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EFFECT OF NANO-UREA ON SUSTAINABLE PRODUCTION OF FODDER SORGHUM

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SUMMARY

The field experiment was conducted during *kharif* season of 2022 at Forage Research Farm of Department of Genetics & Plant Breeding, CCS Haryana Agricultural University, Hisar to study the effect of nano urea on sorghum for sustainable fodder production. The experiment was laid out in randomized block design keeping eleven treatments consisting of nitrogen fertilizers combinations of conventional and nano urea with three replications. There was significant difference among treatments in respect of growth, green and dry fodder yield of single cut forage sorghum. The maximum plant height (248.4 cm), number of leaves (14), leaf: stem (0.29), dry matter accumulation (153.62 g), leaf area index (7.55), green fodder yield (541.9 q/ha) and dry fodder yield (144.1 q/ha) were recorded with the application of 100% RDN by urea fertilizer (75 kg) as followed by 100% RDN: 50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS.

Key words: Sorghum, single-cut, fertilizer, fodder yield, nano-urea

India has become the most populated country in the world and most of the population depends on agriculture sector where animal health is very important. Livestock sector contributes 29.35% of the agricultural GDP and 5.2% of total GDP (Anonymous, 2020). 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. Fodders are one of the least expensive sources of nutrition as they not only meet the requirement of bulk to be fed to cattle, but also provide desired amount of protein, minerals, vitamins as well as energy to a large extent. 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 a warm season and C_4 short-day annual crop, which grows best under relatively high temperatures and sunny conditions. 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. The yearly forage production is 866 metric tonnes, but the annual forage demand is 1706 metric tonnes, which includes 1097 metric tonnes of green forage 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). 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). 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). The use of nano urea can deliver fertilizers that supply 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).

MATERIALS AND METHODS

The field experiment was conducted during *kharif* season of 2022 at Forage Research Farm, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar (Haryana) situated at 29°1¢N Latitude and 75°46¢ E Longitude with a height of 215.2 meters above mean sea level. The soil of experimental field was low in available nitrogen (142.8 kg/ha), medium in available phosphorus (12 kg/ha) and very high in available potassium (254.6 kg/ha) with 0.45% organic carbon. It was moderately alkaline in reaction with pH 7.8 and electrical conductivity of 0.28 dS/m. The experiment was conducted in randomized block design (RBD) with 11 treatments [T1: Control (No RDN); T2: 100% RDN by urea fertilizer (75kg); T3: 100% RDN (100% through nano-urea in three sprays at 15, 30 and 45 DAS); T4: 100% RDN (50% as basal by urea fertilizer + 50% through nano-urea in one spray at 30 DAS); T5: 100% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS); T6: 75% RDN (Through nano-urea in three sprays at 15, 30 and 45 DAS); T7: 75% RDN (50% as basal by urea fertilizer + 50% through nano-urea in one spray at 30 DAS); T8: 75% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS); T9: 50% RDN (Through nano-urea in three sprays at 15, 30 and 45 DAS); T10: 50% RDN (50% as basal by urea fertilizer + 50% through nano-urea in one spray at 30 DAS); T11: 50% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS)] and each treatment was replicated thrice. For sowing of sorghum 50 kg/ha seed rate of variety HJ 541 was used. Seeds were sown in rows at 25 cm apart on 27th July 2022. The crop was fertilized as per treatments considering recommended dose of fertilizers (RDF) in forage sorghum (N: 75 kg/ha and P_2O_5: 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.

A total rainfall of 484.7 mm was received during the cop season. To supplement the rainfall two irrigations were applied during crop life cycle. Pre-emergence application of atrazine at 500 g/ha was used for weed control along with one hand weeding at 30 days after sowing (DAS). One-meter row length was marked for counting plant population and five random plants were selected from each plot for recording data of plant height, number of leaves, dry matter

