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Research article

Performance of bajra napier hybrid under varying levels and frequency of $MgSO_4$ nutrition in humid tropics

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Abstract

A field experiment was conducted at AICRP on Forage Crops and Utilization, College of Agriculture, Vellayani, to assess the influence of varying levels and frequency of $MgSO_4$ application on the performance of bajra napier hybrid during the period October 2020-September 2021. The experiment was laid out in factorial randomized block design (FRBD) with nine treatments and a control replicated thrice. The treatment combinations included three levels of magnesium [m_1**:** 80 kg ha^{-1}, m_2: 100 kg ha^{-1} and m_3: 120 kg ha^{-1}] and three frequencies of application [f_1: Split application once in 6 months, f_2: Split application once in 4 months and f_3: Split application once in 3 months] and a control treatment. Considering the performance of bajra napier hybrid, varying levels and frequencies of $MgSO_4$ application had a significant influence on the growth, yield, biochemical and quality attributes as well as the soil nutrient status after the conduct of the experiment and economics of cultivation. Interaction effect of the treatment combinations revealed higher tiller count (27.07), leaf: stem ratio (1.99), green fodder yield (GFY) (1891.30 q ha^{-1}), dry fodder yield (DFY) (473.00 q ha^{-1}), crude protein content (10.06 %) and benefit-cost ratio (2.11) with split application of 100 kg ha^{-1} $MgSO_4$ once in 6 months.

Keywords: Bajra napier hybrid, Chlorophyll content, Crude protein, Fodder yield, Magnesium nutrition

Introduction

Currently, fodder production in India is not sufficient to cater to the needs of the livestock population. The ever-increasing population in the country is exerting tremendous pressure on the available land for the production of food crops and other commercial crops and, thereby, limiting the scope for further expansion of area under fodder crops (Manoj *et al*., 2022). By and large, the livestock population subsists on agro-by-products and crop residues. Our country is facing an acute fodder deficit and milk production is seriously constrained due to this (Mahanta *et al*., 2020; Kumar *et al*., 2023). The anticipated annual growth in the agricultural sector at 4% can be achieved by enhancing productivity from the livestock sector (GOI, 2019). In Kerala, area available for fodder cultivation is around 5227 ha. Availability of fodder in the state is 94.5 mt against the requirement of 232 mt, thus accounting for a deficit of nearly 60% (FIB, 2020).

Bajra napier hybrid, an interspecific cross between napier grass (*Pennisetum purpureum* Schum.) and bajra (*Pennisetum glaucum* L.), is a popular fodder grass among dairy farmers of Kerala due to its robust growth, higher productivity, quality, palatability, and persistence. The crop is well known for its vigorous growth rate with enhanced response to the external supply of fertilizers, providing guaranteed fodder production all throughout the year. Since the per capita land availability in Kerala is decreasing at an alarming rate, there is limited area available for fodder cultivation. Hence, the need of the hour is improved fodder management for higher yield and nutrient profile to meet the forage needs of ruminants. Availability of magnesium (Mg) is very low in Kerala soils, with nearly 70% of soils deficient in magnesium (GOK, 2018). Indiscriminate application of primary nutrients in intensive crop production systems without proper addition of secondary nutrients like calcium and magnesium may adversely affect the productivity and quality of forage. Magnesium nutrition in plants is often overlooked and deficiencies adversely affect plant growth. Magnesium is crucial for various physiological

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and biochemical processes in plants. Mg plays a vital role in biological functions *viz*., photosynthesis, protein synthesis, root formation, nucleotide metabolism and a lot more. In spite of that, magnesium nutrition in plants often remains little examined when compared with other essential elements (Verbruggen and Hermans, 2013).

Magnesium deficiency in agricultural soils may increase with intensive harvesting of crop products, intensification of cultivation and changes in agricultural practices without concomitant Mg fertilization (Grzebisz, 2011). Magnesium deficiency may also result from imbalanced application of primary nutrients, heavy rainfall coupled with leaching, low pH of the soil and elevated levels of competing cations like calcium and potassium (Biswas *et al.,* 2013).

Magnesium is essential for optimal growth, development and reproduction in cattle. The main roles of magnesium in a plant are in the synthesis of chlorophyll, protein, and enzyme activations (Msiza *et al*., 2022). Dietary deficiency of magnesium can adversely affect nervous system functioning and efficient carbohydrate metabolism. Grass tetany, or hypomagnesemia, is a disorder among lactating beef cows, associated with low magnesium levels in blood and body fluid (Bergmann, 1981). Since, plants are the major source of Mg for animals, maintenance of the internal equilibrium of Mg in plant tissue (Mg homeostasis) is important for attaining better plant productivity and human health.

