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# Organic and Inorganic Fertilization Responses of Common Beans (*Phaseolus vulgaris*) CV. Capitano

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## ABSTRACT

**Background:** Common bean is of the most widely cultivated crops in the world, but climate change and soil fertility depletion are leading to reduced yields, particularly noticeable in recent years. Among the challenges of modern agriculture are, on one hand, increasing the quantity and quality of production and on the other, maintaining a positive balance of macronutrients in the soil. The application of high rates of mineral fertilizers can deteriorate soil properties, while entirely organic fertilization is often insufficient to meet the plants' requirements. This necessitates the use of an integrated approach when selecting fertilizers.

**Methods:** An experiment was conducted with common bean (*Phaseolus vulgaris* 'Capitano'), grown as a late-season crop in 2023. A randomized block design was utilized with four replications and three fertilization treatments (organic, mineral and combined fertilization). Observations on growth parameters and yield attributes were recorded and analysed using analysis of variance technique.

**Result:** Common beans exhibit adaptive responses to different fertilization treatments, which influence their development and productivity. The 100% mineral fertilization treatment (266 kg/ha $N_{15}P_{15}K_{15}$) resulted in the highest values for several key vegetative indicators and a high yield of 10.79 t/ha, as well as maximum nitrogen, phosphorus and potassium content in the plants during the early development stages. In the treatments with entirely organic fertilization (1 t/ha Fertisol), the highest number of nodules in the root system was observed during the Fruiting Stage. However, the slow mineralization of organic fertilizers limited the initial development stages of the beans, reflecting on the final yield. The combined fertilization treatment (500 kg/ha Fertisol + 133 kg $N_{15}P_{15}K_{15}$) leverages the advantages of both approaches. This treatment showed the highest number of nodules in the root system during the flowering phase, the highest values of plastid pigment content, number of inflorescences, number of leaves, leaf area and plant mass during the second measurement and achieved the highest total yield of 11.18 t/ha. Thus, an integrated fertilization approach is effective for the sustainable management of agroecosystems.


**Key words:** Combined organomineral fertilization, Fertilization treatments, Nutrient management, *Phaseolus vulgaris* cv. Capitano, Sustainable agriculture.

## INTRODUCTION

Beans are among the most widely cultivated and consumed crops, accounting for over 5% of the total vegetable consumption worldwide. They are characterized by high nutritional value and are rich in proteins, vitamins, fibers and minerals (Maphosa and Jideani, 2017; Manzoor *et al.,* 2019). Despite this, in recent years, many regions around the world have experienced a decrease in the yields of several major crops due to climate change and soil fertility depletion (Ayisi *et al.,* 2019). According to FAO data, bean yields globally decreased by over 5% during the period from 2017 to 2021. In Europe, Africa and East Asia, this negative trend has been observed over the past 20 years, with reductions estimated at 34%, over 37% and 24%, respectively (FAO, 2023).

Common beans prefer well-drained, sandy-loam or sandy-clay soils, but they are sensitive to soil pH and develop best at a pH between 5.8 and 6.5. They are moderately demanding in terms of soil nutrient content, but the primary macronutrients such as nitrogen (N), phosphorus (P) and potassium (K) are essential for their normal growth and development (Marschner, 2012; Smith and Rao, 2021).

Modern intensive land use necessitates the application of high fertilizer rates to maintain a positive nutrient balance in the soil on one hand and to achieve optimal yields of high quality on the other. Agricultural practice primarily relies on the use of mineral fertilizers due to their well-defined chemical composition and quick uptake by plants (Sorensen *et al.,* 1994; Sady *et al.,* 1995; Thy and Buntha, 2005). However, prolonged use of these fertilizers often conflicts with sustainable soil management practices and may lead to the degradation of soil properties (Albiach

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*et al.,* 2000; Hernández *et al.,* 2010). Numerous studies have shown that organic fertilization can increase the availability of nutrients and improve the microbial population, as well as the physical, biological and chemical properties of degraded or low-fertility soil (Thy and Buntha, 2005; Martínez-Blanco *et al.,* 2013; Gobbi *et al.,* 2016; Demiraj *et al.,* 2018). In commercial agriculture, the use of mineral fertilizers cannot be completely excluded, but there is a need for their integrated use with alternative nutrient sources to maintain crop productivity (Dar *et al.,* 2014). A key aspect of the nutrient management system is ensuring a constant supply of nutrients to plants to achieve a certain yield level by integrating the benefits of all potential nutrient sources.

