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Enhancing lentil growth and yield through organic foliar application for sustainable agriculture

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Abstract The application of 10% Panchagavya significantly enhanced lentil growth metrics, with plant height and dry matter accumulation increasing by 40.40% and 31.60% at 60 and 90 DAS, respectively. This treatment also improved key yield attributes, including the number of pods per plant and seeds per pod, resulting in an impressive 157.60% increase in the number of seeds per plant. Additionally, the seed yield, straw yield, and biological yield were noted to be higher under the 10% Panchagavya treatment which is accompanied by a substantial improvement in the harvest index. These results underscored the effectiveness of Panchagavya as a bio-based foliar application, in enhancing growth and yield in lentil crops, providing a sustainable and eco-friendly alternative to conventional chemical fertilizers.

Keywords: Low cost, Natural farming, Nutrient enhancement, Pulses

Introduction

Lentil (*Lens culinaris* Medik.) is one of the oldest domesticated crops grown in the globe. The background information provided discusses the significance of lentils (*Lens culinaris*) as an ancient crop with nutritional value and global cultivation. Lentils are rich in essential nutrients like vitamin A, fiber, potassium, vitamin B, and iron, making them a staple food in many regions (Samaranayaka and Khazaei, 2024). Despite being the third most produced pulse crop worldwide, lentil cultivation faces challenges in modern chemical-based agriculture due to sustainability issues such as soil degradation, pollution, resource shortages, and low farm income (Kaale *et al.*, 2023). The heavily reliant on chemical fertilizers and pesticides, have been linked to various environmental and health concerns. Excessive use of chemical inputs can lead to soil degradation, a decline in soil fertility, and a loss of biodiversity essential for ecosystem balance (Tilman *et al.,* 2017). Additionally, the increased use of pesticides poses risks to both human health and wildlife, contaminating water sources and reducing biological control potential on farmlands (Geiger *et al.,* 2010). This reliance on synthetic chemicals also contributes to greenhouse gas emissions, exacerbating climate change and impacting long-term food security (Sharma *et al.,* 2019). In

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response to these challenges, there's a growing awareness and adoption of alternative farming methods, particularly the use of organic fertilizers. For practical use, farmers could incorporate these organic treatments as part of an integrated nutrient management plan to reduce reliance on chemical fertilizers and promote soil health. Organic fertilizers, including fermented liquid variants, have gained traction in modern agriculture as they improve soil quality and provide benefits like enhanced crop tolerance to environmental stressors (Rathore *et al*., 2023). Focusing on lentil cultivation, studies have shown that foliar application of nutrients, particularly NPK (nitrogen, phosphorus, and potassium), during specific growth stages can address issues like poor growth, nodule senescence, and low seed setting in pulses (Ashraf *et al*., 2023). Additionally, organic substances like cow urine (Devasena and Sangeetha, 2022), Panchagvaya (a mix of cow dung, urine, milk, curd, and ghee) (Bajaj *et al*., 2022), and Jeevamrutha (a bioenhancer) (Reshma *et al*., 2019) have been found to promote soil fertility, plant development, and immunity. Studies show that Panchagavya applications in rice enhance growth, yield, and grain quality. Applied as a foliar spray, it improves nutrient absorption, leading to higher biomass and productivity (Prabhu *et al*., 2010). Panchagavya has been shown to increase fruit yield and improve quality traits such as vitamin C content and shelf life in tomatoes. Its use has demonstrated improved plant health and reduced incidence of pests, making it a popular choice for organic tomato cultivation (Choudhary *et al.,* 2012). Panchagavya has been applied to leafy vegetables like spinach, where it stimulates leaf growth, increases chlorophyll content, and improves nutrient profiles, making the produce more nutritious and marketable (Kumari *et al.,* 2017). Micronutrients like boron also play a crucial role in lentil yield and quality by aiding in various physiological processes such as carbohydrate metabolism, flower retention, and seed development (Tariq *et al.,* 2023). Similarly, Vermiwash, derived from earthworm products, is an eco-friendly plant tonic that enhances root growth, plant development, and overall crop productivity (Singh *et al.,* 2022) By exploring the effectiveness of organic fertilizers and micronutrients, the research seeks to contribute valuable insights into sustainable lentil cultivation practices amidst challenges posed by conventional agriculture methods. The research finding aimed to optimize the foliar application of nutrients on lentil crops to assess their impact on crop yield and quality.