At present the nutrient recommendation for bajra napier hybrid in Kerala includes only 200:50:50 kg ha^{-1} NPK and 25 t ha^{-1} farmyard manure (KAU, 2016). In a study conducted by Thampi (2017) in bajra napier hybrid, it was observed that magnesium application @ 80 kg ha^{-1} resulted in the highest tiller number, total green fodder yield and dry fodder yield compared to control treatments. Further, the magnesium present in the soil is highly amenable for leaching loss because of its weak bonding with soil colloids. George (2018) reported that split application of magnesium fertilizer had a profound effect on crop performance. Thomas *et al.* (2020) observed an increasing trend in green and dry fodder yield as well as enhanced quality and physiochemical characteristics of bajra napier hybrid with an external supply of magnesium. With this background, the present study was undertaken with the objective of assessing the impact of varying doses and frequency of application of $MgSO_4$ on the growth, yield and quality attributes of bajra napier hybrid.

Materials and Methods

Location of the study: The present study was conducted at AICRP on forage crops and utilization, College of Agriculture, Vellayani, Kerala during the period October 2020-September 2021 to record the optimum dose and time of application of $MgSO_4$ for growth and yield enhancement in bajra napier hybrid. The farm is geographically located at 8º 25′ 46″ N latitude and 76º 59′ 24″ E longitude, at an altitude of 30 m above the mean sea level. The soil in the experimental site was identified as sandy clay loam in texture, moderately acidic (pH 5.75) in reaction, medium in organic carbon (0.90%), available nitrogen (398.55 kg ha^{-1}) and available potassium (202.11 kg ha^{-1}), high in available phosphorus (38.86 kg ha^{-1}) and deficient in available calcium (259.13 mg kg^{-1}) and magnesium (20.67 mg kg^{-1}) status.

Treatments: The experiment was laid out in a randomized block design with 3 x 3 treatment combination replicated thrice. The treatment included three levels of magnesium [m_1: 80 kg ha^{-1}, m_2: 100 kg ha^{-1} and m_3: 120 kg ha^{-1}] and three frequencies of application [f_1: Split application once in 6 months, f_2: Split application once in 4 months and f_3: Split application once in 3 months] and a control treatment. Bajra napier hybrid variety, Suguna, released from Kerala Agricultural University was used for the study. Suguna was developed by crossing composite 9 and FD 431 and has got high tillering capacity of about 40 tillers plant^{-1}. Three nodded stem cuttings of bajra napier hybrid were used for planting. The crop was raised as per the POP recommendations of KAU, comprising 25 t ha^{-1} FYM and 200:50:50 kg ha^{-1} NPK (KAU, 2016). The entire dose of phosphorus and potassium was applied as basal. Nitrogen was applied in equal split doses after every harvest. As the treatment comprised of different levels and split application of magnesium fertilizer, required amounts were calculated and applied to respective plots as per the experimental design.

Biometric observations and chemical analysis: Observations were recorded on growth characters (plant height, tiller count per hill and leaf: stem ratio), yield characters (GFY and DFY), physiological characters (chlorophyll content) and crop quality characters (crude protein and crude fibre contents). The weighted representative sample of green fodder collected from each net plot was shade-dried and then oven dried @ 65 ± 5°C till a constant weight was attained. Dry matter content was calculated and the dry fodder yield was worked out for each harvest and expressed in t ha^{-1}. The fully opened second leaf from the top of the sample plant was used for the estimation of total chlorophyll content. The dimethyl sulphoxide (DMSO) method suggested by Yoshida *et al.* (1976) was adopted for the estimation and absorbance was measured at 663 and 645 nm using a spectrophotometer. Plant samples were ground to pass through a 0.5 mm mesh and the required quantity of samples was digested and used for crude protein and crude fiber content analysis. The total nitrogen (N) content of dried samples were determined using the micro Kjeldahl method and crude protein was estimated by multiplying N content with a factor of 6.25 (Simpson *et al*., 1965). The crude fibre content in the plant sample at harvest was determined using the standard method (AOAC, 1975).

