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Optimizing Growth and Yield of Lentil (*Lens culinaris* Medik) via Foliar Nutrient Application in Rice-Lentil Relay Cropping System

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ABSTRACT: The study entitled "Optimizing Growth and Yield of Lentil (*Lens culinaris* Medik) via Foliar Nutrient Application in Rice-Lentil Relay Cropping System" was conducted at Tirhut College of Agriculture, Dholi (Muzaffarpur) during 2020-21. The research utilized a Randomized Block Design with ten treatments, each replicated three times, using the HUL-57 lentil variety. The treatments included; T_1- Water Spray, T_2- 2% Urea, T_3- 2% DAP, T_4- 0.5% Potassium Nitrate, T_5- 0.5% NPK@ 19:19:19, T_6- 0.5% Zinc Sulphate, T_7- 2% Urea + 0.5% Zinc Sulphate, T_8- 2% DAP + 0.5% Zinc Sulphate, T_9- 0.5% Potassium Nitrate + 0.5% Zinc Sulphate, T_{10}- 0.5% NPK@19:19:19 + 0.5% Zinc Sulphate. In all the above treatments, nutrients were applied invariably at two growth stages as foliar application, *i.e.*, first at pre-flowering stage and second at pod initiation stage.

Foliar spray treatments significantly influenced lentil growth, yield and protein content. The application of nutrients via foliar sprays enhanced plant height, dry matter production, the number of branches and nodules plant^{-1} which helped in producing higher seed yield. Significantly greater plant height, dry matter production, and the number of branches per plant were observed with the foliar application of 0.5% NPK (19:19:19) + 0.5% Zinc Sulphate spray at pre-flowering and pod initiation (T_{10}) at 90 days after sowing. This treatment notably influenced growth due to the varied foliar nutrient applications. Additionally, it resulted in significantly higher seed (1477 kg ha^{-1}) and stover yields (2838 kg ha^{-1}). However, these nutrient applications did not affect the harvest index. The protein content in the seeds was also significantly impacted by the different treatments.

Keywords: Lentil, Relay cropping, Protein, Pulse, Foliar spray, Biofortification.

INTRODUCTION

Pulses are a global staple, crucial for nutritional diets. In India, pulses are vital for nutritional security, contributing to the national food basket and addressing environmental challenges. The UN declared 2016 as the International Year of Pulses to highlight their significance. India leads globally in pulse area (34%), production (26%), and consumption (30%). Pulses are the second most important food source after cereals, containing 22-34.6% protein, which is 2 to 3 times more than cereals. They are key dietary protein sources and contribute to atmospheric nitrogen fixation (Mandi *et al*., 2017). Pulses enhance soil fertility, improve soil physical condition, and increase water retention. They also provide health benefits by producing flavonoids, phytosterols, and polyphenols, reducing the risk of diseases like colon cancer and cardiovascular diseases (Jukanti *et al*., 2012). The lentil is a "clean plant", relatively free of antinutritive factors, low in flatulence and has a low post-prandial glycemic index, which is good for diabetic patient (Singh *et al*., 2023).

Lentil (*Lens culinaris* Medik), commonly known as 'Masoor,' is a highly nutritious winter pulse crop widely grown in India, particularly in temperate regions, often cultivated alongside chickpea. This versatile crop can be grown as a mixed, single, or relay crop and is used for pulse production, forage, and green manure. Lentil seeds are an excellent source of protein (340-346 g), calories (340-346 g), and carbohydrates (65%), surpassing many other legumes in nutritional value.

They are rich in essential nutrients, including calcium, fiber, iron, phosphorus, thiamine, sodium, potassium, niacin, and riboflavin. Additionally, lentils provide high levels of vital amino acids such as leucine, arginine, lysine, and sulfur-containing amino acids (Kumar and Gupta 2019).

In India, lentils are cultivated on 1.51 million ha, producing 1.22 million tonnes with an average yield of 1032 kg/ha. In Bihar, they occupy 0.15 million ha, yielding 0.148 million tonnes at 985 kg/ha (MoA & FW 2018-19). As an annual crop, lentils are often grown as a relay or paira crop, utilizing residual soil moisture on marginal lands. Relay cropping with rice expands lentil cultivation by leveraging residual fertility and moisture. This practice, termed Utera cropping in West Bengal and Paira cropping in Chhattisgarh and Bihar, involves broadcasting lentil seeds 15-20 days before rice harvest to optimize moisture use and ensure timely establishment.

