Forage Res., **50**(3) : pp. 267-271 (2024) **http://forageresearch.in**

FODDER QUALITY, NUTRIENT CONTENT AND UPTAKE OF SORGHUM AS INFLUENCED BY FOLIAR APPLICATION OF NITROGEN BASED FORMULATIONS

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(Received : 1 November 2024; Accepted : 26 December 2024)

SUMMARY

A field experiment was conducted to assess the effect of foliar application of nitrogen-based formulations on quality and yield of fodder sorghum during summer 2022 at Forage Section Research Farm, Department of Genetics & Plant Breeding, CCS Haryana Agricultural University, Hisar (India). The experiment was laid out in randomized block design with fourteen treatments and replicated thrice. Among all the treatments, maximum green fodder yield (445.4 q/ha) was recorded with the application of T_{14} (nano-urea spray @ 0.6% at 35 DAS and 50 DAS), which was on a par with T_{11}, T_{12} and T_{13}. At harvest, significantly higher nutrient uptake (N, P and K) 202.79, 25.72, 161.81 kg/ha and crude protein 9.94 % were recorded with foliar application of nano-urea @ 0.6% at 35 DAS (days after sowing) and 50 DAS, which was on a par with T_{11} (one nano-urea spray @ 0.4% at 35 DAS), T_{12} (two nano-urea spray @ 0.4% at 35 and 50 DAS) and T_{13} (one nano-urea spray @ 0.6% at 35 DAS) when RDF (recommended dose of fertilizer) was also applied. The HCN content across all treatments was non-significant at 30 DAS. However, the lowest HCN value (89.56 ppm) was observed in the treatment with absolute control (No RDF).

Key words: Sorghum, fodder yield, foliar spray, nano-urea, nutrient uptake, HCN and proline content

Sorghum, a key cereal fodder crop from the Poaceae family, is widely grown in arid and semi-arid regions due to its exceptional drought tolerance. It is primarily cultivated for fodder, grain, and ethanol production (Devi *et al*., 2018). Single-cut sorghum contributes to 23.1% of all sorghum varieties (Prabhakar Babu, 2018), and while it has a short life cycle, its high biomass yield (Satpal *et al*., 2020) makes it a significant crop. As a warm-season annual grass that thrives under short-day conditions using the C_4 photosynthetic pathway, sorghum is one of the top five globally cultivated cereal species. Its diverse uses include food, feed, fuel, fiber, and fermentation, making it economically vital worldwide. In India, with a livestock population of 536 million (Anonymous, 2020) and a green fodder shortage of 11.3% (Roy *et al*., 2019), drought-tolerant fodder crops like sorghum are crucial in addressing fodder security. Given its resilience to drought, fodder sorghum is particularly valuable during summer months when green fodder is scarce. However, the success of sorghum cultivation depends on proper fertilization and selecting suitable cultivars. Balanced fertilization plays a crucial role in improving forage yields under moisture stress conditions, particularly focusing on the right balance of primary nutrients (NPK) (Tokas *et al*., 2021).

Nutrient use efficiency for nitrogen, phosphorus, and potassium remains low - around 30-40% for nitrogen and 10-20% for phosphorus, while potassium efficiency is 40-50% - largely due to deteriorating soil health (Asghar *et al*., 2010). Foliar application of nutrients can enhance productivity, especially under moisture stress. Recently, nano fertilizers have gained traction in agriculture for boosting crop yields, improving nutrient use efficiency, and minimizing excessive chemical fertilizer usage. Nano fertilizers offer sustained nutrient release over 40-50 days, compared to the 4-10 days typical of synthetic fertilizers, and help plants tolerate biotic and abiotic stresses (Mejias *et al*., 2021).

