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RESEARCH ARTICLE

Split application of nitrogen: A strategy for improving fodder yield and quality in *Kharif* sorghum

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Abstract

A field experiment was carried out during *kharif* season of 2023 at MFRS, AAU, Anand-388 110, Gujarat to evaluate the "Effect of split application of nitrogen levels on *kharif* fodder sorghum". The experiment was laid out in randomized block design (Factorial) with three replications. There were 12 treatment combinations which included four nitrogen levels. According to results, application of 120 kg N/ha (N_3) was reported significantly higher plant height at 45 DAS and at harvest, number of leaves per plant and leaf stem ratio, maximum green forage yield (356.14 q/ha), dry matter yield (104.49 q/ha), crude protein yield (5.70 q/ha) and dry matter content, ash content and lower acid detergent fiber (ADF) and neutral detergent fiber (NDF) content and higher nutrient content and uptake by fodder sorghum over other level of nitrogen. Response of nitrogen on plant population at 15 DAS, plant height at 30 DAS, available phosphorus in soil and phosphorus content in plant was found non-significant. Split application of nitrogen treatment S_3(25 % N at Basal + 37.5 % N at 30 DAS + 37.5 % N at 45 DAS) reported significant response on growth parameters like periodical plant height, numbers of leaves per plant, leaf stem ratio and yield and quality parameters like green fodder yield, dry matter yield, dry matter content, crude protein content, crude protein yield, ADF, NDF, ash content and nutrient content and uptake by fodder sorghum as compared to rest of treatments. Interaction effect between N_3S_3 (120 kg N/ha applied as 25 % N at Basal + 37.5 % N at 30 DAS + 37.5 % N at 45 DAS) exhibited maximum green fodder yield (386.15 q/ha), dry matter yield (132.90 q/ha), crude protein yield (8.42 q/ha) with higher net return (₹1,17,787/ha) and benefit-cost ratio (4.21) of fodder sorghum during *kharif* season.

Keywords: acid detergent fiber; crude protein yield; dry matter yield; green fodder yield; neutral detergent fiber; nitrogen; split application

Introduction

Animal husbandry in India is deeply intertwined with agriculture and plays a vital role in the socio-economic development of millions of rural households, significantly contributing to the national economy. Livestock rearing is one of the most important economic activities in rural areas, providing both supplementary and stable income throughout the year. This sector has also emerged as a crucial component in promoting a more inclusive and sustainable agricultural system. The shortage of feed and fodder is a significant constraint in achieving the desired level of livestock productivity, particularly in India. This issue is exacerbated by factors such as climate change, land-use changes and inadequate infrastructure for fodder production and storage (1). Food security, nutritional security, maintenance of soil health, enhancement of productivity and leaving rightful heritage for future generations are the focus of our agricultural development (2).

The "Great millet" and "King of millets" Sorghum is originated in the Africa and has disseminated throughout the world. Sorghum [*Sorghum bicolour* L. Moench] belongs to the family *Poaceae* and it is important cereal crop in India popularly known as 'Jawar'. Traditionally, it was produced for grain and after harvest of grain it use as animal feed and fodder. It has very fast growth, quick tillering ability, high dry matter content, leafiness, high palatability, hardiness and appropriateness for silage production, it is currently one of the most important sources of fodder, especially during *kharif*, winter and summer season to meet out dual requirement of green and dry fodder. Additionally, it supplies silage and hay as needed during the lean period. Single cut fodder sorghum is primarily planted as rainfed crops in *kharif* season and multi-cut fodder sorghum is grown under irrigation (3). The HCN (dhurrin) is anti-quality components in sorghum at early stage of crop (up to 50 % flowering). It would be preferred to harvest at 50 % flowering stage because HCN content found below levels and safe for animal feeding. India comes in sixth place and makes up 8 % of the world's total sorghum production and 2.6 million hectares of forage sorghum planted overall (4). India's top producing states for forage sorghum include Karnataka, Maharashtra, Rajasthan, Tamil Nadu, Andhra Pradesh, Uttar Pradesh and Madhya Pradesh.

Gujrat has a total animal population of 18.44 million heads and their optimum fodder requirement worked out is 42.2 million tonnes, whereas only 20.0 million tonnes of fodder are made available in normal year (5). Overcome this deficit, dairy farmers resort to the increased use of costly concentrate feeds, which increase the cost of production. The feed cost alone accounts for 60 to 70 % of the total milk production (6). It is therefore essential to maximize quality forage production per unit area and time. Sorghum being an exhaustive crop, improper fertilizer application severely reduces both yield and quality.