The need for the present study emerged from several key research gaps in the field of lentil production within the rice-lentil relay cropping system. Despite the recognized importance of lentil as a nutrient-rich pulse crop, its productivity remains suboptimal due to various agronomic and nutritional limitations. The following research gaps were identified, necessitating the current study.

In India yield of lentil in rice-based relay cropping system remains below its potential due to poor management, nutrient deficiencies, and water stress (Ali *et al.*, 2012). Traditional fertilization often fails to meet nutrient demands at critical stages, and farmers rely on residual soil fertility from rice, which is insufficient. Limited research exists on foliar nutrient application as an alternative strategy to enhance yield (Sharma *et al.*, 2012). Conventional soil fertilization in lentils has limitations like low nutrient-use efficiency due to fixation, leaching, and volatilization. Nutrient uptake is often delayed, making them unavailable at critical growth stages. Additionally, soil-applied fertilizers may not meet micronutrient demands, particularly zinc, which is essential for plant metabolism and protein synthesis (Kumar *et al.*, 2015; Hegazy *et al.*, 1990). Nutrient deficiency during pre-flowering and pod initiation stages hampers lentil productivity. Poor soil fertility and inefficient root absorption limit nitrogen, phosphorus, and potassium uptake, while zinc deficiency affects enzyme activation, hormonal balance, and protein synthesis (Thakur *et al.*, 2017). Apart from that lentil depends on biological nitrogen fixation (BNF) via Rhizobium bacteria, but poor nodulation due to low phosphorus and micronutrient deficiencies limits nitrogen fixation (Singh *et al.*, 2020). Protein content, a key quality trait, is influenced by zinc and nitrogen, though soil-applied nitrogen is often lost through leaching. Foliar-applied nitrogen ensures better absorption, enhancing amino acid synthesis and protein accumulation in seeds (Gowda *et al.*, 2014).

Nutrient foliar spray is the easiest way to boost crop growth (Kuttimani, 2012). During flowering and pod development, foliar spray of nutrients showed positive impact on increasing the no. of pods per plant which ultimately increased the lentil yield (Shankarappa *et al.*, 2020; Reid *et al.*, 2011). Foliar spraying efficiently delivers water and nutrients to the plant's active food synthesis sites with minimal waste, quickly supplying the necessary nutrients (Nayak *et al.*, 2020; Kannan, 2010). This helps regulate the plant's source-sink relationships, especially under adverse or stress conditions (Premaradhya *et al.*, 2018). Using microelements through foliar application is more beneficial than soil application (Darwesh, 2011).

Based on the provided research context, the present study titled "Optimizing Growth and Yield of Lentil (*Lens culinaris* Medik) via Foliar Nutrient Application in Rice-Lentil Relay Cropping System" was conducted during the *rabi* season of 2020-21. Given the limitations of conventional soil fertilization, foliar application of NPK and Zinc Sulphate was explored as an alternative strategy. Limited research existed on its effectiveness in improving plant height, dry matter accumulation, seed yield, nodulation, and nitrogen fixation in relay-cropped lentils. Additionally, the study aimed to assess the role of foliar fertilization in enhancing protein content, addressing a key gap in existing research.

MATERIALS AND METHODS

A. Field layout and experimental conditions

In this experiment, lentils were sown in a standing paddy crop as a paira/utera crop, eliminating the need for preparatory tillage. The layout was designed to meet experimental requirements, and the trial was conducted using a Randomized Block Design (RBD) with three replications and a net plot size of 12.6 m² (4.2 m x 3.0 m). Treatments were randomized according to the procedure provided by Cochran and Cox (1957). The detailed description of the treatments was given in below; T_1- Water Spray at pre-flowering and pod initiation, T_2- 2% Urea spray at pre-flowering and pod initiation, T_3- 2% DAP spray at pre-flowering and pod initiation, T_4- 0.5% Potassium nitrate spray at pre-flowering and pod initiation, T_5- 0.5% NPK@ 19:19:19 spray at pre-flowering and pod initiation, T_6- 0.5% Zinc sulphate spray at pre-flowering and pod initiation, T_7- 2% Urea + 0.5% Zinc sulphate spray at pre-flowering and pod initiation, T_8- 2% DAP + 0.5% Zinc sulphate spray at pre-flowering and pod initiation, T_9- 0.5% Potassium nitrate + 0.5% Zinc sulphate spray at pre-flowering and pod initiation and T_{10}- 0.5% NPK@ 19:19:19 + 0.5% Zinc sulphate spray at pre-flowering and pod initiation.