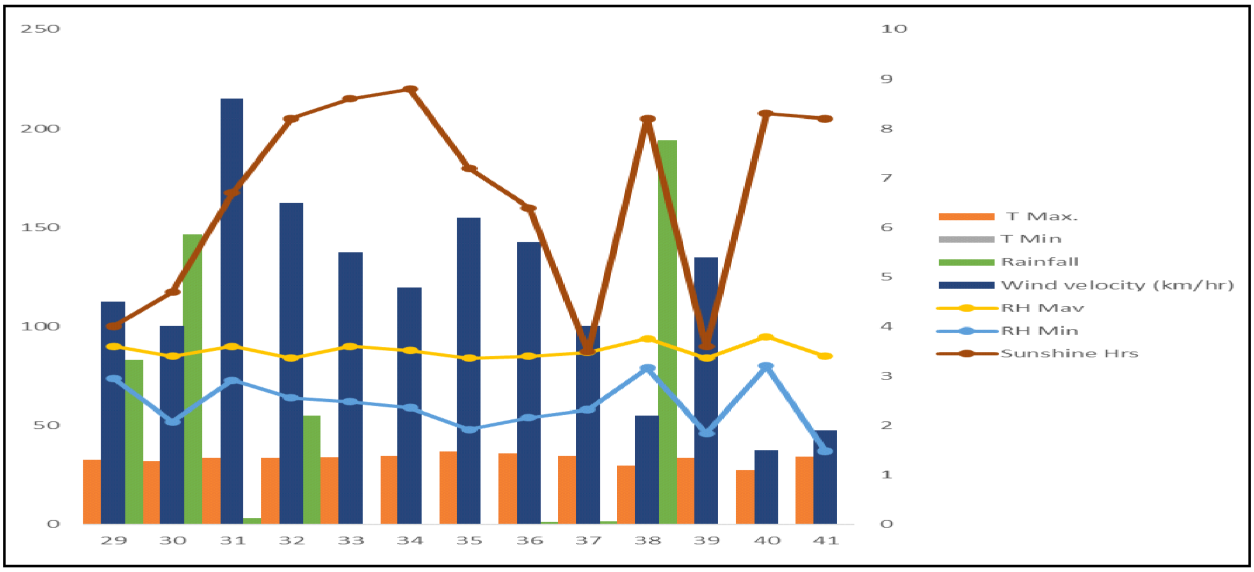

Fig. 1. Weekly mean weather parameters during crop season 2022.

accumulation and leaf: stem. Leaf area index was calculated directly by taking sample of foliage from a plant canopy, measuring the green leaf area and dividing it by the ground area covered by each plant. Green fodder yield from net plot in kg/ha was recorded and converted into q/ha. A known quantity of green fodder sample was kept in oven for drying at 63°C for 72 h and final weight was recorded to calculate dry fodder yield.

RESULTS AND DISCUSSION

Plant height

The effects of nitrogen management practices on plant height of forage sorghum at 20, 40, 60 DAS and at harvest are presented in Table 1. The perusal of plant height data recorded at various crop growth periods revealed that the plant height increased from 20 DAS till maturity irrespective of the treatments. The increase in plant height was maximum during 40 to 60 DAS and thereafter it slowed down. There was no significant difference in plant height at 20 and 40 DAS, although it was numerically higher with 100% RDN by urea fertilizer. However, plant height was influenced significantly by nitrogen management practices at 60 DAS and harvest. The plant height was recorded highest with the application of 100% RDN by urea fertilizer (T2) at 60 DAS (198.2 cm) and at harvest (248.4 cm) which was statistically at par with 100% RDN (50% as basal by urea fertilizer + 50% through nano-urea in one spray at 30 DAS (T4) and 100% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS (T5) treatments. The higher value of plant height with application of 100% RDN by urea fertilizer might be due to positive impact of nutrients which were available in optimum amount at all growth periods. Furthermore, it was attributed to more availability and uptake of nitrogen which accelerated the process of protoplasm synthesis, cell division, expansion, vigorous plant growth (Chavan *et al*., 2023; Kashyap and Bainade, 2022), chlorophyll formation, photosynthetic rate, dry matter production (Srivani *et al*., 2022) and protein synthesis (Samanta *et al*., 2022).

Number of leaves per plant

The effects of nitrogen management practices on number of leaves per plant of forage sorghum at

TABLE 1

Plant height and number of leaves per plant of forage sorghum as influenced by nitrogen management practices.

