PLANT SCIENCE TODAY
Vol 12(sp4): 01–16
https://doi.org/10.14719/pst.10607

eISSN 2348-1900

RESEARCH ARTICLE

Influence of various organic amendments on yield, nutrient uptake and protein content of mung bean (*Vigna radiata* L.)

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Received: 12 July 2025; Accepted: 18 September 2025; Available online: Version 1.0: 27 October 2025

Cite this article: Smita K, Dhamni P, Shivani, Khushboo S, Chandan KP, Rama DB, Chandrakumar SKH, Renuka, Amit L, Manoj KP, Aman T, Rupesh K, Rajneesh K, Ajaz AL. Influence of various organic amendments on yield, nutrient uptake and protein content of mung bean (*Vigna radiata* L.). Plant Science Today. 2025;12(sp4):01–16. https://doi.org/10.14719/pst.10607

Abstract

This study evaluated the impact of various organic amendments on yield, nutrient uptake and protein content in mung bean (*Vigna radiata* L.) during the *Kharif* 2022 in a randomized block design (RBD) with four replications and eleven treatments. The results indicated that the application of TRDF + R + J (Recommended dose of fertilizers + *Rhizobium* + Jeevamrutam) significantly increased the grain yield compared to TRDF (Recommended dose of fertilizers) and was statistically at par with TRDF + R (Recommended dose of fertilizers + *Rhizobium*). However, the treatment TRDF + V + R + J (Recommended dose of fertilizers + Vermicompost + *Rhizobium* + Jeevamrutam) resulted in a significantly higher grain yield compared to TRDF + V + R (Recommended dose of fertilizers + Vermicompost + *Rhizobium*). The combined application of organic manures specifically a mixture of vermicompost, *Rhizobium* and Jeevamrutam (T_{V+R+J}) significantly enhanced nitrogen (N) and phosphorus (P) uptake in both grain and straw compared to individual applications. Notably, the application of recommended doses of fertilizers (T_{RDF}) yielded higher N uptake in grain relative to Jeevamrutam and vermicompost alone, but did not surpass the combined organic amendment application. Enhanced N and P uptake was also observed with (T_{RDF}) in conjunction with organic amendments, particularly when combined with *Rhizobium* and vermicompost. Furthermore, protein content in mung bean grains significantly increased with the application of (T_{V+R+J}), outperforming single applications of *Rhizobium*, Jeevamrutam and vermicompost. While (T_{RDF}) alone raised protein levels compared to Jeevamrutam, it was not significantly different from (T_{V+R+J}). The study concludes that integrated organic amendments provide superior benefits in nutrient uptake and protein enhancement in mung bean, suggesting a sustainable approach to improve crop yield and nutritional quality. These findings underscore the importance of combining organic and inorganic fertilizers for optimal mung bean cultivation.

Keywords: Jeevamrutam; protein; RDF; RBD; *Rhizobium*; vermicompost

Introduction

Mung bean (*Vigna radiata* L.), a fast-growing leguminous crop, is widely cultivated across tropical and subtropical regions, particularly in South and Southeast Asia. It is valued for its high nutritional content containing approximately 20 %-30 % protein as well as essential amino acids (notably lysine and leucine), dietary fiber, vitamins (such as folate and B12) and minerals like iron and potassium, making it a critical protein source in plant-based diets

(1, 2). In addition to its dietary contributions, *Vigna radiata* plays a significant ecological role by fixing atmospheric nitrogen through symbiotic associations with *Rhizobium* and *Bradyrhizobium* species, thus improving soil fertility and reducing dependence on chemical fertilizers (3, 4).

India continues to be the leading global producer of mung bean where the crop is cultivated across diverse agro-climatic zones throughout nearly all states. During 2023–24, mung bean was grown over an estimated 3.8 to 4 million hectares, with a total production reaching approximately 3.2 million tonnes, contributing more than 50 % to the global output of the crop as per Directorate of Pulses Development, ICAR, India (5, 6). The crop accounts for nearly 16 % of the total area under pulses in India and productivity remains modest at approximately 550 kg ha^{1}, owing to factors such as rainfed cultivation and regional soil nutrient variability. Despite its significance, pulse consumption in India remains below recommended dietary guidelines. According to the Food and Agriculture Organization (FAO) and the World Health Organization (WHO), a minimum daily intake of 75 g $capita^{1}$ day^{1} of pulses is necessary to meet essential protein requirements. However, current availability in India averages only 40-55 g $capita^{1}$ day^{1}, underscoring the need to enhance both production and awareness of pulses like mung bean in dietary planning as per FAS, 2024 (7). This gap highlights the urgency of adopting sustainable production strategies including organic nutrient management which can improve the yield as well as quality and at the same time address nutritional security.

Despite its potential yield of 1.5–2.0 t ha^{1}, mung bean productivity is often limited by poor soil fertility and imbalanced nutrient management in many regions (8). To address this, sustainable alternatives such as vermicompost, compost, poultry manure, green manures, seaweed extracts and microbial inoculants have been increasingly promoted. These inputs enhance soil physical properties, microbial biomass, enzymatic activity and nutrient availability, thereby improving overall plant performance (9, 10). Research has demonstrated that vermicompost either alone or in combination with mineral fertilizers significantly improves nitrogen, phosphorus and potassium uptake, ultimately increasing yield and seed protein levels (11, 12). Similarly, poultry manure and compost have shown positive effects on nitrogen mineralization and seed protein concentration (10). Seaweed-based bio-stimulants have also gained popularity for their role in improving vegetative growth, yield and seed mineral composition in pulses (13).

Integrated nutrient management (INM) strategies that combine organic inputs with microbial inoculants such as *Rhizobium* and phosphate- solubilising bacteria (PSB) have proven effective in enhancing nodulation, nutrient uptake and protein biosynthesis (14, 15, 16). Long-term application of these integrated systems not only supports productivity but also improves soil organic carbon and nutrient-use efficiency (8). *Rhizobium* plays a pivotal role in sustainable agriculture by enhancing biological nitrogen fixation and facilitating phosphorus solubilisation, both of which are essential for legume productivity. These gram-negative soil bacteria enter legume roots and form nodules where they convert atmospheric nitrogen into ammonia which is then utilized by the plant for protein synthesis and growth (16, 17).

Similarly, vermicompost, a biologically active organic amendment produced through earthworm-mediated decomposition is known for its rich content of humic substances, macro and micronutrients and beneficial microbial populations. Studies confirm its ability to enhance soil structure, nutrient availability and crop productivity when applied alone or in integrated nutrient management systems (10, 18). Jeevamrutam, a fermented liquid organic input made from cow dung, cow urine, jaggery, pulse flour and native soil, is gaining popularity for its capacity to increase microbial activity and nutrient availability in soil. It functions as both a plant growth stimulant and biofertilizer showing promising results in enhancing crop vigour and yield attributes in pulses (19).

Nitrogen and phosphorus remain two of the most critical macronutrients for crops. Nitrogen is vital for chlorophyll formation and protein synthesis, contributing directly to photosynthetic efficiency and biomass production. Phosphorus, on the other hand, plays a central role in energy transfer via ATP and supports early root development, seed formation and stress resistance (9). While these findings are promising, comparative studies evaluating multiple organic amendments under uniform agro-ecological conditions remain limited. Therefore, this study aims to assess the influence of various organic inputs used singly and in combination on yield, nutrient uptake and seed protein content of mung bean under field conditions, thereby contributing to the development of resource-efficient and sustainable pulse production systems.

Materials and Method

Experimental site

The experiment was conducted at the Agricultural Research Farm of School of Agriculture, Lovely Professional University, Phagwara, Punjab during *kharif* season of 2022. The agriculture farm is situated at latitude of 31°15.435' N and longitude of 75°42.426' E. This falls under central plain zone of agro-climatic zones of Punjab at an altitude of about 252 m above Arabian Sea level in the north-western part of India.

Weather and climatic condition

The region of the experiment site falls under the subtropical region in the central plane of the state agro-climatic zone (Trans-Gangetic plain region). The area comes under the semi-arid zone with an annual rainfall of 527.1 mm. Six agro-climatic zones have been classified to characterize climatic zone distribution in Punjab and the research farm lies in the northern plain zone.

Soil characteristics

Before the conduct of the experiment, a soil sample was collected from various places of the field randomly of 0-15 cm depth and was mixed from which a homogenous composite sample was drawn. This composite sample was dried under shade and thereafter, crushed and passed through a 2 mm sieve and then stored in a properly labelled sample bag. The sample was analysed for various physical and chemical characteristics given below:

Varietal descriptions

The variety SML668 released in (2002) for summer cultivation in Punjab with average yield of 4.5 q $acre^{-1}$. Plant height is around 44.6 cm having wide green leaves and bear long pods on the upper portion of plant. Pods are long with thick coat and each pod contain 10-11 seeds. Grains are bold with good cooking

quality. It possesses resistance against yellow mosaic virus and bears pods in clusters and possesses early and synchronous maturity in about 60 days.

Treatment details

The experiment comprised eleven different treatments, each involving varied combinations of organic inputs and soil nutrient management strategies aimed at enhancing mung bean performance. These treatments are tabulated in Table 1.

T_1 served as the control (T_C), receiving no external inputs. T_2 (T_R) involved *Rhizobium* inoculation, where seeds were treated with *Rhizobium* culture to promote biological nitrogen fixation. T_3 (T_J) included the application of Jeevamrutam at 25 L ha^1, a traditional organic bio-enhancer applied to the soil. T_4(T_V) received vermicompost at 2 tonnes per hectare, serving as an organic nutrient source rich in beneficial microbes and humus. T_5 (T_{V+R+J}) was a combination treatment involving vermicompost, *Rhizobium* inoculation and Jeevamrutam, integrating multiple organic amendments for synergistic effects. T_6(T_{RDF}) applied the recommended dose of fertilizer (RDF) based on soil test values comprising 27.5 kg Urea ha^{-1}, 250 kg PO_5 ha^1 and no KO. T_7 (T_{RDF+R}) combined RDF with *Rhizobium* while T_8 ($T_{RDF+R+J}$) integrated RDF, *Rhizobium* and Jeevamrutam. T_9 (TRDF+V) involved the combination of RDF with vermicompost and T_{10}($T_{RDF+V+R}$) further enhanced this with *Rhizobium* inoculation. Finally, T_{11}($T_{RDF+V+R+J}$) represented the most integrated approach, combining RDF, vermicompost, *Rhizobium* and Jeevamrutam, aiming to explore the full potential of organic–inorganic synergy. These treatment combinations provided a comprehensive framework for evaluating the effects of individual and combined organic amendments and fertilizer practices on mung bean growth, yield and nutrient dynamics.

