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Impact of various nutrient sources on growth dynamics, microbial biomass, and yield in field bean (*Dolichos lablab* L.)

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Abstract
A field experiment was conducted during the summer of 2024 at the Agriculture Research Station in Nelamakanahalli, Chikkaballapur, Karnataka, India, to investigate the "Impact of various nutrient sources on growth dynamics, microbial biomass, and yield in field bean (*Dolichos lablab* L.)". The experiment included eleven treatments arranged in a Randomized Complete Block Design (RCBD) with three replications. The primary objective was to evaluate the effects of different nutrient sources on the growth dynamics, microbial activity, and overall yield of field bean. The results indicated that applying 100% of the recommended dose of fertilizers, combined with two nano-fertilizer sprays at 30 and 45 days after sowing, significantly enhanced plant growth. This treatment led to an increased number of branches per plant (6.22) and a larger leaf area per plant (841.5 cm^2) at harvest. Furthermore, it achieved the higher seed yield (1139 kg ha^{-1}) and haulm yield (2114 kg ha^{-1}), outperforming all other nutrient treatments and the absolute control. In contrast, the absolute control consistently recorded the lower values across all measured parameters. Hence, the study demonstrates that applying 100% RDF along with two nano-fertilizer sprays at 30 and 45 DAS effectively boosts field bean growth and yield. This approach not only maximizes productivity but also supports soil health, making it a recommended practice for sustainable field bean cultivation.

Keywords: Field bean, growth dynamics, microbial biomass, nano-fertilizer, yield

Introduction

Field bean (*Dolichos lablab* L.), commonly referred to as lablab beans, hyacinth beans, Indian beans, and Egyptian beans, is a bushy to spreading leguminous crop belonging to the Fabaceae family, with a diploid chromosome number of 2n = 22. This ancient crop is believed to have originated in India and has been cultivated for various purposes, including as a vegetable, pulse grain, fodder, cover crop, and green manure. In India, the field bean is predominantly grown in Karnataka, along with bordering districts of Tamil Nadu, Andhra Pradesh, Gujarat, and Maharashtra, where it is cultivated both as an intercrop and a pure crop. Notably, Karnataka accounts for approximately 80 percent of the total area under field bean cultivation in the country (Raghupathi *et al.*, 2021) [15]. Field beans thrive in high temperatures ranging from 18°C to 30°C and are known for their drought tolerance due to their deep root systems, which allow them to utilize residual soil moisture effectively (Rao *et al.*, 2021) [16]. However, the crop is sensitive to waterlogging, making it essential to cultivate it in deep sandy to clay soils with good drainage (Ntukamazina *et al.*, 2017) [13].

The growth and yield of field beans are significantly influenced by various nutrient sources, which can be broadly categorized into organic and inorganic fertilizers (Karavidas *et al.*, 2022) [7]. Effective nutrient management is crucial for optimizing agricultural practices, particularly for legumes like *Dolichos lablab* with specific nutritional requirements. The balance and interaction between key macro and micronutrients are essential for maximizing growth and yield potential (Kumar *et al.*, 2021) [9]. For instance, organic fertilizers supply essential nutrients but also improve soil structure and microbial activity, creating a conducive environment for plant growth (Singh *et al.*, 2020) [17]. In contrast, inorganic fertilizers provide immediate nutrient availability, promoting rapid growth (Verma *et al.*, 2023) [20]. The timing and method of nutrient application are equally vital in shaping the growth dynamics of field beans (Uebersax *et al*., 2023) [19]. Moreover, the choice of nutrient sources has implications for soil health and sustainability. The integration of organic amendments enhances microbial biomass in the soil, which is crucial for nutrient cycling and maintaining soil fertility over time (Diacono and Montemurro, 2011) [3]. Understanding the relationship between nutrient management and microbial dynamics can lead to more effective agricultural practices that not only boost crop yields but also promote environmental sustainability (Bargaz *et al.*, 2018) [1].