Meteorological parameters (morning & evening relative humidity, maximum & minimum temperature etc.) were recorded as standard meteorological week during the period of experimentation is mentioned in Fig. 1.

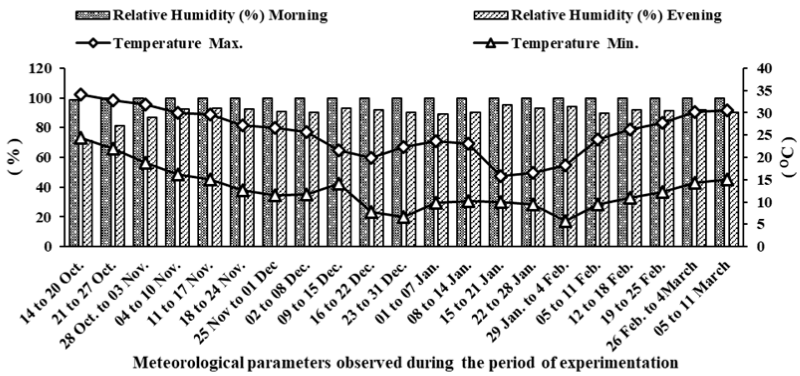

Fig. 1. Meteorological parameters observed during the period of experimentation (Standard meteorological week).

B. Varietal details, seed treatment and sowing

The HUL-57 lentil variety, developed by the Institute of Agricultural Sciences, BHU as Malaviya Jankalyani, is recommended for the North Eastern Plain Zone (NEPZ) including U.P., West Bengal, Assam, and Bihar. It is a short-duration, rust-resistant, moderately wilt-resistant, and yellow mosaic virus-resistant variety with a yield potential of 1800 kg ha^{-1}. Pure and healthy seeds were used, treated with Bavistin at 2g kg^{-1} and sown at a rate of 30 kg ha^{-1}. A basal dose of 20 kg N, 40 kg P_2O_5, and 20 kg K_2O per hectare was applied 10-15 days after sowing.

C. Foliar application of treatments

For each experimental treatment, the appropriate amounts of foliar nutrients/chemicals and water were measured and mixed to prepare a uniform solution. This solution was then evenly sprayed using conical-shaped nozzles with a knapsack sprayer. The first foliar application was carried out 74 days after sowing (DAS) at the pre-flowering stage, and the second application was given at the pod initiation stage, coinciding with 99 DAS of the crop under study.

D. Observation recorded

Representative sampling was used to record observations of different agronomic parameters of lentil plants at various growth stages. Five plants per plot were randomly chosen and marked for measurement. Plant height was recorded at 30, 60, 90 DAS, and at harvest. These plants were labeled and measured from base to tip, then averaged. Additionally, five random plant samples were collected at these intervals, washed, sun-dried, and oven-dried at 70°C to a constant weight to determine the final dry weight.

E. Nodulation studies and yield attributes

Nodule counts per plot were taken at 30 and 60 DAS by randomly selecting and carefully uprooting five plants per plot, followed by washing and counting nodules on the roots. The total number of pods on five sampled plants was averaged. A sample of 100 lentil seeds per plot was sun-dried to 12% moisture and weighed. The plot-wise grain weight was recorded in kg/ha after threshing, winnowing, and sun-drying. The stover yield was calculated after completely drying the crop residues. Harvest Index (H.I.), the ratio of economic yield (seed) to biological yield (seed + stover), was expressed as a percentage.

$$\text{H.I.(\%)} = \frac{\text{Seed yield (kg/ha)}}{\text{Seed + Stover yield (kg/ha)}} \times 100$$

F. Qualitative Analysis

(i) Protein content in seed (%). Samples from various experimental plots were dried, crushed into powder, and analyzed for nitrogen content using the micro Kjeldahl technique. The protein content of the seeds was then calculated by multiplying the percentage of nitrogen in the seeds by a constant factor of 6.25.

