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CONTENTS

Effect of tillage, fertilizer placement and nitrogen levels on green foliage, brix, sucrose, juice and ethanol production of sweet sorghum *(Sorghum bicolor* L.) in Mollisols of Uttarakhand

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ABSTRACT: A field experiment was conducted at Instructional Dairy Farm, Nagla, G.B. Pant University of Agriculture and Technology, Pantnagar (India) during *Kharif* seasons of 2011 and 2012 to study the effect of tillage, fertilizer placement and nitrogen levels on green foliage, brix, sucrose, juice and ethanol production of sweet sorghum (*Sorghum bicolor* L.) in Mollisols of Uttarakhand. The experimental results revealed that the highest growth attributes, fodder yield, brix%, sugar%, juice and ethanol yield were recorded under subsoiling-cum-differential rate placement of fertilizer. The subsoiling-cum-differential rate placement produced 16.7, 26.7 and 32.7% higher green fodder and 19.2, 33.4 and 42.2% higher dry fodder yield than conventional tillage, subsoiling and subsoiling-cum-deep placement, respectively. Similarly, the brix%, sucrose%, juice and ethanol yield were recorded 21.9, 13.2, 31.2 and 45.0% higher under subsoiling-cum-differential rate placement than conventional tillage, respectively. The nitrogen levels also influenced the quality attributes of sweet sorghum with 8.1, 21.3, 36.4 and 74.0% higher brix%, sucrose%, juice and ethanol yield, respectively under 120 kg N/ha than control, however the green and dry fodder yield increased significantly up to 80 kg N/ha. It is therefore concluded that the fertilizer should be placed at differential depth (20cm and 50 cm) coupled with 80 kg N/ha for higher green foliage as well as brix, sucrose, juice and ethanol production of sweet sorghum in Mollisols of Uttrakhand and may be replicated in similar agro-climatic zones of India.

Key words: Brix, ethanol, juice yield, subsoiling, sucrose

In India, sorghum occupies 4.09 m ha area with production and productivity of about 3.48 mt and 849 kg/ha, respectively (Agricultural Statistics at a Glance, 2020). Presently, the sweet sorghum [*Sorghum bicolor* (L.) Moench.] is gaining popularity among farming communities mainly because of its fast-growing habit, wide adaptability, tolerance to abiotic stress and good quality of green fodder. Its stalk contains 15-17% fermentable sugars, 47% juice with 7.24% sugar content. Besides, sweet sorghum is a promising source of biofuel like ethanol, jaggery and syrup that can be produced nearly 2000-2500 $1ha^{-1}$. It belongs to family Poaceae and attains height up to 3.50m. The leaves are broad ~12 cm and long ~25cm. The stalk contributes 70-80% to biomass. The grains can also be used for making potable ethanol with a recovery rate of 400 lt^{-1} of grain.

Tillage and balanced fertilization are two major aspects of crop production. Heavy tillage with regular use of disc harrow is pulverizing only top 15 to 20 cm soil. The soil below 15-20 cm led to formation of compact/hard layer over long period of cultivation. Kumar (2003) also reported that continuous tillage at top 30cm of soil depth for crop cultivation developed hard pan in the *Tarai* region of Uttarakhand. The hard pan reduces percolation resulting into water stagnation in rhizosphere that is not only unfavourable to soil flora and fauna but also for proper root growth and development which subsequently reduces nutrient and water uptake of crop plants. Hard compacted layers could be alleviated with the help of deep soil loosening equipment like chisel plough and subsoiler that allow a system of deep cracks and fissures in the subsoil, restoring the soil profile, facilitating the downward movement of water, air and enabling roots to withstand better against short term anaerobic condition (Raper *et al.*, 1998). Subsoiling to a depth of 25-30 cm at 60-90 cm interval improved the yield of autumn planted cane (Chen and Haung, 1972).