Foliar spray of nutrients not only alleviate forage sorghum from moisture stress but also provide nutrients. Foliar spray of either of 2% urea or 2% NPK18-18-18 at panicle initiation and flag leaf emergence stage was promising under moisture stress conditions of Hisar and improved the fodder yields, fodder quality and economics (Satpal *et al*., 2024). Nano-urea is the liquid version of solid urea, and a 500 ml bottle contains 40,000 ppm nitrogen. While conventional urea efficiently provided 30-40 percent nitrogen to plants, the remaining portion is lost. In contrast, the effectiveness of nano-urea liquid is over 80 percent (IFFCO, 2022). The efficacy of foliar fertilization of nitrogen is seven times more than soil application under drought conditions due to reduced denitrification and leaching losses (Dixon, 2003). The latest production technology involving the use of foliar fertilizer application under water stress conditions can be used to increase forage sorghum production as well as net profitability for farmers under arid and semi-arid conditions. In this experiment, different concentrations of nano-urea were compared with prilled urea, granular urea along with simple water spray treatment in forage sorghum to study their efficacy.

MATERIALS AND METHODS

A field experiment was conducted at the Forage Section Research Area, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar, Haryana (India) during the summer season of 2022. Hisar is situated at 29°10' N latitude and 75°46' E longitude at an altitude of 215.2 m above mean sea level, having a semi-arid and sub-tropical climate with hot, dry summers and severe cold winters and receives 450 mm of precipitation per annum. Weekly weather parameters, *i.e*., temperature (°C), relative humidity (%), and rainfall (mm) during the season are given in Fig. 1.

The soil of the experimental field was sandy loam in texture with a pH of 7.8, low in organic carbon (0.47%), and 124.4 - 12.3 - 276.5 kg/ha of available N-P-K at the start of the study in the plough layer. The experiment consisted of 14 treatments: S_1: control (No RDF), S_2: no spray (only RDN), S_3: water spray @ 500 L/ha at 35 DAS, S_4: water spray @ 500 L/ha at 35 DAS and 50 DAS, S_5: prilled urea spray @ 2% at 35 DAS, S_6: prilled urea spray @ 2% at 35 DAS and 50 DAS, S_7: granular urea spray @ 2% at 35 DAS, S_8: granular urea spray @ 2% at 35 DAS and 50 DAS, S_9: nano-urea spray @ 0.2% at 35 DAS, S_{10}: nano-urea spray @ 0.2% at 35 DAS and 50 DAS, S_{11}: nano-urea spray @ 0.4% at 35 DAS, S_{12}: nano-urea spray @ 0.4% at 35 DAS and 50 DAS, S_{13}: nano-urea spray @ 0.6% at 35 DAS, and S_{14}: nano-urea spray @ 0.6% at 35 DAS and 50 DAS. A single-cut variety of fodder sorghum, 'CSV 32F', was used in the said experiment conducted in Randomized Block Design (RBD) with three replications. Sowing was done manually with a row spacing of 25 cm on March 20, 2022. RDF (Recommended Dose of Nitrogen) used was 75 kg nitrogen + 30 kg P_2O_5 + 30 kg K_2O per ha. All other standard agronomic practices were followed uniformly in all the treatments as per the package of practices for *kharif* crops of CCS Haryana Agricultural University, Hisar, India (Anonymous, 2021).

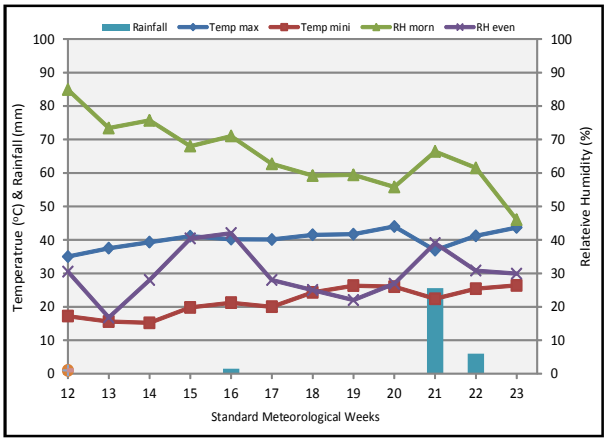

Fig. 1. Mean weekly meteorological data during *summer* season (2022).

