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Research Article

Effect of Tillage and Nitrogen Rates on Fodder Productivity and Juice Quality of Sweet Sorghum (*Sorghum bicolar* L.) in Himalayan Foothills of India

Manoj Kumar[1] and Mahendra Singh Pal[2]*

[1]Ph.D. Student, Department of Agronomy, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

2Professor, Department of Agronomy, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

***Corresponding Author:** Mahendra Singh Pal, Professor, Department of Agronomy, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India.

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Abstract

A field experiment was conducted at Instructional Dairy Farm, Nagla, G.B. Pant University of Agriculture & Technology, Pantnagar (India) during Kharif seasons of 2011 and 2012 to study the effect of tillage and nitrogen rates on fodder productivity and juice quality of sweet sorghum (*Sorghum bicolar* L.) in Himalayan foothills of India. The tillage options i.e. conventional tillage (CT), subsoiling followed by rotatvator (SSfbR)), subsoiling deep placement (40cm) followed by rotatvator (DPfbR) and differential rate placement of fertilizer (25 & 50 cm depth) followed by rotavator (DRFfbR)) in main plot and nitrogen rates i.e. control, 40, 80 and 120 kg/ha in subplot was planted in split plot design with foutr replications. The experimental results revealed that the growth attributes, fodder yield, crude protein content, crude protein yield, HCN content, sugar yield, and ethanol yield were recorded highest under DRFfbR that produced 23.8, 13.5, and 6.3% higher green fodder yield and 19.3, 17.1 and 9.8% higher dry fodder yield than conventional tillage, SSfbR, and DPfbR, respectively. Similarly the crude protein content, crude protein yield, HCN content, sugar yield and ethanol yield were also recorded higher under DRFfb R that gave 3.2, 23.7, 2.7, 43.8 and 47.4% higher than CT, respectively. The green and dry fodder yields increased significantly with increasing levels and highest values were obtained at 120 Kg N/ha that had 6.9 and 7.1% higher than 80 kg N/ha, respectively. The crude protein content, crude protein yield, HCN content, sugar yield and ethanol yield were also 4.9, 48.5, 3.1, 73.2 and 70.6% higher under 120 kg N/ha, respectively than control. It is therefore concluded that the phosphorus and potash should be placed at differential depth (25cm and 50cm) coupled with 120 kg N/ha as recommended for higher yield and juice quality of sweet sorghum in Himalayan foothills of India and may also be replicated in similar agro-climatic zones of India..

Keywords: Conventional Tillage; Ethanol; HCN; Rotavator; Subsoiling; Sugar Yield

Introduction

Five F's i.e. food, fodder, fuel, fibre and forest are the basic need of men and animals in present scenario of sustainable development of the world. In present era of development and population burst, increasing demand of fodder and fuel beside food has alarmed to fulfill in years to come. Presently India is a house of highest cattle population but short of nearly 35% green fodder, 11% dry fodder and 44% concentrates and seriously affecting the of animals' productivity. Similarly, the mismatch between fuel availability and production is serious concern for the nation. Therefore it is urgent need to explore the options available to match these requirements, hence, sweet sorghum (*Sorghum bicolor* (L.) Moench) is one of the options that can provide food, fodder and fuel, however sugarcane, sugar beet, corn and wheat may also be harnessed for these purpose. Sorghum is 4th most important cereal after rice, wheat and maize in India and mainly grown in *Kharif* season on an area of 3.81 mha and 4.23 mt production with 1110 kg/ha productivity [2]. Sweet sorghum is known for sugar and ethanol production due to high sugar content in stem. It is a C_4 plant and highlighting its great bioenergetic potential mainly because of its ability of high biomass and stem sugar accumulation [17]. It has multiple cultivation cycles each year with high productivity agronomic stability and minimal demand for nitrogen [14].

Presently the sweet sorghum is gaining popularity among farming communities mainly because of its fast growing habit, wide adaptability, tolerance to abiotic stress, good quality of green fodder and moreover the potential source of energy. Its stalk contains 15-17% fermentable sugars and 47% juice with 7.24% sugar content [5]. Besides the single cut sweet sorghum produced 35-50 t ha^{-1} stalk, 1.5-2.5 t ha^{-1} grain and 2760 lha^{-1} ethanol [12]. So, it is a promising source of biofuel likes ethanol, jaggery and syrup that can be produced nearly 2000-2800 $1ha^{-1}$ and grains can also be used for making potable ethanol with a recovery rate of 400 lt^{-1} of grain [6]. In general, sorghum plant attains height up to 3.50m, leaves are broad ~12 cm and long ~125cm and stalk contributes 70-80% to biomass.