G. Statistical analysis

The data for growth, yield, and other characteristics were analyzed using the Variance Analysis technique and tested for significance with the "F" test at a 5% significance level, as proposed by Cochran and Cox (1957). Critical difference values at the 5% probability level were used to compare treatments.

RESULTS AND DISCUSSION

A. Growth attributes

(i) Plant height (cm) & dry matter accumulation (g plant^{-1}). Plant height is a critical growth parameter that reflects the overall vigor and development of plants. The results indicate significant differences among the treatments at later stages of growth (90 DAS and harvest), while the differences were non-significant at earlier stages (30 and 60 DAS). At 30 DAS, the tallest plants of 11.7 cm were observed in T_5 and T_3 (11.6 cm), while T_6 (0.5% Zinc Sulphate) exhibited the least plant height (10.6 cm). Similarly, at 60 DAS, T_4 (20.6 cm) and T_2 (20.5 cm) recorded higher plant heights, whereas the lowest plant height was recorded in T_9 (19.2 cm). At 90 DAS, T_{10} (41.3 cm) recorded the maximum plant height, followed by T_8 (39.7 cm), while the lowest height was recorded in T_1 (31.2 cm). At harvest, T_{10} (46.7 cm) continued to show superior performance, followed by T_8 (43.4 cm), whereas the minimum plant height was recorded in T_1 (33.5 cm). Foliar-applied fertilizers increase nutrient applications efficiency, reduce leaching losses, and provide a consistent supply of important nutrients for growth and development, as indicated by the increased plant height with nutrient-rich treatments. Similar results regarding plant height were reported by Thakur *et al.* (2017), who found that foliar sprays of 19:19:19 (N:P:K) during flowering and also during the pod development stage in chickpea resulted in a notable increase in plant height.

Plant dry matter accumulation is an important indicator of biomass accumulation and overall plant health. The data revealed non-significant differences at 30 DAS and 60 DAS, but significant differences at 90 DAS and harvest. At 30 DAS, the dry matter accumulation ranged from 0.36 g (T_9) to 0.44 g (T_5), indicating marginal variations. At 60 DAS, the highest dry weight was observed in T_2 (3.17 g), followed by T_4 (3.14 g), while the lowest was recorded in T_9 (2.94 g). At 90 DAS, T_{10} (9.47 g) recorded the highest dry matter accumulation, followed by T_8 (8.94 g), whereas the lowest was found in T_1 (5.62 g). At harvest, T_{10} (14.02 g) again showed the maximum biomass accumulation, followed by T_8 (13.21 g), while the lowest dry matter accumulation was observed in T_1 (8.87 g). Nutritional uptake and nutritional status in plant elements are improved by foliar spraying. The leaves will sustain an increased rate of photosynthesis as a result, increasing their dry weight. These results are similar to those of Muthal *et al.* (2016); Singh *et al.* (2014).

Table 1: Impact of foliar application of nutrients on plant height (cm) and dry weight (g plant^{-1}) of lentil plant.

Treatments	Plant height (cm)				Dry matter accumulation (g plant^{-1})			
	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest
T_1	10.9	20.3	31.2	33.5	0.37	3.10	5.62	8.87
T_2	11.3	20.5	35.1	37.9	0.40	3.17	7.57	11.45
T_3	11.6	19.4	35.4	38.6	0.43	2.95	7.74	11.67
T_4	11.2	20.6	34.6	37.2	0.37	3.14	7.23	11.29
T_5	11.7	19.9	37.4	40.8	0.44	3.05	8.30	12.10
T_6	10.6	19.3	33.5	36.0	0.39	3.00	6.69	10.16
T_7	11.4	19.8	36.8	40.4	0.42	2.97	8.21	12.02
T_8	11.2	19.6	39.7	43.4	0.40	3.04	8.94	13.21
T_9	10.7	19.2	36.2	39.9	0.36	2.94	8.12	11.94
T_{10}	11.0	20.2	41.3	46.7	0.38	3.08	9.47	14.02
SEm ±	0.50	1.07	1.27	1.93	0.02	0.19	0.36	0.62
CD(P=0.05)	NS	NS	3.79	5.79	NS	NS	1.08	1.87

(ii) Number of branches plant^{-1}. The number of branches plant^{-1} is an important vegetative growth parameter influencing the photosynthetic area and, consequently, crop productivity. The results indicate significant variation among treatments at 90 DAS and harvest stage, with the highest number of branches (18.67) recorded in T_{10} followed by T_8 (16.91). The lowest number of branches was observed in T_1 (water spray control, 11.23 at harvest stage).