The benefits of combining organic and inorganic nutrient sources over using each component separately have been well-documented (Mohanty *et al.,* 2018; Rasool *et al.,* 2019). Numerous studies have demonstrated that the use of organo-mineral fertilizers is an effective strategy for achieving optimal growth, yield and quality in leguminous crops (Okalebo *et al.,* 2002; Datt *et al.,* 2013; Ghosh *et al.,* 2014; Fekadu *et al.,* 2018).

The present study aims to investigate the influence of different fertilization methods such as organic, mineral and combined-on the vegetative development and fruiting of common beans grown outdoors as a late season (second) crop.

## MATERIALS AND METHODS

### Experimental design

A field experiment with common beans (*Phaseolus vulgaris* Capitano) was conducted on the experimental field of the Institute of Soil Science, Agrotechnology and Plant Protection, Nikola Pushkarov (ISSAPP), Agricultural Academy, in the area of the village of Tsalapitsa (42.18376°N, 24.56712°E). The soil in the experimental plot is Fluvisol (FAO, ISRIC World Soils), with a neutral reaction in the 0-40 cm layer ($pH_{H20}$ was 7.45), very low in total nitrogen (11.69 mg/kg) and well supplied with $P_2O_5$ and $K_2O$ (15.03 mg/100 g and 25.69 mg/100 g, respectively). A randomized block design was utilized, incorporating three different fertilization treatments, each with four replications: Control ($T_1$)-No fertilization treatment; Organic fertilization ($T_2$)-1 t/ha Fertisol; Mineral fertilization ($T_3$)-266 kg/ha $N_{15}K_{15}P_{15}$; Combined fertilization ($T_4$)-500 kg/ha Fertisol + 133 kg $N_{15}K_{15}P_{15}$.

The seeds were sown on August 1, 2023 in plots of 30 m² in two rows with a spacing of 35 cm between the planting holes at a depth of 3 cm. The plants were irrigated using drip irrigation-three times until seed emergence and then every 2-3 days thereafter.

### Indicators and methods

Biometric measurements and phenological observations were made according to the different treatments and replications during both the Flowering and Fruiting Stage of plant development. Leaf area (LA) was determined using the image processing and analysis software ImageJ (Vasileva, 2021). The contents of chlorophyll a and b and β-carotene were determined spectrophotometrically based on the methodology by Lichtenthaler and Wellburn (1985). The total nitrogen (N) content in the leaves was determined using the Kjeldahl method (Horneck and Miller, 1998), while the contents of potassium (K) and phosphorus (P) were determined using EPA Method 3052.

### Statistical analysis

All collected data was analyzed using a multi-factor ANOVA (analysis of variance) with a significance level of 0.05 (95% confidence level) and a subsequent Duncan's multiple range test to determine the significance of the differences between the treatment means. The statistical analyses were performed using the STATGRAPHICS Centurion software package.

## RESULTS AND DISCUSSION

The release of nutrients from most organic amendments is a slow process, primarily dependent on soil mineralization processes and the uptake of these elements by plants influences a range of physiological processes and morphological characteristics (Tiemens-Hulscher *et al.,* 2014). When growing crops with a short growing season, this must be taken into account because organic fertilization requires time for decomposition and nutrient release. Therefore, in the initial phases of plant development, an

**Table 1:** Flowering Stage growth parameters of common bean (*Phaseolus vulgaris*) in response to different fertilization treatments.

| Treatment | Stem diameter cm | Plant height cm | Leaf number per plant | LA $cm^2$ | Inflorescences number per plant | Nodules number per plant | Fresh weight g/plant |
|---|---|---|---|---|---|---|---|
| $T_1$ | 0.50a | 44.00a | 6.50a | 508.28a | 10.50a | 14.50a | 23.42a |
| $T_2$ | 0.65b | 50.00b | 13.50b | 1449.02b | 26.00c | 33.50b | 59.09b |
| $T_3$ | 0.70b | 57.00c | 19.00c | 1722.01b | 18.00b | 49.00c | 84.47c |
| $T_4$ | 0.75b | 53.00bc | 18.00c | 1631.44b | 28.50c | 61.00d | 76.80bc |
| LSD≥95% | 0.115 | 4.707 | 2.208 | 353.153 | 3.706 | 9.624 | 18.909 |