Sweet sorghum has great variation in its agronomy due to its diverse genetic makeup, so tillage and balanced nutrient management mainly nitrogen is important to achieve higher productivity. It has been reported that N influences biomass production, content and types of sugars in the juice and soil properties which can be handled favorably if the right tillage method is selected [1]. Tillage methods can alter the degree of soil compaction and yield potential [7]. Subsoiling and differential rate of deep tillage along with fertilizer application have proved its suitability for not only breaking the hard pan but also making nutrients availability at different depths for higher crop productivity [6]. Chen and Haung reported that differential rate of subsoiling at a depth of 25-30 and 60-90 cm improved the yield of autumn planted cane. Thakur and Mandal 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 place of fertilizers, very little research work has been conducted so far on commercial use of 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 nitrogen management on yield and quality of sweet sorghum in Himalayan foothills of 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 subtropical 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 options in main plot i.e. conventional tillage (CT), subsoiling (20cm) fb rotavator x1(SSfbR), subsoiling-cum-deep placement (40cm) fb rotavator x1(DPfbR) and subsoiling-cum-differential rate fertilizer placement (25 and 50 cm) fb rotavator x1(DRFfbR) and four N levels in sub plot i.e. control (zero nitrogen), 40, 80 and 120 kg N/ha, was laid out in split plot design with four replications. The recommended dose of phosphorus (60 kg/ha) and potash (40 kg/ha) was deep placed as per the subsoiling treatments, while in conventional tillage it was applied at last tillage operation. The nitrogen was applied manually as per treatments in two equal splits i.e. 50% basal and 50% at 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, number of internodes, internodes length, dry matter accumulation/plant, leaf area index (LAI) were recorded at harvest based on five plants tagged in each plot, while green and dry fodder yields were recorded at harvesting from net plots and reported into t/ha at harvest i.e. 120 DAS of the crop. HCN content was estimated at 40 days after sowing of crop by Picric acid method [4]. The crude protein content, crude protein yield, sugar yield and ethanol yield were estimated [18] at harvest. The sugar and ethanol yield were calculated as follows

- Sugar yield (t/ha) = Available sugar (%) x Juice yield (kl/ha) /100
- Ethanol yield (l/ha) = Sugar yield (t/ha) x 3.78 x1000 x 0.8

Results and Discussion

Effect of tillage

Growth attributes

The growth attributes i.e. number of leaves, internodes, internodes' length and plant dry matter were affected significantly by tillage, and however the plant height and leaf area index remained non significant (Table 1). The tallest plant was measured under DRF*fb*R while the shortest plants under CT. The number of leaves differed significantly among tillage options with highest values under DRF*fb*R that was statistically at par with DP*fb*R and the lowest reported in CT followed by SS*fb*R. Similarly the number of internodes per plant was recorded significantly highest under DRF*fb*R and the lowest under CT. The internodes' length varied among tillage options and DRFfbR gave the maximum values that were significantly similar to DP*fb*R and SS*fb*R. López-Sandin e*t al*. also observed differential internodes length under different till-

Treatment	Plant Height (cm/plant)	Number of Leaves/plant	Number of Internodes/plant	Internodes' Length(cm/plant)	Dry matter accumulation (g/m^2)	LAI
Tillage options						
CT	294.8	5.8	7.4	12.8	1043	2.4
SS fb R	301.2	7.9	9.2	13.4	1053	2.4
DP fb R	304.5	8.4	10.8	14.2	1094	2.5
DRF fb R	311.1	9.4	11.9	14.5	1174	2.6
SEm±	11	0.3	0.3	0.6	22	0.1
LSD (p = 0.05)	35	1.0	0.9	1.9	69	0.2
Nitrogen levels (Kg/ha)						
Control	297	7.3	8.6	12.9	898	2.3
40	298	7.5	9.5	13.3	1048	2.3
80	306	8.2	10.1	14.0	1170	2.6
120	311	8.6	11.1	14.6	1246	2.6
SEm±	10	0.3	0.4	0.4	23	0.1
LSD (p = 0.05)	28	0.9	1.2	1.2	66	0.3

Table 1: Effect of subsoiling and nitrogen management on growth attributes of sweet sorghum in Mollisols of Uttarakhand (Pooled data of two years).

age options. The plant dry matter accumulation per plant was also weighed highest that was statistically higher than other tillage options. The leaf area index was also measured highest, however it was non-significant among tillage options. The higher values of different growth parameters were attributed to higher availability of nutrients and moisture under DRF*fb*R and DP*fb*R compared to CT. The subsoil breaks the plow floor and make the soil pulverized [20] and favors the penetration and exploration of the roots in the soil, seeking greater water and nutrient availability, increasing the possibilities of the plant adaptation to different soil types and conditions [13]. Kumar *et al.* also reported higher dry matter accumulation under differential fertilizer placement tillage conditions.

