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IMPACT OF NANO UREA ON SORGHUM FODDER PRODUCTIVITY, NUTRIENT CONTENT, ECONOMICS AND SOIL HEALTH

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SUMMARY

A field experiment was conducted at Forage Section Research Farm, CCS Haryana Agricultural University, Hisar, during *kharif* 2022 on single-cut forage sorghum grown as rainfed crop to assess the impact of nano urea on fodder productivity, nutritional content, economics along with soil health. The experiment consisting of eleven treatments i.e., T_1: Control (No RDN); T_2: 100% RDN by urea fertilizer (75kg); T_3: 100% RDN (100% through nano-urea in three sprays at 15, 30 and 45 DAS); T_4: 100% RDN (50% as basal by urea fertilizer + 50% through nano-urea in one spray at 30 DAS); T_5: 100% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS); T_6: 75% RDN (Through nano-urea in three sprays at 15, 30 and 45 DAS); T_7: 75% RDN (50% as basal by urea fertilizer + 50% through nano-urea in one spray at 30 DAS); T_8: 75% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS); T_9: 50% RDN (Through nano-urea in three sprays at 15, 30 and 45 DAS); T_{10}: 50% RDN (50% as basal by urea fertilizer + 50% through nano-urea in one spray at 30 DAS); T_{11}: 50% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS) were evaluated in randomized block design with three replications. The results of pre soil analysis revealed that the experimental field was low in organic carbon (0.45) and available nitrogen (142.8 kg/ha), medium for available phosphorus (12 kg/ha) and higher in potassium content (254.6 kg/ha). Furthermore, the lowest HCN content of fodder sorghum was recorded with 50% RDN (Through nano-urea in three sprays at 15, 30 and 45 DAS), while the highest crude protein, N, P and K content in sorghum were observed with application of 100% RDN by urea fertilizer (75 kg). Available soil nutrients were found highest with application of 100% RDN by urea fertilizer having highest available nitrogen (145.60 kg/ha), phosphorus (12.88 kg/ha) and potassium (253.60 kg/ha) content. The cost of cultivation was found lowest with control whereas, maximum gross returns (Rs. 81,292/ha), net returns (Rs. 41,167/ha) and B:C (2.03) were found with 100% RDN by urea fertilizer.

Key words: Sorghum, single-cut, fodder, nano urea, productivity, crude protein

Sorghum (*Sorghum bicolor* L.) which is known as camel crop is among one of the five most imperative crop species grown in the world, having multiple commercially important potential uses including food, feed, fodder and fuel in arid and semi-arid regions of the country. It is grown mainly in the states of Punjab, Haryana, Delhi, Uttar Pradesh and adjoining areas of Madhya Pradesh etc. (Harinarayana *et al.*, 2005) under rain fed situation. Forage sorghum and pearl millet serve as alternative to maize in rain fed areas (Bhattarai *et al.*, 2019). It is a warm season and C4 short-day annual crop, which grows best under relatively high temperatures and sunny conditions. Although, India has 535.78 million animals but their productivity in respect of meat and milk yield is very low due to imbalanced and improper feeding as compared to developed countries (Anonymous, 2023). The fodder productivity and quality are major concern for low milk production of India. Only 4.4 % of India’s land is dedicated to fodder crops, with fodder sorghum accounting for 2.3 million hectares. The yearly forage production is 866 metric tonnes, but the annual forage demand is 1706 metric tonnes, which includes 1097 metric tonnes of green fodder and 690 metric tonnes of dry fodder (Anonymous, 2022). India has a net shortage of green fodder of 11.24% and dry fodder of 23.4%. Total green fodder and dry fodder availability is 734.2 and 326.4 metric tonnes against demand of 827.19 and 426.1 metric tonnes, respectively (Roy et al., 2019). Nitrogen management, moisture stress and time of crop harvesting influence the succulency, dry matter accumulation, crude protein content, and other quality criteria of fodder. Sorghum produces HCN, a poisonous and anti-nutritional substance, which can be reduced by proper management of water and fertilizer along with appropriate harvesting time. To overcome these problems, nanotechnology has the potential ability to revolutionize agricultural systems (Saitheja *et al*., 2022) enabling slow and controlled release of nutrient for the plants benefit and ultimately increasing crop production with low environmental impact (Scott and Chen, 2013). Nano fertilizers have been developed to replace conventional fertilizers and found effective and efficient for plant nutrition which increases the production with enhanced fodder quality (Kumar et al., 2021). Nano fertilizers are gaining importance in agriculture in increasing crop yields, enhancing nutrient use efficiency and reducing excessive use of chemical fertilizers. They produced positive effects in terms of crop yield as well as reduced environmental hazards. Nano fertilizers can release nutrients in 40-50 days as compared to synthetic fertilizers in 4-10 days. Additionally, the tolerance of plants has been increased with application of nano fertilizers against biotic and abiotic stresses (Mejias et al., 2021). Nano urea is among one of the imperative approaches in agriculture to enhance crop production, to supply adequate nitrogen by supplementary foliar application and feed the world's fast-growing population (Lal, 2008). The current condition of nitrogen (30-40%), phosphorus (10-20%), and potassium (40-50%) use efficiency is very poor. The use of nano urea can deliver fertilizers that supply release of nitrogen when crops require it, eventually leading to increases in nitrogen use efficiency by decreasing nitrogen leaching along with emissions and long-term incorporation by soil micro-organisms (Kannoj *et al*., 2022). Furthermore, supplemental foliar spray of nano urea is a viable option for dealing with the problem of insufficient nutrient delivery, leaching losses and environmental hazards.