Soil analysis: Composite soil samples for doing analysis were drawn from a depth of 15 cm before the experiment. After the completion of the experiment, soil was also collected from individual plots of the experimental field, dried for one week, cleaned and sieved using a 2 mm sieve for available N, P and K estimations. Available nitrogen content in soil was estimated by the alkaline permanganate method (Subbiah and Asija, 1956) and expressed in kg N ha^{-1}. Available phosphorus content in soil is determined by the bray colorimetric method (Jackson, 1973) and expressed in kg P_2O_5 ha^{-1}. Available potassium content in soil was estimated by ammonium acetate method (Jackson, 1973) using a flame photometer and expressed in kg K_2O ha^{-1}. Available calcium and magnesium content in soil was estimated by the ammonium acetate method (Jackson, 1973), using an atomic absorption spectrophotometer and expressed in kg ha^{-1}.

Economics and statistical analysis: The economics of cultivation was estimated based on the cost of cultivation and the prevailing market price of the fodder crop. The benefit-cost ratio was calculated by the ratio of gross income to cost of cultivation. The data generated from the experiment were statistically analyzed using analysis of variance techniques (ANOVA) for 3 x 3 factorial randomized complete block design and significance was tested by applying the 'F' test (Snedecor and Cochran, 1967). Wherever the F test values were found to be significant, the critical difference was computed at a 5% probability level.

Results and Discussion

Growth parameters: The experimental data revealed that the increased levels of magnesium fertilization and its frequency of application had a significant influence on the growth attributes of bajra napier hybrid. Pooled data (Table 1) over six cuts revealed that the highest plant height (215.7 cm) was recorded by the treatment combination T_5. The highest number of tillers (27.07) and leaf stem ratio (1.99) were recorded in the treatment combination T_4 (100 kg ha^{-1} $MgSO_4$ given as split application once in 6 months). Thampi (2017) reported that the higher tiller count in bajra napier hybrid was due to the enhanced photosynthetic rate resulting from higher chlorophyll content in response to varying doses of magnesium fertilization. The application of magnesium fertilizers favorably influenced the nitrogen uptake and assimilation in rice plants, which thereby resulted in a higher tiller count (Ding *et al*., 2006). Split application of the optimum dose of $MgSO_4$ was found to be effective in higher tiller production than the single application.

Yield parameters: The results of the pooled data (Table 1) revealed that varying doses and frequency of application of $MgSO_4$ and their interaction had a significant effect on yield characters like green and dry fodder yield in bajra napier hybrid. In the case of interaction effects, significantly superior GFY (1891.30 q ha^{-1}) and DFY (473.00 q ha^{-1}) were obtained with treatment combination T_4 (100 kg ha^{-1} $MgSO_4$ given as split application once in 6 months). Results of DFY were comparable with T_6 (100 kg ha^{-1} $MgSO_4$ given as split application once in 3 months) and T_8 with yield values of 438.4 and 441.50 q ha^{-1}, respectively. The profound influence of higher levels of $MgSO_4$ application on yield might be attributed to the crucial role magnesium plays in photosynthesis as a phosphorus carrier, sugar synthesis, enhancement in nutrient uptake and starch translocation. Moreover, magnesium being a major constituent of the chlorophyll molecule, is actively involved in rapid plant growth cell division and plays a significant role in plant metabolic activities which, thereby resulting in higher GFY in bajra napier hybrid (Thampi, 2017). Split application of fertilizer resulted in an increase in accumulated herbage biomass and also allowed for a much greater distribution of herbage mass accumulation over the growth period (Loaiza *et al*., 2019). Split fertilizer applications have been reported to produce maximum dry biomass than the crops subjected to single fertilizer treatment (Kartika *et al*., 2018). This might be due to the reduced potential

Table 1. Effect of magnesium levels and frequency of application on growth characters and yield of bajra napier hybrid

Treatment	Plant height (cm)	Tillers/ culm (nos)	Leaf stem ratio	GFY (q/ha)	DFY (q/ha)
T_1	195.3	21.65	1.72	1685.0	421.3
T_2	182.3	22.23	1.69	1612.3	403.2
T_3	185.0	21.84	1.62	1518.0	379.6
T_4	200.0	27.07	1.99	1891.3	473.0
T_5	215.7	25.40	1.81	1706.7	426.8
T_6	200.0	23.80	1.83	1752.3	438.4
T_7	187.0	22.83	1.65	1577.0	394.4
T_8	212.0	24.95	1.75	1765.7	441.5
T_9	213.3	22.78	1.52	1594.0	398.8
T_{10}	179.7	20.07	1.65	1507.0	376.8
SEM	8.316	0.454	0.041	14.95	12.622
CD (p <0.05)	24.7	1.348	0.121	44.419	37.503