This study focuses on the "Impact of various nutrient sources on growth dynamics, microbial biomass, and yield in field bean (*Dolichos lablab* L.)." The objective is to explore the effects of different nutrient management strategies on the growth and yield attributes of field beans while assessing their impact on soil microbial biomass. By investigating these relationships, the study aims to provide valuable insights that can enhance cultivation practices, improve crop performance, and support sustainable agricultural systems.

Materials and Methods

The field experiment took place at the Agriculture Research Station in Nelamakanahalli, Chikkaballapur, during the summer of 2024. This location is situated in Karnataka's Eastern Dry Zone (Zone-V) at an elevation of 930 meters above sea level, with geographic coordinates of 13°37' N latitude and 77°82' E longitude. From January to April 2024, the area experienced a total rainfall of 269.6 mm, which was 560 mm below the normal average for this period. The soil at the experimental site is classified as red sandy loam within the *Alfisols* order, known for its coarse texture, low fertility, and deficiencies in nitrogen, phosphorus, and organic matter. The experiment was designed using a Randomized Complete Block Design (RCBD) with three replications and involved a total of eleven treatments applied to the field bean variety HA-5. These treatments consisted of different combinations of recommended fertilizer doses along with foliar sprays of nano fertilizer, pulse magic, panchagavya, and humic acid, in addition to an absolute control. Each plot measured 4.5 m x 3.0 m (gross size) and 3.6 m x 2.7 m (net size), with a planting spacing of 45 cm x 15 cm. Fertilizer applications adhered to the recommended rate of 25:50:25 kg NPK ha^{-1}, with modifications based on the specific treatment groups. Foliar nutrition was administered at 30 and 45 days after sowing (DAS).

Seeds of the HA-5 variety were sown on January with one to two seeds placed per hill in furrows prepared at the specified spacing. Manual thinning was conducted to ensure optimal plant density by removing excess seedlings, while gap filling was performed by dibbling seeds into larger gaps. Hand weeding was carried out at 30 DAS to maintain weed-free plots. To safeguard the seedlings from diseases and pests, the fungicide carbendazim was applied at a concentration of 2 g L^{-1} during the seedling stage, followed by sprays of Chlorantraniliprole and Chlorpyrifos at 65 and 85 DAS, respectively. The field beans were harvested on April, when the pods had matured and turned golden.

Biometric observations

The growth parameters of field bean were systematically recorded at 30 days after sowing (DAS), 60 DAS, and at harvest. Among these parameters, the number of branches per plant was measured by counting the branches that emerged directly from the main stem. The average count from five randomly selected plants was used to express the number of branches per plant. Additionally, leaf area was assessed by removing the green leaves from the same five plants at 30 DAS, 60 DAS, and harvest. The leaf area for each plant was measured using a LICOR leaf area meter and expressed in square centimeters (cm^2) per plant. Further finally, Seed yield was determined by threshing and cleaning the pods from each net plot, followed by recording the seed weight. This data was used to compute the seed yield per hectare, expressed as kilograms per hectare (kg ha^{-1}). Additionally, haulm yield was assessed by drying the plants from the net plot after threshing and recording their weight. This provided the haulm yield per hectare, also expressed as kilograms per hectare (kg ha^{-1}).