MATERIALS AND METHODS

The field experiment was carried out the during the kharif seasons of 2022 at Forage Section, Department of Genetics & Plant Breeding CCS Haryana Agricultural University, Hisar. Hisar with a sub-tropical and semi-arid climate is situated between 29° 10' N and longitude 75° 46' E Longitude with a height of 215.2 m above mean sea level. The mean average annual rainfall is nearly around 455 mm, maximum and minimum temperature ranged from 27.7 to 36.7 ^{0}C and 20.1 to 28.4 ^{0}C, respectively. The relative humidity during morning was around 84 to 95 % and in evening nearly around 37 to 80 %. A total rainfall of 484.7 mm was received during the crop period. Experimental soil was texturally sandy loam. Soil samples were collected before sowing and after harvesting of the soil from 0-15 cm depth and were subjected to analysis as per standard procedures. The results revealed that the soil was non- saline with EC 0.28 dS/m and pH 7.8. The soil of experimental field was rated low for organic carbon (0.45), available nitrogen (142.8 kg/ha) and medium for available phosphorus (12 kg/ha) and high potassium content (254.6 kg/ha).

Experiment comprising of 11 foliar spray treatments [T_1: Control (No RDN); T_2: 100% RDN by urea fertilizer (75kg); T_3: 100% RDN (100% through nano-urea in three sprays at 15, 30 and 45 DAS); T_4: 100% RDN (50% as basal by urea fertilizer + 50% through nano-urea in one spray at 30 DAS); T_5: 100% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS); T_6: 75% RDN (Through nano-urea in three sprays at 15, 30 and 45 DAS); T_7: 75% RDN (50% as basal by urea fertilizer + 50% through nano-urea in one spray at 30 DAS); T_8: 75% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS); T_9: 50% RDN (Through nano-urea in three sprays at 15, 30 and 45 DAS); T_{10}: 50% RDN (50% as basal by urea fertilizer + 50% through nano-urea in one spray at 30 DAS); T_{11}: 50% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS)] were evaluated in randomized block design with three replications.

Single cut sorghum (HJ 541) was sown with row spacing of 25 cm using 50 kg seed/ha on 27 July 2022 and was harvested at 50% flowering stage. The crop was fertilized as per treatment considering recommended dose of fertilizers (RDF) in forage

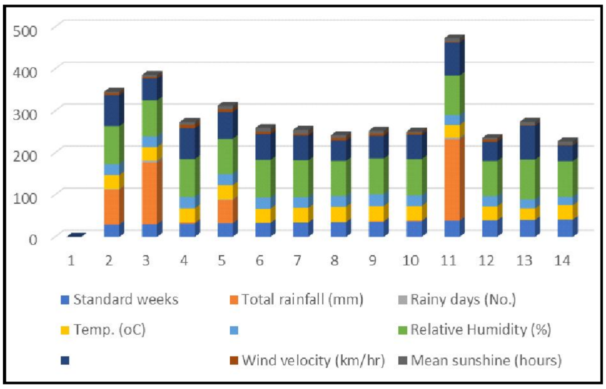

Fig. 1. Mean weekly meteorological data during *kharif* season, 2022.