*$T_1$: Control-No fertilization treatment; $T_2$: Organic fertilization-fertisol; $T_3$: Mineral fertilization-$N_{15}K_{15}P_{15}$; $T_4$: Combined fertilization-Fertisol + $N_{15}K_{15}P_{15}$.

inorganic source is also necessary to meet their needs. The results obtained in this study correspond with these observations and during the first assessment in the Flowering phase, the growth response of leguminous plants to different fertilization methods (organic, mineral, combined) is clearly evident. The data clearly indicates that the plants in $T_1$ exhibited the least vegetative growth (Table 1). The largest stem diameter was observed in beans subjected to organo-mineral fertilization $T_4$ (0.75 cm), but all three fertilized treatments fall into the same homogeneous group and the differences between them are not statistically significant. The combined fertilization also resulted in the highest number of inflorescences and nodules in the root system (28.50 and 61.00 per plant, respectively) with significant differences between the treatments. Similar results have been reported by Santosa *et al.* (2017), Ahmadi and Arain (2021) and Qadiri *et al.* (2023).

For the other indicators (plant height, number of leaves, leaf area (LA) and biomass) the highest values were obtained with mineral fertilization (Table 1). Unlike leaf area, where no significant differences were found depending on the type of fertilization and all treatments fell into the same homogeneous group, the highest values for leaf mass were recorded with mineral and combined fertilization. The differences with the other varians are significant at 95% confidence (LSD≤9.994). The recorded stem masses of the fertilized treatments show differences within the limits of statistical error and only their differences with the control are significant (LSD≤9.243) (Fig 1a).

The trend of better vegetative development in plants fertilized with mineral and combined organo-mineral fertilizers is also observed during the assessment in the fruiting stage (Table 2). The highest number of pods and their mass were obtained from the with entirely organic fertilization ($T_2$). The number of pods from all tested variants falls into one homogeneous group, with no significant difference between them. However, the differences in pod mass are significant between $T_2$ and the others treatments (LSD≤34.358). Additionally, the number of nodules in the root system of bean plants under organic fertilization is several times higher than in the other fertilization treatments (122.50 per plant). This clearly indicates that organic fertilization creates better conditions for the development of nitrogen-fixing bacteria, which in turn leads to better nitrogen availability from the soil-this reflects positively on the growth and fruit-bearing of the plants. It is well known that beans absorb nitrogen most intensively during their reproductive phase (from the beginning of flowering to seed maturation) and the higher quantity of nitrogen-fixing bacteria in the roots could be considered the main reason for the higher number of pods and their mass. Nevertheless, the vegetative indicators (Fig 1b, Table 2) suggest that entirely organic fertilization is insufficient to optimally meet the plants' needs. This observation is confirmed by Mitchell and Tu (2005) and Mohanty *et al.* (2018), who state that neither organic nor mineral fertilizers alone can address the challenges of sustainable agriculture. However, there are proven benefits from combining them to improve plant nutrition and fruit-bearing.

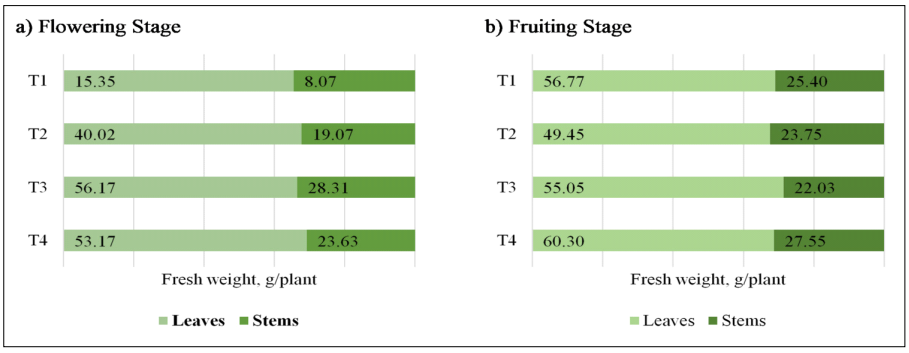



**Fig 1:** Leaves and stems biomass of common bean plants as influenced by fertilization treatments.

**Table 2:** Fruiting stage growth parameters of common bean (*Phaseolus vulgaris*) in response to different fertilization treatments.