Laboratory analysis

To evaluate microbial biomass carbon and nitrogen, the chloroform fumigation and extraction method, as proposed by (Carter, 1991) [2], was employed. Each soil sample was divided into two sets: one set was fumigated with ethanol-free chloroform, while the other remained unfumigated. Ten grams of each soil sample were placed in screw-capped tubes and fumigated for five days. After removing the caps, the tubes were placed in an oven at 40°C overnight to evaporate the chloroform. The contents were then extracted with 2M KCl using a reciprocal shaker for 30 minutes, and the resulting suspension was filtered using Whatman No. 1 filter paper. A similar extraction was performed on the unfumigated samples. To determine nitrogen content, 4 mL of freshly prepared ninhydrin reagent was added to 2 mL of the filtrate and boiled in a water bath for 20 minutes. After cooling, the volume was adjusted to 10 mL with a 1:1 mixture of methoxy ethanol and distilled water. The intensity of the purple colour developed was measured using a Bosch and Lamb spectrophotometer at a wavelength of 570 nm. A standard curve was generated with five different concentrations of L-Leucine nitrogen (3.5-16.8 micrograms N mL^{-1}) dissolved in 2M KCl, allowing for the calculation of microbial biomass carbon and nitrogen by comparing absorbance values with the standard curve and the microbial biomass carbon and nitrogen were calculated using the following formula

$$\text{Biomass carbon } (\mu g/g \text{ soil}) = \frac{\text{Ninhydrin reactive 'N' in Unfumigated soil} - \text{Ninhydrin reactive 'N' in fumigated soil}}{\text{Weight of soil sample (g)}} \times 24$$

$$\text{Biomass nitrogen } (\mu g/g \text{ soil}) = \frac{\text{Ninhydrin reactive 'N' in Unfumigated soil} - \text{Ninhydrin reactive 'N' in fumigated soil}}{\text{Weight of soil sample (g)}} \times 2.8$$

Results and Discussion

Number of branches per plant

The data on a number of branches plant^{-1} at 30, 60 DAS, and at harvest of field bean as influenced by the application of different sources of nutrients are presented in Table 1 and Fig. 1. Initially at 30 DAS, there was a significant difference in number of branches plant^{-1} among the treatments. Basal dose application of 100% RDF treatments shows a higher number of branches plant^{-1} compared to 75% RDF and 50% RDF and a lower number of branches per plant recorded in absolute control. At 60 DAS, the number of branches per plant of field bean was significantly influenced by foliar application of different sources of nutrients. The higher number of branches plant^{-1} (5.73) was observed in 100% RDF + 2 sprays of nano fertilizer at 30 and 45 DAS which was on par with 100% RDF + 2 sprays of pulse magic @ 1% at 30 and 45 DAS (5.65). Whereas, a lower number of branches plant^{-1} (2.95) was recorded in absolute control. At harvest, significantly maximum number of branches plant^{-1} (6.22) was observed in 100% RDF + 2 sprays of nano fertilizer at 30 and 45 DAS which was on par with 100% RDF + 2 sprays of pulse magic @ 1% at 30 and 45 DAS (6.09). Whereas, a lower number of branches plant^{-1} (3.97) was recorded in recorded in absolute control.

The increase in a number of branches plant^{-1} up to 30 DAS was very slow because of the initial slow growth rate of field bean and limited nutrient availability to the crop. The increase in a number of branches plant^{-1} after 30, 60 DAS, and at harvest might be due to sufficient availability of nutrients through soil applied conventional fertilizers and foliar applied nano DAP, nano-K, and nano-Zinc to crop (Nehra *et al.*, 2024) [12]. As nitrogen and phosphorus play important roles in improving plant growth and increasing photosynthesis, the adequate supply of nitrogen at the right concentration would help in breaking the apical sovereignty resulting in increased branching in the plant (Leghari *et al.*, 2016) [10].

Table 1: Number of branches per plant of field bean at different growth stages as influenced by the application of different sources of nutrients

