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EFFECT OF POLYHALITE AND SECONDARY NUTRIENTS APPLICATION ON YIELD AND QUALITY OF SUMMER CLUSTER BEAN

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SUMMARY

Balanced nutrients application has become increasingly important for enhancing productivity and quality of cluster bean under intensive cultivation systems of semi-arid regions. A field experiment was conducted during the summer season of 2025 at CCS Haryana Agricultural University, Hisar, to evaluate the response of summer cluster bean (*Cyamopsis tetragonoloba* L.) to graded levels of polyhalite in comparison with conventional sources of sulphur and potassium under recommended fertilizer dose (RDF). The study was laid out in a randomized block design with ten treatments comprising recommended dose of fertilizers (RDF) alone and in combination with graded levels of polyhalite, sulphur supplied through gypsum and bentonite, and potassium through muriate of potash. The results revealed that supplementation of RDF with polyhalite significantly improved plant height, yield components, seed yield, straw yield, guar gum content, and protein content over RDF alone. Application of RDF + 250 kg/ha polyhalite recorded the highest seed yield (822 kg/ha), straw yield (3491 kg/ha), gum content (39.0%), and protein content (30.75%), though these values remained statistically comparable with lower polyhalite levels and potassium-based treatments. Economic analysis indicated that despite higher biological yields under higher polyhalite doses, the maximum net returns (Rs 17,186/ha) and benefit-cost ratio (1.50) were obtained with RDF + 40 kg/ha K_2O. Overall, balanced fertilization involving secondary nutrients enhanced productivity, quality, and profitability of summer cluster bean, with potassium supplementation emerging as the most cost-effective option under the prevailing conditions.

Key words: Cluster bean, polyhalite, gypsum, bentonite, potassium

Cluster bean (*Cyamopsis tetragonoloba* L.), popularly known as guar, is an important short-duration legume crop grown extensively under rainfed and irrigated conditions of the semi-arid regions of India, particularly in Haryana. The crop plays a vital role in forage and seed production systems owing to its drought tolerance, ability to fix atmospheric nitrogen, and suitability for cultivation during the summer season when options for green fodder and legume crops are limited. Although, cluster bean is generally cultivated as rainy season (*kharif*) crop in Haryana (Satpal *et al.*, 2020) but can also be cultivated as summer crop under assured irrigation facilities. Haryana contributes significantly to guar cultivation due to favorable conditions like sandy loam soils, high summer temperatures and irrigation facilities, making the crop an integral component of sustainable cropping systems in the state (Yadav and Singh, 2018).

Despite its adaptability to marginal environments, the productivity and quality of cluster bean remain sub-optimal, largely due to imbalanced nutrient management. While the crop responds well to recommended doses of nitrogen and phosphorus, deficiencies of some other nutrients such as potassium (K), sulphur (S), calcium (Ca), and magnesium (Mg) have emerged as major constraints under intensive cultivation. Continuous use of high-analysis fertilizers with little or no secondary nutrient supplementation has aggravated multi-nutrient deficiencies in the soils of Haryana, particularly under summer cropping, where higher evapotranspiration and rapid nutrient depletion are common (Sharma *et al.*, 2019).

Sulphur plays a crucial role in protein synthesis, nodulation, and nitrogen fixation in legumes. Sulfur-containing compounds such as Fe-S clusters-containing proteins are required in multiple biological processes, such as photosynthesis, energy generation, photoprotection, and metabolic reactions (Narayan *et al*., 2023). Potassium is essential for photosynthate translocation, enzyme activation, and stress tolerance. Calcium and magnesium contribute to cell wall development, root growth, and chlorophyll formation, thereby influencing both yield and quality attributes. Recent emphasis has therefore shifted towards balanced fertilization strategies that ensure the simultaneous supply of macro- and secondary nutrients to meet crop demand under semi-arid conditions (Meena *et al*., 2020).

Polyhalite (POLY4) is a hydrated sulphate evaporate mineral containing potassium, calcium, magnesium and Sulphur with chemical formula $K_2Ca_2Mg(SO_4)_4.2H_2O$ (Tiwari *et al*., 2015). Polyhalite, a naturally occurring multi-nutrient fertilizer containing potassium, calcium, magnesium, and sulphur, has gained attention as a potential source for correcting secondary nutrient deficiencies in a single application. Its slow-release nature and chloride-free composition make it suitable for sensitive legume crops and light-textured soils prevalent in Haryana. However, information on the comparative performance of polyhalite with conventional sulphur and potassium sources in cluster bean, particularly under summer conditions, remains limited.