| Treatment | Stem diameter cm | Plant height cm | Leaf number per plant | LA $cm^2$ | Fresh weight g/plant | Number per plant | Pods mg | Nodules number per plant |
|---|---|---|---|---|---|---|---|---|
| $T_1$ | 0.64a | 51.00a | 13.00a | 1711.00a | 82.15a | 17.00a | 112.85a | 30.50a |
| $T_2$ | 0.70a | 50.50a | 17.00ab | 1721.54a | 77.00a | 22.50a | 170.25b | 122.50b |
| $T_3$ | 0.70a | 57.50b | 19.00ab | 1791.57a | 77.35a | 20.00a | 133.70a | 30.00a |
| $T_4$ | 0.65a | 51.00a | 20.00b | 1816.14a | 84.05a | 19.50a | 121.65a | 56.50ab |
| LSD≥95% | 0.102 | 6.488 | 6.454 | 591.408 | 25.537 | 6.690 | 34.358 | 70.837 |

* $T_1$: Control-No fertilization treatment; $T_2$: Organic fertilization-fertisol; $T_3$: Mineral fertilization-$N_{15}K_{15}P_{15}$; $T_4$: Combined fertilization-fertisol + $N_{15}K_{15}P_{15}$.

The chlorophyll content in leaves is used as an indicator of photosynthetic activity, the nitrogen status of the plant and the presence of a potential deficiency of nitrogen (Jongschaap and Booij, 2004; Costache *et al.,* 2011; Larimi *et al.,* 2014).

The content of plastid pigments in the leaves of beans in the present experiment was determined in both assessment phases (Fig 2). Predictably, the overall pigment content was higher at the first sampling. A trend of the highest values is observed in $T_4$ (combined fertilization treatment). While the differences with the other variants were not strongly pronounced in the first assessment, they were statistically significant for all examined pigments in the second phase.

The content of N, P and K in plants, recorded during the flowering phase of the leguminous plants, follows the phenological observations and biometric measurements. The highest values were recorded in $T_3$ (mineral fertilization treatment) (Table 3). In the second assessment, the better conditions for the development of nitrogen-fixing bacteria with the application of an organic nutrient source contributed to nitrogen uptake by the plants, with the highest nitrogen content observed in $T_2$ (4.59% N), followed by $T_4$ (4.54% N). The content of P and K was highest in the leaves and stems of the plants from the organo-mineral fertilization variant, with 0.48% P and 3.32% K, respectively. These results support Qadiri *et al.* (2023), who stated that the integrated application of organic and mineral fertilizers is an effective way to supply plants with phosphorus and potassium in bean production.

A comprehensive measure of the productivity of the agroecosystem is the yield obtained, formed as a result of the impact of all environmental components. One of the frequently used indicators for predicting potential yields is leaf area, which is also an indicator of the use of water and nutrients by plants during their vegetative period. Gunton and Evenson (1980) reported a strong correlation between leaf area in the early stages of bean development and the yields obtained. In an experiment with 12 different bean varieties, Bascur *et al.* (1985) confirmed the critical nature of changes in this indicator. The results obtained in the present study correspond with this finding, as the correlation established between LA and the yields obtained is high (Fig 3).

In many cases, yields are genetically determined and the observed differences are due to fluctuations within the variety's genetic limits. These variations are typically induced by optimizing the nutritional regime. The total yield of beans obtained at the end of the present experiment supports these statements (Fig 4). The highest yield was recorded in $T_3$ and $T_4$ (mineral and combined fertilization treatments), with the data being almost equal and falling into one homogeneous group, with no statistically significant difference between them. According to numerous researchers, beans respond well to the integrated use of mineral fertilizers in combination with