The most important plant nutrient needed in huge amounts to produce fodder crops is nitrogen (7). Nitrogen (N) is considered a major important nutrient and its management is an important agronomical factor of economic production, it is essential for plant growth and development. It is also the main constituent of protein, chlorophyll content, protoplasm, amino acids, plastids, mitochondria and energy components along this its role in encouraging the cell division, expansion and elongation of living cell and photosynthesis as well as vegetative growth (8). Application of nitrogen elements improves the succulence and palatability of feed by reducing the amount of fiber, lignin and NDF (9). Excessive use of fertilization lowers yield quality, increases lodging and increases susceptibility to diseases and insect pests. However, an excessive amount of nitrogen could create a severe risk to the ecosystem, resulting in eutrophication, greenhouse effects and acid rain (10).

Time of application is more important than quantity another main purpose is to conduct study to enhance vegetative growth and improved forage yield and quality. Split application of nitrogen is one of the methods to improve nitrogen use by crops while reducing nutrient losses through leaching and volatilization (11). Split application of total N doses coordinates the N supply with the capacity of plants to utilize the nutrient effectively, improving nitrogen use efficiency, productivity and quality of fodder crops.

Materials and Methods

Experiment site and climate

The field experiment was conducted at Main Forage Research Station, Anand Agricultural University, Anand, Gujarat (22°35′ North latitude, 72°56′ East longitude and 45.1 m above mean sea level) during *kharif* season of the year 2023 (Fig. 1). The mean weekly weather parameter recorded at the Department of Agricultural Meteorology Bansilal Amrutlal College of Agriculture, Anand Agricultural University, Anand, during the experimental period of the year 2023 is graphically depicted in Fig. 2.

Analysis of soil sample for basic properties and soil fertility status

Before sowing, a composite soil sample was taken from different spots in experimental plot at a depth of 0 -15 cm according to standard sampling processes. It was examined to ascertain the physico-chemical characteristics of soil. Data obtained from soil analysis indicates that the experimental site had low in organic carbon (0.45 %) and available nitrogen (257.69 kg/ha), medium in available phosphorus (35.8 kg/ha) and potassium (218.12kg/ha) and slightly alkaline (pH:8.2) in reaction. Electrical conductivity of experimental field was (0.28 dS/m).

The experimental was laid out in Randomized Block Design (Factorial) with three replications. There were 12 treatment combinations comprising of 4 level of nitrogen viz., N_1 (80 kg N/ha), N_2 (100 kg N/ha), N_3 (120 kg N/ha) and N_4 (140 kg N/ha) and three levels split application of nitrogen *viz*.,S_1 (common practices, 50 % N at Basal + 50 % N at 30 DAS), S_2 (25 % N at Basal + 50 % N at 30 DAS + 25 % N at 45 DAS) and S_3 (25 % N at Basal + 37.5 % N at 30 DAS + 37.5 % N at 45 DAS). Nitrogen was applied as a split treatment a basal before sowing the crop in furrows and remaining dose was applied as top dressing at 30 and 45 DAS through urea. The crop was uniformly fertilized with full dose of phosphorus (40 kg P_2O_5/ha) was applied in form of single super phosphate and 25 kg $ZnSO_4$/ha as basal application. Sorghum variety GAFS 12 was sown by drilling during *kharif* season and using 80 kg/ha seed. Seed was placed at 30 cm between rows. Recommended agronomical practices were adopted. Five spots in net plot area were selected randomly for the measurement of growth, yield and quality parameters of fodder sorghum.

Plant harvesting and proximate analysis from plant sample

The crop was ready to harvest at 50 % flowering stage, which is better for fodder purposes. Necessary observations from net plot area were harvested separately and weighed and samples were stored in sealed bags for further analysis. A fresh sample of 500 g green forage was taken from each net plot, chopped into small pieces and was air dried for three to four days, after that dry in hot dryer. After drying griding sample, make it powder form for analysis of quality parameters in terms of crude protein, dry matter, crude protein yield, ash content, ADF, NDF content and nutrient content in plant through different standard protocol (Table 1). All data required for economic analysis were computed and the benefit-cost ratio (BCR) was calculated for each individual treatment to identify the most profitable treatment combination based on net realization.

Dry matter content: Dry matter content (%) was calculated by using the following formula

$$\text{Dry matter content (\%)} = \frac{\text{Oven dried forage weight (g)}}{\text{Fresh forage weight (g)}} \times 100$$

Dry matter yield was calculated by green forage yield (q/ha) was multiplied by respective dry matter content (%).

Table 1. Different methods for fodder sorghum analysis

Sr. No.	Parameters	Method of analysis
1.	Neutral detergent fiber (%)	Forage fiber analysis US method (12)
2.	Acid detergent fiber (%)	Forage fiber analysis US method (12)
3.	Crude protein content (%)	Kjeldal's method (13)
4.	Nitrogen content (%)	Kjeldal's method (13)
5.	Phosphorus content (%)	Ammonium vanadomodybadate yellow colour method (13)

Fig. 1. Experiment location at Main Forage Research Station Farm AAU, Anand.