Considering the increasing importance of nutrient use efficiency, crop quality, and economic viability, there is a need to evaluate integrated nutrient management approaches involving different sources and levels of secondary nutrients. Therefore, the present investigation was undertaken to study the effect of polyhalite at graded levels in comparison with sulphur supplied through gypsum and bentonite and potassium through muriate of potash, in conjunction with the recommended dose of fertilizers, on growth, yield, nodulation, quality parameters, and economics of summer cluster bean grown under semi-arid conditions of Haryana.

MATERIALS AND METHODS

The field experiment was conducted during the summer season of 2025 at the Dryland Research Area of Forage Section, CCS Haryana Agricultural University, Hisar, located in the semi-arid zone of Haryana. The region is characterized by hot summers with high evaporative demand and low to moderate relative humidity. The climate during the crop season remained typically semi-arid, with high day temperatures and limited rainfall, necessitating assured irrigation for successful crop establishment and growth.

The experimental field represents the sandy loam soils of the region, which are generally low in organic carbon and available nitrogen, medium in available phosphorus, and often deficient in secondary nutrients due to continuous cropping and imbalanced fertilizer use. Such soil and climatic conditions make the site appropriate for evaluating secondary nutrient management strategies in summer grown cluster bean. The experiment was laid out in a Randomized Block Design (RBD) with three replications. The treatments consisted of different sources and levels of secondary nutrients applied in conjunction with the recommended dose of fertilizers (RDF). The treatment details were as follows: T_1 : Control, T_2 : Recommended dose of fertilizers (RDF: 20 kg N/ha + 40 kg P_2O_5/ha), T_3: RDF + Polyhalite @ 62.5 kg/ha, T_4 : RDF + Polyhalite @ 125 kg/ha, T_5 : RDF + Polyhalite @ 187.5 kg/ha, T_6 : RDF + Polyhalite @ 250 kg/ha, T_7 : RDF + Sulphur @ 20 kg/ha through gypsum, T_8 : RDF + Sulphur @ 20 kg/ha through bentonite, T_9 : RDF + Potassium @ 20 kg K_2O/ha and T_{10} : RDF + Potassium @ 40 kg K, O/ha. Polyhalite used in the experiment contained 14% K_2O, 17% CaO, 6% MgO and 19% sulphur, serving as a multi-nutrient source of potassium and secondary nutrients.

The cluster bean variety HG 2-20 was used in this study. The recommended dose of fertilizer RDF (N 20 kg/ha + P_2O_5 40 kg/ha) and nutrient sources were applied as basal doses at the time of sowing. Standard agronomic practices recommended for summer cluster bean in Haryana were uniformly followed throughout the crop period. Irrigation was applied as per crop requirement to avoid moisture stress, particularly during critical growth stages. Weeds were controlled through manual hoeing to maintain weed-free conditions during the early growth period.

Various parameters were determined to evaluate the sequence of characters of the different treated plants throughout the entire period of the experiment. Plant height, yield attributing characters and yield were measured at harvest in each plot. Quality parameter, namely guar gum content was analyzed using standard laboratory procedures.

Statistical analysis

The data recorded for various growth, yield, quality, and nodulation parameters were subjected to statistical analysis using the analysis of variance (ANOVA) technique appropriate for a randomized block design. Treatment means were compared at the 5 per cent level of significance to test the statistical validity of the results. These calculations followed standard statistical methods as outlined earlier (Panse and Sukhatme, 1989).

RESULTS AND DISCUSSION

Plant height: The study demonstrated that that the highest plant height (115.67 cm) at harvest was noticed under the treatment T_6 (RDF + 250 kg/ha polyhalite) which was found comparable with treatments T_5, T_4, T_3, T_9 and T_{10} (Table 1). Polyhalite ensures the availability of other essential nutrients like calcium (Ca), magnesium (Mg), and sulphur (S) along with K and provides balanced nutrition which resulted in optimum plant growth. The increased plant height may be attributed to the balanced supply of potassium, calcium, magnesium, and sulfur through the use of POLY4. These associated nutrients likely contributed to rapid cell division and elongation, thereby enhancing photosynthesis rate and activity (Sunitha *et al*., 2023).