Agronomic practices

Vermicompost application

Two days before sowing, vermicompost @ 2 t ha^{-1} was applied in the plots of the treatments involving vermicompost.

Rhizobium inoculation

30 g of jaggery was boiled in one and half litres of water and then cooled, 50 g of *Rhizobium* culture was mixed in jaggery solution. The required quantity of seed was thoroughly mixed with the paste of culture to inoculate them with *Rhizobium* then the seed were allowed to dry in shade.

Jeevamrutam

Jeevamrutam was mixed with water in a ratio of 1:10 (it means 1 L of Jeevamrutam was mixed with 10 L of water) and then applied to the field. Jeevamrutam @ 25 L ha^{-1} was applied to the field. It was applied three times in every 20 days interval after sowing until the crop reaches the harvesting stage.

Fertilizer application

The quantity of fertilizer dose was calculated as per the soil test basis and applied in the plots and mixed thoroughly into the soil after layout. Nitrogen and phosphorus were applied in the form of urea (27.5 kg N ha^{-1}) and SSP- single superphosphate (250 kg P_2O_5 ha^{-1}) and potassium was not applied as per the recommendation of soil test basis and the whole quantity of fertilizer were applied as basal dose (before sowing).

Observations recorded

Yield parameters

Grain yield (kg ha^{-1}), Straw yield (kg ha^{-1}) and Biological yield (kg ha^{-1}).

Quality parameters

Protein content in grain (%), N, P and K uptake in grain and N, P and K uptake in straw

Quality parameters

Protein content

Protein analysis of grain was calculated by multiplying N content (%) by 6.25 (based on assumption that N content 16 % of protein).

Protein content (%) =N content in % X 6.25

Physical and chemical properties of soil of the experimental site

Components	Value	Method
Organic carbon (%)	0.32	Walkley and Black rapid titration method
Soil pH	8.60	Glass electrode pH meter
E.C (dS m^{-1})	0.19	Conductivity meter method
Soil texture	Sandy loam	Hydrometer method
Available phosphorus (P_2O_5 kg ha^{-1})	4.51	0.5 N NaHCO3 extractable Olsen method
Available potassium (K_2O kg ha^{-1})	90.0	Flame photometer method

Table 1. Treatment details of the experiment

Treatments	Description	Designation
T_1	Control	T_C
T_2	*Rhizobium* (seed inoculation)	T_R
T_3	Jeevamrutam @ 25 L ha^{-1} soil application	T_J
T_4	Vermicompost @ 2 t ha^{-1}	T_V
T_5	Vermicompost + *Rhizobium* + Jeevamrutam	T_{V+R+J}
T_6	Recommended dose of fertilizer (RDF) based on the soil test (27.5 kg Urea ha^{-1}, 250 kg P_2O_5 ha^{-1} and no K_2O)	T_{RDF}
T_7	RDF + *Rhizobium*	T_{RDF+R}
T_8	RDF + *Rhizobium* + Jeevamrutam	$T_{RDF+R+J}$
T_9	RDF + Vermicompost	T_{RDF+V}
T_{10}	RDF + Vermicompost + *Rhizobium*	$T_{RDF+V+R}$
T_{11}	RDF + Vermicompost + *Rhizobium* + Jeevamrutam	$T_{RDF+V+R+J}$

Protein yield (kg ha^{-1}) =

$$\frac{\text{Protein content (\%) x grain yield (kg/ha)}}{100}$$

Chemical analysis

N content in grain and straw

N content in grain and straw was determined by micro-Kjeldahl method as per procedure suggested by AOAC (20).

N uptake in grain (kg ha^{-1}) =

$$\frac{\text{N content in grain (\%) x grain yield (kg/ha)}}{100}$$

N uptake in straw (kg ha^{-1}) **=**

$$\frac{\text{N content in straw (\%) X straw yield (kg/ha)}}{100}$$

P content in grain and straw

The P content in grain and straw was determined by the wet digestion (diacid) Vanadomolybdo phosphoric acid yellow colour method.

P uptake in grain (kg ha^{-1}) =

$$\frac{\text{P content in grain (\%) X grain yield (kg/ha)}}{100}$$

P uptake in straw (kg ha^{-1}) =

$$\frac{\text{P content in straw (\%) X straw yield (kg/ha)}}{100}$$

K content in grain and straw

K content in grain and straw was determined using the flame photometry method (21).

K uptake in grain (kg ha^{-1}) =

$$\frac{\text{K content in grain (\%) X grain yield (kg/ha)}}{100}$$

K uptake in straw (kg ha^{-1}) =

$$\frac{\text{K content in straw (\%) X straw yield (kg/ha)}}{100}$$

Statistical analysis

To determine the significance of the various variables or the effects of the different treatments used in the experiment, the data were analysed using the Microsoft Excel and OPSTAT software at a 95 % level of significance (LSD (0.05).

Results and Discussion

Influence of organic amendments on yield and yield attributes of mung bean

Grain yield (kg ha^{-1})

The data of the grain yield are presented in Table 2 and Fig. 1. The application of various biofertilizers, organic manures and recommended dose of fertilizers significantly affected the grain yield at harvest. The grain yield data of mung bean crop revealed that the addition of alone *Rhizobium* (T_R) and vermicompost (T_V) significantly increased the grain yield as compared to control (T_C) but addition of alone Jeevamrutam (T_J) failed to increase significantly as compared with control (T_C). The combined application of *Rhizobium* + Jeevamrutam + vermicompost (T_{V+R+J}) significantly increased the grain yield as compared to application of alone Jeevamrutam (T_J), vermicompost (T_V) and *Rhizobium* (T_R). The application of recommended dose of fertilizers (T_{RDF}) significantly increased the grain yield as compared with application of alone *Rhizobium* (T_R), Jeevamrutam (T_J) and vermicompost (T_V) but failed to cause any significant increase as compared with combined application of organic manures (T_{V+R+J}). The application of $T_{RDF+R+J}$ significantly increased the grain yield as compared with T_{RDF} but was at par with T_{RDF+R}. The application of $T_{RDF+V+R}$ significantly increased the grain yield as compared with $T_{RDF+R+J}$. However, the application of $T_{RDF+V+R+J}$ increased the grain yield significantly as compared with $T_{RDF+V+R}$. Application of *Rhizobium* and PSB alone increased the grain yield of mung bean significantly compared to the control, while their combined application further increased the grain yield compared to their individual applications (22). Application of vermicompost at 6 t ha^{-1} and *Rhizobium* alone significantly increased the grain yield of cowpea compared to the control, while their combined application resulted in a further significant increase in grain yield compared to their individual applications (23). Application of Jeevamrutam alone did not significantly increase the fruit yield of bell pepper compared to the control, whereas the application of FYM (10 t ha^{-1}) and vermicompost (7 t ha^{-1}) alone significantly increased the yield. However, the combined application of Jeevamrutam, vermicompost and FYM resulted in a significantly higher fruit yield compared to their individual applications (24). Application of cow dung alone did not significantly increase the grain yield compared to the control, whereas the application of vermicompost and RDF alone significantly increased the yield. However, the combined application of cow dung, vermicompost and RDF resulted in a significantly higher grain yield compared to their individual applications (25).

Table 2. Influence of organic amendments on yield attributes of mung bean

Treatments		Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})
T_c	T_1	748.5	1612.5	2397.0
T_R	T_2	855.5	1750.9	2606.8
T_J	T_3	778.0	1654.0	2432.3
T_V	T_4	816.5	1688.0	2504.8
T_{V+R+J}	T_5	926.3	1815.5	2741.3
T_{RDF}	T_6	911.5	1785.8	2696.8
T_{RDF+R}	T_7	952.3	1871.5	2823.5
$T_{RDF+R+J}$	T_8	995.3	1908.0	2903.0
T_{RDF+V}	T_9	883.6	1838.8	2767.3
$T_{RDF+V+R}$	T_{10}	1127.3	2086.3	3212.5
$T_{RDF+V+R+J}$	T_{11}	1242.5	2181.1	3405.3
LSD (0.05)		38.52	128.07	31.64