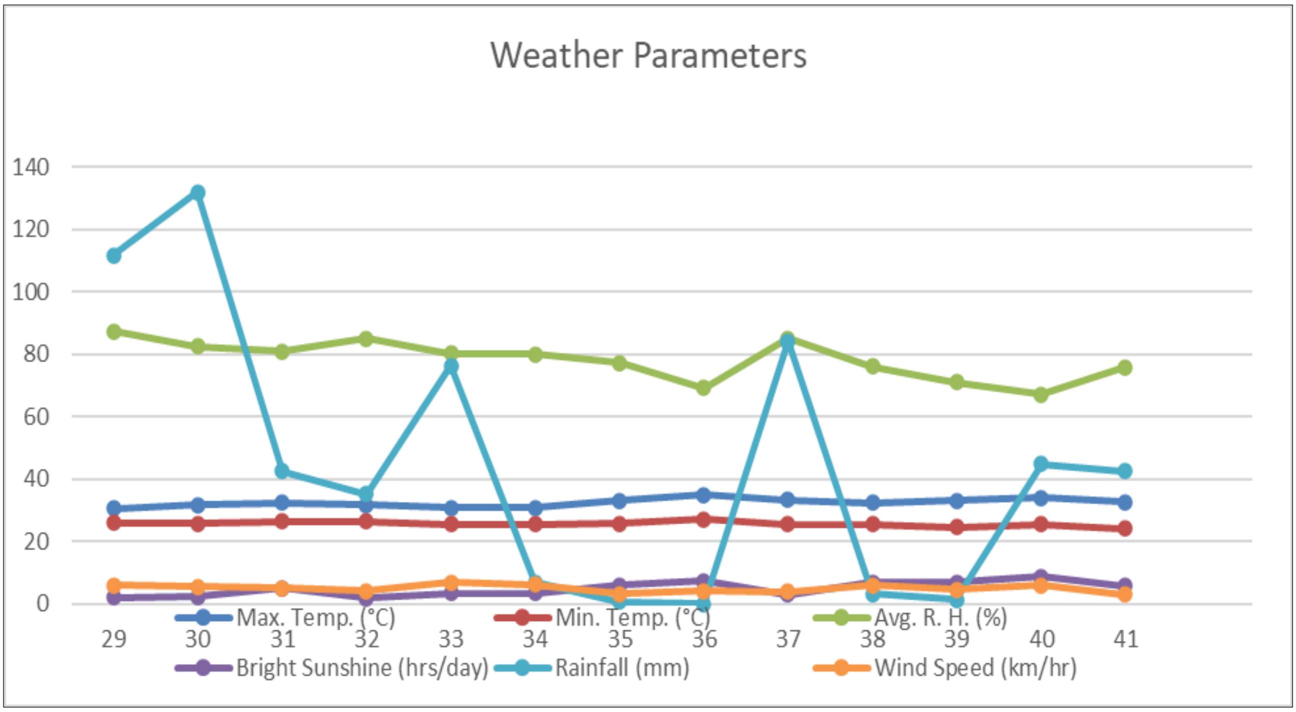

Fig. 2. Mean weekly weather parameters during crop growth period 2023 experimental design, treatment and crop husbandry.

Crude protein yield (q/ha): crude protein yield by employing the following formula

$$\text{Crude protein yield (q/ha)} = \frac{\text{Dry matter yield (q/ha) x Crude protein content (\%)}}{100}$$

Ash content (%): ash content calculated by using following formula.

$$\text{Ash content (\%)} = \frac{\text{(Wt. of crucible + Ash Wt. (after cooling) - Wt. of crucible)}}{\text{Wt. of fresh sample (g)}} \times 100$$

Nutrient uptake (kg/ha): Nutrient uptake by the crop was calculated by using the following formula:

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Nutrient content (\%) x Dry fodder yield (kg/ha)}}{100}$$

Statistical analysis

The field experiment was conducted in Factorial Randomized Block Design (FRBD). Take all data randomly from net plot area and collect replicated data after it is converted into mean data. For statically analysis used obtained mean data in analysis of (ANOVA) of variance were tested by "F-test" and compared with the value of Table-F at 5 % level of significance. Standard error of mean (S.Em±), critical difference and coefficient of variation (CV %) were calculated and interpret statistical analysis data for scientific elaboration purpose (14).