The attributes of polyhalite like quick solubility, slow-release pattern, and prolonged nutrient availability that matches the crop's demand over time, resulted in the maximum height (Kumar *et al*., 2023). Calcium (Ca) is an essential plant nutrient playing multiple roles in the cell. It is important for membrane stability, cell integrity, cell division, elongation so regulates growth and nutrient absorption in plants (Vaahtera *et al.*, 2019; Weng *et al.,* 2022). Magnesium essential nutrient for a wide array of fundamental physiological and biochemical processes in plants. It is part of chlorophyll in all green plants and is essential for photosynthesis and carbohydrate partitioning (Ishfaq *et al*., 2022). Gransee and Führs (2013) unraveled new insights into the role of Mg in increasing crop tolerance to various stresses that indicate changes in the crop Mg demand under adverse growth conditions. Sulfur (S) is recognized as the fourth major plant nutrient after N, P, and K (Khan *et al*., 2005), and has been associated with high productivity (Kovar and Grant, 2011). Sulfur is a structural component of protein disulfide bonds, amino acids, vitamins, and cofactors (Narayan *et al*., 2023). Sulfur often interacts with N to significantly enhance crop productivity (Jamal *et al*., 2010).

Yield attributes and yield: Results from this experiment revealed that the highest number of pods per plant (107.00), length of pod (6.07 cm) and number of seeds per pod (7.33) were attained under the application of the treatment T_6 (RDF + 250 kg/ha polyhalite) however, these were found statistically at par with treatments T_5, T_4, T_3, T_9 and T_{10} (Table 1). Similarly, the present investigation revealed that among different treatments doses, maximum seed yield (822 kg/ha) and straw yield (3491 kg/ha) of summer cluster bean was recorded with the application of T_6 (RDF + 250 kg/ha polyhalite) which was on a par with T_5, T_4, T_3, T_9 and T_{10}. The different fertilization treatments did not affect the harvest index (Table 2).

The yield of any plant is the cumulative response of yield attributing characters that depend upon the overall growth and development of the plant. The maximum yield obtained under the treatment T_6 probably due to higher CO_2 assimilation, and greater dry matter partitioning into economic parts of plants with multi-nutrient supply to plant through polyhalite.

TABLE 1
Effect of different secondary nutrients on growth of cluster bean (Summer 2025)

Treatment	Plant height (cm)	No. of pods/ plant	Length of Pod	No. of seeds/pod
T_1–Control	75.67	50.33	4.37	5.25
T_2–Recommended dose of fertilizer (RDF)	92.11	66.00	5.00	6.13
T_3–RDF + 62.5 kg/ha polyhalite	106.67	92.00	5.83	7.08
T_4–RDF + 125 kg/ha polyhalite	111.35	99.00	5.90	7.17
T_5–RDF 187.5 kg/ha polyhalite	112.78	103.00	5.90	7.25
T_6–RDF + 250 kg/ha polyhalite	115.67	107.00	6.07	7.33
T_7–RDF + 20 kg/ha S through Gypsum	97.00	67.67	5.03	6.33
T_8–RDF + 20 kg/ha S through Bentonite	94.44	66.00	5.03	6.25
T_9–RDF + 20 kg/ha K_2O	104.89	88.00	5.63	6.75
T_{10}–RDF + 40 kg/ha K_2O	109.78	95.00	5.83	7.08
SEm±	6.22	6.62	0.34	0.31
C.D. at 5%	18.49	19.66	1.00	0.93

The remarkable effect on the yields was an outcome of more number of pod per plant, length of pod and number of seeds per pod (Tiwari *et al.*, 2015). The increase in the number of pods per plant can be attributed to the improved availability of essential nutrients provided by Poly4 (Sunitha *et al*., 2023). Similarly, other studies have provided evidence for the effectiveness of polyhalite in increasing crop output, Melgar *et al*., 2018; Utkarsha *et al*., 2023; Gopinath *et al*., 2024; Arunachalam *et al*., 2025.

ECONOMICS

Gross returns were highest with RDF + 250 kg/ha polyhalite (T_6), followed by RDF + 187.5 kg/ha polyhalite (T_5) however, the higher cost of inputs under these treatments limited gains in net profitability. Compared with RDF alone (T_2), net returns increased only marginally under T_6 (+3.6%) and moderately under T_5 (+15.3%). In contrast, RDF + 40 kg/ha K, O (T_{10}) proved most remunerative, recording the highest net returns (Rs 17,186/ha) and B:C ratio (1.50), representing a 58% increase in net returns over T_2. This was followed by RDF + 20 kg/ha K, O (T_9) with a 44.5% improvement in net returns and a BC ratio of 1.46. Application of sulphur through gypsum (T_7) also enhanced profitability, increasing net returns by 30.2% over T_2 and showing economic performance comparable to RDF + 62.5 kg/ha polyhalite (T_3) (+35.9%).