T_1: 80 kg ha^{-1} $MgSO_4$ given as split application once in 6 months; T_2: 80 kg ha^{-1} $MgSO_4$ given as split application once in 4 months; T_3: 80 kg ha^{-1} $MgSO_4$ given as split application once in 3 months; T_4: 100 kg ha^{-1} $MgSO_4$ given as split application once in 6 months; T_5: 100 kg ha^{-1} $MgSO_4$ given as split application once in 4 months; T_6: 100 kg ha^{-1} $MgSO_4$ given as split application once in 3 months; T_7: 120 kg ha^{-1} $MgSO_4$ given as split application once in 6 months; T_8: 120 kg ha^{-1} $MgSO_4$ given as split application once in 4 months; T_9: 120 kg ha^{-1} $MgSO_4$ given as split application once in 3 months; T_{10}: Control; 10 quintals (q) = 1 ton (t) loss of fertilizer material in split fertilizer application. The increased fodder yield in response to magnesium nutrition could be attributed to the enhancement in tiller production and leaf: stem ratio, which might be due to accelerated photosynthetic rate resulting from higher chlorophyll content.

Biochemical characters: Total chlorophyll content in bajra napier hybrid responded positively to the application of magnesium fertilizer. Application of 100 kg $MgSO_4$ ha^{-1} given as split application once in 4 months (T_4) recorded significantly higher chlorophyll content (1.02 mg g^{-1}) (Table 2). The significant increase in chlorophyll accumulation in response to Mg fertilization could be attributed to the significance of magnesium for net assimilation, photosynthesis and transpiration ratio (Thalooth *et al*., 2006). Moreira *et al*. (2015) reported a significant increase in total photosynthetic rate with the application of higher levels of magnesium in rice plants. This might be due to the fundamental role magnesium plays in photosynthesis export through phloem and partitioning of dry matter within roots and shoots. These findings indicated that the split application of fertilizer was effectively utilized by the crop, thereby facilitating the efficient translocation of carbohydrates into the plant organs, as suggested by Kartika *et al*. (2018).

Fodder quality: Crude protein content (10.06%) in bajra napier hybrid was the highest with the application of 100 kg $MgSO_4$ ha^{-1} given as split application once in 6 months (T_4) and it was at par with T_5 (100 kg ha^{-1} $MgSO_4$ given as split application once in 4 months), T_8 (120 kg ha^{-1} $MgSO_4$ given as split application once in 4 months) and T_7 (120 kg ha^{-1} $MgSO_4$ given as split application once in 6 months) with the crude protein content of 9.62, 9.05 and 9.30%, respectively (Table 2). The higher crude protein content in response to magnesium fertilization could be attributed to the mineralization of $MgSO_4.7H_2O$ by microorganisms in the soil and its mobilization, thereby enhancing magnesium and sulfur uptake and translocation of phosphorus, all of which, particularly sulfur, play an important role in protein synthesis (Thampi, 2017). The crude fiber content of the bajra napier hybrid decreased with increasing levels of magnesium application and the lowest crude fiber content (28.60 %) was obtained in the control treatment. The lowering of crude fiber content in response to magnesium fertilization might be attributed to the reduction in rapidity of lignification in grasses as suggested by Fajemilehin *et al*. (2008) in guinea grass. The varying frequency of $MgSO_4$ application failed to elicit any significant influence on crude protein and crude fiber content of bajra napier hybrid. The interaction effect on crude fiber content was non-significant.

Table 2. Effect of magnesium levels and frequency of application biochemical and quality characters of bajra napier hybrid

Treatment	Chlorophyll (mg g^{-1})	Crude protein (%)	Crude fiber (%)
T_1	0.89	7.44	34.86
T_2	0.88	8.31	34.56
T_3	0.78	8.64	34.85
T_4	1.02	10.06	33.39
T_5	0.92	9.62	33.46
T_6	0.93	8.74	33.41
T_7	0.85	9.30	32.39
T_8	0.98	9.05	32.81
T_9	0.78	8.75	32.43
T_{10}	2.90	8.08	28.60
SEM	0.02	0.37	0.14
CD ($p < 0.05$)	0.055	1.094	NS

Soil nutrient status: Data on soil nutrient status after the study (Table 3) revealed that varying doses and frequency of application of $MgSO_4$ and their interaction had a significant effect on available phosphorus, calcium and magnesium content in soil. However, varying levels and frequency of $MgSO_4$ application and its interaction failed to elicit any significant influence on available nitrogen and potassium content in the soil after the experiment.