Results and Discussion

Effect of nitrogen levels

Nitrogen is an essential primary nutrient that promotes vigorous plant growth and plays a crucial role in forage productivity. Its application to fodder crops is one of the most effective practices for enhancing forage yield. The mean data of fodder sorghum furnished in Table 2 indicated that plant population per meter row at 15 DAS in fodder sorghum was found non-significant. It indicates that uniform plant population is found among the different treatments. Mean data of growth attributes of fodder sorghum significantly influenced by nitrogen levels (Table 2). The periodical plant height of fodder sorghum was affected by application of nitrogen levels, at 45 DAS and at harvest, an application of 120 kg N/ha (N_3) resulted in significantly higher plant height (184.47 and 263.60 cm, respectively) but it remained at par with treatment N_4 (140 kg N/ha). Plant height at 30 DAS found to be non-significant. The increase in plant height by application of nitrogen might be due to the positive effect of nitrogen on growth characteristics, leading to enhanced cell division and cell elongation and differentiation and there resulting in luxuriant growth (15-17). Application of 80 kg N/ha reported lower plant height (163.24 and 245.53 cm) at 45 DAS and at harvest, respectively.

Nitrogen is involved in increasing the protoplasmic constituents and accelerating the process of cell division which in turn results in luxuriant vegetative growth. Data reported in Table 2 indicated that an application 120 kg N/ha (N_3) recorded a significantly higher number of leaves per plant (11.20) and leaf stem ratio (0.90), but it was statistically at par with treatment N_2 (100 kg N/ha). Increase in number of leaves per plant and leaf stem ratio with increasing levels of nitrogen mainly due to enhanced production of leaf material as compared to stem of plant, which could intercept and utilization the incident solar radiation in the production of photosynthesis and increasing meristematic activity which leads to numerically a higher number of leaves of fodder sorghum (15, 17-18).

Green fodder yield of fodder sorghum significantly affected by different levels of nitrogen (Table 2). An application of 120 kg N/ha (N_3) recorded significantly the highest green forage yield (356.14 q/ha) over the rest of the nitrogen levels. It was 6.87, 13.44 and 18.01 percent higher over treatment N_4 (140 kg N/ha), N_2 (100 kg N/ha) and N_1 (80 kg N/ha), respectively. Significantly lower green fodder yield (301.78 q/ha) was reported in N_1 (80 kg N/ha) treatment. Linear trend was observed in case of green fodder yielding up to 120 kg N/ha (N_3). Nitrogen is a key nutrient for plant growth, especially in promoting leaf and stem development. Higher nitrogen availability accelerates cell division and elongation, leading to larger foliage and stems, which ultimately contributes to increased green fodder yield. Overall, nitrogen plays a fundamental role in plant physiology, impacting various aspects of growth, development and metabolism. Its availability and utilization are critical factors in maximizing plant productivity and biomass accumulation (15-17). Further application of nitrogen may be effect on lower nitrogen use efficiency, leaching loss of

Table 2. Growth and yield attributes of fodder sorghum as influenced by split application of nitrogen levels

Treatments	Plant population per meter row length	Plant height (cm)			No: of leaves/ plant	Leaf: Stem ratio
		At 30 DAS	At 45 DAS	At harvest		
Level of nitrogen (kg N/ha)						
N_1:80	43.24	109.09	163.24	245.53	9.51	0.71
N_2:100	44.49	117.33	169.27	249.04	11.00	0.83
N_3:120	45.31	121.20	184.47	263.60	11.20	0.90
N_4:140	46.73	122.18	175.22	257.87	9.91	0.78
SEm±	1.41	3.71	4.78	3.26	0.40	0.04
CD (P=0.05)	NS	NS	14.03	9.56	1.19	0.12
Split application (S)						
S_1	45.13	106.05	156.17	237.37	8.75	0.67
S_2	44.52	118.52	173.67	257.30	10.33	0.82
S_3	45.19	127.78	189.32	267.37	12.13	0.93
SEm±	1.22	3.22	4.14	2.82	0.35	0.03
CD (P=0.05)	NS	9.43	12.15	8.28	1.03	0.10
Interaction (N*S)						
SEm±	2.44	6.43	8.28	5.65	0.70	0.07
CD (P=0.05)	NS	NS	NS	16.57	NS	NS
CV (%)	9.42	9.48	8.29	3.85	11.66	14.91

nitrogen and logging of crops. Analyzed data presented in Table 3 indicate that significantly higher the dry matter yield (104.49 q/ha) and dry matter content (28.77 %) was produced by the application 120 kg N/ha (N_3) over the rest of treatments. Increasing dry matter content can be attributed to enhanced growth and development of crops. Nitrogen elements are important in plants because they provide higher vegetative growth of crops, which increases light interception on the crop canopy and as a result ultimately increases the amount of dry matter (17, 19). Another reason to increase green fodder yield and dry matter might be due to This increase may primarily be attributed to improved growth and yield parameters such as plant height, number of tillers per meter row length and leaf-to-stem ratio. The beneficial effects of nitrogen on cell division and elongation, as well as its role in the formation of nucleotides and co-enzymes, enhance meristematic activity and expand the photosynthetic area. These physiological improvements lead to greater production and accumulation of photosynthates, ultimately resulting in higher green fodder and dry matter yields (20).