HCN (Hydrogen cyanide) content was estimated using spectrophotometer by Gilchrist *et al*., (1967) and was calculated from standard curve. The samples for estimation of HCN were taken at 30 DAS from the portion of the plant immediately below the uppermost leaf collar. Proline content was estimated one day before the foliar spray application and again at seven days after spray, using the picric acid method and the method of Bates *et al*. (1973), respectively. Three plants were randomly selected from each treatment to observe quality characteristics such as crude protein and nutrient content (N, P, and K) at maturity. These were analyzed using conventional methods, including the Micro-Kjeldahl method for crude protein, and the Vanadomolybdo-phosphoric acid yellow colour method for phosphorus, as described by Jackson (1973). The crop was harvested 80 days after sowing (on June 8, 2022) in all treatments. Data were analyzed using appropriate analysis of variance (ANOVA) techniques through the OPSTAT software available on the CCS Haryana Agricultural University website (Sheoran *et al*., 1998). Results are presented at the five percent level of significance (p=0.05) to compare treatments.

TABLE 1
HCN, crude protein and proline content of fodder sorghum as influenced by foliar application of nitrogen-based formulations

Treatment	Crude protein content (%)	HCN content on fresh wt. basis (ppm)	Proline Content (µg/g dry weight basis)			
			One day before spray	7 days after first spray	One day before spray	7 day after second spray
S_1: Absolute Control (No RDF)	7.06	89.56	94.33	88.33	88.25	84.66
S_2: No spray (only RDF)	7.69	100.78	92.33	82.67	83.40	81.66
S_3: Water spray @ 500 L/ha at 35 DAS	7.83	95.27	85.00	72.67	76.33	69.66
S_4: Water spray @ 500 L/ha at 35 DAS and 50 DAS	7.87	94.59	82.67	68.67	75.67	65.33
S_5: Prilled urea spray @ 2% at 35 DAS	8.16	96.40	86.00	72.00	76.00	67.80
S_6: Prilled urea spray @ 2% at 35 DAS and 50 DAS	8.60	97.40	97.33	65.00	75.33	65.33
S_7: Granular urea spray @ 2% at 35 DAS	8.16	95.17	96.67	72.00	77.00	67.00
S_8: Granular urea spray @ 2% at 35 DAS and 50 DAS	8.48	97.50	91.33	69.33	76.00	65.00
S_9: Nano-urea spray @ 0.2% at 35 DAS	8.44	97.97	90.33	74.00	75.67	65.66
S_{10}: Nano-urea spray @ 0.2% at 35 DAS and 50 DAS	8.54	96.70	99.33	68.00	74.00	63.33
S_{11}: Nano-urea spray @ 0.4% at 35 DAS	8.73	95.60	82.67	64.00	66.33	59.66
S_{12}: Nano-urea spray @ 0.4% at 35 DAS and 50 DAS	9.04	90.62	86.00	56.00	61.35	53.33
S_{13}: Nano-urea spray @ 0.6% at 35 DAS	8.98	95.13	97.33	62.00	65.00	55.33
S_{14}: Nano-urea spray @ 0.6% at 35 DAS and 50 DAS	9.94	92.90	96.67	58.67	65.30	53.83
SEm ±	0.42	2.01	4.38	4.40	2.24	1.66
CD at 5%	1.24	NS	NS	12.87	6.54	4.85

Note: Recommended dose of fertilizer (RDF) was also applied in treatment S_3 to S_{14}.

RESULTS AND DISCUSSION

Fodder yield

The fodder yield of different treatments depicted in Fig. 2 revealed that maximum green fodder and dry matter yield (445.4 and 128.2 q/ha, respectively) was recorded with T_{14} treatment, which were on a par with T_{11} (423.1 and 120.1 q/ha, respectively), T_{12} (438.2 and 123.1 q/ha, respectively) and T_{13} (428.3 and 120.9 q/ha, respectively). The findings of Morsy *et al.*, (2021) were also found similar to these results.