	Treatment	Number of branches plant^{-1}		
		30 DAS	60 DAS	At harvest
T_1	100% RDF	2.79	4.90	5.47
T_2	100% RDF + 2 Sprays of nano fertilizer	2.89	5.73	6.22
T_3	100% RDF + 2 Sprays of pulse magic @ 1%	2.83	5.65	6.09
T_4	75% RDF + 2 Sprays of nano fertilizer	2.45	4.75	5.27
T_5	75% RDF + 2 Sprays of pulse magic @ 1%	2.59	4.62	5.08
T_6	50% RDF + 2 Sprays of nano fertilizer	2.39	4.45	4.89
T_7	50% RDF + 2 Sprays of pulse magic @ 1%	2.33	4.23	4.71
T_8	100% RDF + 2 sprays of panchagavya @ 3%	2.72	4.98	5.51
T_9	100% RDF + 2 sprays of humic acid @ 0.1%	2.62	4.92	5.33
T_{10}	FYM @ 7.5 t ha^{-1} + 2 Sprays of nano fertilizer	2.30	4.12	4.68
T_{11}	Absolute control	1.54	2.95	3.97
	F-test	*	*	*
	S.Em. ±	0.11	0.20	0.21
	CD @ 5%	0.31	0.58	0.64

Note: RDF – 25:50:25 kg NPK ha^{-1} Foliar spray done at 30 and 45 DAS
Nano fertilizer (Nano DAP @ 4 ml L^{-1} + Nano-K @ 4 ml L^{-1} + Nano-Zn @ 2 ml L^{-1})
'*' indicates significant at 5% C.D. value

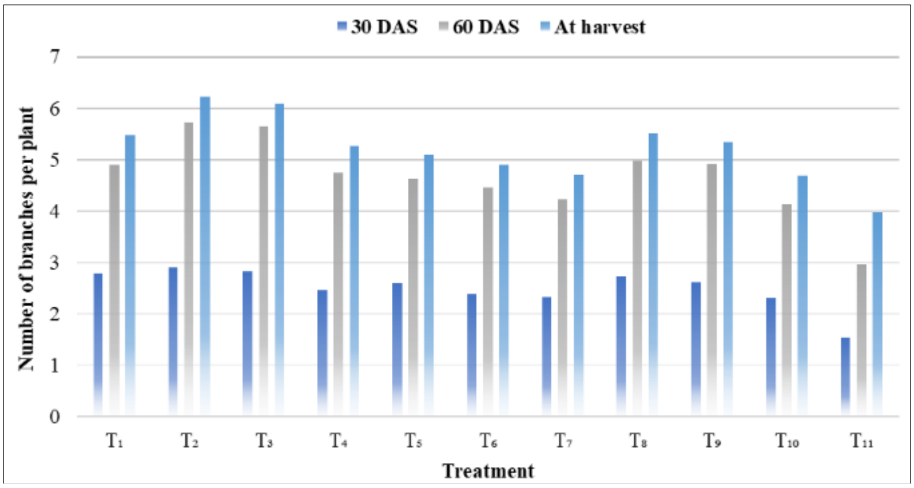

Fig 1: Number of branches per plant of field bean at different growth stages as influenced by the application of different sources of nutrients

Leaf area per plant

The data on leaf area plant^{-1} at 30, 60 DAS, and at harvest of field bean as influenced by the application of different sources of nutrients are presented in Table 2 and Fig 2. Initially, at 30 DAS, there was a significant difference in leaf area plant^{-1} among the treatments. Basal dose application of 100% RDF treatments shows higher leaf area plant^{-1} compared to 75% RDF and 50% RDF and lower leaf area plant^{-1} recorded in absolute control. At 60 DAS, the leaf area plant^{-1} of field bean was significantly influenced by foliar application of different sources of nutrients. Higher leaf area (1231 cm^2 $plant^{-1}$) was observed in 100% RDF + 2 sprays of nano fertilizer at 30 and 45 DAS which was on par with 100% RDF + 2 sprays of pulse magic @ 1% at 30 and 45 DAS (1166 cm^2 $plant^{-1}$). Whereas, lower leaf area (598.5 cm^2 $plant^{-1}$) was recorded in recorded in absolute control. At harvest, significantly maximum leaf area $plant^{-1}$ (890.2 cm^2 $plant^{-1}$) was observed in 100% RDF + 2 sprays of nano fertilizer at 30 and 45 DAS which was on par with 100% RDF + 2 sprays of pulse magic @ 1% at 30 and 45 DAS (841.5 cm^2 $plant^{-1}$). Whereas, lower leaf area $plant^{-1}$ (357 cm^2 $plant^{-1}$) was recorded in recorded in absolute control.