Significantly higher available phosphorus content (73.65 kg ha^{-1}) was recorded with the application of 100 kg ha^{-1} $MgSO_4$ given as split application once in 4 months (T_5). Higgins *et al.* (2011) also observed that magnesium application enhanced the mineralization of P and increased the available status of P in soil. The control treatment recorded the highest available calcium content (267.93 mg kg^{-1}) and was comparable with the application of 80 kg ha^{-1} $MgSO_4$ given as a split application once in 6 months (T_1). The highest soil magnesium content (43.67 mg kg^{-1}) was observed in treatment combination T_9 (120 kg ha^{-1} $MgSO_4$ given as split application once in 3 months) and was statistically at par with the application of 120 kg ha^{-1} $MgSO_4$ given as split application once in 4 months (T_8) (Table 3). Higher concentrations of magnesium in soil exhibited a depressing effect on calcium status. There exists an antagonistic interaction between K, Mg and Ca. With the additional supply of magnesium to the soil, the solution concentration of Mg increases, which in turn suppresses the calcium activity, resulting in lower available calcium in the soil (Jakobsen, 1993). Magnesium with its large hydrated radius binds weakly with soil colloids compared to other cations and is highly prone to leaching, particularly in acidic soil with low cation exchange capacity (Grzebisz, 2011).

Economics: Economics of the results (Table 3) revealed that variation in levels of magnesium fertilization and frequency of application had a significant effect on B: C ratio of the crop. Treatment combination T_4

Table 3. Effect of magnesium levels and frequency of application on available nutrient (kg ha^{-1}) status of soil and B: C ratio of bajra napier hybrid

Treatment	N	P	K	Ca	Mg	B: C ratio
T_1	301.49	49.95	225.96	257.67	26.00	1.89
T_2	290.19	44.55	216.07	256.67	27.67	1.80
T_3	292.83	42.23	202.00	241.00	38.33	1.71
T_4	305.57	54.27	203.25	248.00	32.33	2.11
T_5	282.24	73.65	199.66	240.00	34.67	1.90
T_6	290.09	53.50	196.19	233.33	39.00	1.95
T_7	291.37	60.44	192.85	188.67	29.67	1.78
T_8	295.07	53.65	194.16	215.00	41.33	1.97
T_9	298.85	57.36	191.63	191.00	43.67	1.73
T_{10}	233.62	18.17	202.71	267.93	16.68	1.49
SEM	9.13	1.76	3.87	4.73	1.17	0.02
CD (P<0.05)	NS	5.263	NS	14.190	3.496	0.063

(100 kg ha^{-1} $MgSO_4$ given as split application once in 6 months) recorded the highest B: C ratio (2.11). The result was in consonance with the observations of Thampi (2017), who reported a yield increase of 12.07% and a higher B: C ratio with the application of 100 kg $MgSO_4$ ha^{-1}. The increment in B: C ratio was attributed to the higher green and dry fodder yield obtained from these treatments. Srivastava *et al*. (2006) revealed that a significant increase in B: C ratio in response to magnesium application in rice was due to the marked increment in crop yield. A similar finding in B: C ratio was observed by Khadtare *et al*. (2017). Gehl *et al*. (2005) suggested that timing and frequency of fertilizer application was one of the best low-cost strategies employed for reducing nutrient leaching, thereby synchronizing the nutrient supply with the crop nutrient demand. George (2018) pointed out that soil application of optimum levels of $MgSO_4$ in split doses, ensuring the availability of Mg in soil could be recommended to farmers for getting better yield and monetary returns in rice.

Conclusion

The study revealed that growth, yield, biochemical and quality parameters in the bajra napier hybrid, as well as soil nutrient status and economics of cultivation, were significantly influenced by varying levels and frequency of application of $MgSO_4$. In light of the above-mentioned findings, 100 kg $MgSO_4$ ha^{-1} given as a split application once in 6 months (T4) was found to be the most promising recommendation for better fodder yield and meeting farmer's needs.

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