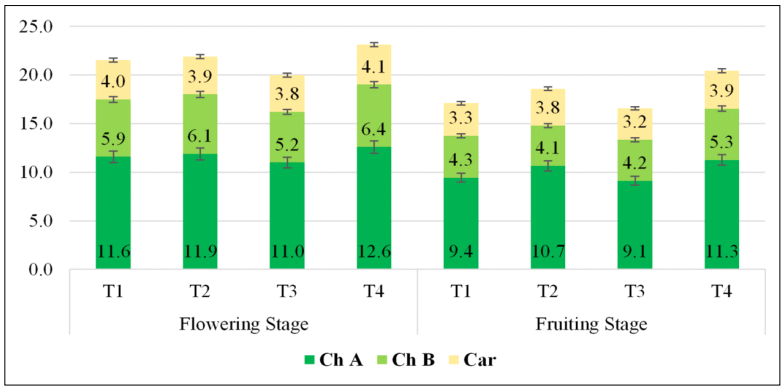



**Fig 2:** Plastid pigments content in the leaves of common bean as influenced by fertilization treatments.

**Table 3:** Nutrient content (N, P, K) in common bean as influenced by fertilization treatments.

| Treatment | Flowering stage | | | Fruiting stage | | |
|---|---|---|---|---|---|---|
| | N % | P % | K % | N % | P % | K % |
| $T_1$ | 2.34 | 0.18 | 1.11 | 4.48 | 0.32 | 2.18 |
| $T_2$ | 2.74 | 0.16 | 1.23 | 4.59 | 0.34 | 1.98 |
| $T_3$ | 3.19 | 0.20 | 1.44 | 4.20 | 0.34 | 2.38 |
| $T_4$ | 2.87 | 0.18 | 1.32 | 4.54 | 0.48 | 3.32 |

* $T_1$: Control-No fertilization treatment; $T_2$: Organic fertilization-fertisol; $T_3$: Mineral fertilization-$N_{15}K_{15}P_{15}$; $T_4$: Combined fertilization-fertisol + $N_{15}K_{15}P_{15}$.

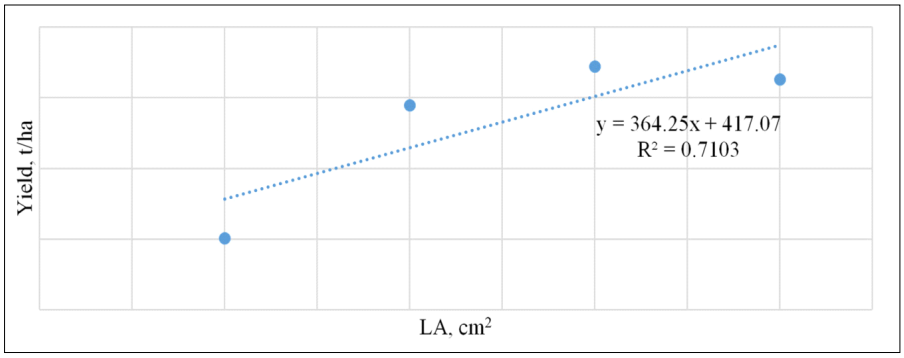



**Fig 3:** Correlation between leaf area and total yield of common bean.

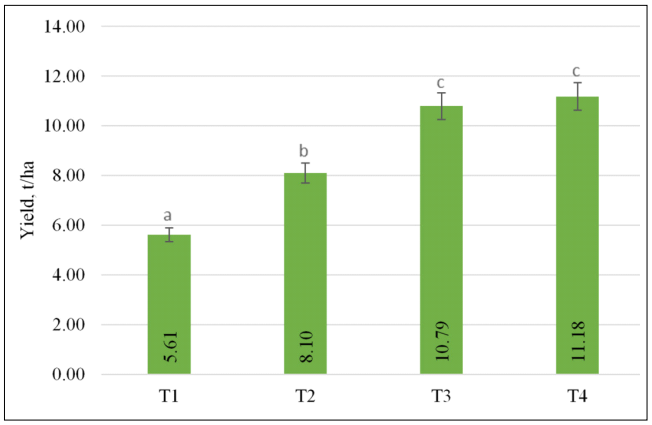



**Fig 4:** Total yield of common bean (*Phaseolus vulgaris*) in response to different fertilization treatments.

organic ones, thus improving soil physical properties and, consequently, the delivery of nutrients. Organic amendments are also a source of key micronutrients in optimal quantities, which further improves the conditions for bean growth and development (Band *et al.,* 2007; Shwetha *et al.,* 2012; Srinivasan *et al.,* 2015; Kamble *et al.,* 2016; Sachan and Krishna, 2021). The results obtained in the present study correspond with those reported by (Lima *et al.*, 2009; Dash *et al.* 2019) and Barcchiya and Kushwah (2017).

Sustainable resource management in agriculture is a significant challenge today. There is a need to boost yields while also maintaining a positive nutrient balance and preserving soil fertility over time. The obtained results confirm that mineral fertilization is crucial and should not be excluded from sustainable land use strategies. Instead, it should serve as the foundation and be integrated with organic substrates to achieve ecological sustainability goals.