The leaf area $plant^{-1}$ of field bean increased linearly at different crop growth stages and reached a maximum at 60 DAS and thereafter starts declining due to leaf senescence at the time of harvest. The higher leaf area per plant was recorded with the application of 100% RDF + 2 sprays of nano fertilizer at 30 and 45 DAS. This might be due to the supply of 100% of the recommended dosage of NPK which supports the initial establishment and growth of the plants (Souza *et al.*, 2011) [18]. Foliar application of nitrogen in nano form having a sufficient number of nitrogen molecules and surface area favours more nitrogen absorption (Iqbal *et al.*, 2019) [6]. Nitrogen being an important component of chlorophyll plays a crucial role and adequate nitrogen supply at the right concentration helps in the production of a greater number of leaves reducing competition among the plants for nutrients (Fageria and Baligar, 2005) [5]. Additionally, the direct role of nano DAP, nano-K and nano-Zinc to crop fertilizer in increasing cell division and expansion, especially in leaf cells positively influences the plant's leaf area.

Table 2: Leaf area per plant of field bean at different growth stages as influenced by the application of different sources of nutrients

	Treatment	Leaf area (cm^2 $plant^{-1}$)		
		30 DAS	60 DAS	At harvest
T_1	100% RDF	355.4	1058	721.2
T_2	100% RDF + 2 Sprays of nano fertilizer	373.2	1231	890.2
T_3	100% RDF + 2 Sprays of pulse magic @ 1%	363.5	1166	841.5
T_4	75% RDF + 2 Sprays of nano fertilizer	321.7	1033	692.3
T_5	75% RDF + 2 Sprays of pulse magic @ 1%	341.9	1009	673.2
T_6	50% RDF + 2 Sprays of nano fertilizer	290.4	975.6	651.9
T_7	50% RDF + 2 Sprays of pulse magic @ 1%	286.8	930.8	621.8
T_8	100% RDF + 2 sprays of panchagavya @ 3%	359.5	1102	791.6
T_9	100% RDF + 2 sprays of humic acid @ 0.1%	360.3	1068	753.3
T_{10}	FYM @ 7.5 t ha^{-1} + 2 Sprays of nano fertilizer	266.4	921.3	661.5
T_{11}	Absolute control	178.0	598.5	357.0
	F-test	*	*	*
	S.Em. ±	13.50	41.91	28.89
	CD @ 5%	39.59	122.9	84.73

Note: RDF – 25:50:25 kg NPK ha^{-1} Foliar spray done at 30 and 45 DAS
Nano fertilizer (Nano DAP @ 4 ml L^{-1} + Nano-K @ 4 ml L^{-1} + Nano-Zn @ 2 ml L^{-1})
'*' indicates significant at 5% C.D. value

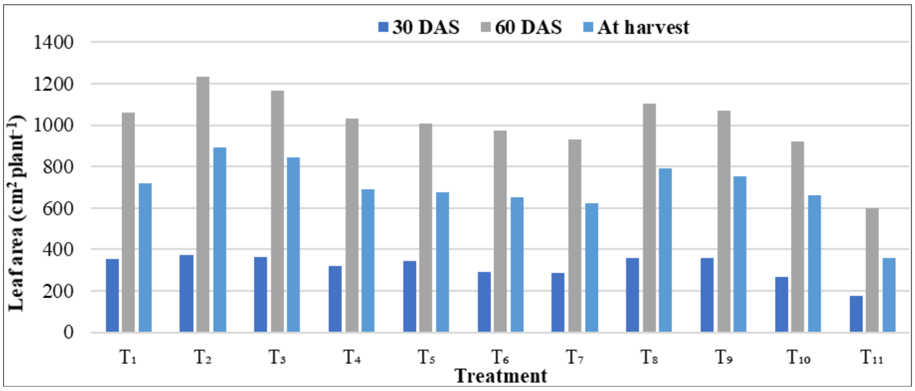

Fig 2: Leaf area per plant of field bean at different growth stages as influenced by the application of different sources of nutrients