The increase in branch number in T_{10} and T_8 can be attributed to the combined effect of macronutrients (NPK and DAP) and micronutrients (Zinc Sulphate). Nitrogen plays a crucial role in vegetative growth, promoting cell division and expansion, while phosphorus is essential for root development and energy transfer (Sharma *et al.*, 2017). Zinc further enhances enzyme activity and hormonal balance, particularly auxin synthesis, which promotes lateral branching (Alloway, 2008). The higher branch number in T_{10} (NPK + Zinc Sulphate) indicates that a balanced foliar application of macro and micronutrients optimizes shoot growth and branching potential (Ali *et al.*, 2017). Similar result also found by Krishnan *et al.* (2014).

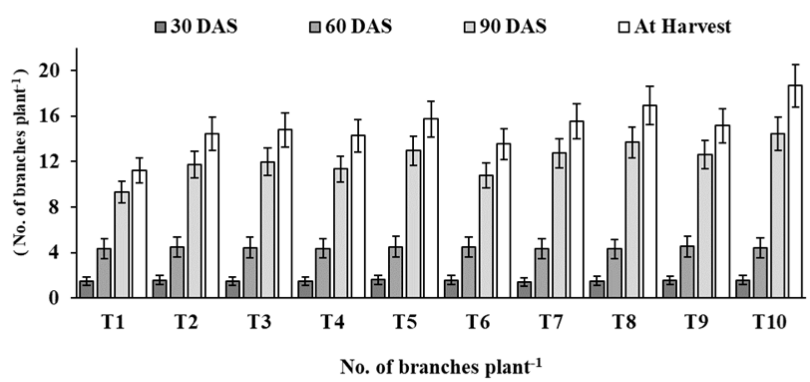

Fig. 2. Impact of foliar application of nutrients on No. of branches plant^{-1} of lentil.

(iii) Number of nodules plant^{-1}. Nodule formation is a key parameter in leguminous crops as it determines biological nitrogen fixation (BNF). The results show a moderate variation in nodule count at 30 DAS and 60 DAS, with the highest number of nodules at 60 DAS in T_9 (9.94 nodules), followed closely by T_3 (9.87 nodules) and T_8 (9.67 nodules). It is happened because of nodulation started much before the application of foliar nutrition. For those causes there was no greater influenced root growth and plant development, as well as prolific nodulation. There was whatever variation found only due to difference in soil physical conditions.

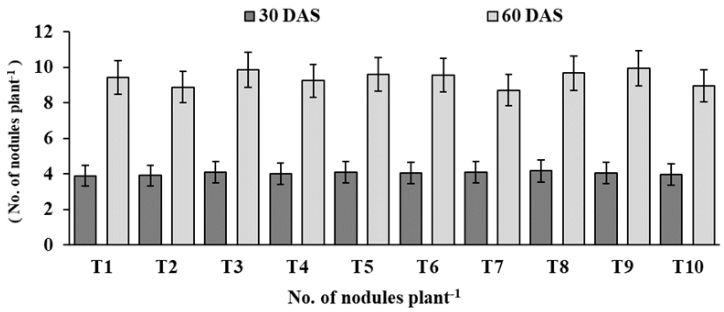

Fig. 3. Impact of foliar application of nutrients on No. of nodules plant^{-1} of lentil.

B. Yield attributes and yield

Seed yield is a crucial agronomic parameter that determines the economic viability of a crop. The results indicate significant differences among the treatments. The highest seed yield (1477 kg/ha) was recorded in T_{10} (0.5% NPK @ 19:19:19 + 0.5% Zinc Sulphate), followed by T_8 (2% DAP + 0.5% Zinc Sulphate with 1411 kg ha^{-1}), whereas the lowest yield (976 kg ha^{-1}) was observed in T_1 (Water Spray control). It is mainly due to reduced nutrient losses and enhanced nutrient supply. During the reproductive period, when nutrient demand is at its highest, the lentil plant's indeterminate growth habit could promote quick nitrogen absorption. It might have been owing to increased nitrogen availability throughout crop season due to basal application N, N-fixation, and NPK@ 19-19-19 spray. As a result, flower drop or abortion were decreased, which ultimately increased pod setting and resulted in a higher seed yield. These findings are in close conformity with Hoque *et al.* (2022).