Fodder yield

Tillage had significant impact on the green and dry fodder yields (Table 2). The pooled values of two years field experimentation indicated that DRF*fb*R produced significantly highest green fodder yield. The DRF*fb*R had 6.3, 13.5 and 23.8% greater green fodder yield than DP*fb*R, SS*fb*R and CT, respectively. Similarly DP*fb*R gave 6.6, while SS*fb*R gave 9.1% more green fodder yield than SS*fb*R and CT, respectively. The dry fodder yield was also estimated significantly higher under DRF*fb*R, while DP*fb*R produced 6.7% higher dry fodder yield than SS*fb*R that also had 1.9% higher dry fodder yield than CT. The DPfbR and DRF*fb*R also had 8.6% and 19.3% higher dry fodder yield than CT, respectively. Further, it was also noted that DP*fb*R and DRF*fb*R also produced 6.7% and 17.1% more dry fodder yield than SSfbR, respectively. The higher values of green and dry fodder yield under differential rate fertilizer placement favoured better utilization of nutrient and moisture resulting into higher growth attributes. Kumar *et al.* also reported significantly higher green and dry fodder yields than CT and SS*fb*R.

Treatment	Green Fodder Yield (q/ha)	Dry Fodder Yield (q/ha)	CP Content (%)	CP yield (q/ha)	HCN Content (ppm)	Sugar Yield (q/ha)	Ethanol Yield (Kl/ha)
Tillage Options							
CT	514.6	123.9	6.1	7.6	98.4	6.4	1.9
SS *fb* R	561.7	126.2	6.3	7.9	99.8	6.5	2.0
DP *fb* R	599.3	134.6	6.3	8.4	100.1	6.9	2.1
DRF *fb* R	637.5	147.8	6.3	9.5	101.1	9.2	2.8
SEm±	5.7	1.4	0.02	0.1	0.4	0.2	0.1
LSD(p=0.05)	18.1	4.4	0.08	0.4	1.3	0.6	0.2

Nitrogen levels(kg/ha)							
Control	529.3	107.4	6.1	6.6	98.5	5.6	1.7
40	554.0	128.0	6.2	7.9	99.1	6.1	1.8
80	594.4	143.4	6.3	9.0	100.3	7.6	2.3
120	635.4	153.6	6.4	9.8	101.6	9.7	2.9
SEm±	7.3	1.3	0.02	0.1	0.3	0.2	0.1
LSD(p=0.05)	20.8	3.8	0.06	0.3	0.9	0.6	0.4

Table 2: Effect of subsoiling and nitrogen management on fodder yield and juice quality of sweet sorghum in Mollisolss of Uttarakhand (Pooled data of two years).

Fodder quality.

Quality attributes of sweet sorghum i.e. crude protein and HCN content were affected significantly by different tillage options (Table 1). Significantly higher crude protein content was recorded under DRF*fb*R that was non-significant with DP*fb*R and SS*fb*R and the CT had the lowest values. The crude protein yield had similar pattern with the highest values under DRF*fb*R that was non-significant with DP*fb*R. The lowest crude protein yield was estimated under CT that was statistically equal to SS*fb*R and DPfbR. The HCN content was found significantly higher under DRF*fb*R that was non- significant with DPfb R and SSfbR and the lowest values at CT. The CT had 5.3, 10.5 and 47.4% lower ethanol yield than SS*fb*R, DP*fb*R and DRF*fb*R, respectively. The higher values were attributed to better green fodder yield. Malagi., *et al*. reported that deep tillage recorded significantly higher grain yield (18.0 q/ha) and green biomass yield (35.5 t/ha) of sweet sorghum as compared to shallow tillage (13.7 q/ha and 28.6 t/ha) grain yield and green biomass yield, respectively.

Juice quality

The sugar and ethanol production were affected significantly by tillage options (Table 2). The highest sugar production was obtained significantly highest under DRFfbR that had nearly 43.8% higher than CT, thought, SSfbR and DPfbR were significantly equal to each other. The sugar yield was also influenced by different tillage options and significantly highest and the lowest values were recorded under DRF*fb*R and CT, respectively. Further, the sugar yield was 1.6% higher under SS*fb*R than CT, 6.2% higher under DPfbR than SSfbR and 33.3% higher under DRF*fb*R than DP*fb*R. Similarly ethanol production was also recorded significantly highest under DRF fb R that gave 47.4%, 10.5 and 5.3% higher than CT, SSfbR and DPfbR, respectively. The higher values were ascribed to higher biomass production under subsoiling treatments. López-Sandin *et al.* found the highest values of total soluble solids (14.89%), juice sugar content (22.91 g), juice sugar concentration (527.46 mg g^{-1} DW), percentage of dry biomass (60.04%), and dry biomass yield (19.01 t ha-1) at the physiological maturity stage of sweet sorghum.