Microbial biomass

Microbial biomass at harvest has significant differences in soil microbial biomass carbon and nitrogen among the different treatments in the field bean rhizosphere soil at harvest (Table 3 and Fig. 3). Higher soil microbial biomass carbon and nitrogen were recorded in the treatment FYM @ 7.5 t ha^{-1} + 2 Sprays of nano fertilizer at 30 DAS and 45 DAS (280.4 and 35.65 µg g^{-1} soil, respectively) followed by 100% RDF + 2 sprays of humic acid @ 0.1% at 30 and 45 DAS (208.9 and 20.35 µg g^{-1} soil, respectively) and the least soil microbial biomass carbon and nitrogen was obtained in absolute control (95.87 and 7.89 µg g^{-1} soil, respectively). FYM @ 7.5 t ha^{-1} + 2 Sprays of nano fertilizer at 30 DAS and 45 DAS showed significantly higher soil microbial biomass carbon and nitrogen (280.43 and 35.65 µg g^{-1} soil, respectively) compared to the treatments that received other organic nutrient sources. This could be due to higher decomposition, a higher amount of organic matter as it's a good source and helps in the proliferation of microorganisms (Kögel-Knabner, 2002 and Paul, 2016) [8, 14].

Table 3: Microbial biomass carbon and nitrogen after harvest of field bean as influenced by the application of different sources of nutrients

	Treatment	Microbial biomass carbon (µg g^{-1} soil)	Microbial biomass nitrogen (µg g^{-1} soil)
T_1	100% RDF	107.6	13.05
T_2	100% RDF + 2 Sprays of nano fertilizer	121.3	14.18
T_3	100% RDF + 2 Sprays of pulse magic @ 1%	110.4	16.32
T_4	75% RDF + 2 Sprays of nano fertilizer	130.4	16.98
T_5	75% RDF + 2 Sprays of pulse magic @ 1%	142.9	17.52
T_6	50% RDF + 2 Sprays of nano fertilizer	138.4	13.12
T_7	50% RDF + 2 Sprays of pulse magic @ 1%	142.3	15.48
T_8	100% RDF + 2 sprays of panchagavya @ 3%	198.7	19.65
T_9	100% RDF + 2 sprays of humic acid @ 0.1%	208.9	20.35
T_{10}	FYM @ 7.5 t ha^{-1} + 2 Sprays of nano fertilizer	280.4	35.65
T_{11}	Absolute control	95.87	7.89
	F-test	*	*
	S.Em. ±	6.61	0.75
	CD @ 5%	19.39	2.19

Note: RDF – 25:50:25 kg NPK ha^{-1} Foliar spray done at 30 and 45 DAS
Nano fertilizer (Nano DAP @ 4 ml L^{-1} + Nano-K @ 4 ml L^{-1} + Nano-Zn @ 2 ml L^{-1})
'*' indicates significant at 5% C.D. value