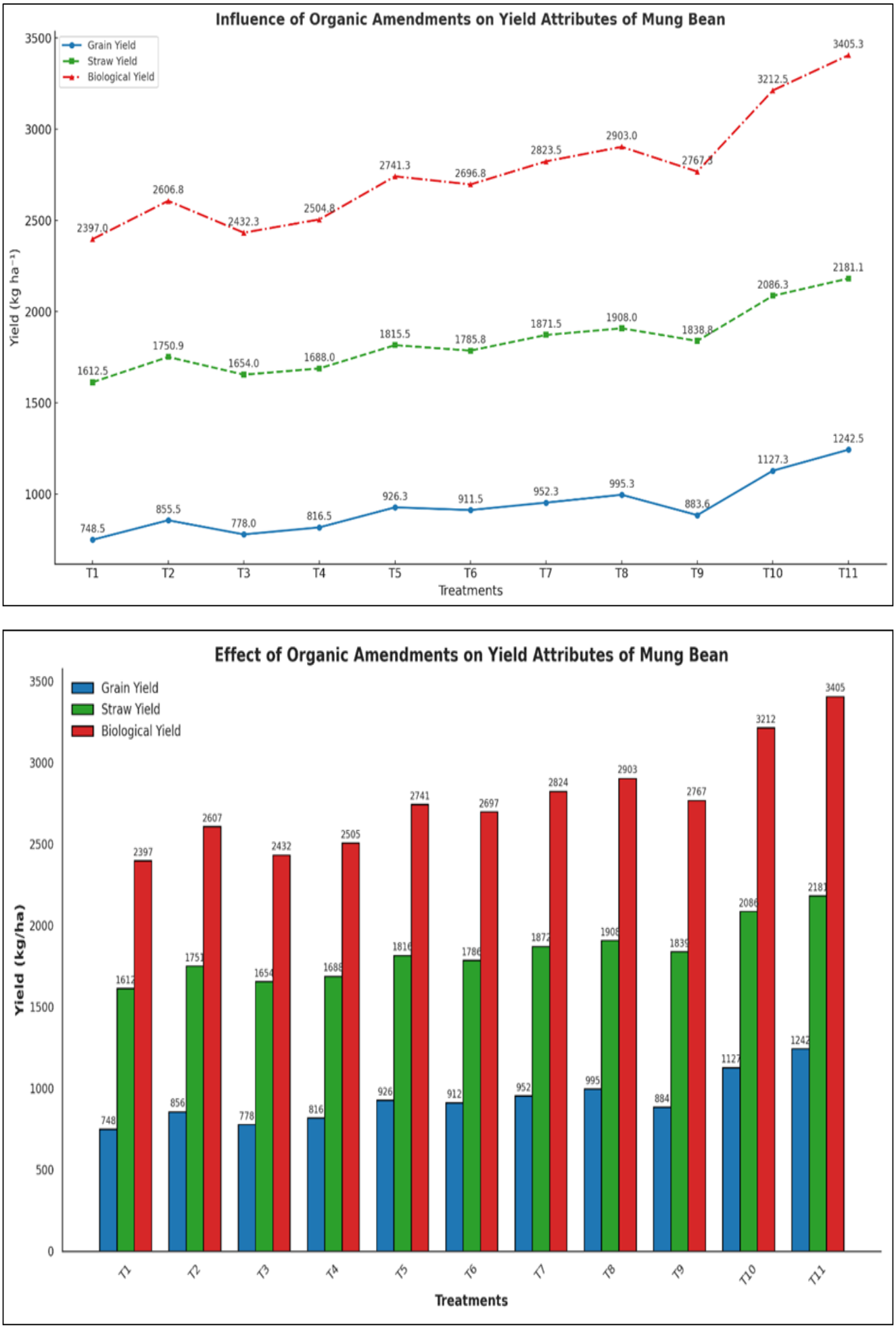

Fig. 1. Influence of organic amendments on yield attributes of mung bean.

Straw yield (kg ha^{-1})

The data of the straw yield are presented in Table 2 and Fig. 1. The application of various biofertilizers, organic manures and recommended dose of fertilizers significantly affected the straw yield at harvest. The data regarding straw yield of the mung bean crop revealed that the addition of alone *Rhizobium* (T_R) significantly increased the straw yield as compared to control (T_C) but application of alone Jeevamrutam (T_J) and vermicompost (T_V) failed to increase straw yield significantly as compared with (T_C). The combined application of *Rhizobium* + Jeevamrutam + vermicompost (T_{V+R+J}) significantly increased the straw yield as compared to application of alone Jeevamrutam (T_J) and vermicompost (T_V) but was at par with application of alone *Rhizobium* (T_R). The application of recommended dose of fertilizers (T_{RDF}) significantly increase the straw yield as compared with application of Jeevamrutam alone (T_J) but was at par with application of alone vermicompost (T_V), *Rhizobium* (T_R) and combined application of organic manures (T_{V+R+J}). The application of $T_{RDF+V+R}$ significantly increased the straw yield as compared with T_{RDF}, T_{RDF+R}, $T_{RDF+R+J}$ and T_{RDF+V}. The application of $T_{RDF+V+R+J}$ failed to cause significant increase in straw yield as compared with $T_{RDF+V+R}$. Application of PSB and *Rhizobium* alone failed to increase the straw yield significantly compared to the control, but their combined application increased the straw yield significantly compared to both the control and their individual applications (26). Combined application of RDF, PSB and Azotobacter in chickpea significantly increased the straw yield compared to the application of RDF and Azotobacter alone (27). Application of 75 % RDN through FYM, Jeevamrutam @ 500 L ha^{-1} and foliar spray of Panchagavya @ 4 % alone failed to cause a significant increase in straw yield of pearl millet over the control, whereas their combined application (75 % RDN through FYM + Jeevamrutam @ 500 L ha^{-1} + foliar spray of Panchagavya @ 4 %) significantly increased the straw yield compared to both the control and individual applications (28). Application of vermicompost at 6 t ha^{-1} and *Rhizobium* alone significantly increased the straw yield compared to the control, while their combined application resulted in a further significant increase in straw yield compared to their individual applications (23).

Biological yield (kg ha^{-1})

The biological yield is total biomass resulted in whole life cycle of plants. The data of biological yield of the crop are presented in Table 2 and Fig. 1. The application of various biofertilizers, organic manures and recommended dose of fertilizers significantly affected the biological yield at harvest. The data revealed that the addition of *Rhizobium* alone (T_R) and vermicompost (T_V) significantly increased the biological yield as compared to control (T_C) but application of Jeevamrutam alone (T_J) failed to increase biological yield significantly as compared to control (T_C). The combined application of *Rhizobium* + Jeevamrutam + vermicompost (T_{V+R+J}) significantly increased the biological yield as compared to application of alone *Rhizobium* (T_R), Jeevamrutam (T_J) and vermicompost (T_V). The application of recommended dose of fertilizers (T_{RDF}) significantly increased the biological yield as compared with application of alone Jeevamrutam (T_J) and vermicompost (T_V) but was at par with application of alone *Rhizobium* (T_R) and combined application of organic manures (T_{V+R+J}). The application of $T_{RDF+R+J}$ significantly increased the biological yield as compared with T_{RDF} but was at par with T_{RDF+R}. The application of $T_{RDF+V+R}$ significantly increased the biological yield as compared with T_{RDF+V} and $T_{RDF+R+J}$. However, the application of $T_{RDF+V+R+J}$ significantly increased the biological yield as compared with $T_{RDF+V+R}$. Application of PSB and VAM alone failed to significantly increase the biological yield of cowpea compared to the control, but their combined application increased the biological yield significantly compared to the control and the individual application of VAM, while being at par with PSB alone (29). Soil application of Jeevamrutam @ 1000 L ha^{-1} and foliar spray of Panchagavya (3 %) recorded a significantly higher biological yield of French bean compared to no Jeevamrutam and no Panchagavya application (30). Application of vermicompost at 6 t ha^{-1} and *Rhizobium* alone significantly increased the biological yield of cowpea compared to the control, while their combined application resulted in a further significant increase in biological yield compared to their individual applications (23). Application of *Rhizobium* and RDF alone significantly increased the biological yield compared to the control, whereas their combined application led to a significantly higher biological yield compared to their individual applications (31).

Chemical analysis of mung bean

Nitrogen (N) analysis in mung bean

N content in grain : The data related to N content in grain of mung bean crop are presented in Table 3 and Fig. 2. The application of various biofertilizers, organic manures and recommended dose of fertilizers significantly affected the N content in grain. The data recorded revealed that the addition of alone *Rhizobium* (T_R), Jeevamrutam (T_J) and vermicompost (T_V) significantly increased the N content in grain as compared to control (T_C). The combined application of *Rhizobium* + Jeevamrutam + vermicompost (T_{V+R+J}) significantly increased the N content in grain as compared to alone *Rhizobium* (T_R), Jeevamrutam (T_J) and vermicompost (T_V). The application of recommended dose of fertilizers (T_{RDF}) failed to cause significant increase in the N content in grain as compared with application of alone *Rhizobium* (T_R), vermicompost (T_V) and combined application of organic manures (T_{V+R+J}) but was significantly higher as compared with alone Jeevamrutam (T_J). The application of T_{RDF+R} significantly increased the N content in grain as compared with T_{RDF} and the application of $T_{RDF+R+J}$ failed to increase the N content in grain significantly as compared with T_{RDF+R}. The application of $T_{RDF+V+R}$ significantly increased the N content in grain as compared with T_{RDF+V} but was at par with $T_{RDF+R+J}$. However, the application of $T_{RDF+V+R+J}$ failed to cause significant increase in N content in grain as compared to $T_{RDF+V+R}$. Application of *Rhizobium* significantly increased the nitrogen content in the grain of cluster bean compared to the control (32). Application of 125 % RDF along with seed inoculation using *Rhizobium* significantly increased the nitrogen content in grain compared to the application of 125 % RDF alone (33). Application of *Rhizobium* and PSB alone significantly increased the nitrogen content in the grain of field pea compared to the control, but their combined application failed to produce any further increase compared to their individual applications (34).

Table 3. Influence of various treatments on N content (%) and N uptake (kg ha^{-1}) of mung bean

Treatments		N content (%) and N uptake (kg ha^{-1})				
		N content in grain (%)	N content in straw (%)	N uptake in grain (kg ha^{-1})	N uptake in Straw (kg ha^{-1})	Total N uptake (kg ha^{-1})
T_c	T_1	1.90	0.331	14.2	5.3	19.5
T_R	T_2	2.44	0.442	20.9	7.7	28.9
T_J	T_3	2.15	0.370	16.7	6.1	22.8
T_V	T_4	2.43	0.436	19.8	7.4	27.2
T_{V+R+J}	T_5	2.87	0.521	26.5	9.5	36.0
T_{RDF}	T_6	2.63	0.496	24.0	8.9	32.9
T_{RDF+R}	T_7	3.32	0.564	31.6	10.5	42.1
$T_{RDF+R+J}$	T_8	3.53	0.579	35.0	11.1	46.1
T_{RDF+V}	T_9	3.21	0.547	28.3	10.1	38.4
$T_{RDF+V+R}$	T_{10}	3.75	0.629	42.2	13.1	55.4
$T_{RDF+V+R+J}$	T_{11}	3.96	0.670	49.2	14.6	63.8
LSD (0.05)		0.241	0.0443	3.17	0.97	4.67