Broadcasting of fertilizer results in low fertilizer use efficiency due to various losses (Rababi, 2006). Surface applied nitrogenous fertilizers are more prone to volatilization i.e., 40 to 50% of applied nitrogen and only 22 to 30% of applied phosphorus and potassium fertilizers are effectively used by the crop and the remaining get either washed away, volatilized, leached to ground water or get fixed with soil (Rowse and Stone, 1980). Broadcasting is common method of fertilizer application just before last tillage or seeding. These fertilizers are localized in the upper layer of soil, so its larger portion is not available to plant roots. Therefore, it is essential to place P and K fertilizers in root zone for higher availability and use efficiency. The vertical placement of fertilizer in different soil layers is more important than horizontal distribution. Thakur and Mandal (2010) reported greater nutrient uptake and higher sugarcane yield under sub-soiling, deep and differential rate placement of fertilizers in the root zone of crop. Besides having such great importance of deep and differential placement of fertilizers, very little research work has been conducted so far on commercial crops including sweet sorghum. Considering above facts, the present study was carried out to study the effect of subsoiling, deep and differential rate placement of fertilizer and N levels on yield and quality of sweet sorghum in Mollisols of Uttrakhand (India).

MATERIALS AND METHODS

The field experiment was conducted during the *Kharif* season of 2011 and 2012 at the Instructional Dairy Farm, Nagla, G.B. Pant University of Agriculture and Technology, Pantnagar, U. S. Nagar (Uttarakhand).The climate of experimental site was humid sub-tropical with hot summers and cold winter. The mean annual rainfall is 1554.1mm of which 80 to 90 per cent is received from June to October. The total rainfall received during crop period in 2011 and 2012 was 2007.8mm and 752.8mm, respectively. The soil of experimental field was well drained and slight silty clay loam in texture with pH 7.21. The available organic carbon was 0.72% and available nitrogen and phosphorus and potash were 272.3, 29.0, and 236.1 kg/ha, respectively. The experiment consisted of four tillage levels in main plot i.e., conventional tillage (CT), subsoiling (20cm) followed by (fb) rotavator x1(S), subsoiling-cum-deep placement (40cm) fb rotavator x1(SDP) and subsoiling-cum-differential rate placement (25 & 50 cm) fb rotavator x1(SDRP) and four N levels in sub plot i.e. control (zero nitrogen), 40, 80 and 120 kg/ ha, was laid out in split plot design with four replications. The recommended dose of P (60 kg/ha) and K (40 kg/ha) was deep placed as per the subsoiling treatments, while in conventional tillage it was applied at the time last tillage manually. The nitrogen was applied manually as per treatments in two equal splits i.e. 50 % basal and 50% after 30 days after sowing in all treatments. Sweet sorghum variety SPSSV-6 was planted on 27 May 2011 and 4 May 2012. The growth parameters *viz*., plant height, number of leaves and number of internodes per plant were recorded at 30, 60, 90 DAS and yield attributes were recorded at harvesting i.e., 120 DAS of the crop. The juice quality parameters i.e., brix, sucrose and available sugar were determined by the method described by Spencer and Meade (1955). The experiment data on growth, fodder yield and quality were recorded at harvest of the crop and later were analyzed statistically as per standard method prescribed by Cochran and Cox (1957).

RESULTS AND DISCUSSION

a. Effect of tillage options

i. Growth attributes

Plant population and plant height did not differ significantly with tillage options but the highest values were recorded under subsoiling-cum-differential rate placement fb rotavator which was non-significant with other tillage options. Both plant population and plant height were recorded higher under subsoiling treatment than conventional tillage. Tillage had significant effect on L: S ratio with higher values under subsoiling-cum-differential rate placement fb rotavator that was non-significant with subsoiling-cum-deep placement during both years. It was due to better availability of nutrient and moisture under subsoiling compared with conventional tillage as observed by Thakur and Mandal (2010).