Table 2: Impact of foliar application of nutrients on seed, stover yield (t ha^{-1}) and harvest index of lentil plant.

Treatments	Seed Yield (kg ha^{-1})	Stover Yield (kg ha^{-1})	Harvest Index (%)
T_1	976	2067	32.07
T_2	1065	2164	32.98
T_3	1215	2372	33.87
T_4	1057	2158	32.88
T_5	1260	2435	34.10
T_6	1040	2157	32.53
T_7	1251	2420	34.08
T_8	1411	2715	34.20
T_9	1235	2392	34.05
T_{10}	1477	2838	34.23
SEm ±	71.17	117.17	1.55
CD (P=0.05)	213.10	350.83	NS

Stover yield represents the total biomass produced, which is crucial for assessing nutrient assimilation and crop residue management. The results show that T_{10} (2838 kg ha^{-1}) had the highest stover yield, followed by T_8 (2715 kg ha^{-1}), while the lowest was recorded in T_1 (2067 kg ha^{-1}). The increased stover yield in T_{10} can be attributed to better vegetative growth, improved nutrient translocation, and enhanced metabolic activities. The role of NPK and Zinc Sulphate in stimulating shoot elongation, leaf expansion, and biomass accumulation is well-documented (Sharma *et al.*, 2017).

Harvest index (HI) is the ratio of economic yield (seed yield) to biological yield (total biomass). The values in the study ranged from 32.07% (T_1) to 34.23% (T_{10}), indicating non-significant differences among treatments. Although T_{10} and T_8 had the highest harvest indices, the lack of significant differences suggests that nutrient management primarily influenced total biomass production rather than the partitioning efficiency between grain and stover. This aligns with previous findings that higher nutrient availability enhances both seed and stover yield (t ha^{-1}) without significantly altering the HI (Singh *et al.*, 2020).

C. Quality Parameters

(i) Protein content in seeds (%). The highest protein content (24.23%) was recorded in T_{10}, while the lowest

(21.06%) was in T_1. The increased protein content in T_{10} (24.23%) compared to T_1 (21.06%) can be attributed to the synergistic effects of combined nitrogen and zinc applications. Nitrogen is a fundamental component of amino acids, the building blocks of proteins, and plays a critical role in nitrogen metabolism. Enhanced nitrogen availability, provided by nitrogen fertilization, leads to increased amino acid synthesis and subsequently higher protein content in the seeds (Kumar *et al.,* 2015). Zinc, on the other hand, is crucial for several enzymatic reactions involved in protein synthesis. It acts as a cofactor for various enzymes that catalyze the synthesis of amino acids and proteins, ensuring efficient metabolic processes (Cakmak, 2008). The application of zinc improves the functionality of these enzymes, resulting in better protein formation, Boonchuay *et al.* (2013); Gowda *et al.* (2014).

Therefore, the combined application of nitrogen and zinc enhances the overall protein metabolism in lentil plants, leading to a significant increase in protein content. This highlights the importance of balanced nutrient management in optimizing crop nutritional quality and yield.

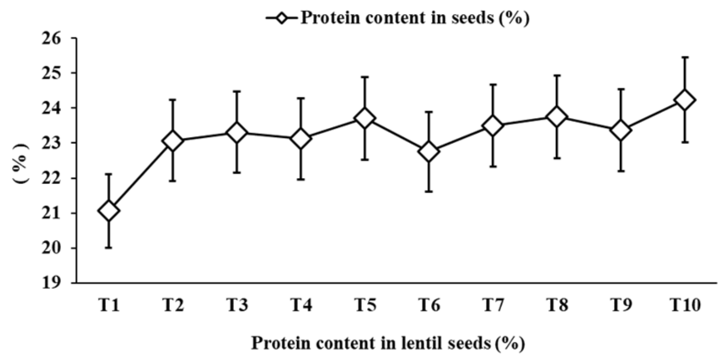

Fig. 4. Impact of foliar application of nutrients on seed protein content (%) of lentil plant.