Materials and methods

An experiment was conducted in a Randomized Completely Block Design with seven treatments, each replicated three times, during the *Rabi* season of 2022-2023 at the Agricultural Research Farm of Graphic Era Hill University Dehradun, Uttarakhand. The soil in the experimental plots was identified as loamy sand with a pH ranging from slightly acidic to neutral.

The seven treatments, namely, T1 (control), T2 (1% NPK), T3 (10% cow urine), T4 (10% Panchagavya), T5 (10% Jeevamrutha), T6 (50 ppm Boron), and T7 (5% Vermiwash), were applied to the Pant Lentil-09 (PL-09) variety. Panchagavya was prepared by combining five traditional cow-derived products in specific proportions: fresh cow dung (500 g), cow urine (1 L), cow milk (200 mL), curd (200 mL), and ghee (100 mL). These ingredients were mixed and allowed to ferment for 7–10 days, with daily stirring to promote microbial activity. After fermentation, the mixture was diluted to a 3% concentration for foliar application. Jeevamrutha was prepared by combining cow dung (5 kg), cow urine (5 L), jaggery (500 g), pulse flour (500 g), and a handful of soil. These ingredients were mixed thoroughly and left to ferment for 3–5 days, with regular stirring. For foliar application, Jeevamrutha was diluted to a 5% concentration. Foliar applications were applied at two stages, specifically at 45 DAS (vegetative stage) and 65 DAS (reproductive stage). The crop, sown on November 5, 2022, with a seed rate of 45 kg/ha, was harvested on March 15, 2023. Thinning was performed 20 days after sowing, and two irrigations were applied after sowing. Meteorological data (Figure 1) were collected through meteorological and weather stations at the Research Farm, Graphic Era Hill University, Dehradun. Growth parameters such as plant height (cm) and dry weight (g/m^2) were recorded at 30, 60, and 90 DAS. Yield parameters, including the number of pods/plant, number of seeds/pod, number of seeds/plant, test weight (g), seed yield, straw yield, biological yield and harvest index, were recorded at physiological maturity.

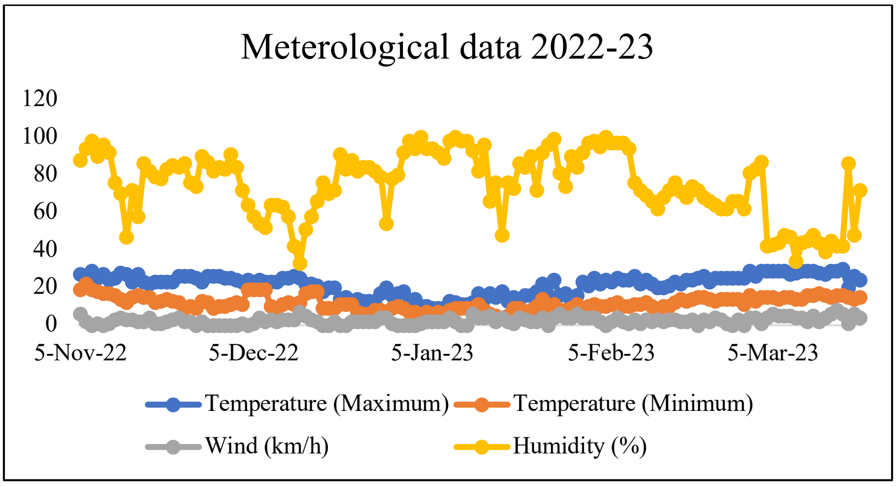


Figure 1. Meteorological data recorded during Rabi season

A post hoc test was conducted for statistical analysis, particularly after analysis of variance (ANOVA), to explore and compare specific pairs of groups. When the ANOVA indicates a significant difference among multiple groups, a post hoc test helps identify which pairs of groups exhibit significant

differences. Tukey's honestly significant difference (HSD) test was used in the present study to compare all possible pairs of group means.
The formula for Tukey's HSD is as follows:

$$\text{HSD} = q \times \sqrt{MS\frac{within}{n}}$$

where:q is the critical value obtained from Tukey's HSD distribution table, MS within is the mean square within groups (residual mean square) from the ANOVA and n is the number of observations in each group. The formula provides a threshold value, and the difference between any two group means that exceed this threshold is considered statistically significant. Statistical analysis was conducted using SPSS software.

