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RESEARCH ARTICLE

Improving fodder yield and nutritional quality of *Vigna unguiculata* L. through crop establishment and nutrient management techniques

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Abstract

Cowpea, botanically known as *Vigna unguiculata* L., is recognized as a source of nutritious fodder due to the presence of high protein content, biomass and nitrogen-fixing ability, establishing it as a good fodder crop. To maintain its biomass growth and high quality, special attention needs to be given while selecting the best method of sowing and nutrient management to produce healthy and nutritious fodder. Keeping in view, the experiment was conducted in the factorial RBD with two factors and three replications, i.e. crop establishment methods and nutrient management during the *Kharif* seasons of 2023 and 2024. The crop establishment methods include raised-bed and drilling methods, while the eight possible combinations of nutrients were used as nutrient management. Results obtained from the study indicated that the raised-bed method of sowing was significantly superior (p <0.05 %) for most of the traits as compared to the drilling method. As per nutrient management is concerned, B_6 i.e. a combination of nutrient with 100 % Recommended Dose of Fertilizer (RDF) + 1 spray of 0.5 % boron was recorded significantly highest value (p <0.05 %) for the plant height, dry matter accumulation, total number of leaves, total leaf area, number of primary branches, number of nodules, leaf area index and crop growth rate, green and dry fodder yield which was followed by B_3 i.e. a combination of 100 % RDF + 1 spray of 1 % $MgSO_4$. The quality parameters, such as SPAD index, crude protein, crude fiber, crude fat and ash content, were also detected significantly highest in B_6 as compared to the remaining treatments. These findings reveal the integrated approach of the raised bed method in combination with 100 % RDF + 1 spray of 1 % $MgSO_4$ can effectively enhance both green and dry fodder yield, along with the nutritional quality of cowpeas.

Keywords: boron; cowpea; fodder; protein; *Vigna*

Introduction

Agriculture is the backbone of the Indian economy, contributing around 17.9 % to the national gross domestic product at present. Approximately 65–70 % of the population of India is directly relying on it for their livelihood (1). However, conventional production systems have emerged as a major obstacle, significantly undermining agricultural profitability (2). Although the country is rich in terms of cattle populations, it confronts a significant deficiency of quality feed (3). The disparity between fodder demand and supply has resulted in elevated feed expenses and diminished animal health, which impacts milk yield and meat quality (4). Fodder cowpea is one of the most nutritious forage crops because it contains around 25–30 % protein. Additionally, it is a member of the Leguminosae family; thus, they fix freely available molecular nitrogen into the soil, thereby enhancing soil fertility and supporting crop growth and yield (5). It is frequently intercropped with maize and millet, thus optimizing Land Use Efficiency (LUE) and enhancing farm productivity (6).

Magnesium (Mg) and boron (B) are crucial elements for supporting the metabolic process of the plant, thereby promoting the vigorous growth of biomass in most plants, including cowpeas. Magnesium regulates key physiological processes, notably chlorophyll synthesis, which directly influences the rate of photosynthesis. Additionally, activating several enzymes involved in protein metabolism consequently good biomass quality of fodder crop (7,8). Similarly, boron triggers biomass by mediating sugar translocation, strengthening the cell wall and maintaining membrane integrity (9). Therefore, the present work was undertaken to analyse the individual and integrated approach of crop establishment method and nutrient management through foliar application of $MgSO_4$ and boron to increase the production of fodder and improve its quality.

Materials and Methods

The studies were carried out at the Agricultural Research Farm of Lovely Professional University, Punjab, India, during the *Kharif* seasons of 2023 and 2024.

Experimental details

The experiment was executed using the Russian Giant fodder variety of cowpea in a Factorial Randomized Block Design (FRBD) with two main factors (A and B) and three replications, whereas factor (A) was the crop establishment methods, comprising two sub-factors i.e. raised-bed methods [A_1] and drilling method [A_2]. The second factor of the research work was the nutrient management (B) consisting eight possible combinations i.e. control, 100 % RDF,100 % RDF +1 spray of 1 % $MgSO_4$, 75 % RDF + 2 spray of 1 % $MgSO_4$, 50 % RDF+3 spray of 1 % $MgSO_4$, 100 % RDF+1 spray of 0.5 % boron, 75 % RDF + 2 spray of 0.5 % boron and 50 % and RDF + 3 spray of 0.5 % boron. The foliar application of $MgSO_4$ and boron was done at 15, 25 and 40 DAS using a knapsack hand sprayer. The pre-sowing soil analysis was carried out to analyse the soil properties by considering the parameters like soil pH (7.94), bulk density (1.39 g/cm^3) and nitrogen (0.43 %), phosphorus (0.36 %) and potassium (0.30 %), respectively as per the standard procedures. The standard spacing of 40 x 10 cm between row to row and plant to plant was used for the planting of cowpea.