T_c = Control, T_R = *Rhizobium*, T_J = Jeevamrutam, T_V = Vermicompost, T_{V+R+J} =Vermicompost + *Rhizobium* + Jeevamrutam, T_{RDF} = Recommended dose of fertilizers, T_{RDF+R} = Recommended dose of fertilizers + *Rhizobium*, $T_{RDF+R+J}$ = Recommended dose of fertilizers + *Rhizobium* + Jeevamrutam, T_{RDF+V} = Recommended dose of fertilizers + Vermicompost, $T_{RDF+V+R}$ = Recommended dose of fertilizers + Vermicompost + *Rhizobium*, $T_{RDF+V+R+J}$ = Recommended dose of fertilizers + Vermicompost + *Rhizobium* + Jeevamrutam

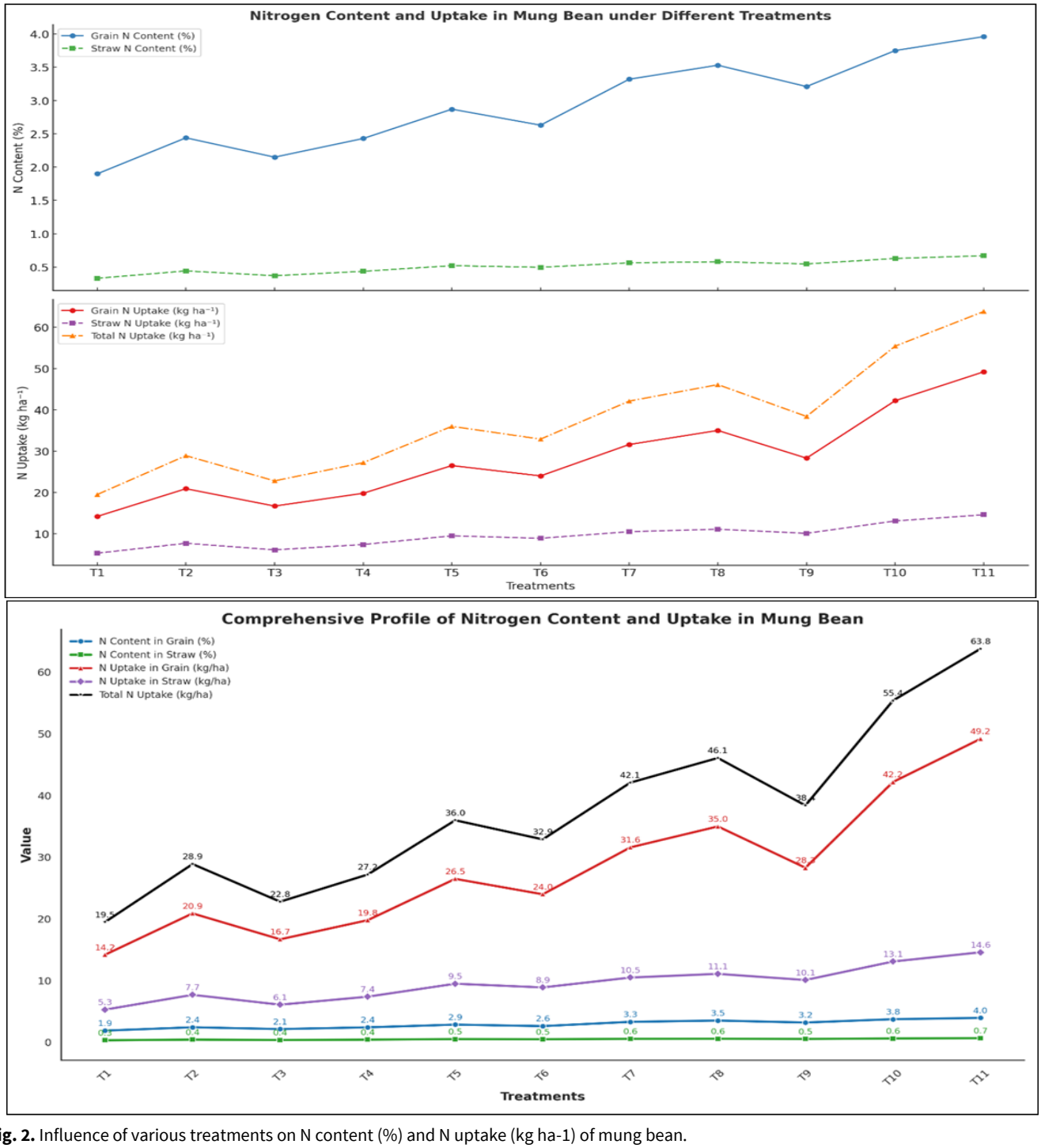

Fig. 2. Influence of various treatments on N content (%) and N uptake (kg ha-1) of mung bean.

N content in straw: The data regarding the N content in straw of mung bean is presented in Table 3 and Fig. 2. The application of various biofertilizers, organic manures and recommended dose of fertilizers significantly affected the N content in straw. The data recorded revealed that the addition of alone *Rhizobium* (T_R) and vermicompost (T_V) significantly increased the N content in straw as compared to control (T_C) but application of Jeevamrutam alone (T_J) failed to cause significant increase as compared with control (T_C). However, the combined application of *Rhizobium* + Jeevamrutam + vermicompost (T_{V+R+J}) significantly increased the N content in straw as compared to application of alone Jeevamrutam (T_J), vermicompost (T_V) and *Rhizobium* (T_R). The application of recommended dose of fertilizers (T_{RDF}) significantly increased the N content in straw as compared with application of alone *Rhizobium* (T_R), vermicompost (T_V) and Jeevamrutam (T_J) but failed to increase significantly as compared with combined application of organic manures (T_{V+R+J}). The application of T_{RDF+R} significantly increased the N content in straw as compared with T_{RDF} and the application of $T_{RDF+R+J}$ failed to cause significant increase in N content in straw as compared with T_{RDF+R}. The application of $T_{RDF+V+R}$ significantly increased the N content in straw as compared with T_{RDF+V} and $T_{RDF+R+J}$ and the application of $T_{RDF+V+R+J}$ failed to increase the N content in straw significantly as compared with $T_{RDF+V+R}$. Application of vermicompost and *Rhizobium* alone significantly increased the nitrogen content in straw compared to the control, but their combined application failed to produce a significant increase compared to their individual applications (35). Application of FYM @ 2 t ha^{-1}, seed inoculation with *Rhizobium* and 100 % RDF alone significantly increased the nitrogen content in straw compared to the control, while their combined application (FYM @ 2 t ha^{-1} + seed inoculated with *Rhizobium* + 100 % RDF) resulted in a significantly higher nitrogen content compared to their individual applications (36).

N uptake in grain: The data regarding the N uptake in grain of mung bean are presented in Table 3 and Fig. 2. The application of various biofertilizers, organic manures and recommended dose of fertilizers significantly affected the N uptake in grain. The data recorded revealed that the addition of alone *Rhizobium* (T_R) and vermicompost (T_V) significantly increased the N uptake in grain as compared to control (T_C) but application of alone Jeevamrutam (T_J) failed to cause significant increase as compared with control (T_C). However, the combined application of *Rhizobium* + Jeevamrutam + vermicompost (T_{V+R+J}) significantly increased the N uptake in grain as compared to application of alone Jeevamrutam (T_J), vermicompost (T_V) and *Rhizobium* (T_R). The application of recommended dose of fertilizers (T_{RDF}) significantly increased the N uptake in grain as compared with application of alone vermicompost (T_V) and Jeevamrutam (T_J) but failed to cause significant increase as compared with application of alone *Rhizobium* (T_R) and combined application of organic manures (T_{V+R+J}). The application of T_{RDF+R} significantly increased the N uptake in grain as compared with T_{RDF} and further application of $T_{RDF+R+J}$ significantly increased the N uptake in grain as compared with T_{RDF+R}. The application of $T_{RDF+V+R}$ significantly increased the N uptake in grain as compared with T_{RDF+V} and $T_{RDF+R+J}$ and the application of $T_{RDF+V+R+J}$ further increased the N uptake in grain significantly as compared with $T_{RDF+V+R}$. Application of *Rhizobium* and PSB alone significantly increased the nitrogen uptake in the grain of field pea compared to the control, but their combined application failed to produce any further increase compared to their individual applications (34). Application of Jeevamrutam @ 500 L ha^{-1} and Panchagavya @ 3 % alone significantly increased the nitrogen uptake in seed compared to the control, while their combined application resulted in a significantly higher nitrogen uptake in grain compared to their individual applications (37).

N uptake in straw: The data regarding the N uptake in straw of mung bean are presented in Table 3 and Fig. 2. The application of various biofertilizers, organic manures and recommended dose of fertilizers significantly affected the N uptake in straw. The data recorded revealed that the addition of *Rhizobium* alone (T_R) and vermicompost (T_V) significantly increased the N uptake in straw as compared to control (T_C), but application of Jeevamrutam alone (T_J) failed to cause significant increase as compared with control (T_C). However, the combined application of *Rhizobium* + Jeevamrutam + vermicompost (T_{V+R+J}) significantly increased the N uptake in straw as compared to application of Jeevamrutam alone (T_J), vermicompost (T_V) and *Rhizobium* (T_R). The application of recommended dose of fertilizers (T_{RDF}) significantly increased the N uptake in straw as compared with application of alone *Rhizobium* (T_R), vermicompost (T_V) and Jeevamrutam (T_J) but failed to increase significantly as compared with combined application of organic manures (T_{V+R+J}). The application of T_{RDF+R} significantly increased the N uptake in straw as compared with T_{RDF} and the application of $T_{RDF+R+J}$ failed to cause significant increase in N uptake in straw as compared with T_{RDF+R}. The application of $T_{RDF+V+R}$ significantly increased the N uptake in straw as compared with T_{RDF+V} and $T_{RDF+R+J}$ and the application of $T_{RDF+V+R+J}$ significantly increased the N uptake in straw as compared with $T_{RDF+V+R}$. Application of RDF and *Rhizobium* alone significantly increased the nitrogen uptake in straw compared to the control, while their combined application resulted in a further significant increase compared to their individual applications (38). Application of 125 % RDF along with seed inoculation using *Rhizobium* significantly increased the nitrogen uptake in straw compared to the application of 125 % RDF alone (39).