ii. Fodder yield

The green fodder yield and dry fodder yield were affected significantly by tillage during both the years (Table. 2). The green fodder yield was recorded significantly higher under subsoiling treatments than conventional tillage. Subsoiling-cum-differential rate placement recorded significantly higher green fodder yield that was on par with subsoiling-cum-deep placement during both the years. Subsoiling, subsoiling-cum-deep placement and subsoiling-cum-differential rate placement gave average 16.7, 26.7 and 32.3% higher average green fodder yield than conventional tillage, respectively, however subsoiling-cum deep placement and subsoiling-cum-differential rate placement yielded 8.6 and 13.4% higher green foliage than subsoiling alone, respectively. Subsoiling-cum-differential rate placement gave only 4.4% higher green fodder yield than subsoiling cum deep placement. Similarly the dry fodder yield was found on an average 2.1, 9.1 and 20.7% more under subsoiling, Subsoiling-cum-deep placement and subsoiling-cum-differential rate placement, respectively than conventional tillage. Subsoiling-cum-deep placement and subsoiling-cum-differential rate placement had 6.9 and 18.7% higher dry fodder yield than subsoiling, similarly subsoiling-cum-differential rate placement produced 10.6% more dry fodder yield than subsoiling-cum-deep placement. The higher values under subsoiling treatments were attributed to better growth and development of plants due to higher availability of nutrient and moisture from deeper soil layers (Thakur and Mandal, 2010).

ii Fodder quality

The brix%, juice yield and ethanol yield were influenced significantly by tillage during both the years (Table.2). The subsoiling-cum-differential rate placement recorded significantly higher brix% that was on par with subsoiling-cum-deep placement in 2011 while it was non-significant with both subsoiling-cum-deep placement and subsoling in 2012. The conventional tillage had the lowest brix% during both the years. Subsoiling, subsoiling-cum-deep placement and subsoiling-cum-differential rate placement gave 10.8, 15.2 and 21.9% higher average brix% than conventional tillage, respectively, however subsoiling-cum-deep placement and subsoiling-cum-differential rate placement had 4.0 and 10.1% higher values than subsoiling, respectively. The sucrose% was not affected significantly by tillage options during both years, however, the highest values were found under subsoiling-cum-differential rate placement followed by subsoiling-cum-deep placement during both years. The juice yield was recorded significantly highest under subsoiling cum differential rate placement during both years but conventional tillage had significantly equal juice yield to subsoiling in 2011 and subsoiling as well as subsoiling cum deep placement in 2012. On an average the juice yield was 2.2, 6.5 and 31.2% higher under subsoiling, subsoiling-cum-deep placement and subsoilng-cum-differential rate placement, respectively than conventional tillage but the subsoiling had 4.2 and 28.4% lower juice yield than subsoiling cum deep placement and subsoiling cum differential rate placement, respectively. The subsoiling cum differential rate placement yielded 23.2% more juice than subsoiling cum deep placement. The ethanol yield was recorded significantly highest under subsoiling-cum-differential rate placement during both the years (Table 2). Conventional tillage had the lowest ethanol yield which was at par with subsoiling and subsoiling-cum-deep placement during both the years. The conventional tillage had 5.0, 10.0 and 45% lower ethanol yield than subsoiling, subsoiling-cum-deep placement and subsoiling-cum-differential rate placement, respectively but subsoiling-cum-differential rate placement had 31.1% more ethanol yield than subsoiling-cum-deep placement. The higher values of brix%, sugar%, juice yield and ethanol yield were the cumulative effect of better growth and green fodder yield. These findings were close conformity with those of Mandal (2007) and Singh (2008). The interaction was non-significant.