Morpho-phenological traits

Morphological traits, including plant height (cm), dry matter accumulation (grams per plant), number of leaves per plant, number of primary branches per plant, number of nodules per plant and leaf area per plant (cm^2), were analyzed through destructive sampling. Leaf area was measured using a leaf area meter (Model number 211). Leaf Area Index (LAI) and Crop Growth Rate (CGR mg cm^2 per day) were calculated at 30 and 60 DAS and between the 30-60 DAS by using the following formula given below (10–11).

Leaf Area Index (LAI) = Total leaf area (cm^2)/ground area (cm^2)

Crop Growth Rate (CGR) = $(W_2-W_1)/(T_2-T_1) * (1/A)$

Where,

W_1 and W_2 represent the dry weight of the first and second time intervals.

T_1 and T_2 represent the time intervals at which dry matter was recorded.

SPAD index

SPAD (Soil Plant Analysis Development) meter is a small device by which the chlorophyll index was measured with an accuracy of ±1.0. The working principle of the SPAD meter is based on non-destructive sampling. Before recording the data, the instrument was calibrated at a high level of accuracy. The SPAD meter, Model 502, Konica Minolta Sensing Singapore Pte Ltd, was used to analyse the chlorophyll index at intervals of 30 and 60 DAS. The measurement of SPAD index is a rapid and non-destructive method correlating well with the result of the direct method of chlorophyll content.

Proximate analysis of cowpea

Proximate analysis of cowpea leaves was carried out by using the standard procedure (12–15). This method was used to determine the amount of crude protein, ether extract (crude fat), crude fiber and ash content. The calculation of each analysis was done as per the following formula.

Nitrogen content (%)= (HCl used * Molarity of HCl * 0.01401 * 100)/(weight of sample * 0)

Crude protein (%) = Nitrogen % * 6.25

Crude fat (%) = (Weight of extract/Weight of cowpea leaf sample) * 100

Crude Fiber (%) = $(W_2-W_1)/W_0) * 100$

Where,

W_2 = Weight of sample after acid and alkali digestion

W_1 = Weight of residue after ashing

W_0 = Weight of sample

Yield parameters

To find out the green yield of cowpeas, the whole plot was harvested and its fresh weight was taken. The same plant materials were placed in a hot air oven for 48 hr at 60 °C to find out the dry yield. The values of both the yields were converted into q ha^{-1} to know the final values of green and dry yield of cowpea.

Statistical analysis

The data recorded from the study were subjected to the FRBD carried out using the software OPSTAT. The significance between the treatments was analyzed by using the CD value received at (P <0.05 %).

Results and Discussion

Morphological traits

Data presented in Table 1 revealed the significance of the treatments on the morphological traits i.e. Plant Height (PH), dry matter accumulation (g plant^{-1}), number of leaves and leaf area (47 cm^2 per plant). All the morphological characters presented in Table 1 were found statistically significant at (p <0.05 %) for both factors i.e. crop establishment method and nutrient management (A and B), wherein the interaction among the factors was noticed as nonsignificant. Among the methods of sowing, raised method was noticed superior than the drilling method for the PH (32.54 and 82.43 cm), dry matter accumulation (10.58 and 49.07 grams per plant), number of leaves (17.57 and 46.44 per plant) and leaf area (955.04 and 1998.12 cm^2 per plant) at both the time of observation (30 and 60 DAS). It is also evident from Table 1 that factor B, which is nutrient management, indicates the best treatment combination is B_6, which is a combination of 100 % RDF + 1 Spray of 0.5 % boron was recorded significantly highest value for the at (p <0.05 %) for the PH (34.92 and 87.26 cm), dry matter accumulation (13.38 and 63.52 grams per plant), number of leaves (21.15 and 50.50 per plant) and leaf area (993.83 and 2136.47 cm^2 per plant) at both the time of observations (30 and 60 DAS). However, treatment B_3, which is a combination of 100 % RDF + 1 spray of 1 % $MgSO_4$, was noted at par with B_6.