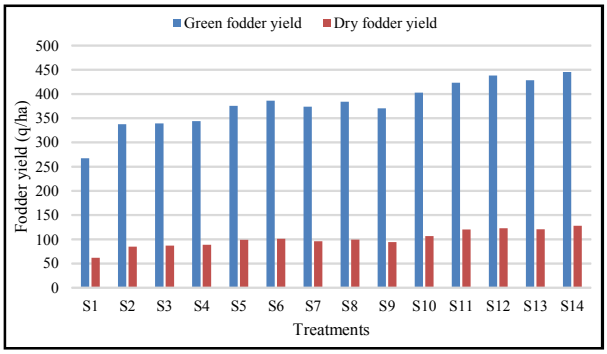

Fig. 1. Fodder yield as influenced by different treatments.

Crude protein and HCN

Perusal of the data from Table 1 revealed that among the different foliar nutrition treatments, the maximum crude protein (CP) content (%) was estimated in treatment S_{14} (9.94%), which was on a par with S_{11} (8.73%), S_{12} (9.04%), and S_{13} (8.98%). The control treatment (S_1) had the lowest crude protein content (7.06%), which was significantly lower than all the other treatments. The increase in crude protein content could be due to increased N uptake. In plants, nitrogen is crucial for metabolism. As a component of amino acids, it transmits genetic information, controls the cellular metabolism of proteins and amino acids that function as structural building blocks and as biological catalysts for phosphorylated chemicals involved in energy conversions, and is a constituent of amino acids. It is an important structural component of cells and cell walls, enhancing the protein content and raising the quality of the feed. Since the plant's nitrogen content is multiplied by 6.25 to determine the crude protein content, a higher nitrogen supply raises the crude protein content also. As a result of the accumulation of more dry matter and nitrogen in the plant, which in turn increases the yield of crude protein, the S_{14} treatment has recorded the crude protein content. In addition, Amrutkar *et al.* (1985), Alodiares *et al.* (2009) and Gholami *et al.* (2011) have also presented similar results. The HCN content across all treatments was non-significant at 30 DAS. However, the minimum value of HCN was found in treatment S_1 (89.56 ppm), which was the absolute control (no RDF). At 30 days after sowing, the estimated HCN content was below the critical limit (200 ppm) in all the treatments.

Proline content

For different treatments, the estimated proline content on dry weight basis (µg g^{-1}) is mentioned in Table 1. The accumulation of proline content in plant

was an indicator of stress. The proline content was estimated one day before the application of foliar spray and it was observed that the proline content was not affected significantly. However, proline content estimated seven days after spray significantly influenced with foliar application nitrogen-based formulations along RDF. The maximum proline was estimated in S_1 (88.33 µg g^{-1}) which was on a par with S_2. However, the minimum proline content estimated in S_{12} (56.00 µg g^{-1}) which was on a par S_3, S_4, S_5, S_6, S_7, S_8, S_9, S_{10}, S_{11} and S_{14}. The maximum proline content one day before second spray was estimated in S_1 and S_2 and minimum in S_{12}. Similar trend was also observed after the seven days after the second spray.