Treatments	Plant height (cm)				Number of leaves per plant			
	20 DAS	40 DAS	60 DAS	At harvest	20 DAS	40 DAS	60 DAS	At harvest
T_1: Control (No RDN)	25.6	60.2	125.3	152.9	4.66	8.66	9.22	10.33
T_2: 100% RDN by urea fertilizer (75 kg)	36.9	85.4	198.2	248.4	5.89	10.00	12.33	14.00
T_3: 100% RDN (100% through nano-urea in three sprays at 15, 30 and 45 DAS)	30.6	72.2	160.2	205.0	5.15	9.40	11.18	12.22
T_4: 100% RDN (50% as basal by urea fertilizer+50% through nano-urea in one spray at 30 DAS)	34.7	80.9	180.2	225.7	5.42	9.65	11.77	13.56
T_5: 100% RDN (50% as basal by urea fertilizer+50% through nano-urea in two sprays at 30 and 45 DAS)	35.3	80.1	189.0	232.2	5.55	9.57	12.00	13.67
T_6: 75% RDN (Through nano-urea in three sprays at 15, 30 and 45 DAS)	29.6	70.1	160.9	198.1	5.00	9.33	11.03	12.00
T_7: 75% RDN (50% as basal by urea fertilizer+50% through nano-urea in one spray at 30 DAS)	33.5	74.7	164.5	206.0	5.22	9.50	11.07	12.33
T_8: 75% RDN (50% as basal by urea fertilizer+50% through nano-urea in two sprays at 30 and 45 DAS)	32.9	73.1	165.1	210.2	5.37	9.46	11.50	12.81
T_9: 50% RDN (Through nano-urea in three sprays at 15, 30 and 45 DAS)	28.3	67.4	157.8	192.8	5.05	9.22	10.61	11.11
T_{10}: 50% RDN (50% as basal by urea fertilizer+50% through nano-urea in one spray at 30 DAS)	30.8	71.4	159.7	195.9	5.11	9.44	10.78	12.11
T_{11}: 50% RDN (50% as basal by urea fertilizer+50% through nano-urea in two sprays at 30 and 45 DAS)	30.7	70.7	160.8	200.2	5.33	9.40	11.00	12.30
S. Em±	2.4	4.7	10.2	12.5	0.41	0.67	0.71	0.86
C. D. (P=0.05)	NS	NS	30.3	37.1	NS	NS	NS	NS

20, 40, 60 DAS and at harvest are presented in Table 1. Number of leaves increased with the advancement of crop age irrespective of different treatments. There was no significant difference in number of leaves at 20, 40, 60 DAS and at harvest. Although, the number of leaves at 20 DAS (5.89), 40 DAS (10.00), 60 DAS (12.33) and at harvest (14.00) were found numerically higher with 100% RDN by urea fertilizer (T2). The increase in number of leaves per plant might be associated with higher availability of nitrogen which is constitutive of chlorophyll, primary absorber of light energy required for photosynthesis. Increase in plant height leads to higher numbers of nodes per plant which ultimately contributed towards more leaves per plant (Srivani *et al*., 2022). Furthermore, this may be due to photosynthetic enzymes which largely depend on nitrogen element and under adequate supply of nitrogen fodder sorghum significantly increased its growth and photosynthetic rate which finally increases number of functional leaves (Kaur and Satpal, 2019). These results are in conformity with the findings of Chavan *et al.* (2023), Chaudhary *et al.* (2018) and Satpal *et al.* (2016).

Leaf area index

The effects of nitrogen management practices on leaf area index of forage sorghum at 20, 40, 60 DAS and at harvest are presented in Table 2. Leaf area index was not influenced significantly by different treatments at 40 DAS, although it was influenced significantly at 60 DAS and harvest. The leaf area index at 60 DAS (4.44) and at harvest (7.55) was recorded highest with 100% RDN by urea fertilizer (T_2) which was statistically at par with 100% RDN (100% through nano-urea in three sprays at 15, 30 and 45 DAS (T_3), 100% RDN (50% as basal by urea fertilizer + 50% through nano-urea in one spray at 30 DAS (T_4), 100% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS (T_5), 75% RDN (50% as basal by urea fertilizer + 50% through nano-urea in one spray at 30 DAS (T_7) and 75% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS (T_8) treatments at 60 DAS and 100% RDN (50% as basal by urea fertilizer + 50% through nano-urea in one spray at 30 DAS (T_4) and 100% RDN (50% as

TABLE 2

Leaf area index and leaf: stem of forage sorghum as influenced by nitrogen management practices