The data (Table 3) indicate that comparatively higher crude protein content (5.21 %) was recorded in treatment N_4 (140 kg N/ha) than rest of treatments except treatment N_3 (120 kg N/ha). Whereas crude protein yield (5.70 q/ha) was significantly maximum observed in treatment N_3 (120 kg N/ha) as compared to rest of nitrogen levels treatment. Crude protein content increases with nitrogen application might be due to fact that nitrogen being an essential constitute of chlorophyll, protoplasm, protein and nucleic acid and needed for protein synthesis. Crude protein yield recorded higher might be directly influenced by crude protein content and dry matter yield under application of higher dose of nitrogen (15-17). Significantly lower ADF (38.51 %) and NDF (58.27 %) content was observed in treatment N_3 (120 kg N/ha) and N_4 (140 kg N/ha), respectively. Which did not differ significantly from the application of N_4 (140 kg N/ha) and N_3 (120 kg N/ha), respectively. Reducing the ADF fiber content is associated with higher nitrogen levels, possibly because of the higher content nitrogen, which primarily constitutes amino acids and proteins and decreased the pectin, cellulose, hemi-cellulose and proportion of carbohydrates, which are major constitutes of fiber content (5,17). Application of 120 kg N/ha (N_3) reported higher ash content (16.22 %) than rest of levels of nitrogen except treatment N_2 (100 kg N/ha).

Adequate N fertilization can increase concentrations of protein and other nutrients in plant tissues. This leads to higher nutritional quality of the fodder, improving its value for livestock feeding. Analyzed data (Table 4) indicate that higher nitrogen content (0.83 %) and maximum nitrogen as well as phosphorus uptake (91.14, 24.56 kg/ha, respectively) by fodder sorghum was obtained in treatment N_4(140 kg N/ha) and N_3(120 kg N/ha), respectively. Nitrogen content, treatment N_3 did not significantly differ from treatment N_4(140 kg N/ha).

Effect of split application

Applying nitrogen fertilizer in split doses, improves nutrient uptake and efficiency, resulting in higher economical yields and better overall crop health. Plant population per meter row length at 15 DAS was not significantly influenced due to split application of nitrogen, uniform germination found in all experimental plots. Split application of nitrogen significantly affected growth and yield

Table 3. Yield and quality parameters of fodder sorghum as influenced by split application of nitrogen levels

Treatments	GFY (q/ha)	DM (%)	DMY (q/ha)	CP (%)	CPY (q/ha)	ADF (%)	NDF (%)	ASH (%)
				Level of Nitrogen (kg N/ha)				
N_1:80	301.78	24.49	75.93	4.10	3.26	41.06	64.74	14.54
N_2:100	313.95	25.68	81.84	4.39	3.66	41.91	59.09	15.34
N_3:120	356.14	28.77	104.49	5.10	5.70	38.51	58.71	16.22
N_4:140	333.23	24.63	83.48	5.21	4.60	38.62	58.27	14.75
SEm±	7.80	0.74	3.80	0.12	0.25	0.73	1.12	0.32
CD (P=0.05)	22.90	2.17	11.15	0.36	0.74	2.13	3.30	0.94
				Split application (S)				
S_1	291.26	18.76	54.79	3.60	1.99	41.80	61.88	13.99
S_2	324.18	26.89	88.04	4.95	4.46	40.96	61.17	15.22
S_3	363.39	32.03	116.47	5.54	6.46	37.32	57.57	16.44
SEm±	6.76	0.64	3.29	0.11	0.22	0.63	0.97	0.28
CD (P=0.05)	19.83	1.88	9.66	0.32	0.64	1.85	2.86	0.82
				Interaction (N*S)				
SEm±	13.52	1.28	6.59	0.21	0.44	1.26	1.95	6.59
CD (P=0.05)	39.67	3.76	19.32	0.63	1.29	NS	NS	19.32
CV (%)	7.18	8.57	13.20	7.93	17.71	5.45	5.6	13.20

Table 4. Nutrient content and uptake by fodder sorghum as influenced by split application of nitrogen levels