## CONCLUSION

Common bean, as a crop capable of forming symbiotic relationships with nitrogen-fixing bacteria and assimilating atmospheric nitrogen, demonstrate an adaptive response to different fertilization treatments. The results obtained highlight the role of mineral nutrition in plants and the rapid provision of available nutrients in the early stages of crop development. The treatments with 100% mineral fertilization showed the best vegetative indicators and content of N, P and K in the plants was highest during the flowering phase.

With 100% organic fertilization, more favorable conditions and active development of nitrogen fixing bacteria were observed in the later stages of plant development, leading to a significant increase in the number of nodules in the root system compared to the other treatments. However, due to the slow mineralization, organic fertilizer failed to provide the necessary nutrients to the plants in the early vegetative phases, leading to developmental limitations.

Our results clearly indicate that neither organic nor mineral fertilizers alone can ensure sustainable agriculture, but their integrated application emerges as a balanced approach to managing agroecosystems. Organo-mineral fertilization proved to be the most effective for achieving high productivity and improving soil fertility, as it combines the rapid provision of nutrients from mineral sources with the long-term benefits of organic amendments.

Therefore, adopting an integrated fertilization approach can be considered a viable and effective solution for sustainable agricultural practices, ensuring high productivity while maintaining soil health and fertility.

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### Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

### Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal care and handling techniques were approved by the University of Animal Care Committee.

### Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish or preparation of the manuscript.

## REFERENCES

Ahmadi, A., Arain, M. (2021). The response of common bean (*Phaseolus vulgaris* L.) to different levels of organic and inorganic fertilizers. *International Journal of Life Sciences and Biotechnology*. **4(3):** 439-450. https://doi.org/10.38001/ijlsb.981373.

Albiach, R., Canet, R., Pomares, F., Ingelmo, F. (2000). Microbial biomass content and enzymatic activities after the application of organic amendments to a horticultural soil. *Bioresource Technology.* **75(1):** 43-48. https://doi.org/10.1016/S0960-8524(00)00030-4.

Ayisi, K.K., Munjonji, L., Masekela, K. (2019). Yield and physiological response of common bean in three semi-commercial farmers fields in limpopo province. *Indian Journal of Agricultural Research*. **54(1):** 19-26. https://doi.org/10.18805/IJARe.A-455.

Band, A., Mendhe, S., Kolte, H., Choudhary, R., Verma, R., Sharma, S. (2007). Nutrient management studies in French bean (*Phaseolus vulgaris* L.). *Journal of Soils and Crops.* **17(2):** 367-372.

Barcchiya, J., Kushwah, S. (2017). Influence of integrated nutrient management on growth, yield parameters and yield in French bean (*Phaseolus vulgaris* L.). *Legume Research.* **40(5):** 920-923. https://doi.org/10.18805/lr.v0i0.8398.

Bascur, G., Oliva, M., Laing, D. (1985). Termometria infrarroja en selección de genotipos de frijol (*Phaseolus vulgaris* L.) resistentes a la sequía. I. Bases fisiológicas. *Turrialba*. **35(1):** 43-47.

Costache, M., Campeanu, G., Neata, G. (2011). Research on the methodology of extraction of chlorophyll and carotene content of tomatoes grown in the south of Romania area. Scientifical Papers U.S.A.M.V. Bucharest, Seria B, LV. pp: 069-073.

Dar, M., Singh, N., Dar, S., Rizvi, S., Rani, P., Kataria, N. (2014). Response of yield and yield components of common bean (Cv. Shalimar Rajamsh) to integrated phosphorous supply and co-innoculation with Rhizobium, VAM, azotobacter in temperate conditions of Kashmir. *Life Sciences Leaflets.* **51:** 10-17.

Dash, S., Ansaba, V., Tripathy, L., Pathak, M. (2019). Effect of integrated nutrient management on growth, yield and yield attributing parameters of French bean (*Phaseolus vulgaris* L.). *The Pharma Innovation Journal.* **8(11):** 98-100.

Datt, N., Dubey, Y., Chaudhary, R. (2013). Studies on impact of organic and integrated use of nutrients on symbiotic parameters, yield, quality of French bean (*Phaseolus vulgaris* L.) vis-a vis soil properties of an acid alfisol. *African Journal of Agricultural Research.* **8(22):** 2645-2654. https://doi.org/10.5897/AJAR12.942.

Demiraj, E., Libutti, A., Malltezi, J., Rroço, E., Brahushi, F., Monteleone, M., Sulçe, S. (2018). Effect of organic amendments on nitrate leaching mitigation in a sandy loam soil of Shkodra district, Albania. *Italian Journal of Agronomy.* **13(1136):** 93-102.