Total N uptake : The data regarding the total N uptake of mung bean are presented in Table 3 and Fig. 2. The application of various biofertilizers, organic manures and recommended dose of fertilizers significantly affected the total N uptake. The data recorded revealed that the addition of alone *Rhizobium* (T_R) and vermicompost (T_V) significantly increased the total N uptake as compared to control (T_C) but application of Jeevamrutam alone (T_J) failed to cause significant increase as compared with control (T_C) (14). However, the combined application of *Rhizobium* + Jeevamrutam + vermicompost (T_{V+R+J}) significantly increased the total N uptake as compared to application of alone Jeevamrutam (T_J), vermicompost (T_V) and *Rhizobium* (T_R). The application of recommended dose of fertilizers (T_{RDF}) significantly increased the total N as compared with application of alone vermicompost (T_V) and Jeevamrutam (T_J) but failed to cause significant increase as compared with application of alone *Rhizobium* (T_R) and combined application of organic manures (T_{V+R+J}). The application of T_{RDF+R} significantly increased the total N uptake as compared with T_{RDF} and further application of $T_{RDF+R+J}$ failed to cause significant increase in total N uptake as compared with T_{RDF+R}. The application of $T_{RDF+V+R}$ significantly increased the total N uptake as compared with T_{RDF+V} and $T_{RDF+R+J}$ and the application of $T_{RDF+V+R+J}$ increased the total N uptake significantly as compared with $T_{RDF+V+R}$.

Application of RDF, cow dung and vermicompost alone significantly increased the total nitrogen uptake in mung bean compared to the control, while their combined application (RDF + cow dung + vermicompost) resulted in a significantly higher total nitrogen uptake compared to their individual applications (25). Application of *Rhizobium* and vermicompost alone failed to significantly increase the total nitrogen uptake in urdbean compared to the control; however, their combined application (*Rhizobium* + vermicompost) significantly increased the total nitrogen uptake compared to both the control and their individual applications (40).

Phosphorus (P) analysis in mung bean

P content in grain

The data related to P content in grain of mung bean crop are presented in Table 4 and Fig. 3. The application of various biofertilizers, organic manures and recommended dose of fertilizers significantly affected the P content in grain. The data recorded revealed that the addition of alone *Rhizobium* (T_R), jeevamrutam (T_J) and vermicompost (T_V) significantly increased the P content in grain as compared to control (T_C). The combined application of *Rhizobium* + Jeevamrutam + vermicompost (T_{V+R+J}) significantly increased the P content in grain as compared to alone Jeevamrutam (T_J) and vermicompost (T_V) but was at par with application of alone *Rhizobium* (T_R). The application of recommended dose of fertilizers (T_{RDF}) failed to cause significant increase in the P content in grain as compared with application of alone *Rhizobium* (T_R), vermicompost (T_V) and combined application of organic manures (T_{V+R+J}) but was significantly higher as compared with alone Jeevamrutam (T_J). The application of $T_{RDF+R+J}$ significantly increased the P content in grain as compared with T_{RDF} but was at par with T_{RDF+R}. The application of $T_{RDF+V+R}$ significantly increased the P content in grain as compared with T_{RDF+V} and $T_{RDF+R+J}$. However, the application of $T_{RDF+V+R+J}$ failed to cause significant increase in P content in grain as compared to $T_{RDF+V+R}$. Application of *Rhizobium* and PSB alone significantly increased the phosphorus content in the grain of field pea compared to the control, but their combined application failed to produce any further increase compared to their individual applications (34). Application of RDF, *Rhizobium* and foliar spray of Jeevamrutam @ 5 % alone significantly increased the phosphorus content in the grain of pigeon pea compared to the control, while their combined application (RDF + *Rhizobium* + Jeevamrutam @ 5 %) resulted in a significantly higher phosphorus content compared to their individual applications (41).

P content in straw

The data regarding the P content in straw of mung bean are presented in Table 4 and Fig. 3. The application of various biofertilizers, organic manures and recommended dose of fertilizers significantly affected the P content in straw. The data recorded revealed that the addition of alone *Rhizobium* (T_R) and vermicompost (T_V) significantly increased the P content in straw as compared to control (T_C) but application of alone Jeevamrutam (T_J) failed to cause significant increase as compared with control (T_C). However, the combined application of *Rhizobium* + Jeevamrutam + vermicompost (T_{V+R+J}) significantly increased the P content in straw as compared to application of alone Jeevamrutam (T_J) and vermicompost (T_V) but was at par with application of alone *Rhizobium* (T_R). The application of recommended dose of fertilizers (T_{RDF}) significantly increased the P content in straw as compared with application of alone vermicompost (T_V) and Jeevamrutam (T_J) but failed to increase significantly as compared with application of alone *Rhizobium* (T_R) and combined application of organic manures (T_{V+R+J}). The application of T_{RDF+R} significantly increased the P content in straw as compared with T_{RDF} and further application of $T_{RDF+R+J}$ significantly increased the P content in straw as compared with T_{RDF+R}. The application of $T_{RDF+V+R}$ significantly increased the P content in straw as compared with T_{RDF+V} and $T_{RDF+R+J}$ but the application of T_{RDF+V} was at par with the application of $T_{RDF+R+J}$. The application of $T_{RDF+V+R+J}$ significantly increased the P content in straw as compared with $T_{RDF+V+R}$. Application of vermicompost and *Rhizobium* alone significantly increased the phosphorus content in straw compared to the control, but their combined application failed to produce a significant increase compared to their individual applications (35). Application of FYM @ 2 t ha^{-1}, seed inoculation with *Rhizobium* and 100 % RDF alone significantly increased the phosphorus content in straw compared to the control, while their combined application (FYM @ 2 t ha^{-1} + seed inoculated with *Rhizobium* + 100 % RDF) resulted in a significantly higher phosphorus content compared to their individual applications (36).

Table 4. Influence of various treatments on P content (%) and P uptake (kg ha^{-1}) of mung bean crop

Treatments		P content (%) and P uptake (kg ha^{-1})				
		P content in grain (%)	P content in straw (%)	P uptake in grain (kg ha^{-1})	P uptake in Straw (kg ha^{-1})	Total P uptake (kg ha^{-1})
T_C	T_1	0.313	0.163	2.34	2.63	4.97
T_R	T_2	0.424	0.200	3.63	3.50	7.13
T_J	T_3	0.377	0.169	2.93	2.80	5.73
T_V	T_4	0.405	0.190	3.31	3.21	6.31
T_{V+R+J}	T_5	0.452	0.216	4.19	3.94	8.13
T_{RDF}	T_6	0.438	0.210	3.99	3.75	7.74
T_{RDF+R}	T_7	0.473	0.231	4.51	4.31	8.82
$T_{RDF+R+J}$	T_8	0.490	0.252	4.87	4.80	9.67
T_{RDF+V}	T_9	0.479	0.269	4.23	4.95	9.18
$T_{RDF+V+R}$	T_{10}	0.529	0.299	5.96	6.24	12.20
$T_{RDF+V+R+J}$	T_{11}	0.547	0.321	6.80	6.98	13.78
LSD (0.05)		0.0387	0.0175	0.485	0.422	1.145

T_C = Control, T_R = *Rhizobium*, T_J = Jeevamrutam, T_V = Vermicompost, T_{V+R+J} =Vermicompost + *Rhizobium* + Jeevamrutam, T_{RDF} = Recommended dose of fertilizers, T_{RDF+R} = Recommended dose of fertilizers + *Rhizobium*, $T_{RDF+R+J}$ = Recommended dose of fertilizers + *Rhizobium* + Jeevamrutam, T_{RDF+V} = Recommended dose of fertilizers + Vermicompost, $T_{RDF+V+R}$ = Recommended dose of fertilizers + Vermicompost + *Rhizobium*, $T_{RDF+V+R+J}$ = Recommended dose of fertilizers + Vermicompost + *Rhizobium* + Jeevamrutam

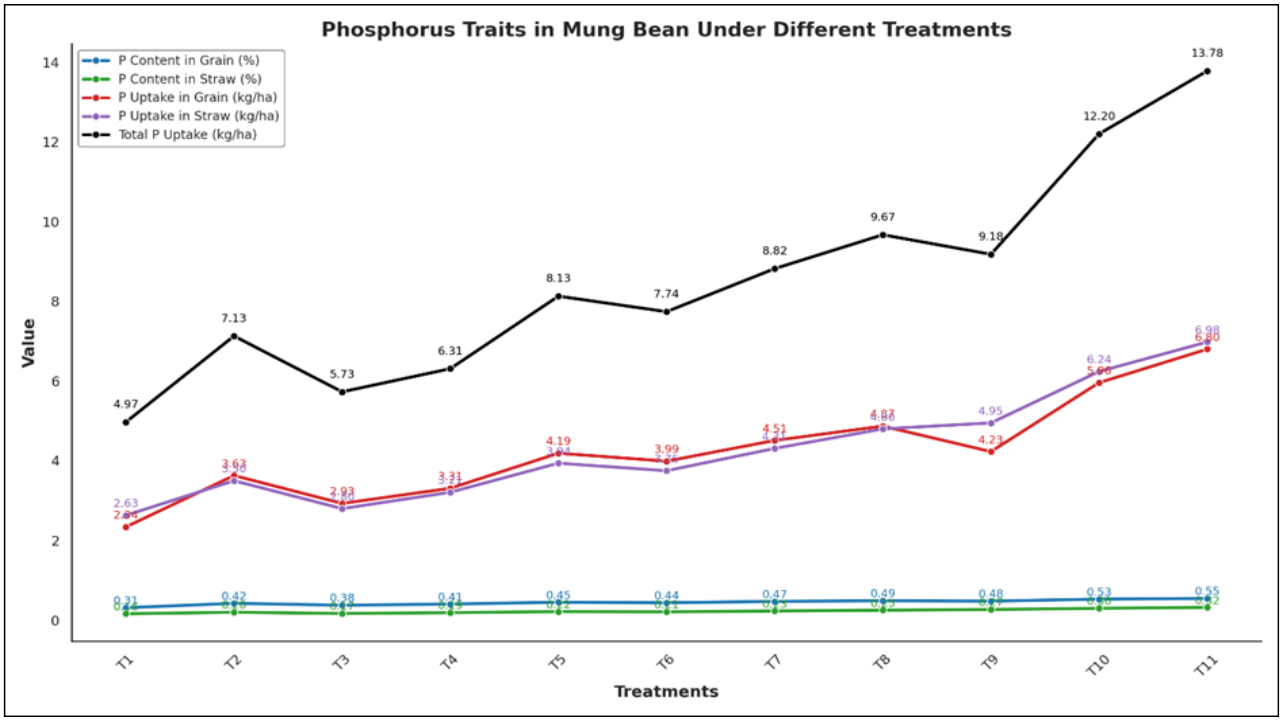

Fig. 3. Influence of various treatments on P content (%) and P uptake (kg ha^{-1}) of mung bean crop.