Treatments	Leaf area index			Leaf: stem		
	40 DAS	60 DAS	At harvest	40 DAS	60 DAS	At harvest
T_1: Control (No RDN)	1.55	3.22	4.83	0.32	0.25	0.17
T_2: 100% RDN by urea fertilizer (75 kg)	1.58	4.44	7.55	0.48	0.37	0.29
T_3: 100% RDN (100% through nano-urea in three sprays at 15, 30 and 45 DAS)	1.57	4.01	6.40	0.40	0.31	0.24
T_4: 100% RDN (50% as basal by urea fertilizer+50% through nano-urea in one spray at 30 DAS)	1.57	4.33	7.19	0.45	0.34	0.26
T_5: 100% RDN (50% as basal by urea fertilizer+50% through nano-urea in two sprays at 30 and 45 DAS)	1.57	4.37	7.21	0.43	0.35	0.27
T_6: 75% RDN (Through nano-urea in three sprays at 15, 30 and 45 DAS)	1.56	3.90	6.16	0.39	0.30	0.22
T_7: 75% RDN (50% as basal by urea fertilizer+50% through nano-urea in one spray at 30 DAS)	1.57	4.06	6.52	0.42	0.31	0.23
T_8: 75% RDN (50% as basal by urea fertilizer+50% through nano-urea in two sprays at 30 and 45 DAS)	1.56	4.15	6.62	0.41	0.32	0.24
T_9: 50% RDN (Through nano-urea in three sprays at 15, 30 and 45 DAS)	1.55	3.76	6.00	0.37	0.29	0.21
T_{10}: 50% RDN (50% as basal by urea fertilizer+50% through nano-urea in one spray at 30 DAS)	1.56	3.82	6.03	0.39	0.31	0.21
T_{11}: 50% RDN (50% as basal by urea fertilizer+50% through nano-urea in two sprays at 30 and 45 DAS)	1.56	3.84	6.32	0.38	0.31	0.22
S. Em±	0.00	0.18	0.26	0.02	0.02	0.01
C. D. (P=0.05)	NS	0.52	0.77	0.07	0.05	0.03

basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS (T_5) treatments at harvest. Leaf area index is a measure of total area of leaves over ground area of plant and is directly related to the amount of light energy that can be intercepted by the plants. Nitrogen as an essential nutrient will play role in expansion of leaf and also in chlorophyll formation (Ilmudeen *et al*., 2022). Moreover, the higher LAI might be due to a greater number of leaves per plant which resulted in better light interception that ultimately enhanced the rate of photosynthesis. The results are in close collaboration with Chavan *et al*. (2023), Samanta *et al*. (2022), Paul and Singh (2019) and Singh and Sumeriya (2010).

Leaf: Stem

The effects of nitrogen management practices on leaf: stem of forage sorghum at 20, 40, 60 DAS and at harvest are presented in Table 2. The leaf: stem was influenced significantly by different treatments at 40, 60 DAS and at harvest. It was recorded highest with 100% RDN by urea fertilizer (T2) at 40 (0.48), 60 DAS (0.37) and at harvest (0.29) which was statistically at par with 100% RDN (50% as basal by urea fertilizer + 50% through nano-urea in one spray at 30 DAS (T4), 100% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS (T5), 75% RDN (50% as basal by urea fertilizer + 50% through nano-urea in one spray at 30 DAS (T7) and 75% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS (T8) treatments at 40 DAS, while with 100% RDN (50% as basal by urea fertilizer + 50% through nano-urea in one spray at 30 DAS (T4), 100% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS (T5) and 75% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS (T8) treatments at 60 DAS and 100% RDN (50% as basal by urea fertilizer + 50% through nano-urea in one spray at 30 DAS (T4) and 100% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS (T5) at harvest. It was attributed to rapid expansion of leaves that could intercept and utilize more solar energy in production of photosynthates with increasing nitrogen levels, which resulted in higher meristematic activity. Furthermore, this might also be due to favorable effect of nitrogen on cell division and cell elongation which could have resulted in a greater number of leaves for a longer period of time (Somashekar *et al*., 2015). Similar results are also found by Satpal *et al.* (2020), Kaur and Satpal (2019), Yadav *et al.* (2019) and Crawford *et al.* (2018).

Dry matter accumulation

Dry matter accumulation in sorghum increased progressively with the crop age, maximum being during 40 to 60 DAS in all the treatments. There was no significant difference in dry matter accumulation at 20 and 40 DAS, although it was influenced significantly at 60 DAS and harvest. The dry matter accumulation was recorded highest with 100% RDN by urea fertilizer (T2) at 60 DAS (131.10 g) and at harvest (153.62 g) which was statistically at par with 100% RDN (50% as basal by urea fertilizer + 50% through nano-urea in one spray at 30 DAS (T4) and 100% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS (T5) treatments. This increase in dry matter was due to synergistic effect of increase in plant height and number of leaves. Better crop growth and photosynthetic activity depends on efficient assimilating area with appropriate supply of nitrogen at different growth stages led to proper supply of photosynthates which contribute in higher rate of dry matter production per plant. Furthermore, as nitrogen is involved in processes like cell division and expansion, its appropriate supply ultimately increases photosynthetic rate and overall growth. These results are in conformity with findings of Chavan *et al.* (2023) and Chaudhary *et al.* (2018) who also observed higher values of dry matter with higher nitrogen levels.