Higher rates of polyhalite beyond 62.5 to 125 kg/ha did not yield proportional increases in net income due to rising cultivation costs. The control (T_1) recorded the lowest returns and BC ratio (1.11), underscoring the advantage of balanced nutrient supplementation. Overall, supplementing RDF with 40 kg/ha K_2O emerged as the most economically viable option under the prevailing conditions (Table 3).

TABLE 2

Effect of different secondary nutrients on yield and quality of cluster bean (Summer 2025)

Treatment	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Gum content (%)	Protein content (%)
T_1–Control	502	2463	16.84	27.75	23.06
T_2–Recommended dose of fertilizer (RDF)	658	2948	18.26	28.65	25.25
T_3–RDF + 62.5 kg/ha polyhalite	760	3270	18.87	31.65	29.50
T_4–RDF + 125 kg/ha polyhalite	792	3370	19.01	34.65	29.63
T_5–RDF 187.5 kg/ha polyhalite	803	3420	19.02	36.25	30.50
T_6–RDF + 250 kg/ha polyhalite	822	3491	19.04	39.00	30.75
T_7–RDF + 20 kg/ha S through Gypsum	715	3107	18.84	31.65	27.56
T_8–RDF + 20 kg/ha S through Bentonite	705	3043	18.83	30.60	27.00
T_9–RDF + 20 kg/ha K_2O	742	3203	18.85	29.55	25.63
T_{10}–RDF + 40 kg/ha K_2O	771	3305	18.90	29.55	26.00
SEm±	34.90	128.77	0.66	0.48	0.40
C.D. at 5%	103.70	411.94	NS	1.42	1.18

TABLE 3

Effect of different secondary nutrients on economics of cluster bean (Summer 2025)

Treatment	Cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	B : C
T_1–Control	31543	34937	3394	1.11
T_2–Recommended dose of fertilizer (RDF)	33824	44693	10869	1.32
T_3–RDF + 62.5 kg/ha polyhalite	36324	51096	14772	1.41
T_4–RDF + 125 kg/ha polyhalite	38824	53079	14255	1.37
T_5–RDF 187.5 kg/ha polyhalite	41324	53852	12528	1.30
T_6–RDF + 250 kg/ha polyhalite	43824	55084	11260	1.26
T_7–RDF + 20 kg/ha S through Gypsum	34024	48178	14154	1.42
T_8–RDF + 20 kg/ha S through Bentonite	34824	47414	12590	1.36
T_9–RDF + 20 kg/ha K_2O	34216	49924	15708	1.46
T_{10}–RDF + 40 kg/ha K_2O	34608	51794	17186	1.50
SEm±	-	2083	2083	0.06
C.D. at 5%	-	6190	6190	0.17

Quality Parameter: The laboratory analysis of the crop reported that significantly topmost value of guar gum content was also reflected in response to the treatment T_6 (RDF + 250 kg/ha polyhalite). Seed protein content was also found maximum due to the application of the treatment T_6 (RDF + 250 kg/ha polyhalite) despite this, these did not show significant variation from the treatments T_5 and T_4 (Table 2).

Since N and S are essential components of amino acids and protein, the increased uptake of these nutrients may have increased the total protein content (Liu *et al.*, 2020). Polyhalite application increase protein content compared with RDF alone, mainly by improving sulfur and overall nutrient supply that supports more efficient protein synthesis. Sulphur is an important constitute of S-bearing amino acid cystine, cysteine and methionine and building block of protein. So application of polyhalite supplies K, Ca, Mg and especially S, which is required for sulfur-containing amino acids and thus increases the protein content. These results are in accordance with Pramanick *et al.*, 2023; Arunachalam *et al.*, 2025.

CONCLUSION

The present investigation clearly demonstrated that secondary nutrient management plays a decisive role in improving growth, yield, quality, and economic returns of summer cluster bean under semi-arid conditions of Haryana. Application of polyhalite in conjunction with the recommended dose of fertilizers enhanced plant growth and yield attributes by ensuring a balanced supply of potassium, sulphur, calcium, and magnesium. However, economic evaluation revealed that yield advantages obtained with higher polyhalite levels did not translate into proportionate monetary gains due to increased input costs. Supplementation of RDF with potassium at 40 kg K_2O/ha proved to be the most remunerative treatment, recording the highest net returns and benefit-cost ratio. Application of sulphur through gypsum also emerged as an economically viable option, offering appreciable yield and profitability benefits over RDF alone. Thus, while polyhalite is agronomically effective in enhancing yield and quality of summer cluster bean, integration of RDF with potassium fertilization appears to be the most economically sustainable strategy for farmers in semi-arid regions. Balanced fertilization involving secondary nutrients should therefore be promoted for improving productivity and resource-use efficiency of summer cluster bean in Haryana.

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