Results

Plant height and dry matter content showed non-significant variations at 30 days after sowing (DAS) across all plots. At 60 and 90 DAS, plants treated with 10% Panchagavya was significantly increased in plant height, with a 40.4% increase at 60 DAS and a 31.6% increased at 90 DAS as compared to the control group. Dry matter accumulation was significantly higher in plants treated with 10% Panchagavya, showing a 152.1% increase at 60 DAS and a 106% increase at 90 DAS compared to the control group (Table 1). The number of pods per plant significantly increased at 10% Panchagavya (36.7%), followed by 1% N:P:K (34.7%) and 50 ppm Boron (32.7%). Similarly, the percentage of seeds/pods significantly increased in the 10% Panchagavya (1.8%) and 1% NPK (1.8%) treatments (Table 2). The number of seeds/plant under 10% panchgavya treatment markedly increased by 157.6% as compared to control. The test seed weight significantly increased under the 10% Panchagavya treatment (24.8g), followed by the 1% N:P:K treatment (24.4g) (Figure 2). The impact of foliar spray on seed yield was found to be significant across all treatments (Figure 3).

Maximum seed yield showed in 12.5q/ha which observed with the 10% panchagavya treatment and statistically comparable to that of the 1% NPK treatment. Significant differences in straw yield (q/ha) were also observed among all treatments (Table 3). The highest straw yield (21.5q/ha) and biological yield was achieved with the 10% panchagavya treatment. The harvest index, a measure used in agriculture to quantify the yield of a crop species relative to the total biomass produced, showed a greater percentage (36.8%) with the 10% panchagavya treatment, followed by the 1% N.P.K. This correlation matrix illustrates the relationships among different crop growth stages (DAS), yield components, and quality traits in Lentil. Figure 4 presents the correlation coefficients between various growth and yield parameters of lentil at different days after sowing (DAS) intervals and yield-related traits. Plant height (PH) at 60 DAS and 90 DAS exhibited significant positive correlations with each other (r = 0.952) and with dry matter (DM) accumulation at 60 DAS and 90 DAS, highlighting a consistent increase in growth over time. DM at 60 DAS and 90 DAS correlated strongly with traits like seeds per pod, seeds per plant, and test weight, suggesting that DM accumulation at later stages contributes positively to seed development and overall yield. Specifically, seeds per pod had strong correlations with seeds per plant ($r = 0.983$) and test weight ($r = 0.978$), emphasizing its role in determining yield potential. In terms of yield components, pods per plant, seeds per plant, and test weight all showed highly significant positive correlations with straw yield, biological yield, and harvest index. It indicated that higher pod and seed counts and seed weight positively influence both vegetative (straw) and reproductive (seed) yields. Harvest index showed a strong correlation with seed yield ($r = 0.986$), underscoring its importance in the effective allocation of biomass toward seed production.

Table 1. Variation in plant height and dry matter at 30 days interval under different treatment

Treatments	**Plant height (m^2)**			**Dry matter (g/m^2)**		
	30 DAS	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
T$_1$ Control (Water spray)	8.4±0.47^{a}	12.1±1.1^{a}	21.5±0.50^{a}	5.9±0.77^{a}	9.1±0.17^{a}	23.9±0.18^{a}
T$_2$ 1% N:P:K	8.1±0.74^{a}	16.7±3.5^{b}	27.6±1.9^{bc}	5.2±0.15^{a}	21.2±0.10^{d}	45.4±0.20^{d}
T$_3$ 10% Cow urine	8.5±1.89^{a}	12.6±0.37^{a}	23.5±1.3^{ab}	5.0±0.60^{a}	11.1±0.96^{ab}	26.5±0.31^{a}
T$_4$ 10% Panchagavya	8.6±0.90^{a}	17.0±1.5^{b}	28.3±4.3^{c}	5.7±0.20^{a}	23.4±0.97^{e}	49.3±0.37^{e}
T$_5$ 10% Jeevamrutha	9.0±1.20^{a}	12.1±1.8^{a}	23.8±0.90^{abc}	5.6±0.86^{a}	13.3±2.66^{b}	30.9±0.50^{b}
T$_6$ 50 ppm Boron	9.8±1.50^{a}	13.9±1.0^{ab}	24.7±0.37^{abc}	5.1±0.05^{a}	17.6±1.15^{c}	35.6±0.61^{c}
T$_7$ 5% Vermiwash	9.3±0.45^{a}	13.8±1.4^{ab}	23.9±0.90^{abc}	5.9±0.05^{a}	17.2±0.72^{c}	32.5±0.71^{bc}
Sem±	0.699	1.108	1.269	0.303	0.736	1.285
CD at 5%	N/S	3.45	3.954	N/S	2.292	4.002