Treatments	Nutrient content (%) and uptake by plant (kg/ha)			
	Nutrient content (%)		Nutrient uptake (kg/ha)	
	Nitrogen	Phosphorus	Nitrogen	Phosphorus
		Level of Nitrogen (kg N/ha)		
N_1:80	0.66	0.213	52.21	16.50
N_2:100	0.70	0.223	58.53	18.53
N_3:120	0.82	0.236	91.14	24.56
N_4:140	0.83	0.231	73.55	19.31
SEm±	0.02	0.006	4.06	1.24
CD (P=0.05)	0.06	NS	11.92	3.62
		Split application (S)		
S_1	0.58	0.223	31.82	12.39
S_2	0.79	0.230	71.40	20.52
S_3	0.89	0.224	103.36	26.25
SEm±	0.02	0.005	3.52	1.07
CD (P=0.05)	0.05	NS	10.32	3.14
		Interaction (N*S)		
SEm±	0.03	0.011	7.04	2.14
CD (P=0.05)	0.10	NS	20.64	NS
CV (%)	7.86	8.13	17.71	18.81

parameters of fodder sorghum (Table 2). Application of nitrogen in three split (S_3: 25 % N at Basal + 37.5 % N at 30 DAS + 37.5 % N at 45 DAS) treatment reported higher periodical plant height, number of leaves per plant at harvest and leaf stem ratio. Treatment S_3 (25 % N at Basal + 37.5 % N at 30 DAS + 37.5 % N at 45 DAS) reported significantly higher plant height (127.78 cm) at 30 DAS, while same treatments reported the tallest plant (189.32 and 267.37 cm) at 45 DAS and at harvest respectively (Table 2). It is marked from data (Table 2) that indicate significantly maximum numbers of leaves per plant (12.13) and leaf stem ratio (0.93) at harvest of fodder sorghum were recorded in treatment S_3 (25 % N at Basal + 37.5 % N at 30 DAS + 37.5 % N at 45 DAS). Application of nitrogen in split might be due to supply of proper amount of nitrogen at different growth stages of fodder sorghum. The nitrogen promotes plant growth, increased cell division, cell elongation, as well as green foliage. It also may be since split applications make better utilization of nitrogen by reducing its leaching loss and matching the nitrogen supply with crop demand (11, 21). Split application of nitrogen is one of the methods to improve nitrogen use by the crops while reducing nutrient loss through leaching and increases activity of photosynthesis and efficiency of the leaves have been increased which contributed to dry matter production (11, 21). Studies show that split applications, especially in three splits, can significantly boost both green and dry matter yields compared to a single application at planting. The attained results showed (Table 3) that treatment S_3 (25 % N at Basal + 37.5 % N at 30 DAS + 37.5 % N at 45 DAS) produced significant maximum green fodder yield (363.39 q/ha), dry matter yield (116.47 q/ha) and crude protein yield (6.46 q/ha) over the rest of splits application. Treatment S_3 (25 % N at Basal + 37.5 % N at 30 DAS + 37.5 % N at 45 DAS) reported 12.09 and 24.76 % higher green fodder yield over S_2 (25 % N at Basal + 50 % N at 30 DAS + 25 % N at 45 DAS) and S_1 (Common practices, 50 % N at Basal + 50 % N at 30 DAS). Upon examining the data (Table 3) on dry matter content (32.03 %), crude protein content (5.54 %) and ash content (16.44 %) observed maximum in treatment S_3 (25 % N at Basal increases in crude protein content could be + 37.5 % N at 30 DAS + 37.5 % N at 45 DAS) than rest of split application of treatments. Increase dry matter content and crude protein content could be due to better utilization of nitrogen at proper time and growth stage through split application, which leads to produce more biomass assimilation by sorghum crops. It is marked from data (Table 3) that indicates significantly lower ADF (37.32 %) and NDF (57.57 %) content was observed in split nitrogen application S_3 (25 % N at Basal + 37.5 % N at 30 DAS + 37.5 % N at 45 DAS) over the rest of split treatments. Split application nitrogen decreasing crude fiber content might be due continues supply nitrogen throughout all growth stages accelerating the protein formation from manufacture carbohydrate and help in reducing the rate of lignification's there by maintaining the fodder quality (11, 22).

Data presented in Table 4 indicated that significantly the maximum nitrogen content (0.89 %) and nitrogen and phosphorus uptake (103.36 and 26.25 kg/ha, respectively) by fodder sorghum were recorded significantly maximum where nitrogen was applied in three splits (S_3: 25 % N at Basal + 37.5 % N at 30 DAS + 37.5 % N at 45 DAS) over the treatment S_1 (Common practices, 50 % N at Basal + 50 % N at 30 DAS), S_2 (25 % N at Basal + 50 % N at 30 DAS + 25 % N at 45 DAS). Split application of nitrogen has significant impact on content and uptake because continuous availability of nitrogen throughout the growth period of plant.

Interaction effect of nitrogen levels and split applications

Based on experimental interaction effect between nitrogen levels and its split application were presented in Table 5-8. The interaction effect between nitrogen levels and its split application on plant height at harvest (cm), dry matter content (%), green fodder yield (q/ha), dry matter yield (q/ha), crude protein yield (q/ha), crude protein content (%) and nitrogen content (%) and uptake (kg/ha) by plant were found significant.