Green and dry fodder yield

Data in respect of green and dry fodder yield of forage sorghum as influenced by nitrogen management practices is presented in Table 3. The fodder yield is the main criteria for evaluating the efficiency of various treatments as their ultimate effects are reflected in the form of fodder yield. It is a function of growth parameters *viz.,* plant height, number of leaves and dry matter accumulation. Green and dry fodder yield were significantly influenced by different nano urea treatments. Maximum green fodder (541.9 q/ha) and dry fodder (144.1q/ha) yield were recorded with 100% RDN by urea fertilizer (T2) which were statistically at par with 100% RDN (50% as basal by urea fertilizer + 50% through nano-urea in two sprays at 30 and 45 DAS (T5) treatment. Nitrogen is an essential component of plant tissue and plays vital role

TABLE 3
The effects of nitrogen management practices on yield and dry matter accumulation of forage sorghum.

Treatments	Yield (q/ha)		Dry matter accumulation (g/plant)			
	Green fodder	Dry fodder	20 DAS	40 DAS	60 DAS	At harvest
T_1: Control (No RDN)	286.1	77.3	15.53	35.88	72.42	81.87
T_2: 100% RDN by urea fertilizer (75 kg)	541.9	144.1	17.87	53.78	131.10	153.62
T_3: 100% RDN (100% through nano-urea in three sprays at 15, 30 and 45 DAS)	431.9	114.3	16.12	47.00	109.90	112.08
T_4: 100% RDN (50% as basal by urea fertilizer+50% through nano-urea in one spray at 30 DAS)	476.5	122.3	17.37	50.92	118.05	140.07
T_5: 100% RDN (50% as basal by urea fertilizer+50% through nano-urea in two sprays at 30 and 45 DAS)	490.4	133.4	17.27	49.78	120.15	148.25
T_6: 75% RDN (Through nano-urea in three sprays at 15, 30 and 45 DAS)	399.6	104.3	15.78	45.50	106.47	108.37
T_7: 75% RDN (50% as basal by urea fertilizer+50% through nano-urea in one spray at 30 DAS)	444.9	114.4	16.45	48.77	110.08	119.83
T_8: 75% RDN (50% as basal by urea fertilizer+50% through nano-urea in two sprays at 30 and 45 DAS)	456.9	119.4	16.67	47.33	111.57	121.33
T_9: 50% RDN (Through nano-urea in three sprays at 15, 30 and 45 DAS)	351.3	95.1	15.67	44.75	102.55	106.43
T_{10}: 50% RDN (50% as basal by urea fertilizer+50% through nano-urea in one spray at 30 DAS)	395.8	102.4	16.15	49.53	107.00	110.17
T_{11}: 50% RDN (50% as basal by urea fertilizer+50% through nano-urea in two sprays at 30 and 45 DAS)	406.9	108.5	16.18	49.43	108.57	111.13
S. Em±	21.1	5.8	1.01	2.91	4.48	6.16
C. D. (P=0.05)	62.6	17.3	NS	NS	13.32	18.30

in cell division and cell elongation which reflected its cumulative effect on different growth parameters *viz.,* plant height, number of functional leaves, leaf: stem and dry matter accumulation (Srivani *et al.,* 2022). However, higher fodder yield with combined use of conventional urea and nano urea at 100% RDF will be due to slow release of nutrients to enhance the nutrient use efficiency while preventing the loss of nutrients to the environment. These results are in conformity with findings of Chavan *et al.* (2023), Rajesh *et al.* (2022), Munagilwar *et al.* (2020), Kubsad (2018) and Singh *et al.* (2012) in different crops. In contrast, Kumar *et al.* (2020) observed significantly higher yields of different crops with 50% reduction in nitrogen along with two sprays of Nano-N.

CONCLUSION

Based on results of one year investigation, it was concluded that among different nitrogen management practices combined application of conventional and nano urea (100% RDN: 50% nitrogen as basal through urea fertilizer + 50% nitrogen through nano-urea in two sprays at 30 and 45 DAS) can be a comparable 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.,* growth parameters and green and dry fodder yield of single cut forage sorghum. Furthermore, it improves available nitrogen in soil also.

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