Primary branches and the number of nodules

Data related to the primary branches and the number of nodules per plant were also presented in Table 1, revealing the importance of treatments. Both factors (A and B) were statistically significant, while their interaction among AXB was nonsignificant. Among the methods of sowing, the raised method was noticed to be statistically significant at (p <0.05 %) and superior to the drilling method for the primary branches (4.83 per plant) at 60 DAS and the number of nodules (15.61 and 37.94 per plant) at 30 and 60 DAS. Out of all the combinations of factor B (nutrient management), B_6 recorded the highest value for primary branches (5.7 per plant) at 60 DAS and the number of nodules (19.40 and 41.25 per plant) at 30 and 60 DAS, as

Table 1. Response of various treatments on morphological and phenological parameters in cowpea

Treatments	Plant height (cm)		Dry matter accumulation (g per plant)		Number of leaves per plant		Leaf area (cm^2)		Primary branches Per Plant	Number of nodules per plant	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	60 DAS	30 DAS	60 DAS
CEM											
A_1	32.54	82.43	10.58	49.07	17.57	46.44	955.04	1998.12	4.83	15.61	37.94
A_2	30.70	79.85	10.20	47.44	15.99	44.44	951.56	1983.94	4.56	13.46	35.63
CD (p <0.05 %)	0.46	0.49	0.14	0.36	0.70	0.62	1.87	7.86	0.10	0.64	0.53
SE(m ±)	0.15	0.16	0.05	0.12	0.23	0.20	0.61	2.58	0.03	0.21	0.02
NM											
B_1 (control)	27.39	71.13	6.59	38.89	13.20	39.00	890.81	1794.08	3.50	9.65	29.75
B_2	33.02	83.92	12.16	57.71	18.40	48.50	975.28	2077.50	5.10	17.05	39.25
B_3	34.30	86.75	13.20	62.96	20.33	50.00	991.64	2131.88	5.53	18.70	40.50
B_4	31.55	80.92	10.02	46.29	15.25	44.25	951.48	1980.24	4.65	13.90	37.00
B_5	28.81	75.99	7.67	35.32	13.90	41.50	922.72	1865.63	3.90	10.15	33.00
B_6	34.92	87.26	13.38	63.52	21.15	50.50	993.83	2136.47	5.70	19.40	41.25
B_7	32.83	83.11	11.77	52.09	17.30	46.75	962.23	2028.17	5.00	15.55	38.50
B_8	30.13	78.97	8.31	39.28	14.50	43.00	938.40	1914.49	4.20	11.90	35.00
CD (p <0.05 %)	0.93	0.97	0.29	0.72	1.40	1.24	3.73	15.71	0.21	1.28	1.06
SE(m ±)	0.31	0.32	0.09	0.24	0.46	0.41	1.23	5.17	0.07	0.42	0.35

Note:

1- A_1=Raised-bed methods; A_2= Drilling method

2- B_1= control; B_2=100 % RDF; B_3=100 % RDF + 1 spray of 1 % $MgSO_4$; B_4=75 % RDF+2 spray of 1 % $MgSO_4$; B_5= 50 % RDF+3 spray of 1 % $MgSO_4$; B_6=100 % RDF+1 spray of 0.5 % boron; B_7=75 % RDF + 2 spray of 0.5 % boron; B_8=50 % RDF + 3 spray of 0.5 % boron

3- CEM= Crop Establishment Methods; NM= Nutrient Management

4- The interaction of CEM x NM is not significant.

compared to the remaining combinations of the treatment, which was followed by B_3.

Phenological studies

The data presented in Fig. 1 show the significance of the treatments on phenological traits, i.e. LAI and CGR of cowpea. Among the methods of sowing, the raised-bed method showed significantly higher values (p <0.05 %) than the drilling method. Parameters such as LAI showed values of 2.12 and 4.44 at 30 and 60 DAS, while the CGR values of 2.84 mg cm^2 per day were noted between the intervals of 30-60 DAS. Fig. 1 also revealed the significance of factor B among the various treatments for nutrient management. The treatments B_6 i.e. 100 % RDF+1 spray of 0.5 % boron, showed the highest value for LAI (2.21 and 4.75) at 30 and 60 DAS and CGR (3.68 mg cm^2 per day) between 30-60 DAS as compared to the remaining treatment combinations tried. However, B_3 showed values at par with B_6 for both phenological traits.