Nutrient content and uptake

The data presented in Table 2 revealed that different foliar nutrition treatments had an impact on the nitrogen and phosphorous content of fodder sorghum, but not on the potassium content. However, the S_{14} treatment was reported to have a numerically higher potassium content. Treatment S_{14}, which was at par S_{11}, S_{12} and S_{13} had the highest nitrogen content (1.59%). In S_1, where no RDF was used, the lowest nitrogen content (1.13%) was recorded. The maximum phosphorus content (0.201%) was estimated in the S_{14} treatment, which was on a par with the S_{11}, S_{12} and S_{13} treatments. The data presented in Table 2 indicated that the N uptake (202.79 kg ha^{-1}) was found significantly higher in S_{14} treatment followed by treatment S_{12}. The maximum uptake of P (25.72 kg ha^{-1}) in S_{14} treatment which was at par with S_{12}. The highest K uptake (161.81 kg/ha) was recorded in S_{14} treatment which was at par with S_{11}, S_{12} and S_{13}. Absolute control (No RDF) treatment was having lowest N, P and K uptake. The results revealed that foliar application of water and nitrogen significantly influenced N, P and K uptake. This can be attributed to the foliar application of nano-urea fertiliser directly on leaves, which decreased the time lag between application and uptake by the plant during the rapid growth phase. It also improved the efficiency and rapidity of the utilisation of a nutrient, which the plant urgently needs for maximum growth and yield. The nitrogen uptake was enhanced with the use of nano-fertilisers due to improved nutrient uptake by plant cells, which improved the growth of plant parts and metabolic processes like photosynthesis, which resulted in higher photosynthate accumulation and translocation to economically valuable plant parts and increased the yield. The findings of Morsy *et al*. (2021) and Benzon *et al*. (2015) were also found similar to these results.

CONCLUSION

Based on the experimental findings, it may be concluded that the foliar application of different nitrogen-based formulations improved the fodder yield

TABLE 2
Nutrient content and uptake of fodder sorghum as influenced by the effect of foliar application of nitrogen based formulations

Treatment	Nutrient content in plant at harvest (%)			Nutrient uptake in plant at harvest (kg/ha)		
	N	P	K	N	P	K
S_1: Absolute Control (No RDF)	1.13	0.15	1.21	70.04	9.36	75.07
S_2: No spray (only RDF)	1.23	0.17	1.22	104.07	14.41	103.23
S_3: Water spray @ 500 L/ha at 35 DAS	1.25	0.17	1.22	109.38	15.01	106.68
S_4: Water spray @ 500 L/ha at 35 DAS and 50 DAS	1.26	0.17	1.23	111.9	15.36	109.43
S_5: Prilled urea spray @ 2% at 35 DAS	1.31	0.18	1.24	129.27	17.3	122.37
S_6: Prilled urea spray @ 2% at 35 DAS and 50 DAS	1.38	0.18	1.24	139.25	17.93	125.22
S_7: Granular urea spray @ 2% at 35 DAS	1.31	0.17	1.24	125.37	16.64	119.15
S_8: Granular urea spray @ 2% at 35 DAS and 50 DAS	1.36	0.18	1.24	134.81	17.46	123.44
S9: Nano-urea spray @ 0.2% at 35 DAS	1.35	0.17	1.24	127.72	16.33	116.95
S_{10}: Nano-urea spray @ 0.2% at 35 DAS and 50 DAS	1.37	0.18	1.24	146.32	18.88	132.24
S_{11}: Nano-urea spray @ 0.4% at 35 DAS	1.4	0.19	1.24	168.18	22.35	149.54
S_{12}: Nano-urea spray @ 0.4% at 35 DAS and 50 DAS	1.45	0.19	1.25	178.07	23.52	154.11
S_{13}: Nano-urea spray @ 0.6% at 35 DAS	1.44	0.19	1.24	173.93	22.85	150.39
S_{14}: Nano-urea spray @ 0.6% at 35 DAS and 50 DAS	1.59	0.2	1.26	202.79	25.72	161.81
SEm ±	0.06	0.005	0.01	8.51	0.75	4.55
CD at 5%	0.20	0.01	NS	24.88	2.2	13.3

Note: Recommended dose of fertilizer (RDF) was also applied in treatment S_3 to S_{14}.

and quality of sorghum. Higher nutrient uptake (N, P and K) and crude protein were recorded with the foliar application of nano-urea @ 0.6% at 35 DAS and 50 DAS. This was on par with one nano-urea spray @ 0.4% at 35 DAS, two nano-urea sprays @ 0.4% at 35 and 50 DAS, and one nano-urea spray @ 0.6% at 35 DAS, when RDF was also applied in all these treatments.

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