Treatment combination N_3S_3 (120 kg N/ha applied as 25 % N at Basal + 37.5 % N at 30 DAS + 37.5 % N at 45 DAS) reported higher plant height (274.80) at harvest, maximum green fodder yield (386.15 q/ha), dry matter yield (132.90 q/ha), crude protein yield (8.42 q/ha) and nitrogen uptake (134.77 kg/ha) reported over the rest of treatments combinations. The interaction effect between N_1S_3 (80 kg N/ha applied as 25 % N at Basal + 37.5 % N at 30 DAS + 37.5 % N at 45 DAS) reported significantly higher dry matter (34.83 %) but it remain at par with treatment combination N_2S_3 (100 kg N/ha applied as 25 % N at Basal + 37.5 % N at 30 DAS + 37.5 % N at 45 DAS) and N_3S_3 (120 kg N/ha applied as 25 % N at Basal + 37.5 % N at 30 DAS + 37.5 % N at 45 DAS). While treatment combination N_4S_3 (140 kg N/ha applied as 25 % N at Basal + 37.5 % N at 30 DAS + 37.5 % N at 45 DAS) exhibited a significantly higher crude protein content (6.56 %), but it was statistically equivalent to treatment N_3S_3 (6.31 q/ha). Treatment combination N_4S_3 (140 kg N/ha applied as 25 % N at Basal + 37.5 % N at 30 DAS + 37.5 % N at 45 DAS) exhibited maximum nitrogen content (1.05 %) by fodder sorghum as compared to all other possible treatment combinations.

Table 5. Interaction effect of nitrogen levels and its split application on plant height and dry matter content of fodder sorghum

Nitrogen levels (kg/ha)	Split application of nitrogen (S)					
	Plant height (cm) at harvest			Dry matter content (%)		
	S_1	S_2	S_3	S_1	S_2	S_3
N_1	229.67	238.00	268.93	14.80	23.83	34.83
N_2	234.27	256.07	256.80	19.33	25.47	32.23
N_3	254.00	262.00	274.80	20.77	31.07	34.46
N_4	231.53	273.13	268.93	20.13	27.20	26.57
SEm±		5.65			1.28	
CD(P=0.05)		16.57			3.76	

Table 6. Interaction effect of nitrogen levels and its split application on green fodder yield and dry matter yield of fodder sorghum

Nitrogen levels (kg/ha)	Split application of nitrogen					
	Green fodder yield (q/ha)			Dry matter yield (q/ha)		
	S_1	S_2	S_3	S_1	S_2	S_3
N_1	285.55	271.26	348.52	41.90	64.15	121.73
N_2	294.82	305.92	341.11	57.35	77.68	110.50
N_3	306.67	375.59	386.15	63.94	116.63	132.90
N_4	277.99	343.94	377.78	55.97	93.70	100.77
SEm±		13.52			6.59	
CD(P=0.05)		39.67			19.32	

Table 7. Interaction effect of nitrogen levels and its split application on crude protein content and crude protein yield of fodder sorghum

Nitrogen levels (kg/ha)	Split application of nitrogen					
	Crude protein content (%)			Crude protein yield (q/ha)		
	S_1	S_2	S_3	S_1	S_2	S_3
N_1	3.44	4.25	4.59	1.46	2.75	5.58
N_2	4.00	4.46	4.69	2.30	3.46	5.22
N_3	3.44	5.53	6.31	2.24	6.43	8.42
N_4	3.50	5.56	6.56	1.96	5.21	6.62
SEm±		0.21			0.44	
CD(P=0.05)		0.63			1.29	

Table 8. Interaction effect of nitrogen levels and its split application on nitrogen content and uptake by fodder sorghum

Nitrogen levels (kg/ha)	Split application of nitrogen					
	Nitrogen content (%)			Nitrogen uptake (kg/ha)		
	S_1	S_2	S_3	S_1	S_2	S_3
N_1	0.55	0.68	0.73	23.37	43.97	89.30
N_2	0.64	0.71	0.75	36.74	55.35	83.51
N_3	0.55	0.88	1.01	35.76	102.90	134.77
N_4	0.56	0.89	1.05	31.42	83.38	105.87
SEm±		0.03			7.04	
CD(P=0.05)		0.10			20.64	

Data outlined (Fig. 3) indicated that the treatment combination N_3S_3 (120 kg N/ha applied as 25 % N at Basal + 37.5 % N at 30 DAS + 37.5 % N at 45 DAS) resulted in the highest net income (₹117787/ha) and benefit-cost ratio (4.21) than rest of treatment combinations.

Economics

Economics as influenced by different treatments

Data presented in Table 9 revealed that application of 120 kg N/ha (N_3) to fodder sorghum crop resulted in the highest net income (₹109740/ha) and benefit-cost ratio (4.35) as compared to rest of nitrogen levels and split application of nitrogen treatment S_3 (25 % N at Basal + 37.5 % N at 30 DAS + 37.5 % N at 45 DAS) to fodder sorghum crop resulted maximum net income (₹113159/ha) and benefit-cost ratio (4.51) as compared to rest of splits application.