Table 2. Variation in yield attributes in lentil under different treatments

Treatments	**Pods/plant**	**Seeds/pod**	**Seeds/plant**	**Test weight(g)**
T$_1$ Control (Water spray)	22.0±3.4^{a}	1.2±0.1^{a}	26.4±4.1^{a}	21.6±1.5^{a}
T$_2$ 1% N:P:K	34.7±0.57^{bc}	1.8±0.1^{b}	62.4±1.0^{cd}	24.4±2.2^{a}
T$_3$ 10% Cow urine	30.7±1.1^{b}	1.4±0.1^{ab}	42.9±1.8^{b}	22.2±1.0^{a}
T$_4$ 10% Panchagavya	36.7±1.1^{c}	1.8±0.05^{b}	67.2±2.0^{d}	24.8±1.6^{a}
T$_5$ 10% Jeevamrutha	31.0±1.0^{b}	1.5±0.36^{ab}	46.4±1.9^{bc}	22.6±0.5^{a}
T$_6$ 50 ppm Boron	32.7±0.57^{bc}	1.7±0.11^{ab}	54.5±4.3^{bcd}	23.8±0.6^{a}
T$_7$ 5% Vermiwash	31.8±1.5^{b}	1.6±0.20^{ab}	51.0±8.0^{bc}	23.2±0.9^{a}
SEm±	0.979	0.103	4.967	0.686
CD at 5%	3.049	0.321	10.941	2.136