P uptake in grain

The data related to P uptake in grain of mung bean crop are presented in Table 4 and Fig. 3. The application of various biofertilizers, organic manures and recommended dose of fertilizers significantly affected the P uptake in grain. The data recorded revealed that the addition of alone *Rhizobium* (T_R), Jeevamrutam (T_J) and vermicompost (T_V) significantly increased the P uptake in grain as compared to control (T_C). The combined application of *Rhizobium* + Jeevamrutam + vermicompost (T_{V+R+J}) significantly increased the P uptake in grain as compared to alone Jeevamrutam (T_J), vermicompost (T_V) and *Rhizobium* (T_R). The application of recommended dose of fertilizers (T_{RDF}) failed to cause significant increase in the P uptake in grain as compared with application of alone *Rhizobium* (T_R) and combined application of organic manures (T_{V+R+J}) but was significantly higher as compared with alone Jeevamrutam (T_J) and vermicompost (T_V). The application of T_{RDF+R} significantly increased the P uptake in grain as compared with T_{RDF} and $T_{RDF+R+J}$ was at par with T_{RDF+R}. The application of $T_{RDF+V+R}$significantly increased the P uptake in grain as compared with $T_{RDF+R+J}$. However, the application of $T_{RDF+V+R+J}$ significantly increased the P uptake in grain as compared to $T_{RDF+V+R}$. Application of Jeevamrutam @ 500 L ha^{-1} and Panchagavya @ 3 % alone significantly increased the phosphorus uptake in seed compared to the control, while their combined application (Jeevamrutam + Panchagavya) resulted in a significantly higher phosphorus uptake in grain compared to their individual applications (37). Application of *Rhizobium* and PSB alone significantly increased the phosphorus uptake in the grain of cluster bean compared to the control, but their combined application failed to produce a significant increase compared to their individual applications (42).

P uptake in straw

The data regarding the P uptake in straw of mung bean are presented in Table 4 and Fig. 3. The application of various biofertilizers, organic manures and recommended dose of fertilizers significantly affected the P uptake in straw. The data recorded revealed that the addition of alone *Rhizobium* (T_R) and vermicompost (T_V) significantly increased the P uptake in straw as compared to control (T_C) but application of alone jeevamrutam (T_J) failed to cause significant increase as compared with control (T_C). However, the combined application of *Rhizobium* + Jeevamrutam + vermicompost (T_{V+R+J}) significantly increased the P uptake in straw as compared to application of alone Jeevamrutam (T_J), vermicompost (T_V) and *Rhizobium* (T_R). The application of recommended dose of fertilizers (T_{RDF}) significantly increased the P uptake in straw as compared with application of alone vermicompost (T_V) and Jeevamrutam (T_J) but failed to increase significantly as compared with application of alone *Rhizobium* (T_R) and combined application of organic manures (T_{V+R+J}). The application of T_{RDF+R}significantly increased the P uptake in straw as compared with T_{RDF} and further application of $T_{RDF+R+J}$ significantly increased the P uptake in straw as compared with T_{RDF+R}. The application of $T_{RDF+V+R}$significantly increased the P uptake in straw as compared with T_{RDF+V} and $T_{RDF+R+J}$. The application of $T_{RDF+V+R+J}$significantly increased the P uptake in straw as compared with $T_{RDF+V+R}$. Application of *Rhizobium* and vermicompost alone significantly increased the phosphorus uptake in the straw of mung bean compared to the control, while their combined application (*Rhizobium* + vermicompost) further increased the phosphorus uptake compared to their individual applications (42). Application of RDF and *Rhizobium* alone significantly increased the phosphorus uptake in straw compared to the control, whereas their combined application (RDF + *Rhizobium*) resulted in a significantly higher phosphorus uptake compared to their individual applications (43).

Total P uptake

The data regarding the total P uptake of mung bean are presented in Table 4 and Fig. 3. The application of various biofertilizers, organic manures and recommended dose of fertilizers significantly affected the total P uptake. The data

recorded revealed that the addition of alone *Rhizobium* (T_R) and vermicompost (T_V) significantly increased the total P uptake as compared to control (T_C) but application of alone Jeevamrutam (T_J) failed to cause significant increase as compared with control (T_C). However, the combined application of *Rhizobium* + Jeevamrutam + vermicompost (T_{V+R+J}) significantly increased the total P uptake as compared to application of alone Jeevamrutam (T_J) and vermicompost (T_V) but was at par with application of alone *Rhizobium* (T_R). The application of recommended dose of fertilizers (T_{RDF}) significantly increased the total P uptake as compared with application of alone Jeevamrutam (T_J) and vermicompost (T_V) but failed to increase significantly as compared with application of alone *Rhizobium* (T_R) and combined application of organic manures (T_{V+R+J}). The application of $T_{RDF+R+J}$ significantly increased the total P uptake as compared with T_{RDF} but was at par with application of T_{RDF+R}. The application of $T_{RDF+V+R}$ significantly increased the total P uptake as compared with $T_{RDF+R+J}$ and further application of $T_{RDF+V+R+J}$ significantly increased the total P uptake as compared with $T_{RDF+V+R}$. Application of RDF, cow dung and vermicompost alone significantly increased the total phosphorus uptake in mung bean compared to the control, while their combined application (RDF + cow dung + vermicompost) resulted in a significantly higher total phosphorus uptake compared to their individual applications (25). Application of 125 % RDF along with seed inoculation using *Rhizobium* significantly increased the total phosphorus uptake compared to the application of 125 % RDF alone (39). Application of *Rhizobium* and vermicompost alone failed to significantly increase the total phosphorus uptake in urdbean compared to the control; however, their combined application (*Rhizobium* + vermicompost) significantly increased the total phosphorus uptake compared to both the control and their individual applications (40).

Potassium (K) analysis in mung bean

K content in grain

The data related to K content in grain of mung bean crop are presented in Table 5 and Fig. 4. The application of various biofertilizers, organic manures and recommended dose of fertilizers significantly affected the K content in grain. The data recorded revealed that the addition of alone *Rhizobium* (T_R), Jeevamrutam (T_J) and vermicompost (T_V) significantly increased the K content in grain as compared to control (T_C). The combined application of *Rhizobium* + Jeevamrutam + vermicompost (T_{V+R+J}) significantly increased the K content in grain as compared to alone Jeevamrutam (T_J), vermicompost (T_V) and *Rhizobium* (T_R). The application of $T_{RDF+V+R}$ significantly increased the K content in grain as compared with T_{RDF} but was at par with T_{RDF+R}, $T_{RDF+R+J}$ and T_{RDF+V}. However, the application of $T_{RDF+V+R+J}$ failed to cause significant increase in K content in grain as compared to $T_{RDF+V+R}$. Application of FYM @ 10 t ha^{-1} + Jeevamrutam @ 500 L ha^{-1} + Beejamrutam @ 200 L ha^{-1} significantly increased the potassium content in the grain of cowpea compared to the individual application of FYM @ 10 t ha^{-1} and the combined application of Jeevamrutam @ 500 L ha^{-1} + Beejamrutam @ 200 L ha^{-1}. Application of *Rhizobium* and PSB alone significantly increased the potassium content in the grain of field pea compared to the control, but their combined application failed to produce any further increase compared to their individual applications (34). Application of *Rhizobium* significantly increased the potassium content in the grain of cluster bean compared to the control (32). Application of vermicompost and *Rhizobium* alone significantly increased the potassium content in the grain of mung bean compared to the control, but their combined application failed to significantly increase the potassium content compared to their individual applications (35).

K content in straw

The data regarding the K content in straw of mung bean are presented in Table 5 and Fig. 4. The application of various biofertilizers, organic manures and recommended dose of fertilizers significantly affected the K content in straw. The data recorded revealed that the addition of alone Jeevamrutam (T_J) and vermicompost (T_V) significantly increased the K content in straw as compared to control (T_C), but application of alone *Rhizobium* (T_R) failed to cause significant increase as compared with control (T_C). However, the combined application of *Rhizobium* + Jeevamrutam + vermicompost (T_{V+R+J}) significantly increased the K content in straw as compared to application of alone Jeevamrutam (T_J), vermicompost (T_V) and *Rhizobium* (T_R). The application of recommended dose of fertilizers (T_{RDF}) significantly increased the K content in straw as compared with application of alone vermicompost (T_V), *Rhizobium* (T_R) and Jeevamrutam (T_J) but was at par with combined application of organic manures (T_{V+R+J}). The application of $T_{RDF+R+J}$ significantly increased the K content in straw as compared with T_{RDF} but was

Table 5. Influence of various treatments on K content (%) and K uptake (kg ha^{-1}) of mung bean

Treatments		K content (%) and K uptake (kg ha^{-1})				
		K content in grain (%)	K content in straw (%)	K uptake in grain (kg ha^{-1})	K uptake in Straw (kg ha^{-1})	Total K uptake (kg ha^{-1})
T_C	T_1	0.87	1.30	6.51	20.9	27.4
T_R	T_2	1.07	1.45	8.97	25.5	34.5
T_J	T_3	1.06	1.53	8.22	25.8	34.0
T_V	T_4	1.10	1.58	9.16	26.2	35.4
T_{V+R+J}	T_5	1.28	1.80	11.9	32.7	44.6
T_{RDF}	T_6	1.44	1.87	13.2	33.3	46.5
T_{RDF+R}	T_7	1.51	1.99	14.4	37.1	51.5
$T_{RDF+R+J}$	T_8	1.53	2.05	15.2	39.0	54.2
T_{RDF+V}	T_9	1.57	2.10	13.9	38.6	52.5
$T_{RDF+V+R}$	T_{10}	1.64	2.25	18.4	46.9	65.3
$T_{RDF+V+R+J}$	T_{11}	1.72	2.37	21.2	51.8	73.0
LSD (0.05)		0.137	0.167	1.68	3.94	4.35