Effect of nitrogen levels

Growth attributes

The number of leaves, number of internodes, internodes length, plant dry matter accumulation and leaf area index differed significantly and also increased with nitrogen levels with highest values at 120 kg N/ha. The number of leaves, number of internodes, and internodes' length were increased significantly up to 80 kg N/ha but the highest values were recorded at 120 kg N/ha with non significant difference. Similarly the plant dry matter accumulation was found significantly highest at 120 kg N/ha but the leaf area index was increased significantly up to 40 kg N/ha, however the highest values were noted at 120 kg N/ha. The plant height also increased with increasing levels of nitrogen with tallest plant at 120 kg N/ha, however, it remained non-significant among nitrogen levels. Moghimi and Emam also reported similar findings. It was also concluded that an application of nitrogen fertilizer enhanced the growth of sweet sorghum as observed in the plant height, LAI, CGR and other growth indices [11].

Fodder yield

The fodder yields varied significantly among nitrogen levels (Table 1). The green fodder yield increased significantly with increasing levels of nitrogen with highest values at 120 kg N/ha that produced 6.9 and 14.7% higher values than 80 and 40 kg N/ha, respectively. The green fodder yield was also 4.7% higher at 40 kg N/ha than control. Similarly the green fodder yield was 8.2% higher at 80 kg than 40 kg N/ha. The similar trend was also observed in dry fodder yield that was 7.1% higher at 120 kg than 80 kg N/ha. The higher values of fodder yields were attributed to taller plants, higher leaf area index and dry matter accumulation. It was also appraised that the chlorophyll content (SPAD reading) and cane fresh weight increased significantly in line with higher N rates [6,10].

Fodder quality

The nitrogen levels at significant effect on quality attributes i.e. crude protein content, HCN content, sugar yield and ethanol yield with highest values at 120 kg N/ha (Table 2). The crude protein content was increased with increasing level of nitrogen and the highest crude protein content was recorded at 120 kg N/ha and that was statistically at par with 80 kg N/ha, while crude protein content, HCN content, sugar yield and ethanol yield were found significantly highest at 120 kg N/ha. The nitrogen an integral part of amino acids protein, therefore it improve nitrogen content in sorghum plants. Pal also reported higher protein content at application of higher nitrogen doses. The higher crude protein yield was attributed to higher dry fodder yield and crude protein content. Shehab and Guo also reported higher HCN content at 120 kg nitrogen than 90 kg N/ha. The sugar yield was 27.6, 59.0 and 73.2% higher at 120 kg N than 80, 40 kg N/ha and control, respectively. An application of 120 kgN/ha produced 26.1, 61.1 and 70.6% higher ethanol than 80 and 40 kg N/ha and control, respectively. The sugar and ethanol yields were higher at 120 kg N/ha mainly because of greater green fodder yield [11]. Kumar *et al*. also reported similar findings.

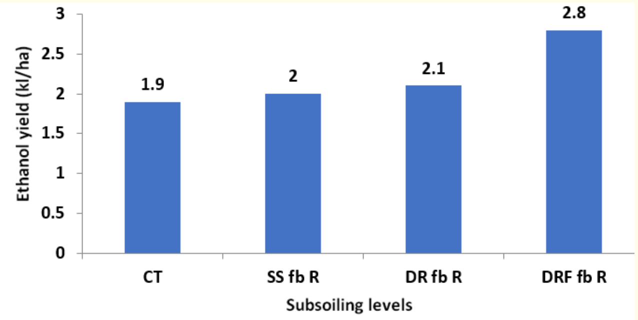

Figure 1: Effect of subsoiling on ethanol production of sweet sorghum.

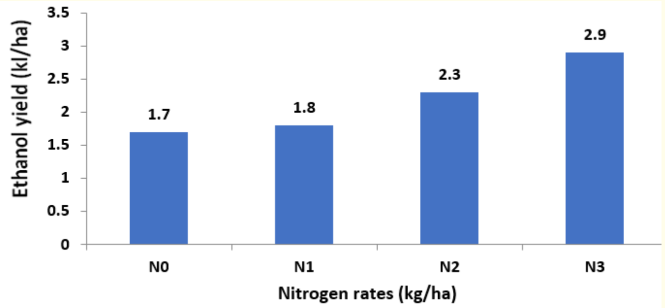

Figure 2: Effect of nitrogen levels on ethanol production of sweet sorghum.

Conclusion

Based on pooled values of two year field experimentation, it may be concluded that sweet sorghum may be grown under differential rate placements of P and K at 25 and 50 cm depth with application of recommended 120 kg N/ha for better growth attribute, fodder yield, sugar and ethanol production in Himalayan foothills of India and similar agro-ecological zones of India.

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