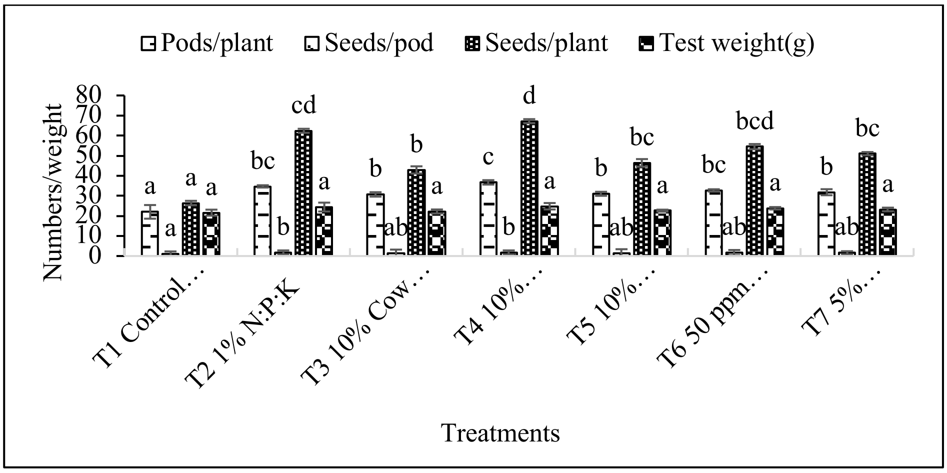


Figure 2. Variation in yield attributes of lentil genotypes

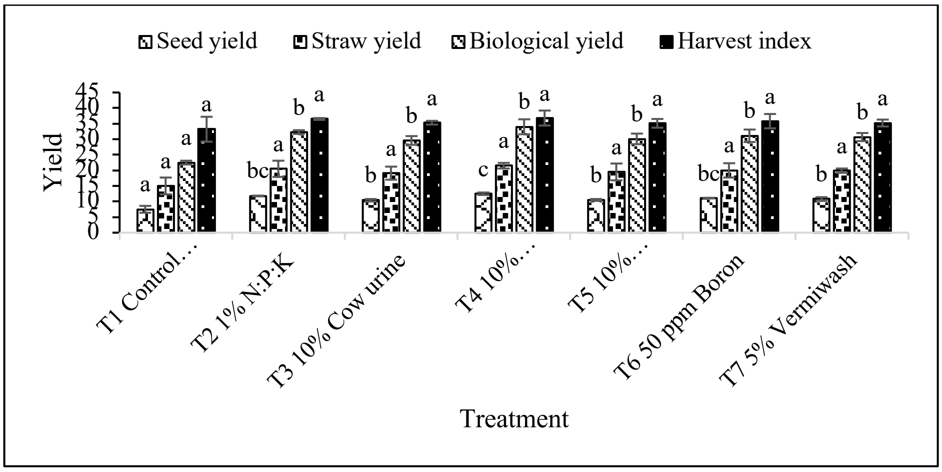
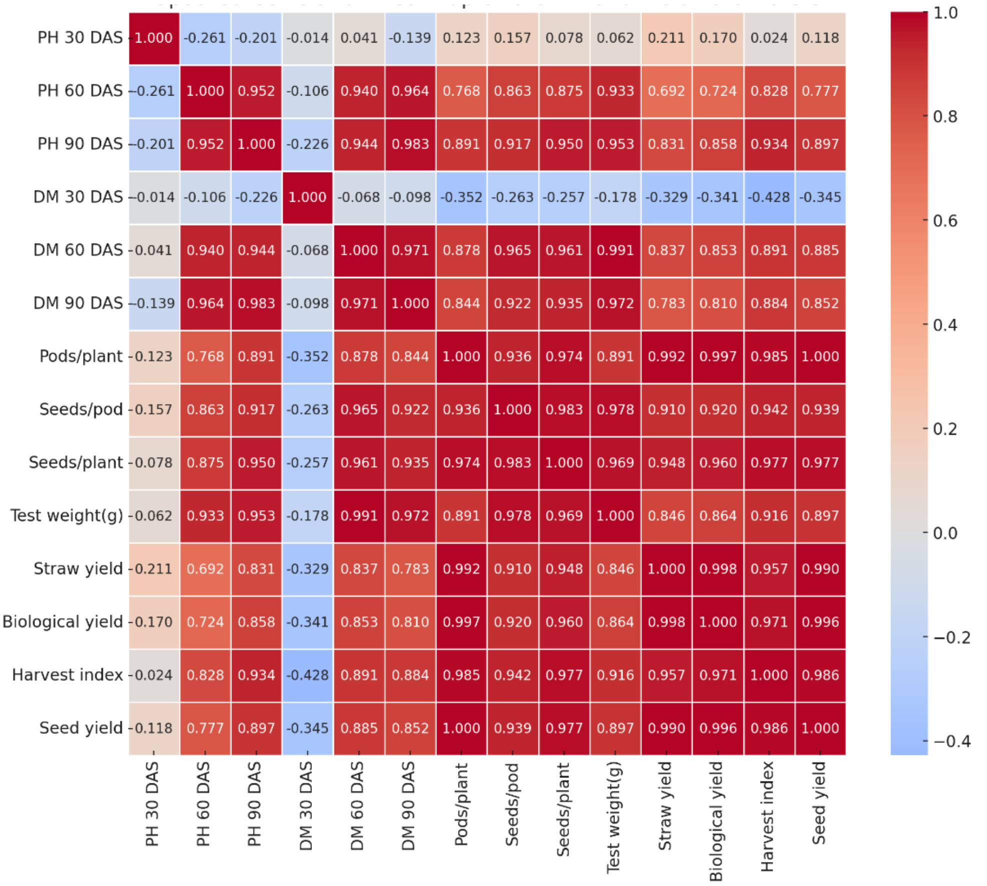


Figure 3. Variation in yield of lentil genotypes

Table 3. Variation in seed yield, straw yield, biological index and harvest index in lentil under different treatment