CONCLUSIONS

The present study demonstrated that foliar nutrient applications significantly influenced the growth, yield, and protein content of lentil. Among the various treatments, the application of 0.5% NPK (19:19:19) + 0.5% Zinc Sulphate (T_{10}) at pre-flowering and pod initiation stages resulted in the highest seed yield (1477 kg ha^{-1}) and stover yield (2838 kg ha^{-1}), along with a notable increase in protein content (24.23%). The enhanced plant height, dry matter accumulation, branch number, and nodulation indicate the beneficial effects of foliar-applied nutrients in optimizing crop growth and productivity. The findings suggest that balanced foliar fertilization can be a viable strategy for improving lentil production in rice-lentil relay cropping systems.

FUTURE SCOPE

Further long-term field experiments are needed to evaluate the cumulative effects of foliar nutrient applications on soil health, sustainability, and overall cropping system productivity. Detailed investigation into the physiological and biochemical mechanisms underlying nutrient uptake and assimilation in relay cropping systems can provide deeper insights into optimizing foliar fertilization strategies. Additional studies can focus on refining nutrient concentrations, combinations, and the best application timing to maximize efficiency under different agro-climatic conditions. Apart from that, cost-benefit analysis of foliar nutrient applications can provide farmers with practical recommendations on the economic feasibility and profitability of adopting these practices. Exploring the impact of foliar nutrient applications under different climatic stress conditions, such as drought and excessive moisture, can help in developing climate-smart nutrient management strategies. The effectiveness of foliar nutrition in improving productivity can be tested in other pulse crops grown in relay systems to broaden the applicability of the findings.

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REFERENCES

Ali, A., Ahmad, B., Hussain, I., Ali, A. & Shah, F. A. (2017). Effect of phosphorus and zinc on yield of lentil. *Pure and Applied Biology (PAB), 6*(4), 1397-1402.

Ali, R. I., Awan, T. H., Ahmad, M. M., Saleem, U. & Akhtar, M. (2012). Diversification of rice based cropping systems to improve soil fertility, sustainable productivity and economics. *Journal of Animal and Plant Sciences, 22,* 108-112.

Alloway, B. J. (2008). Zinc in soils and crop nutrition. *International Fertilizer Industry Association.*

Boonchuay, P., Cakmak, I., Rerkasem, B. & Prom-U-Thai, C. (2013). Effect of different foliar zinc application at different growth stages on seed zinc concentration and its impact on seedling vigor in rice. *Soil Science and Plant Nutrition, 59*(2), 180-188.

Cakmak, I. (2008). Enrichment of cereal grains with zinc: Agronomic or genetic biofortification? *Plant and Soil, 302*(1), 1-17.

Cochran, W. G. & Cox, G. M. (1957). Confounding of a 33 factorial. In: Experimental Designs, *John Wiley & Sons Inc, Londo*, 195-203.

Darwesh, D. A. (2011). Effect of soil and foliar application of iron chelate on nutrient balance in lentil (*Lens esculentum* L.) by using modified DRIS Equation. *Mesopotamia Journal of Agriculture, 39*(3), 39-51.

Gowda, M. K., Halepyati, A. S., Koppalkar, B. G. & Rao, S. (2014). Response of pigeonpea to application of micronutrients through soil and foliar spray of macronutrients on yield, economics, and protein content. *Karnataka Journal of Agricultural Science*, *27*(4), 460-463.

Hegazy, M. H., Fatma, I., Hawary Mel, Ghobrial W. N. (1990). Effect of micronutrient application and brady-rhizobium japnicum inoculation on soybean. *Anals Agric. Sci., Special Issue,* 381-398.

Hoque, A., Singh, H., Srivastava, R. K. & Barman, A. (2022). Response to foliar application of different nutrient on lentil (*Lens culinaris* medik.) as relay crop under rice assessed in terms of performance of yield and economics in the eastern region of India. *Journal of Crop and Weed*, *18*(3), 256-259.

Jukanti, A. K., Gaur, P. M., Gowda, C. L. L. & Chibbar, R. N. (2012). Nutritional quality and health benefits of chickpea (*Cicer arietinum* L.): a review. *British Journal of Nutrition, 108*(S1), S11-S26.