Table 1: Effect of tillage and nitrogen levels on growth and yield of sweet sorghum

Treatment	Plant Population (x 10^3/ha)		Plant height (cm/plant)		L : S ratio		Green fodder yield(q/ha) yield(q/ha)			Dry fodder		
	2011	2012	2011	2012	2011	2012	2011	2012	Mean	2011	2012	Mean
Treatment Options												
Conventional Tillage	116	115	298	292	0.31	0.29	518.2	489.8	504.0	130.1	117.9	124.0
Subsoiling (20cm) fb Rotavator x1	120	120	305	298	0.39	0.38	599.6	576.3	588.0	133.4	119.7	126.5
Subsoiling-cum-deep placement (40 cm) fb Rotavator x1	121	121	308	301	0.40	0.40	645.4	631.4	638.4	142.8	127.7	135.2
Subsoiling-cum-differential rate placement (25 & 50 cm) fb Rotavator x1	123	123	315	308	0.48	0.44	683.3	650.2	666.8	160.6	139.0	149.8
S. Em ±	03	03	12	10	0.02	0.02	15.51	14.93	-	5.60	3.21	-
CD (p=0.05)	NS	NS	NS	NS	0.05	0.05	49.6	47.7	-	17.9	10.3	-
Nitrogen levels (kg/ha)												
0	111	111	300	294	0.29	0.28	541.8	516.2	529.0	114.5	102.0	108.2
40	113	112	301	294	0.34	0.34	577.6	549.7	563.7	136.6	121.4	129.0
80	125	124	309	303	0.43	0.42	635.6	603.2	619.4	153.1	135.6	144.3
120	132	132	315	307	0.51	0.44	691.6	660.6	676.1	162.6	145.3	153.9
S. Em ±	05	05	10	9	0.02	0.02	20.9	18.2		3.57	3.20	
CD (p=0.05)	13	13	NS	NS	0.05	0.05	59.9	52.2		10.3	9.2	

Table 2: Effect of tillage and fertilizer placement and nitrogen level on brix%, sugar%, juice yield and ethanol yield of Sweet Sorghum

Treatment	Brix %			Sucrose %			Juice yield(kl/ha)			Ethanol yield(kl/ha)		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
Tillage Options												
Conventional Tillage	13.44	13.13	13.38	8.34	8.14	8.24	9.44	9.25	9.35	2.14	2.01	2.07
Subsoiling (20cm) fb Rotavator x1	15.27	14.37	14.82	8.83	8.51	8.67	9.56	9.35	9.46	2.22	2.19	2.15
Subsoiling-cum-deep placement (40 cm) fb Rotavatorx1	15.90	14.94	15.42	8.86	8.69	8.77	10.25	9.56	9.91	2.30	2.14	2.22
Subsoiling-cum -differential rate placement (25 & 50 cm) fb Rotavator x1	16.95	15.67	16.31	9.49	9.18	9.33	12.81	11.56	12.19	3.00	2.83	2.91
S.Em±	0.42	0.48	-	0.26	0.28	-	0.28	0.29	-	0.11	0.11	-
CD (p=0.05)	1.36	1.53	-	NS	NS	-	0.89	0.94	-	0.35	0.36	-
Nitrogen levels (kg/ha)												
0	14.79	13.91	14.35	8.27	7.85	8.06	9.50	8.00	8.75	1.73	1.74	1.73
40	14.98	14.40	14.69	8.35	8.15	8.25	10.00	8.88	9.44	2.11	1.92	2.01
80	15.67	14.89	15.28	9.04	8.84	8.94	10.44	10.89	10.67	2.69	2.56	2.62
120	16.12	14.91	15.51	9.88	9.68	9.78	12.13	11.96	12.05	3.19	2.84	3.01
S.Em±	0.49	0.58	-	0.31	0.30	-	0.44	0.27	-	0.11	0.11	-
CD (p=0.05)	NS	NS	-	0.88	0.87	-	1.27	0.76	-	0.32	0.33	-

b. Effect of nitrogen levels

i. Growth attributes

Nitrogen had significant role in establishing the plant stand and the highest plant stand was recorded at application of 120 kg N/ha during both the years. The nitrogen level did not have significant effect on plant height but it increased up to 120 kg N/ha with highest values during both the years. The L:S ratio was also increased with increasing level of nitrogen up to 120 kg N/ha, however it increased significantly up to 120 kg N/ha in 2011 and up to 80 kg N/ha in year 2012. Moghimi and Emam (2015) also reported higher L:S ratio at application of 120 kg N/ha mainly because of broader leaves at higher N rates.