Treatments	Seed yield (q/ha	Straw yield(q/ha)	Biological yield (q/ha)	Harvest index
T1 Control (Water spray)	7.5±1.1^{a}	15.0±2.7^{a}	22.5±0.6^{a}	33.2±4.8^{a}
T2 1% N:P:K	11.8±0.1^{bc}	20.5±2.6^{a}	32.3±0.6^{b}	36.5±0.3^{a}
T3 10% Cow urine	10.4±0.4^{b}	19.1±2.1^{a}	29.6±1.4^{b}	35.3±0.6^{a}
T4 10% Panchagavya	12.5±0.4^{c}	21.5±0.9^{a}	34.0±2.4^{b}	36.8±2.4^{a}
T5 10% Jeevamrutha	10.5±0.3^{b}	19.5±2.7^{a}	30.1±1.7^{b}	35.1±1.4^{a}
T6 50 ppm Boron	11.1±0.1^{bc}	20.0±2.3^{a}	31.1±2.0^{b}	35.8±2.3^{a}
T7 5% Vermiwash	10.8±0.6^{b}	19.9±0.7^{a}	30.7±1.3^{b}	35.2±1.1^{a}
Sem±	0.344	0.885	0.956	1.422
CD at 5%	1.075	2.756	2.977	N/S



	PH 30 DAS	PH 60 DAS	PH 90 DAS	DM 30 DAS	DM 60 DAS	DM 90 DAS	Pods/plant	Seeds/pod	Seeds/plant	Test weight(g)	Straw yield	Biological yield	Harvest index	Seed yield
PH 30 DAS	1.000	-0.261	-0.201	-0.014	0.041	-0.139	0.123	0.157	0.078	0.062	0.211	0.170	0.024	0.118
PH 60 DAS	−0.261	1.000	0.952	-0.106	0.940	0.964	0.768	0.863	0.875	0.933	0.692	0.724	0.828	0.777
PH 90 DAS	−0.201	0.952	1.000	-0.226	0.944	0.983	0.891	0.917	0.950	0.953	0.831	0.858	0.934	0.897
DM 30 DAS	−0.014	-0.106	-0.226	1.000	-0.068	-0.098	-0.352	-0.263	-0.257	-0.178	-0.329	-0.341	-0.428	-0.345
DM 60 DAS	0.041	0.940	0.944	-0.068	1.000	0.971	0.878	0.965	0.961	0.991	0.837	0.853	0.891	0.885
DM 90 DAS	−0.139	0.964	0.983	-0.098	0.971	1.000	0.844	0.922	0.935	0.972	0.783	0.810	0.884	0.852
Pods/plant	0.123	0.768	0.891	-0.352	0.878	0.844	1.000	0.936	0.974	0.891	0.992	0.997	0.985	1.000
Seeds/pod	0.157	0.863	0.917	-0.263	0.965	0.922	0.936	1.000	0.983	0.978	0.910	0.920	0.942	0.939
Seeds/plant	0.078	0.875	0.950	-0.257	0.961	0.935	0.974	0.983	1.000	0.969	0.948	0.960	0.977	0.977
Test weight(g)	0.062	0.933	0.953	-0.178	0.991	0.972	0.891	0.978	0.969	1.000	0.846	0.864	0.916	0.897
Straw yield	0.211	0.692	0.831	-0.329	0.837	0.783	0.992	0.910	0.948	0.846	1.000	0.998	0.957	0.990
Biological yield	0.170	0.724	0.858	-0.341	0.853	0.810	0.997	0.920	0.960	0.864	0.998	1.000	0.971	0.996
Harvest index	0.024	0.828	0.934	-0.428	0.891	0.884	0.985	0.942	0.977	0.916	0.957	0.971	1.000	0.986
Seed yield	0.118	0.777	0.897	-0.345	0.885	0.852	1.000	0.939	0.977	0.897	0.990	0.996	0.986	1.000

Figure 4. Heat map of Pearson correlation analysis among growth and yield parameters

where: PH- Plant height and DM- Dry matter, *and** significant at 1% and 2% level of significance.