T_C = Control, T_R = *Rhizobium*, T_J = Jeevamrutam, T_V = Vermicompost, T_{V+R+J} =Vermicompost + *Rhizobium* + Jeevamrutam, T_{RDF} = Recommended dose of fertilizers, T_{RDF+R} = Recommended dose of fertilizers + *Rhizobium*, $T_{RDF+R+J}$ = Recommended dose of fertilizers + *Rhizobium* + Jeevamrutam, T_{RDF+V} = Recommended dose of fertilizers + Vermicompost, $T_{RDF+V+R}$ = Recommended dose of fertilizers + Vermicompost + *Rhizobium*, $T_{RDF+V+R+J}$ = Recommended dose of fertilizers + Vermicompost + *Rhizobium* + Jeevamrutam

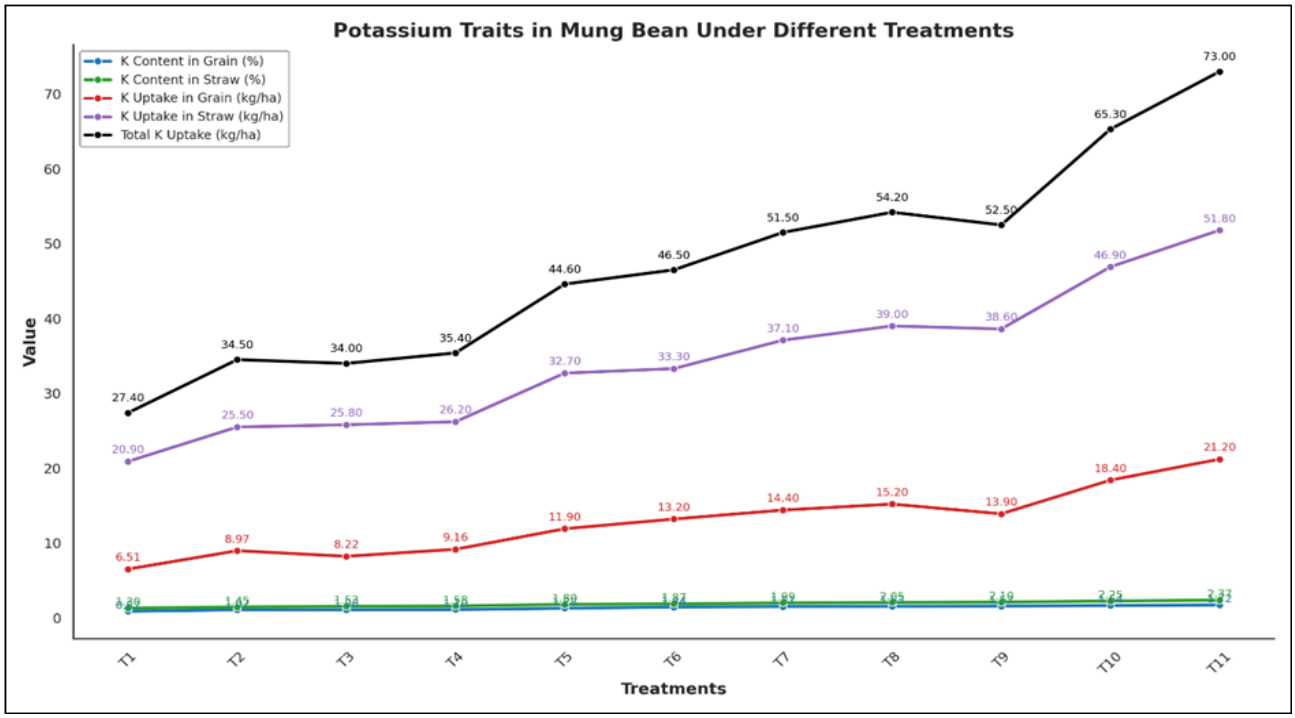

Fig. 4. Influence of various treatments on K content (%) and K uptake (kg ha^{-1}) of mung bean.

at par with application of T_{RDF+R}. The application of $T_{RDF+V+R}$ significantly increased the K content in straw as compared with $T_{RDF+R+J}$ but was at par with T_{RDF+V}. The application of $T_{RDF+V+R+J}$ failed to cause significant increase in K content in straw as compared with $T_{RDF+V+R}$. Application of RDF, *Rhizobium* and foliar spray of Jeevamrutam @ 5 % alone significantly increased the potassium content in the straw of pigeon pea compared to the control, while their combined application (RDF + *Rhizobium* + foliar spray of Jeevamrutam @ 5 %) resulted in a significantly higher potassium content compared to their individual applications (41). Application of FYM @ 2 t ha^{-1}, seed inoculation with *Rhizobium* and 100 % RDF alone significantly increased the potassium content in straw compared to the control, whereas their combined application (FYM @ 2 t ha^{-1} + seed inoculated with *Rhizobium* + 100 % RDF) further increased the potassium content compared to their individual applications (36).

K uptake in grain

The data related to K uptake in grain of mung bean crop are presented in Table 5 and Fig. 4. The application of various biofertilizers, organic manures and recommended dose of fertilizers significantly affected the K uptake in grain. The data recorded revealed that the addition of alone *Rhizobium* (T_R), Jeevamrutam (T_J) and vermicompost (T_V) significantly increased the K uptake in grain as compared to control (T_C). The combined application of *Rhizobium* + Jeevamrutam + vermicompost (T_{V+R+J}) significantly increased the K uptake in grain as compared to alone *Rhizobium* (T_R), Jeevamrutam (T_J) and vermicompost (T_V). The application of recommended dose of fertilizers (T_{RDF}) significantly increased the K uptake in grain as compared with alone *Rhizobium* (T_R), Jeevamrutam (T_J) and vermicompost (T_V) but was at par with combined application of organic manures (T_{V+R+J}). The application of $T_{RDF+R+J}$ significantly increased the K uptake in grain as compared with T_{RDF} but was at par with application of T_{RDF+R}. The application of $T_{RDF+V+R}$ significantly increased the K uptake in grain as compared with $T_{RDF+R+J}$. However, the application of $T_{RDF+V+R+J}$ significantly increased the K uptake in grain as compared to $T_{RDF+V+R}$. Application of *Rhizobium* and PSB alone significantly increased the potassium uptake in the grain of field pea compared to the control, but their combined application failed to produce any further increase compared to their individual applications (34). Application of *Rhizobium* and PSB alone significantly increased the potassium uptake in the grain of cluster bean compared to the control, whereas their combined application failed to cause a significant increase compared to their individual applications (44).

K uptake in straw

The data regarding the K uptake in straw of mung bean are presented in Table 5 and Fig. 4. The application of various biofertilizers, organic manures and recommended dose of fertilizers significantly affected the K uptake in straw. The data recorded revealed that the addition of alone *Rhizobium* (T_R), Jeevamrutam (T_J) and vermicompost (T_V) significantly increased the K uptake in straw as compared to control (T_C). However, the combined application of *Rhizobium* + Jeevamrutam + vermicompost (T_{V+R+J}) significantly increased the K uptake in straw as compared to application of alone Jeevamrutam (T_J), vermicompost (T_V) and *Rhizobium* (T_R). The application of recommended doses of fertilizers (T_{RDF}) significantly increased the K uptake in straw as compared with application of alone *Rhizobium* (T_R), vermicompost (T_V) and Jeevamrutam (T_J) but was at par with combined application of organic manures (T_{V+R+J}). The application of $T_{RDF+R+J}$ significantly increased the K uptake in straw as compared with T_{RDF} and but was at par with application of T_{RDF+R}. The application of $T_{RDF+V+R}$ significantly increased the K uptake in straw as compared with $T_{RDF+R+J}$ and further application of $T_{RDF+V+R+J}$ significantly increased the K uptake in straw as compared with $T_{RDF+V+R}$. Application of RDF and *Rhizobium* alone significantly increased the potassium uptake in straw compared to the control, while their combined application (RDF + *Rhizobium*) resulted in a significantly higher potassium uptake compared to their individual applications (43). Application of *Rhizobium* and vermicompost alone significantly increased the potassium uptake in the straw of mung bean compared to the control, whereas their combined application (*Rhizobium* +

vermicompost) further increased the potassium uptake compared to their individual applications (41).

Total K uptake

The data regarding the total K uptake of mung bean are presented in Table 5 and Fig. 4. The application of various biofertilizers, organic manures and recommended dose of fertilizers significantly affected the total K uptake. The data recorded revealed that the addition of alone *Rhizobium* (T_R), Jeevamrutam (T_J) and vermicompost (T_V) significantly increased the total K uptake as compared to control (T_C). However, the combined application of *Rhizobium* + Jeevamrutam + vermicompost (T_{V+R+J}) significantly increased the total K uptake as compared to application of alone *Rhizobium* (T_R), Jeevamrutam (T_J) and vermicompost (T_V). The application of recommended dose of fertilizers (T_{RDF}) significantly increased the total K uptake as compared with application of alone *Rhizobium* (T_R), Jeevamrutam (T_J) and vermicompost (T_V) but was at par with combined application of organic manures (T_{V+R+J}). The application of T_{RDF+R} significantly increased the total K uptake as compared with T_{RDF} and further application of $T_{RDF+R+J}$ failed to increase significantly as compared with application of T_{RDF+R}. The application of $T_{RDF+V+R}$ significantly increased the total K uptake as compared with $T_{RDF+R+J}$ and further application of $T_{RDF+V+R+J}$ significantly increased the total K uptake as compared with $T_{RDF+V+R}$. Application of *Rhizobium* and vermicompost alone failed to significantly increase the total potassium uptake in urdbean compared to the control; however, their combined application (*Rhizobium* + vermicompost) significantly increased the total potassium uptake compared to both the control and their individual applications (40). Application of RDF, cow dung and vermicompost alone significantly increased the total potassium uptake in mung bean compared to the control, while their combined application (RDF + cow dung + vermicompost) resulted in a significantly higher total potassium uptake compared to their individual applications (25).