sorghum (N: 75 kg/ha and P205: 15 kg /ha). The foliar application of nano urea was done with Knapsack sprayer at 15, 30 and 45 DAS as per respective treatments. The nitrogen was supplied through conventional and nano urea, while phosphorus through Single Super Phosphate. Experimental plots were kept weed free throughout the growing season and one hand weeding was done at 30 days after sowing. At the time of harvesting, samples of green fodder were taken from each plot. The samples were sun dried and then oven dried at 70^{o}C till they attained constant weight, grinded to pass through 1 mm sieve. Plant sample of 0.5 g was analyzed for nutrient contents. Per day productivity was calculated by dividing the total yield of crop by the number of crop days. N content was measured by Micro-Kjeldhal (Parkinson and Allen, 1975), P content by Olsen's method (Olsen et al., 1954) and K content by Flame photometric method (Richards, 1954) in plant. The crude protein content in samples was worked out by multiplying % age nitrogen with factor 6.25 (A.O.A.C., 2005). The samples for HCN estimation were taken below the top collar leaf at 30 DAS from the upper portion of the plant and it was estimated as per Hogg and Ahlgren (1942). The HCN amount was determined by calibrating the absorbance at 520 nm with HCN ($5^{-40}\times10^{-3}$ g/l) in water as standard on fresh weight basis. Analysis of data was done by using online statistical package OPSTAT developed by Sheoran *et al.* (1998).

RESULTS AND DISCUSSION

Per day productivity of green and dry fodder

The effects of nitrogen management practices on per day productivity are presented in Table 1 and Fig. 2. Maximum per day productivity of green fodder (6.23 q/ha) and dry fodder (1.66 q/ha) yield were recorded with T_2 which were statistically at par with T_5 treatment. Per day productivity revealed the rate of crop growth *viz.,* plant height, number of leaves and dry matter accumulation. It was significantly influenced by nitrogen management practices. Maximum per day productivity of green (6.3 q/ha) and dry fodder (1.66 q/ha) yield were recorded with the application of 100% RDN by urea fertilizer which were statistically at par with T5 treatment. The higher per day productivity indicates that with RDF application, there was significant increase in fodder productivity. Satpal *et al.* (2020) and Satpal *et al.*

TABLE 1

Per day productivity of green, dry fodder yield and quality of forage sorghum as influenced by nitrogen management practices

Treatments	Per day productivity of GF (q/ha)	Per day productivity of DF (q/ha)	HCN content at 30 DAS (ug/g)	Crude protein (%)
T1: Control (No RDN)	3.29	0.89	60.2	7.45
T2: 100% RDN by urea fertilizer (75 kg)	6.23	1.66	72.5	9.23
T3: 100% RDN (100% through nano-urea in three sprays at 15, 30 and 45 DAS)	4.97	1.31	66.4	8.74
T4: 100% RDN (50% as basal by urea fertilizer +50% through nano-urea in one spray at 30 DAS)	5.48	1.41	67.1	9.04
T5: 100% RDN (50% as basal by urea fertilizer+50% through nano-urea in two sprays at 30 and 45 DAS)	5.64	1.56	68.4	9.16
T6: 75% RDN (Through nano-urea in three sprays at 15, 30 and 45 DAS)	4.59	1.20	65.5	8.20
T7: 75% RDN (50% as basal by urea fertilizer+50% through nano-urea in one spray at 30 DAS)	5.11	1.32	66.4	8.34
T8: 75% RDN (50% as basal by urea fertilizer+50% through nano-urea in two sprays at 30 and 45 DAS)	5.25	1.37	66.9	8.66
T9: 50% RDN (Through nano-urea in three sprays at 15, 30 and 45 DAS)	4.04	1.09	63.0	7.70
T10: 50% RDN (50% as basal by urea fertilizer+50% through nano-urea in one spray at 30 DAS)	4.55	1.18	63.5	7.96
T11: 50% RDN (50% as basal by urea fertilizer+50% through nano-urea in two sprays at 30 and 45 DAS)	4.68	1.25	64.2	8.07
S.E m±	0.24	0.20	1.82	0.04
C.D. at 5%	0.72	0.07	5.45	0.11

(2016) also reported increase in per day productivity of green fodder and dry matter with increasing recommended dose of fertilizers.