Kannan, S. (2010). Foliar fertilization for sustainable crop production. In: Genetic Engineering, Biofertilization, Soil Quality and Organic Farming. Sustainable Agriculture Reviews 4. E. Lichtfouse (ed). *Springer Verlag, Springer*, 371-402.

Krishnan, A., Indiresh, K. M. & Anjanappa, M. (2014). Effect of water-soluble fertilizers on growth and yield of tomato (*Solanum lycopersicum* L.). *Journal of Tropical Agriculture*, *52*(2), 154-157.

Kumar, D., Pandey, S. & Meena, R. S. (2015). Effect of foliar application of zinc and iron on yield and quality of mung bean (*Vigna radiata*). *Legume Research, 38*(5), 635-640.

Kumar, J. & Gupta, S. (2019). Inheritance of qualitative and quantitative traits in interspecific crosses of lentil. *Indian J. Genet*, *79*(3), 626-631.

Kuttimani, R. (2012). Response of lentil to foliar fertilization of phosphate. *New Agriculturist, 2*(1), 85-86.

Mandi, S. K., Reja, H., Kundu, M. K., Maji, S., Nath, R. & Sarker, S. D. A. (2017). Agronomic management of lentil under relay cropping system. *Indian Journal of Agricultural Research*, *51*(6), 536-542.

Muthal, Y. C., Deshmukh, S. L., Sagvekar, V. V. & Shinde, J. B. (2016). Effect of foliar application of macronutrient and micronutrients on yield attributes, yield and economics of Kharif greengram (*Vigna radiata* L.). *International Journal of Tropical Agriculture*, *34*(7), 2143-214.

Nayak, S., Nayak, D. & Parida, S. (2020). Micronutrient Foliar Spray on Growth Performance of Green Gram (*Vigna radiata* L.). *Asian Journal Biological Life Science, 9*(2), 234-238.

Premaradhya, N., Shashidhar, K. S. & Samuel Jeberson, R. K. (2018). Effect and profitability of foliar application of thiourea on growth and yield attributes of lentil (*Lens culinaris* L.) under Manipur Conditions of North-East, India. *International Journal of Current Microbiology and Applied Sciences, 7*(5), 1040-1050.

Reid, D. E., Ferguson, B. J., Hayashi, S., Lin, Y. H. & Gresshoff, P. M. (2011). Molecular mechanisms controlling legume autoregulation of nodulation. *Annals, 108*, 789-795.

Shankarappa, S. K., Muniyandi, S. J., Chandrashekar, A. B., Singh, A. K., Nagabhushanaradhya, P., Shivashankar, B., El-Ansary, D. O., Wani, S. H. & Elansary, H. O. (2020). Standardizing the Hydrogel Application Rates and Foliar Nutrition for Enhancing Yield of Lentil (*Lens culinaris*). *Processes, 8*(4), p.420.

Sharma, S. N. & Mritunjay, K. (2012). A success story of dual-purpose summer mungbean in climate smart villages in Vaishali District of Bihar. *Fertiliser Marketing News*, *43*(10), 9-16.

Sharma, P., Dubey, R. and Singh, S. (2017). Effect of Foliar Application of Nutrients on Growth and Yield of Crops. *Journal of Plant Nutrition*, *40*(12), 1755-1770.

Singh, A. K., Singh, V. & Chauhan, M. P. (2014). Effect of foliar application (nitrogen and phosphorus) on different agronomic and economic character in lentil (*Lens culinaris* M.). *Research in Environment and Life Sciences*, *7*(1), 65-67.

Singh, R., Meena, R. & Verma, P. (2020). Impact of Nutrient Management on Growth Parameters of Various Crops. *Agricultural Reviews, 41*(3), 210-225.

Singh, K. K., Kumar, T., Gupta, S. K., Solankey, S. S., Singh, S. K., Prasad, S. S. & Kumari, S. (2023). Enhancing Lentil Productivity in the North-West Alluvial Plain Zone through Cluster Front Line Demonstration (CFLD). *Biological Forum – An International Journal*, *15*(7), 32-37.

Thakur, V., Patil, R. P., Patil, J. R., Suma, T. C. & Umesh, M. R. (2017). Influence of foliar nutrition on growth and yield of blackgram under rainfed condition. *Journal of Pharmacognosy and Phytochemistry, 6*(6), 33-37.

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