Quality analysis

Protein content

The data regarding protein content in grain of mung bean crop are presented in Table 6 and Fig. 5. The application of various biofertilizers, organic manures and recommended dose of fertilizers significantly affected the protein content in grain. The data recorded revealed that the addition of alone *Rhizobium* (T_R) and vermicompost (T_V) significantly increased the protein content in grain as compared to control (T_C) but addition of alone Jeevamrutam (T_J) failed to cause significant increase in protein content in grain as compared with control (T_C). However, the combined application of *Rhizobium* + Jeevamrutam + vermicompost (T_{V+R+J}) significantly increased the protein content in grain as compared to application of alone *Rhizobium* (T_R), Jeevamrutam (T_J) and vermicompost (T_V). The application of recommended dose of fertilizers (T_{RDF}) increased the protein content in grain significantly as compared to application of alone Jeevamrutam (T_J) but was at par with combined application of organic manures (T_{V+R+J}). The application of T_{RDF+R} significantly increased the protein content in grain as compared with T_{RDF} and further application of $T_{RDF+R+J}$ failed to cause significant increase in protein content in grain as compared with T_{RDF+R}. The application of $T_{RDF+V+R+J}$ significantly increased the protein content in grain as compared with $T_{RDF+R+J}$ but was at par with $T_{RDF+V+R}$. Application of *Rhizobium* and PSB alone significantly increased the protein content in cluster bean compared to the control, while their combined application (*Rhizobium* + PSB) further increased the protein content significantly compared to their individual applications (44). Application of *Rhizobium* and vermicompost alone failed to significantly increase the protein content in the grain of urd bean compared to the control; however, their combined application (*Rhizobium* + vermicompost) significantly increased the protein content compared to both the control and their individual applications (40). Combined application of FYM @ 2.5 t ha^{-1} + vermicompost @ 1 t ha^{-1} + Jeevamrutam @ 500 L ha^{-1} recorded a significantly higher protein content in pigeon pea compared to the control.

Protein yield

The data regarding grain protein yield of mung bean crop are presented in Table 6 and Fig. 5. The application of various biofertilizers, organic manures and recommended dose of fertilizers significantly affected the protein yield in grain. The data recorded revealed that the addition of alone *Rhizobium* (T_R) and vermicompost (T_V) significantly increased the protein yield in grain as compared to control (T_C) but addition of alone Jeevamrutam (T_J) failed to cause significant increase in protein yield as compared with control (T_C). However, the combined application of *Rhizobium* + Jeevamrutam + vermicompost (T_{V+R+J}) significantly increased the protein yield as compared to application of alone *Rhizobium* (T_R), Jeevamrutam (T_J) and

Table 6. Influence of various treatments on protein content (%) and protein yield (kg ha^{-1}) of mung bean

		protein content (%) and protein yield (kg ha^{-1})	
Treatments		**Protein content (%)**	**Protein yield (kg ha^{-1})**
T_c	T_1	11.8	88.6
T_R	T_2	15.3	130.6
T_J	T_3	13.4	104.4
T_V	T_4	15.2	123.7
T_{V+R+J}	T_5	17.9	165.9
T_{RDF}	T_6	16.5	150.0
T_{RDF+R}	T_7	20.7	197.5
$T_{RDF+R+J}$	T_8	22.0	219.0
T_{RDF+V}	T_9	20.0	177.1
$T_{RDF+V+R}$	T_{10}	23.4	264.0
$T_{RDF+V+R+J}$	T_{11}	24.7	307.3
LSD (0.05)		1.77	19.83

T_c = Control, T_R = *Rhizobium*, T_J = Jeevamrutam, T_V = Vermicompost, T_{V+R+J} =Vermicompost + *Rhizobium* + Jeevamrutam, T_{RDF} = Recommended dose of fertilizers, T_{RDF+R} = Recommended dose of fertilizers + *Rhizobium*, $T_{RDF+R+J}$ = Recommended dose of fertilizers + *Rhizobium* + Jeevamrutam, T_{RDF+V} = Recommended dose of fertilizers + Vermicompost, $T_{RDF+V+R}$ = Recommended dose of fertilizers + Vermicompost + *Rhizobium*, $T_{RDF+V+R+J}$ = Recommended dose of fertilizers + Vermicompost + *Rhizobium* + Jeevamrutam

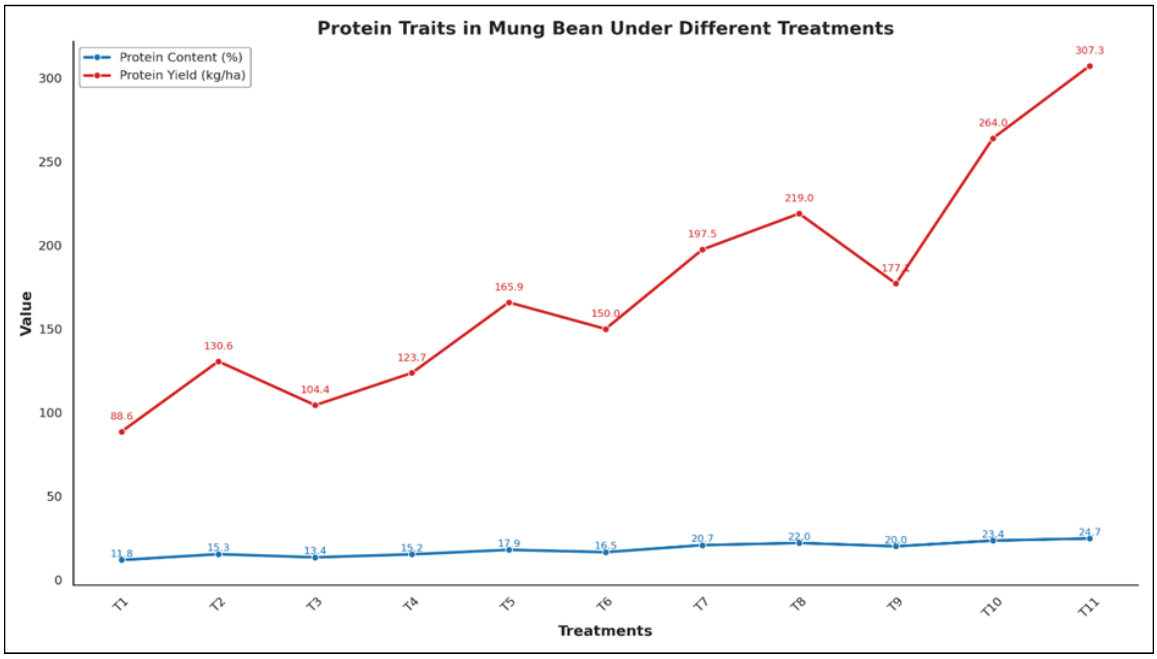

Fig. 5. Influence of various treatments on protein content (%) and protein yield (kg ha^{-1}) of mung bean.

vermicompost (T_V). The application of recommended dose of fertilizers (T_{RDF}) increased the protein yield significantly as compared application of alone Jeevamrutam (T_J) and vermicompost (T_V) but was at par with application of alone *Rhizobium* (T_R) and combined application of organic manures (T_{V+R+J}). The application of T_{RDF+R} significantly increased the protein yield as compared with T_{RDF} and the application of $T_{RDF+R+J}$ significantly increased the protein yield as compared with T_{RDF+R}. The application of $T_{RDF+V+R}$ significantly increased the protein yield as compared with $T_{RDF+R+J}$ and application of $T_{RDF+V+R+J}$ further increased the protein yield significantly as compared with $T_{RDF+V+R}$. Application of *Rhizobium* and PSB alone significantly increased the protein yield of chickpea compared to the control, but their combined application failed to produce a significant increase compared to their individual applications (26). Application of 75 % RDF, vermicompost @ 2 t ha^{-1}, *Rhizobium* and PSB alone failed to cause a significant increase in protein yield compared to the control; however, their combined application (75 % RDF + vermicompost @ 2 t ha^{-1} + *Rhizobium* + PSB) significantly increased the protein yield compared to their individual applications (45). Application of nitrogen @ 25 kg ha^{-1} and phosphorus (P_2O_5) @ 75 kg ha^{-1} individually produced a significantly higher protein yield compared to the control, while their combined application failed to cause a significant increase compared to their individual applications (46).

Conclusion

The combined use of vermicompost, *Rhizobium* culture and Jeevamrutam significantly improved nitrogen and phosphorus uptake in mung bean compared to their individual applications. Applying only Jeevamrutam, vermicompost or *Rhizobium* alone was less effective than their combination. The use of recommended chemical fertilizers improved nutrient uptake over some individual organic inputs but was less effective than combined organic treatments. Adding *Rhizobium* to chemical fertilizers enhanced uptake further, especially in the straw. Including Jeevamrutam with chemical fertilizers and *Rhizobium* improved straw nutrient uptake, though grain uptake gains were limited. Combining vermicompost with fertilizers and *Rhizobium* further improved nutrient uptake in both grain and straw. The most effective treatment included chemical fertilizers along with vermicompost, *Rhizobium* and Jeevamrutam, showing the highest uptake values. This combination also led to the highest protein content in mung bean grain. Organic treatments alone improved protein content, but combining them with fertilizers gave superior results. Overall, integrating organic manures with chemical fertilizers proved most beneficial for nutrient uptake and grain quality in mung bean.

Acknowledgements

Thanks to Lovely Professional University for their support and where this investigation was conducted.

Authors' contributions

SK carried out the experiment, took observations and Rajneesh K analysed the data. AAL and MKP guided the research by formulating the research concept and RK^2, MKP and AAL approved the final manuscript. RK^1, KS, S and CKP participated in the design of the study and performed the statistical analysis. BRD, KHCS, R, AL and AT contributed by imposing the experiment and helped to edit, summarise and revise the manuscript. AAL and RK^2 helped to summarize and revise the manuscript. All authors read and approved the final manuscript. [RK^1 stands for Rupesh Kumar and RK^2 stands for Rajneesh Kumar]

Compliance with ethical standards

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.

Ethical issues: None

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