE	1.24	2.96	7.83	6.42
LSD	1.42	1.46	1.55	3.42
		Potassium		
K1	594.52	1017.97	1421.61	1381.92
K2	617.16	1044.54	1457.02	1416.56

K3	630.61	1061.07	1481.19	1449.18
SE	0.61	1.45	3.85	3.87
LSD	1.24	2.96	7.83	7.86
Phosphorus				
P1	590.33	1007.55	1407.59	1365.2
P2	637.86	1074.84	1498.96	1466.57
SE	0.5	1.19	3.14	3.16
LSD	1.01	2.42	6.39	6.42
Interaction				
N1P1K1	426.56	798.55	1121.69	1083.63
N1P1K2	436.17	807.03	1132.86	1096.81
N1P1K3	439.82	812.55	1139.86	1125.87
N2P1K1	599.76	1018.92	1425.89	1376.69
N2P1K2	619.88	1045.65	1462.9	1409.63
N2P1K3	635.37	1064.94	1488.2	1436.01
N3P1K1	687.91	1134.02	1580.52	1527.99
N3P1K2	723.42	1181.74	1644.34	1589.19
N3P1K3	744.12	1204.54	1672.01	1640.99
N1P2K1	487.58	880.63	1239.22	1216.33
N1P2K2	507.34	903.51	1268.66	1242.3
N1P2K3	514.73	918.42	1282.87	1257.2
N2P2K1	633.68	1072.42	1496.27	1464.74
N2P2K2	651.75	1094.56	1529.16	1491.19
N2P2K3	674.38	1121.12	1586.6	1553.11
N3P2K1	731.61	1203.26	1666.05	1622.14
N3P2K2	764.4	1234.77	1704.19	1670.22
N3P2K3	775.26	1244.83	1717.62	1681.88
SE	1.5	3.57	9.43	9.47
LSD	3.04	7.25	19.17	19.26

In case of nitrogen, N3 (120 kg/ha) gave the highest sugar yield (1664.12 kg/ha) at 100 DAS. In case of potassium, K3 (80 kg/ha) gave the highest sugar yield (1481.19 kg/ha) at 100 DAS and phosphorus fertilizer dose P2 showed high sugar yield (1498.96kg/ha) on 100 DAS. In case of Interaction effects between nitrogen, potassium and phosphorus N3P2K3, the highest sugar yield (kg/ha) was found in 100 DAS (1717.62 kg/ha) treatment combination.

Although N3P2K3 combination shows the highest result, the LSD value is subtracted from the value and the resultant includes a broad range, which indicates that lower doses also equally have the same impact and should be cost-effective rather than the particular higher dose. The effective dose may support the combined dose for plant height but oppose the best combination fertilizer ratio for sugar percentage and green biomass. The time period needed for the previous parameters also vary with best sugar yield DAS time span.

Fig. 1: Field view of sweet sorghum at 30 DAS (Days After Sowing)

Fig. 2: Field view of sweet sorghum at 90 DAS(Days After Sowing)

CONCLUSION

The nutritive application of nitrogen, phosphorus and potassium has a significant effect on Sweet Sorghum when the other conditions remain constant. Although the higher amount of combined fertilizer doses have increased the growth parameters and yield like height, biomass as well as sugar content; when statistically analysing according to LSD values, the results represented more or less a similar outcome. This condition indicates that after a certain amount of application of nitrogen, the excessive use of this fertilizer is statistically at par and not cost-effective at all. Sweet sorghum responded independently and in different manner for each of the combined cases, which indicates that this area of research demands for further study with respect to different climatic zones and cultivars as well.

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