Green and dry fodder yield

The response of the treatments was statistically analyzed for green and dry fodder yield (q ha^{-1}) of cowpeas and found it highly significant as an individual factor (A and B), but its interaction was recorded as nonsignificant at (p <0.05 %). Among the methods of sowing, the raised method of sowing was significantly superior to the drilling method for the green fodder yield (216.22 q ha^{-1}) and dry fodder yield (40.33 q ha^{-1}) at 60 DAS. Data depicted from Fig. 2 also revealed that the significantly highest values of both parameters green and dry fodder yield (225.86 and 41.31 q ha^{-1}) recorded by the B_6 treatments, i.e. a combination of 100 % RDF + 1 spray of 0.5 % boron, which was followed by B_3 i.e. 100 % RDF + 1 spray of 1 % $MgSO_4$.

Crude protein, ether extract (crude fat), crude fiber, ash content and SPAD index

The data given in Fig. 3 shows the significance of the treatment applied in the present study, such as crop establishment methods and nutrient management. Among the methods of sowing, raised bed showed significantly better results than the drilling method for the proximate analysis, i.e. crude protein (7.5 %), crude fat (1.18 %), crude fiber (11.08 %), ash content (3.26 %) and SPAD index (45.76) at 60 DAS. Out of all the combinations of factor B (nutrient management), B_6 recorded the highest value for the proximate analysis i.e. crude protein (7.79 %), crude fat (1.29 %), crude fiber (11.37 %), ash content (3.4 %) and SPAD index (52.52) respectively at 60 DAS. The second-highest values for the proximate analysis were recorded in B_3, 100 % RDF + 1 spray of 1 % $MgSO_4$.

Overall results of the present study indicated that among the crop establishment methods, the raised bed method is technically superior to the drilling method. This is because the raised bed might be able to support a consistent supply of moisture in the soil and allow proper air exchange. Besides this, it ensures efficient use of nutrients, thus contributing to better vegetative growth and dry matter accumulation. Similar results were also reported regarding raised bed method, which is better in terms of moisture supply, nutrient management and proper air exchange (16,17). Among the nutrient management, a

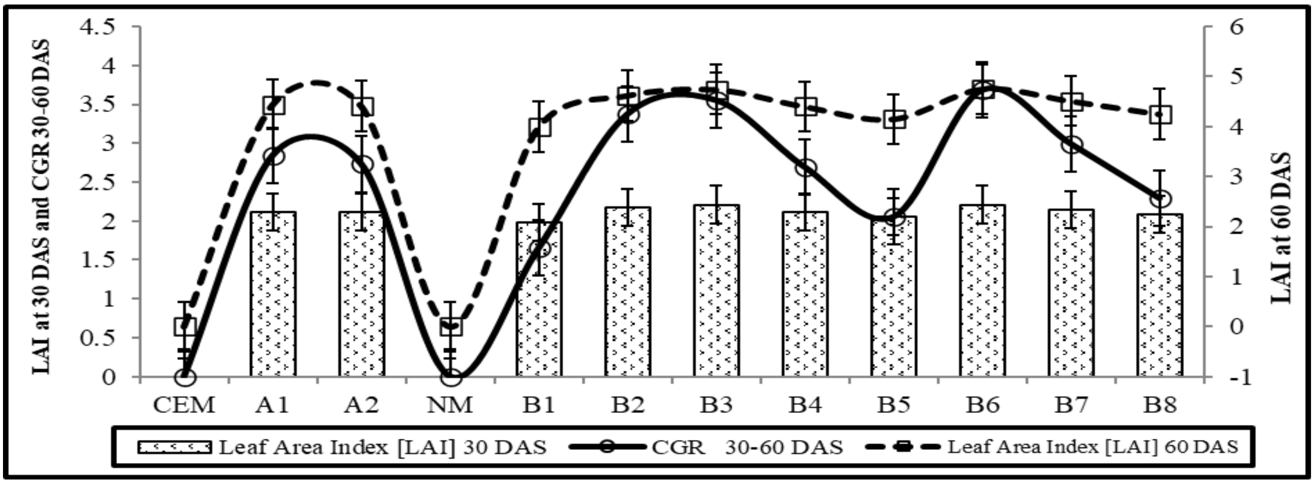

Fig. 1. Effects of various treatments on LAI and CGR (mg cm^2 per day).