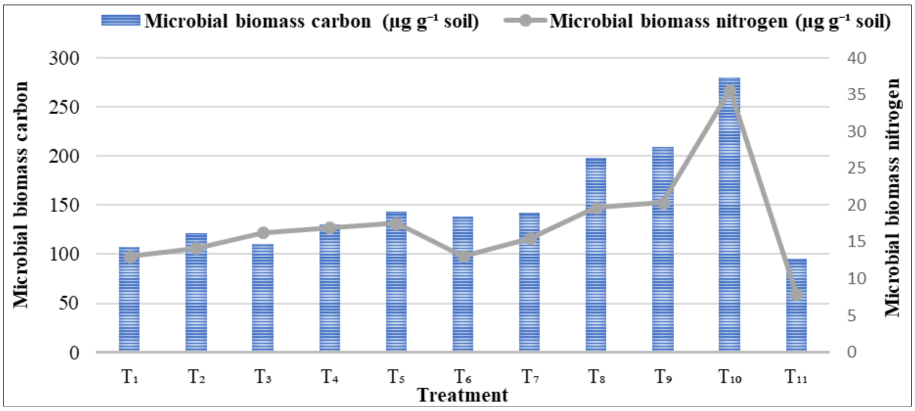

Fig 3: Microbial biomass carbon and nitrogen after harvest of field bean as influenced by the application of different sources of nutrients

Seed yield and Haulm yield

The higher seed yield (1139 kg ha^{-1}) was recorded in the 100% RDF + nano-fertilizer treatment, with a comparable outcome from the Pulse Magic spray (1067 kg ha^{-1}), while the control yielded 403.7 kg ha^{-1}. Enhanced yields were attributed to the synergy between soil-applied urea and foliar nano-fertilizers, which boosted nutrient uptake and supported vigorous plant growth by promoting cell division and reducing flower shedding. This approach also maintained leaf area and delayed senescence, fostering efficient photosynthate translocation to pods. Haulm yield followed a similar trend, with the 100% RDF + nano-fertilizer treatment yielding the highest (2114 kg ha^{-1}), on par with the Pulse Magic treatment (2046 kg ha^{-1}), while the control yielded significantly lower haulm (996.8 kg ha^{-1}). The nanoscale nutrients enhanced absorption due to their small size and high surface area, contributing to increased vegetative growth and higher yields (Monreal *et al.*, 2016 and Elemike *et al*., 2019) [11, 4].

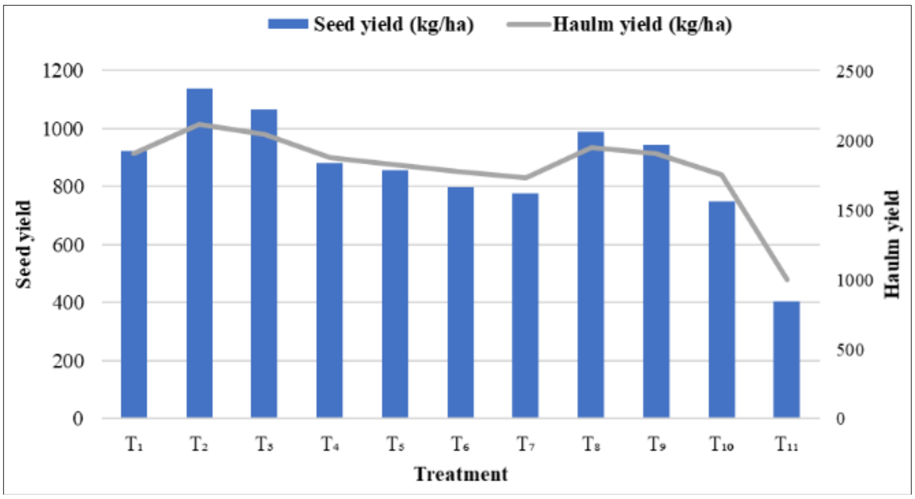

Fig 4: Seed yield and haulm yield of field bean as influenced by the application of different sources of nutrients

Conclusion
The study concludes that applying 100% of the recommended dose of fertilizers combined with two nano-fertilizer sprays significantly enhances the growth and yield of field bean. This treatment effectively improved plant structure and leaf area leading to higher seed and haulm yields than other nutrient treatments and the control. Additionally, microbial biomass was notably higher in plots treated with organic manure, indicating a positive impact on soil health. These findings support the practice of combining RDF with nano-fertilizer sprays as a viable, sustainable approach for maximizing field bean productivity while enhancing soil health.

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