Fodder quality studies

The effects of nitrogen management practices on HCN content are presented in Table 2. HCN content was found below critical limit (200 ug/g) in all the treatments. It was influenced significantly by nitrogen management practices and was recorded highest with the application of 100% RDN by urea fertilizer (72.5 ug/l) which was statistically at par with T_4 and T_5 at 30 DAS. Increase in HCN content was mainly due to increase in nitrogen uptake with appropriate supply of nitrogen at different stages of crop growth which ultimately contribute towards the synthesis of HCN. Nabi *et al.* (2022) and Satpal *et al.* (2018) also reported increase in HCN content with increase in levels of nitrogen fertilizer.

Crude protein content (9.23%) was recorded highest with the application of 100% RDN by urea fertilizer which was statistically at par with T_5 as presented in table 2. Increase in crude protein content of forage sorghum was directly associated with nitrogen supply which contributed in the synthesis of protein. Additionally, enhancement in amino acid synthesis resulted increase in crude protein content with higher fertilizer levels reported by (Yadav *et al.*, 2019; Choudhary and Prabhu, 2014). As crude protein content is computed by multiplying nitrogen content of the plant with 6.25, increased nitrogen supply ultimately increased crude protein content (Satpal *et al.*, 2018). Similar results are reported by several researchers Rajesh *et al.* (2022), Choudhary and Prabhu (2014), Muhammad *et al.* (2011) and Bhilare *et al.* (2002). Likewise, Saklani and Pal (2022) also reported significantly higher values of crude protein with 125% RDN than 125% RDN along with nano urea. In contrast, Rani *et al.* [2019] observed highest protein content with reduction in RDN by 2.5 times through nano fertilizer.

Soil moisture content

The data pertaining to soil moisture content of forage sorghum as influenced by nitrogen management practices is depicted in Table 4. The soil moisture content was not affected significantly by nitrogen management practices. Although, it was found numerically higher under control treatment before each foliar spray at different intervals, and decreased steadily with advancement of crop growth. As the plant growth increases it requires more water for carrying out

TABLE 2

Soil moisture content before foliar spray as influenced by nitrogen management practices

Treatments	Available soil moisture before spray (%)		
	15 DAS	30 DAS	45 DAS
T1: Control (No RDN)	13.54	12.42	11.61
T2: 100% RDN by urea fertilizer (75kg)	13.49	11.41	8.99
T3: 100% RDN (100% through nano-urea in three sprays at 15, 30 and 45 DAS)	13.33	12.09	10.54
T4: 100% RDN (50% as basal by urea fertilizer + 50% through nano-urea in one spray at 30 DAS)	13.35	11.39	9.84
T5: 100% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS)	13.43	11.28	9.37
T6: 75% RDN (Through nano-urea in three sprays at 15, 30 and 45 DAS)	13.45	11.74	10.80
T7: 75% RDN (50% as basal by urea fertilizer + 50% through nano-urea in one spray at 30 DAS)	12.88	11.21	10.24
T8: 75% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS)	13.44	11.15	10.19
T9: 50% RDN (Through nano-urea in three sprays at 15, 30 and 45 DAS)	12.80	12.29	11.27
T10: 50% RDN (50% as basal by urea fertilizer + 50% through nano-urea in one spray at 30 DAS)	13.15	12.05	10.92
T11: 50% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS)	12.91	11.89	10.82
S.E m±	0.24	0.13	0.12
C.D. at 5%	NS	NS	NS

cellular activities *viz.*, photosynthesis and transpiration. When irrigation water was deficient in fulfilling cellular activities of plants, they absorb water hold by soil particles and resulted in depletion of soil moisture.