FAO. (2023). Crop Production and Trade Data. Retrieved from http://www.fao.org/faostat/en/#data.

Fekadu, E., Kibret, K., Melese, A., Bedadi, B. (2018). Yield of faba bean (*Vicia faba* L.) as affected by lime, mineral P, farmyard manure, compost and rhizobium in acid soil of Lay Gayint District, northwestern highlands of Ethiopia. *Agric and Food Security.* **7:** 16. https://doi.org/10.1186/s40066-018-0168-2.

Ghosh, C., Biswas, P., Dhangrah, V. (2014). Effect of organic and inorganic sources of nitrogen on growth and yield of French bean (*Phaseolus vulgaris* L.). *International Journal of Plant Research.* **27(1):** 23-25. https://doi.org/10.5958/j.2229-4473.27.1.005.

Gobbi, V., Bonato, S., Nicoletto, C., Zanin, G. (2016). Spent mushroom substrate as organic fertilizer: Vegetable organic trials, *Acta Horticulturae.* **1146:** 49-56.

Gunton, J., Evenson, J. (1980). Moisture stress in Navy beans. 1. Effect of withholding irrigation at different phonological stages on growth and yield. *Irrigation Science.* **2(1):** 49-65.

Hernández, A., Castillo, H., Ojeda, D., Arras, A., López, J., Sánchez, E. (2010). Effect of vermicompost and compost on lettuce production. *Chilean Journal of Agricultural Research*. **70(4):** 583-589.

Horneck, D., Miller, R. (1998). Determination of Total Nitrogen in Plant Tissue. In: Handbook of Reference Methods for Plant Analysis, (ed.) by Y. Kalra, Taylor and Francis Group, LLC. pp: 75. https://doi.org/10.17660/ActaHortic.2016.1146.6.

Jongschaap, R., Booij, R. (2004). Spectral measurements at different spatial scales in potato: Relating leaf, plant and canopy nitrogen status. *International Journal of Applied Earth Observation and Geo information.* **5(3):** 205-218. https://doi.org/10.1016/j.jag.2004.03.002.

Kamble, M., Kalalbandi, B., Kadam, A., Rohidas, S. (2016). Effect of organic and inorganic fertilizers on growth, green pod yield and economics of french bean (*Phaseolus vulgaris* L.) cv. HPR-35. *Legume Research.* **39(1):**110-113. https://doi.org/10.18805/lr.v0iOF.6790.

Larimi B., Shakiba, M., Mohamadinasab, A., Vahed, M. (2014). Changes in nitrogen and chlorophyll density and leaf area of sweet basil (*Ocimum basilicum* L.) affected by biofertilizer and nitrogen application. *International Journal of Biosciences*. **5(9):** 256-265. https://doi.org/10.12692/ijb/5.9.256-265.

Lichtenthaler, H., Wellburn, A. (1985). Determination of total carotenoids and chlorophylls a and b of leaf in different solvents. *Biochemical Society Transactions*. **11:** 591-592.

Lima, D., Santos, S., Scherer, H., Schneider, R., Duarte, A., Santos, E., Esteves, V. (2009). Effects of organic and inorganic amendments on soil organic matter properties. *Geoderma*. **150(1-2):** 38-45. https://doi.org/10.1016/j.geoderma.2009.01.009.

Manzoor, N., Dar, A.H., Khan, S.A., Hakeem, H.R., Makroo, H.A. (2019). Effect of blanching and drying temperatures on various physico-chemical characteristics of green beans. *Asian Journal of Dairy and Food Research*. **38(3):** 213-223. doi: 10.18805/ajdfr.DR-1430.

Maphosa, Y., Jideani, V. (2017). The Role of Legumes in Human Nutrition. In: Functional Food-Improve Health Through Adequate Food. pp 103-121. http://doi.org/10.5772/intechopen.69127.

Marschner, P. (2012). Marschner's Mineral Nutrition of Higher Plants. Third Edition. ISBN 978-0-12-384905-2. https://doi.org/10.1016/C2009-0-63043-9.

Martínez-Blanco, J., Lazcano, C., Christensen, T., Muñoz, P., Rieradevall, J., Moller, J., Antón, A. (2013). Compost benefits for agriculture evaluated by life cycle assessment. A review. *Agronomy for Sustainable Development*. **33:** 721-732. https://doi.org/10.1007/s13593-013-0148-7.