Conclusion

In view of the field experiment results, it can be concluded that application of 120 kg N/ha getting higher green fodder yield (356.14 q/ha), it is 18.01, 13.44 and 6.88 % higher over rest of levels of nitrogen (80 kg N/ha, 100 kg N/ha and 140 kg N/ha), dry matter yield (104.49 q/ha), crude protein yield (5.70 q/ha) and net returns (₹109740/ha) of fodder sorghum.

Application of nitrogen to *kharif* fodder sorghum in split application (25 % N at Basal + 37.5 % N at 30 DAS + 37.5 % N at 45 DAS) reported 12.09 and 24.76 % higher green fodder yield (363.39 q/ha), dry matter yield (116.47 q/ha), crude protein yield (6.46 q/ha) and net return (₹113159/ha) than two other split application treatments [25 % N at Basal + 50 % N at 30 DAS + 25 % N at 45 DAS and second split application 50 % N at Basal + 50 % N at 30 DAS (common practices)] during *kharif* season.

Table 9. Economics of fodder sorghum as influenced by nitrogen levels and split application

Treatment	Green fodder yield (q/ha)	Green fodder income (₹/ha)	Total cost of cultivation (₹/ha)	Net income (₹/ha)	BCR
A. Level of nitrogen (kg/ha)					
N_1:80	301.78	120712	32178	88534	3.75
N_2:100	313.95	125580	32447	93133	3.87
N_3:120	356.14	142456	32716	109740	4.35
N_4:140	333.23	133292	32992	100300	4.04
B. Split application of nitrogen					
S_1	291.26	116504	30219	86285	3.85
S_2	324.18	129672	32197	97475	4.02
S_3	363.39	145356	32197	113159	4.51

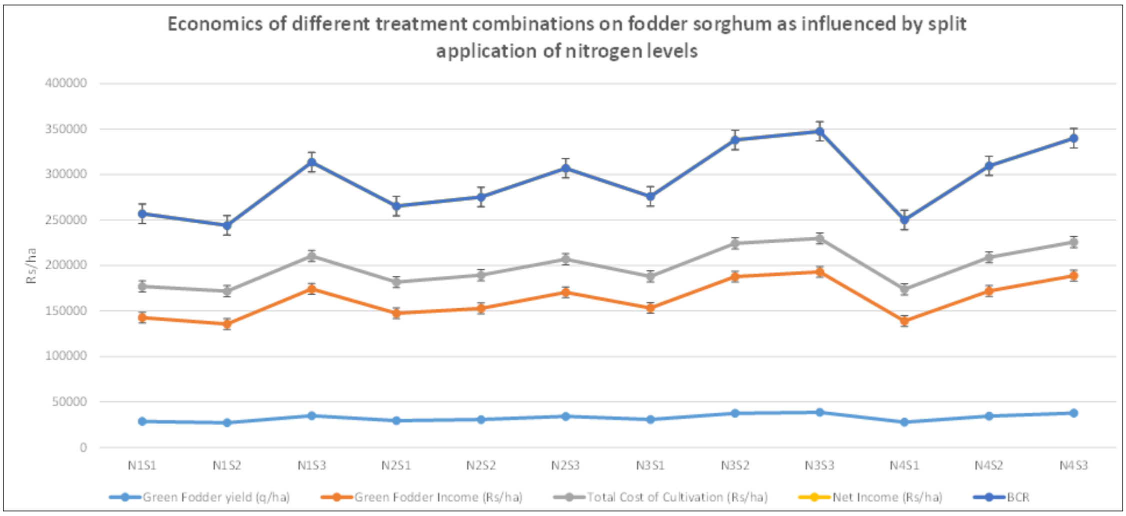

Fig. 3. Economics of different treatment combinations on fodder sorghum as influenced by split application of nitrogen levels.

Interaction effect between N_3S_3 (120 kg N/ha applied as 25 % N at Basal + 37.5 % N at 30 DAS + 37.5 % N at 45 DAS) exhibited maximum green fodder yield (386.15 q/ha), dry matter yield (132.90 q/ha), crude protein yield (8.42 q/ha) with higher net return (₹117787/ha) of fodder sorghum during *kharif* season.

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Authors' contributions

PAJ participated in the carried out an experiment and collect all primary data. HKP participated in the analysis of all primary data with its interpretation, write up and final manuscript. RPH participated in the biochemical analysis of all quality parameters. RCH participated in correction and improvement in research text. PDK participated in the design of the study and performed the statistical analysis. CK participated to assist during collection of all observations during experiment period. KSR participated to assist during collection of all observations during experiment period. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: None

Ethical issues: None

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