Nutrient content of sorghum

The data pertaining to N, P and K content of forage sorghum as influenced by nitrogen management practices is depicted in Table 5. The highest N (1.48%), P (0.217%) and K (1.30%) content were recorded with 100% RDN by urea fertilizer which was statistically at par with T_5. Accumulation of nutrients depends on their concentration at cellular level and dry matter production. Proper supply of nutrients at vegetative growth contributes towards higher uptake and accumulation of nutrients in dry matter (Chaudhary *et al.*, 2018). Improved nutritional level in root and plant system combined with increased metabolic activity at cellular level resulted in increased nutrient uptake and their accumulation in plant. This contributes in greater translocation of nutrients to grain and straw (Sharma *et al.*, 2022). Similar results are reported by Rajesh *et al.* (2022) and Sumeriya *et al.* (2007). In contrast, Rani *et al.* (2019) reported significant increase in content and uptake of N, P, K in grain and straw with application of nano nitrogenous fertilizer in sorghum, whereas Kannoj *et al.* (2022) revealed that combined application of 50% conventional urea along with 50% of nano urea fertilizer significantly increased the nutrient content and uptake of black wheat.

Available nutrients

Data pertaining to available soil nutrients in table 6 revealed that available phosphorus and potassium content of soil was not affected significantly by nitrogen management practices after harvest of crop. Whereas, available nitrogen was affected significantly by nitrogen management practices and highest available nitrogen (145.60 kg/ha) was observed with application of 100% RDN by urea fertilizer which was statistically at par with T_5 treatment. The increase in available nitrogen in the soil after harvesting was probably due to the fact that plants can utilize only 50% of applied nitrogenous fertilizers in ideal conditions. Al-Ethawi and Salem (2019) and Rezvan and Edalatifard (2012) also reported similar results. However, Rathore *et al.* (2022) observed improvement

TABLE 3

N, P, K content and available soil nutrients of forage sorghum after harvest as influenced by nitrogen management practices

Treatments	N, P, K content (%)			Available soil nutrients after harvest (kg/ha)		
	N	P	K	N	P	K
T1: Control (No RDN)	1.19	0.141	1.10	134.88	11.85	246.28
T2: 100% RDN by urea fertilizer (75kg)	1.48	0.217	1.30	145.60	12.88	253.60
T3: 100% RDN (100% through nano-urea in three sprays at 15, 30 and 45 DAS)	1.40	0.190	1.24	138.50	12.39	251.59
T4: 100% RDN (50% as basal by urea fertilizer+50% through nano-urea in one spray at 30 DAS)	1.45	0.201	1.25	140.50	12.59	251.50
T5: 100% RDN (50% as basal by urea fertilizer+50% through nano-urea in two sprays at 30 and 45 DAS)	1.47	0.206	1.29	141.54	12.61	252.46
T6: 75% RDN (Through nano-urea in three sprays at 15, 30 and 45 DAS)	1.31	0.180	1.21	137.32	12.22	249.41
T7: 75% RDN (50% as basal by urea fertilizer+50% through nano-urea in one spray at 30 DAS)	1.33	0.194	1.23	138.79	12.49	250.53
T8: 75% RDN (50% as basal by urea fertilizer+50% through nano-urea in two sprays at 30 and 45 DAS)	1.39	0.197	1.24	139.37	12.56	250.62
T9: 50% RDN (Through nano-urea in three sprays at 15, 30 and 45 DAS)	1.23	0.165	1.17	136.45	12.34	251.51
T10: 50% RDN (50% as basal by urea fertilizer+50% through nano-urea in one spray at 30 DAS)	1.27	0.172	1.21	137.58	12.36	250.51
T11: 50% RDN (50% as basal by urea fertilizer+50% through nano-urea in two sprays at 30 and 45 DAS)	1.29	0.178	1.22	138.44	12.37	249.54
S.E m±	0.01	0.004	0.01	1.34	0.14	0.16
C.D. at 5%	0.02	0.012	0.04	4.55	NS	NS