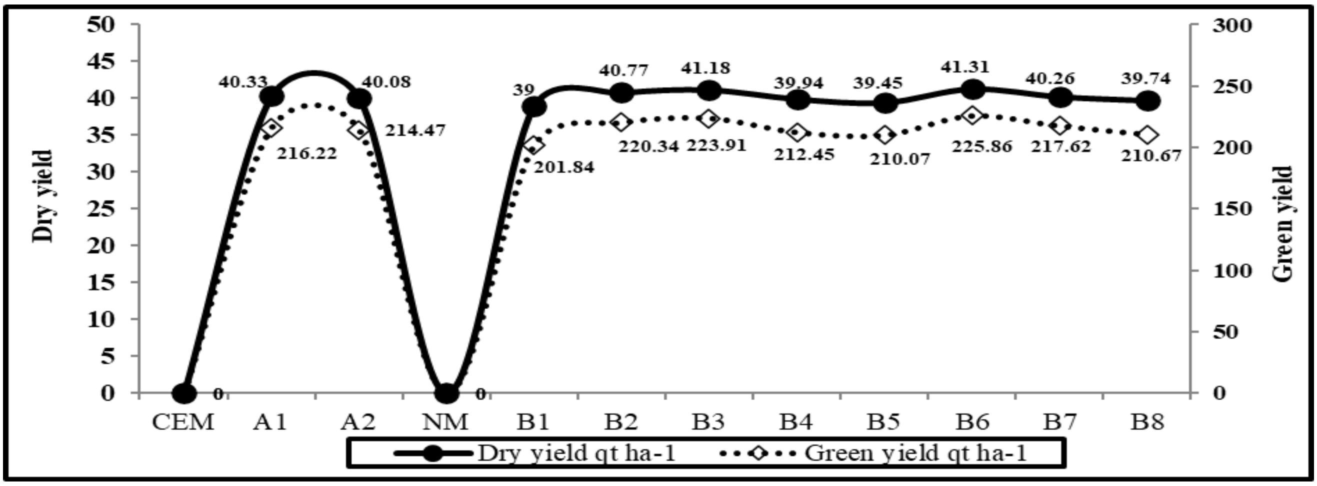

Fig. 2. Effects of various treatments on green and dry yield of fodder (q ha^{-1}).