Discussion

The observed increase in plant height and dry matter accumulation in lentil plants treated with 10% Panchagavya at 60 and 90 DAS indicates the potential growth-promoting effects of Panchagavya. Similar findings were reported by Kumar *et al.* (2022) in chickpea, where maximal plant height was achieved with a 9% Panchagavya application. This growth stimulation is likely due to the presence of essential micro- and macronutrients, growth hormones, and biofertilizers in Panchagavya, which promote cell elongation and division. Furthermore, the combined application of nitrogen and 5% Panchagavya resulted in even greater plant height and biomass accumulation compared to other treatments. This finding is consistent with Kumar *et al.* (2023), who reported increased dry matter accumulation with higher nitrogen levels and Panchagavya concentrations in fodder maize. Overall, these results suggest that Panchagavya, particularly at higher concentrations, can significantly enhance growth parameters such as plant height and dry matter accumulation in lentil crops. The synergistic effects of Panchagavya with nitrogen further contribute to improved plant performance, highlighting the potential of integrated nutrient management strategies in sustainable lentil cultivation. The significant increase in the number of pods per plant with 10% Panchagavya treatment suggests the positive impact of nutrient supplementation on lentil growth. This finding is consistent with previous studies in maize and cowpea, where foliar application of Panchagavya accelerated metabolic processes, leading to increased pod formation (Veeral and Abirami, 2021; Mukherjee *et al.,* 2023). Moreover, the observed increase in seeds per pod and seed yield under 10% Panchagavya treatment aligns with studies in chickpea and soybean, highlighting the role of foliar nutrients in enhancing floral bud development, preventing shedding, and maintaining optimal physiological conditions for yield improvement (Venkatesh and Basu, 2012; Falaknaz *et al.*, 2022). The positive impact on seed weight, grain setting, and overall yield with Panchagavya treatment can be attributed to the balanced supply of major and micronutrients, as well as growth regulators like IAA and GA3, stimulating plant physiological processes such as meristematic activity, cell division, and photosynthetic efficiency (Radha and Rao, 2014; Bhadu *et al.*, 2023; Sakpal *et al.,* 2022). The maximum harvest index observed with 10% Panchagavya treatment emphasizes the importance of efficient nutrient utilization and movement of photoassimilates towards grain formation for yield enhancement, as suggested by earlier studies in various crops (Gifford, 1984). The correlation matrix as a valuable tool for understanding the relationships among different growth stages, yield components, and quality traits in lentil cultivation. Positive correlations between seed-related parameters and certain growth stages indicate the interdependencies influencing plant development and yield. These findings contribute to a comprehensive understanding of factors influencing lentil crop productivity and quality characteristics.

In conclusion, this study focused on optimizing foliar nutrient application in lentil cultivation to enhance growth and yield. The ancient lentil crop, which is a staple food rich in essential nutrients, holds significance globally. Modern chemical-based agriculture faces sustainability challenges, prompting the exploration of alternative systems such as organic fertilizers and foliar sprays. Experiments conducted with various treatments, including organic products such as Panchagavya and Jeevamrutha, demonstrated their positive impact on lentil growth parameters and yield attributes. Notably, Panchagavya treatment significantly improved plant height, dry matter, pod and seed production, test weight, and overall seed yield. These findings contribute valuable insights to sustainable agricultural practices, emphasizing the efficacy of organic foliar fertilizers in optimizing lentil cultivation for increased productivity and environmental well-being. The study was conducted in a temperate climate with a particular soil type (e.g., sandy loam) and pH range, which may not reflect conditions in other regions where lentils are grown. Temperature fluctuations, humidity levels, and seasonal rainfall patterns unique to the area could affect the absorption and efficacy of foliar treatments, potentially limiting the generalizability of these findings to other agro-climatic zones.

Future research should explore the long-term effects of these bio-based applications on soil health, crop quality, and resilience against biotic and abiotic stress. Additionally, multi-location field trials across various climates and soil types would help validate these findings and determine the optimal application methods and concentrations for diverse agricultural contexts. Scaling up these practices for larger farms would require developing standardized preparation protocols and exploring mechanized application methods to make the process more feasible for commercial agriculture. Collaboration with agricultural extension services and farmer cooperatives could further support widespread adoption, contributing to more sustainable and resilient farming systems.

Acknowledgments

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