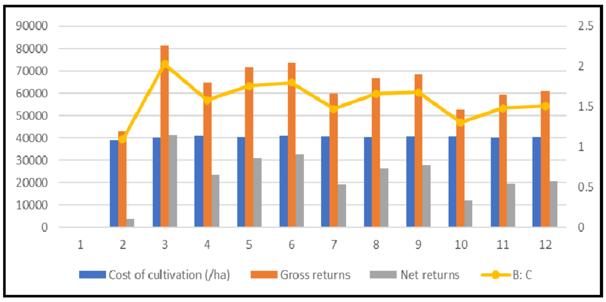

Fig. 2. Economics of fodder sorghum.

in the physical and chemical properties of soil with 100% RDF along with nano urea application. In contrast, Ajithkumar *et al.* (2021) observed improvement in soil fertility when recommended dose of nitrogen was applied through the foliar application of nano fertilizers.

ECONOMICS

Economics of nitrogen management practices was worked out by considering prevailing rates of inputs, labour charges, other expenditures and market price of produce *i.e.*, green fodder yield. The cost of cultivation was found highest in 100% RDN applied through nano-urea in three sprays at 15, 30 and 45 DAS (‘41,083), whereas lowest in control (‘39,225) treatment. This was due to higher cost associated with foliar application of nano urea. The maximum gross returns (₹ 81,292), net returns (₹ 41,167) and B: C (2.03) were found with 100% RDN by urea fertilizer followed by 100% RDN applied through 50% as basal by urea fertilizer along with 50% through nano-urea in two sprays at 30 and 45 DAS

(Rs. 73,567, Rs. 32,655 and 1.80, respectively). The highest green fodder yield and lower cost of cultivation contribute towards highest gross returns, net returns and B: C. Chavan *et al.* (2023), Rajesh *et al.* (2022), Srivani *et al.* (2022), Satpal *et al.* (2020) and Somashekar *et al.* (2015) also showed similar results. Furthermore, application of 100% or 80% RDN with foliar spray of nano urea 4ml/l proved best in terms of profitability in green gram (Saitheja *et al.*, 2022). Samui *et al.* (2022) observed that use of 100% RDN along with foliar spray of nano-urea 4ml/L might be an appropriate strategy for higher returns. In contrast, Ajithkumar *et al.* (2022) computed that application of 50% N, 100% PK and 0% Zinc along with 2 sprays of IFFCO nano N at 4ml/l mixed with IFFCO Sagarika at 2 ml/l produced maximum B: C, whereas Kannoj *et al.* (2022) observed improvement in economic returns with combined application of 50% conventional urea along with 50% nano urea fertilizer in black wheat.

Based on results of investigation, it was concluded that among different nitrogen management practices, combined application of conventional and nano urea (100% RDN: 50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45

TABLE 4
Economics of forage sorghum as influenced by nitrogen management practices

Treatments	Cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	B: C
T1: Control (No RDN)	39225	42908	3683	1.09
T2: 100% RDN by urea fertilizer (75kg)	40125	81292	41167	2.03
T3: 100% RDN (100% through nano-urea in three sprays at 15, 30 and 45 DAS)	41083	64792	23709	1.58
T4: 100% RDN (50% as basal by urea fertilizer + 50% through nano-urea in one spray at 30 DAS)	40511	71475	30964	1.76
T5: 100% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS)	40912	73567	32655	1.80
T6: 75% RDN (Through nano-urea in three sprays at 15, 30 and 45 DAS)	40827	59933	19106	1.47
T7: 75% RDN (50% as basal by urea fertilizer + 50% through nano-urea in one spray at 30 DAS)	40289	66742	26453	1.66
T8: 75% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS)	40689	68533	27844	1.68
T9: 50% RDN (Through nano-urea in three sprays at 15, 30 and 45 DAS)	40611	52700	12089	1.30
T10: 50% RDN (50% as basal by urea fertilizer + 50% through nano-urea in one spray at 30 DAS)	40066	59375	19309	1.48
T11: 50% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS)	40466	61033	20567	1.51

DAS) can be a better substitute to application of 100% RDN (75 N kg/ha) applied through urea fertilizer (half as basal and remaining half at 30 DAS) to get the comparative results *viz.*, productivity, fodder quality, soil quality and economics of single cut forage sorghum. Furthermore, it improves available nitrogen in soil.

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