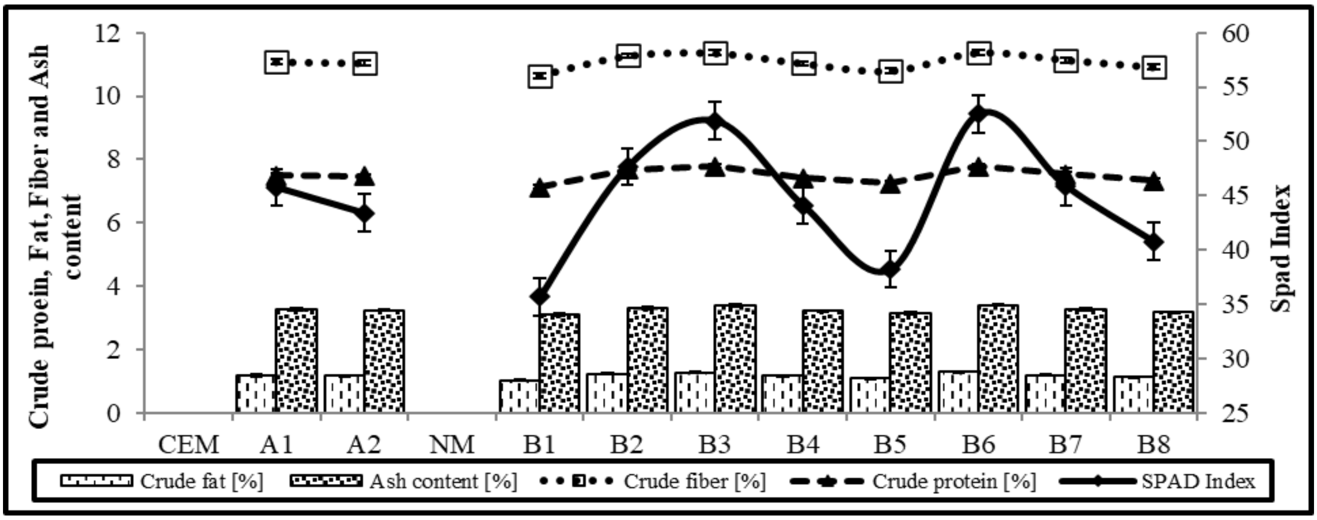

Fig. 3. Effects of various treatments on SPAD index, crude protein, fat, fiber and ash (%).

CEM= Crop establishment methods; NM= Nutrient management

combination of B_6 i.e. 100 % RDF + 1 spray of 0.5 % boron showed significant modification in the parameters such as PH, dry matter accumulation, number of leaves, leaf area, LAI, CGR, primary branches, number of nodules, SPAD index, green fodder and dry fodder yield (18,19). The positive association between boron application and sugar translocation efficiency contributes to enhancing dry matter accumulation in cowpeas because boron accelerates the movement of sugar from the region of source to the growing region of the fodder crop (20). The results of the study also indicated that the combination of B_3, 100 % RDF + 1 spray of 1 % $MgSO_4$, was at par with treatment B_6 for all the parameters. It means boron and $MgSO_4$ both can trigger vegetative growth and dry matter accumulation, but technically, boron is more efficient than magnesium sulphate, influencing the accumulation of green and dry biomass as compared to the rest of the treatments. Cowpea is a leguminous crop that enables it to fix freely available nitrogen in the soil, while boron provides additional support and contributes to increasing the number and size of root nodules, which in turn support the synthesis of chlorophyll and morpho-phenological traits (20). Additionally, the significance of boron in enhancing LAI and photosynthetic efficiency, resulting in biomass accumulation (21). Magnesium sulphate ($MgSO_4$) also intervenes for the improvement of entire morpho-phenological traits because Mg is a most important component of the chlorophyll molecule, while its deficiency leads to a reduction in the chlorophyll content and affects the integrity of the cell wall (22,23). Extended leaf area, vigorous branching and dry matter accumulation are enhanced by the consistent supply of moisture content, which raises the green and dry fodder yield (24). Fodder crops rich in protein play a crucial role in maintaining the health of cattle. An improved amount of Crude Protein (CP), Crude Fat (CF), crude fiber and ash content was noticed in the raised-bed system and the nutrient combination B_6, i.e. 100 % RDF+1 Spray of 0.5 % boron. This work is consistent with the findings of a recent study elaborating the significance of CP, CF, crude fiber and ash content in fodder crops (25). The use of 100 % RDF and boron collectively influence the content of CP, CF, crude fiber and ash content because RDF supplies a balanced amount of nitrogen, phosphorous and potassium that is important for the synthesis of protein (21), lipid (19), crude fiber (26) and enhances the levels of macro elements N, P and K. Additionally, boron enhances nitrogen metabolism and enzyme activity, plays a role in membrane integrity, cell wall formation, lignification and nutrient uptake and translocation of sugar thereby improving the quality of fodder (27).

Conclusion

The present research work is related to the improvement in fodder yield and quality mediated by the methods of crop establishment and nutrient management in cowpeas. The plants grown by the raised bed method showed better growth in terms of yield and quality of cowpea as compared to those raised by the drill method because the consistent supply of moisture, air and improved drainage makes them better for the root growth and their establishment over the field. Additionally, the application of 100 % RDF combined with a foliar spray of 0.5 % boron proved to be the most effective among the nutrient treatments. The use of boron as a foliar application provides a quick response and plays a significant role in the translocation of sugar from the source to the growing region of the plant. This action of boron enables the plant to increase biomass accumulation, hence showing high green and dry fodder yield. Moreover, improvement in CP, CF, crude fiber and ash content noted in these plants might be due to boron, which plays a significant role in nitrogen metabolism, nutrient uptake and cell wall integrity leading to improved fodder quality.

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Authors' contributions

All authors contributed equally to the preparation of the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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