Mitchell, C., Tu, S. (2005). Long term evaluation of poultry litter as a source of nitrogen for cotton and corn. *Agronomy Journal*. **97(2):** 399-407. https://doi.org/10.2134/agronj2005.0399.

Mohanty, S., Sahu, G., Dash, S., Pradhan, S., Nahak, S. (2018). Study of effect of different integrated nutrient management practices on seed quality in French bean. J*ournal of Pharmacognosy and Phytochemistry*. **7(3):** 826-828.

Okalebo, J., Gathua, K., Woomer, P. (2002). Laboratory Methods of Soil and Plant Analysis. 2nd ed. Nairobi: A working Manual.

Qadiri, A., Mutawakel, A., Saeedi, M. (2023). Effect of organic and inorganic fertilizers on yield and yield components of common bean (*Phaseolus vulgaris* L.) in Badakhshan, Afghanistan. *Journal for Research in Applied Sciences and Biotechnology*. **2(2):** 253-258. https://doi.org/10.55544/jrasb.2.2.36.

Rasool, S., Nazir, M., Sofi, P.A., Murtaza, I., Shikari, A.B., Shah, M., Nazir, N., Nehvi, F.A. and Zargar, S.M. (2019). Mineral profiling of common bean (*Phaseolus vulgaris* L.) germplasm. *Indian Journal of Agricultural Research*. **53(3):** 270-276. https://doi.org/10.18805/IJARe.A-5160.

Sachan H.K., Krishna, D. (2021). Effect of organic and inorganic fertilization on growth and yield of French bean (*Phaseolus vulgaris* L.) in Fiji. *Legume Research*. **44(11):** 1358-1361. https://doi.org/10.18805/LR-4376.

Sady, W., Rozek, S., Myczowski, J., Adams, P., Hid Ding, A., Kipp, J., Sonneveld, C., Kreij, C. (1995). Effect of different forms of nitrogen on the quality of lettuce yield. *Acta Horticulturae*. **401:** 409-416. https://doi.org/10.17660/Acta Hortic.1995.401.50.

Santosa, M., Maghfoer, M., Tarno, H. (2017). The Influence of organic and inorganic fertilizers on the growth and yield of green bean, *(Phaseolus vulgaris* L.) grown in dry and rainy season. *AGRIVITA Journal of Agricultural Science*. **39(3):** 296-302. https://doi.org/10.17503/agrivita. v39i3.646.

Shwetha, S., Narayana, J., Shwetha, B., Nirmala, P. (2012). Influence of integrated nutrient management on growth and yield parameters of French bean (*Phaseolus vulgaris* L.). *Mysore Journal of Agricultural Sciences*. **46(3):** 655-657.

Smith, M., Rao, I. (2021). Chapter 12-Common Bean in Crop Physiology Case Histories for Major Crops, [V. Sadras, D. Calderini (eds)]. Academic Press. ISBN 9780128191941. p: 384-406. https://doi.org/10.1016/B978-0-12-819194-1.00012-8.

Sorensen, J., Johansen, A., Poulsen, N. (1994). Influence of growth conditions on the value of crisphead lettuce: 1. Marketable and nutritional quality as affected by nitrogen supply, cultivar and plant age. *Plant Foods for Human Nutrition*. **46(1):** 1-11. https://doi.org/10.1007/BF01088455.

Srinivasan, S., Singaravelan, G., Vinithra, S. (2015). Use of bulky manures and NPK fertilizers for increasing the yield of French bean. *Plant Archives*. **15(1):** 303-306.

Thy, S., Buntha, P. (2005). Evaluation of fertilizer of fresh solid manure, composted manure or biodigester effluent for growing Chinese cabbage (*Brassica pe-kinensis*). *Livestock Research for Rural Development*. **17(3):** 149-154.

Tiemens-Hulscher, M., Lammerts, E., van Bueren, T., Struik, P. (2014). Identifying nitrogen-efficient potato cultivars for organic farming. *Euphytica*. **199:** 137-154. https://doi.org/10.1007/s10681-014-1143-z.

Vasileva, V. (2021). Evaluation of gravimetric method and digital image analysis method or estimating leaf area of tomato plants (*Solanum lycopersicum* Mill.). *Bulgarian Journal of Soil Science, Agrochemistry and Ecology*. **55(3-4):** 22-28.