ii Fodder yield

The nitrogen levels had significantly effect on green and dry fodder yield that were increased significantly up to 80 kg N/ha during both the years (Table.1). Two years average values indicated that green fodder yield was increased 9.9 and 19.9% under 80 and 120 kg N/ha, respectively compared to 40 kg N/ha. Similarly 120 kg N/ha gave 9.6% more green fodder than 80 kg N/ha. The dry fodder yield was also increased with increasing nitrogen levels up to 120 kg N/ha, however it increased significantly up to 80 kg N/ha in 2011 and up to 120 kg N/ha in year 2012. The mean values indicated that dry fodder yield was increased 19.2, 33.4 and 42.2% under 40, 80 and 120 kg N/ha, respectively in comparison to 0 kg N/ha, while 80 and 120 kg N/ha gave 11.9 and 19.3% more dry fodder yield than 40 kg N/ha. Moghimi and Emam (2015) also observed similar findings.

iii Fodder quality

The nitrogen level did not have significant influence on brix%, however the highest and lowest brix values were observed under 120 kg N/ha and control, respectively during both the years (Table 2). The average brix% was 8.5, 5.6 and 1.5% higher under 120 kg N/ha than control, 40 and 80 kg N/ha, respectively. The sucrose% also increased significantly with increasing nitrogen levels with highest values at 120 kg N/ha that was similar to 80 kg N/ha during both years. It was also observed that sucrose% was significantly equal at both control and 40 kg N/ha during both the years. On an average sucrose% was 2.4,10.9 and 21.3% higher under 40, 80 and 120 kg N/ha, respectively than control, while 120 kg N/ha gave 9.3% more sugar% than 80 kg N/ha. The juice yield was also increased with increasing nitrogen levels and significantly highest values were recorded at application of 120 kg N/ha during both the years (Table.2). The juice yield was estimated 7.9, 21.6 and 36.4% higher at 40, 80 and 120 kg N/ha, respectively than control. The juice yield was also recorded 12.6 and 26.3% more at application of 80 and 120 kg N/ha, respectively than 40kg N/ha but the increase in juice yield was 12.1% with increased nitrogen level from 80 to 120 kg N/ha. The ethanol yield was also increased with increasing nitrogen levels with significantly highest values at 120 kg N/ha during both the years. The 120 kg N/ha produced 16.2, 34.0 and 74.0% higher average ethanol yield at application of 80,40 and 0 kg N/ha, respectively. Similarly 40 kg N/ha produced 31.8 and 49.8% lower ethanol yield than 80 and 120 kg N/ha, respectively, while 14.8% higher ethanol yield was recorded at 120 kg N/ha than 80 kg N/ha. The higher values of quality attributes were contributed by better growth and green fodder yield at higher dose of nitrogen application. These findings were in close conformity with those of Uchino *et al*. (2013) and Olugbemi and Ababyomi (2016). Pal (2020) also reported higher fodder and crude protein yield at application of 120 kg N/ha at Pantnagar conditions as the higher N rates increased the L: S ratio and N content in plants.

CONCLUSION

The experimental results revealed that subsoiling-cum-differential rate placement followed by rotavator x1 and 120 kg N/ha produced the highest green foliage, dry matter, juice and ethanol yield, however the green and dry fodder increased significantly up to 80 kg N/ha. It is therefore concluded that the fertilizer should be placed at differential depth (20cm and 50cm) coupled with 80 kg N/ha application manually i.e., 50% basal and 50% at 30 DAS for higher green foliage as well as brix, sucrose, juice and ethanol production of sweet sorghum in Mollisols of Uttrakhand and may be replicated in similar agro-climatic zones of India.

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