Journal of Scientific Research and Reports

Volume 30, Issue 7, Page 1021-1032, 2024; Article no.JSRR.119779
ISSN: 2320-0227

Effect of Integrated Nutrient Management on Nutrient Content and Their Uptake by Soybean Crop (*Glycine max* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jsrr/2024/v30i72212

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/119779

Original Research Article

Received: 05/05/2024
Accepted: 10/07/2024
Published: 12/07/2024

ABSTRACT

Aim: To study the effect of integrated nutrient management practices on nutrient content and uptake by soybean crop (*Glycine max* L.).
Study Design: Randomized block design.
Place and Duration of Study: One-year field experiment at Research Farm, School of Agriculture, Abhilashi University, Chail Chowk, Mandi, (H.P.), during *kharif* of 2023.
Methodology: The experiment was conducted with three replications and nine treatments *viz.* T_1= Absolute control, T_2= 100% RDF, T_3= 100% RDF + *Rhizobium*, T_4 = 75% RDF + 25% N by FYM,

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***Cite as:** Gupta, Ritika, Jay Nath Patel, and Mohd Shah Alam. 2024. "Effect of Integrated Nutrient Management on Nutrient Content and Their Uptake by Soybean Crop (Glycine Max L.)". Journal of Scientific Research and Reports 30 (7):1021-32. https://doi.org/10.9734/jsrr/2024/v30i72212.*

T_5= 75% RDF + 25% N by Vermicompost, T_6= 50% RDF + 50% N by FYM, T_7= 50% RDF + 50% N by Vermicompost, T_8= 50% RDF + *Rhizobium* + 25% N by FYM + 25% N by Vermicompost and T_9= 100% RDF + *Rhizobium* + 25% N by FYM + 25% N by Vermicompost.

Results: The study of the data revealed that there is a non-significant effect of integrated nutrient management practices on the content of nitrogen, phosphorus and potassium in grains and straw of soybean crop, whereas, the application of treatment T_9 noted the highest content of these nutrients in grains and straw of the soybean crop. Treatment T_9 also recorded the significantly maximum uptake of nitrogen, phosphorus and potassium by grains, straw and total uptake by soybean crop, which was statistically at par with treatments T_3 and T_2. However, the minimum content of nitrogen, phosphorus and potassium in grains and straw along with their uptake by grains, straw and total uptake by soybean crop were found under the treatment T_1 during the field experiment.

Conclusion: This study showed that the different integrated nutrient management practices do not affect the content of nutrients in soybean crop significantly, however, it has significantly affected the uptake of nutrients by soybean crop.

Keywords: Soybean; integrated nutrient management; Rhizobium; vermicompost; nutrient content and uptake.

1. INTRODUCTION

Soybean is an essential pulse and oil-seed crop of the Leguminosae family. High-quality protein and necessary amino acids are found in abundance in soybeans. It is also known as the "Golden bean" because of its high dietary fiber content and low saturated fat content. It was introduced in India from China through the Himalayas as soon as it was domesticated in China [1]. Soybean oil is utilized in both cooking and the production of several industrial goods, including paints, soaps, disinfectants, pesticides and vanaspati ghee etc. Seeds of soybean are used to make soy milk, soy nuts, soy tofu and soy sprouts etc. Soybean oil cake is used to make high-protein cattle feed, biscuits, bread and other confections that are high in protein. It is the cheapest and main source of dietary protein of majority vegetarian Indians. Soybean seeds consist of 18-25% oil and 30-50% protein [2]. It is also known as the "Cow of the Orient," the soybean contains about 40% protein and 20% fatty [3]. This composition varies with the location, climate of the planting and variety of soybean.

This legume can obtain some of the nitrogen it needs by nitrogen fixation, however, the seeds must be inoculated with bacterial culture to guarantee a supply of nitrogen. In low N-status soils, 20-30 kg of nitrogen ha^{-1} is thought to be adequate to meet the initial requirements of the soybean crop. Potassium and phosphorus availability in the soil should also be good. Applying 40 kg P_2O_5 ha^{-1} and 20 kg potassium ha^{-1} is recommended to meet the crop's needs of crop for phosphorus.

Brazil ranks first in production (144.000 million metric tons) followed by the United States of America (119.884 million metric tons), Argentina (52.000 million metric tons), China (14.000 million metric tons) and India (11.200 million metric tons). However, Brazil also ranks first in soybean productivity with 3564 kg ha^{-1} followed by the United States of America (3417 kg ha^{-1}), Argentina (3023 kg ha^{-1}), China (1979 kg ha^{-1}), whereas, the productivity of India is 882 kg ha^{-1} [4]. Among the states, Madhya Pradesh stood first with 5.51 m ha followed by Maharashtra (4.69 m ha), Rajasthan (1.16 m ha), Karnataka (0.37 m ha), Gujarat (0.22 m ha) and Telangana (0.16 m ha) [5]. As a result, soybean has traditionally been grown on a small scale in Himachal Pradesh.

Integrated nutrient management is the unified application of chemical fertilizers along with organic resources materials like organic manures, green manures, bio-fertilizers and other organic decomposable materials for crop production. IPNS (Integrated plant nutrition system) is ecologically, socially and economically viable and environment friendly which can be practiced by farmers to derive higher productivity with simultaneously maintaining soil fertility. Integrated nutrient management encourages the use of on-farm organics; thus, it reduces the cost of fertilizers for crop production. It involves a proper combination of synthetic fertilizers, organic manure, crop residues, N_2-fixing crops like pulses such as rice bean, black gram, other pulses and oil-seeds such as soybean and bio-fertilizers suitable to the system of land use and ecological, social and economic conditions [6]. The cropping system rather than an individual crop and farming system rather than an individual field, are the focus of attention in this approach for developing INM practices for various categories. The fundamental idea behind integrated nutrition management (INM) is the prudent and effective use of fertilizers to maintain soil fertility, increase agricultural output over time, and improve profitability. The major components of INM are fertilizers, organic manures, legumes, crop residues and *Rhizobium*. The application of fertilizer significantly increases the growth parameters and yield of the component crops. Increasing the quantity of NPK fertilizer resulted in significant increases in the yield and growth parameters of soybean. It has been discovered that combining *Rhizobium* with both organic and inorganic nutrition sources increases soybean productivity and yields financial benefits [7,8]. Additionally, organic sources have a significant lasting impact on subsequent harvests, in contrast to inorganic ones [9,10,11] investigated that the preservation of the physical, chemical, and biological characteristics of soil is greatly aided by INM. It increases stable aggregates, increases porosity, decreases in bulb density and improves soil structure.

Farmyard manure is prepared basically by using cow dung, cow urine, waste straw and other dairy wastes. It is highly useful manure because it is rich in essential plant nutrients. A smaller amount of N is available to the plants immediately and a bigger amount is released when the FYM breaks down. Jarvan et al. [12] said that farm yard manure is one of the more valuable that the application of FYM significantly increased the potassium and magnesium in the soil.

Vermicompost is rich in essential plant nutrients and thus, it is widely used as organic manure in agriculture and nutrifying the crops. Fudzagbo et al. [13] said that vermicomposting is one of the most sustainable methods of handling food waste and are completely environmentally friendly technology that is a viable method of diverting the organic portion of waste streams, avoiding the costs of disposal and converting it to a value-added vermicompost. The vermicompost is not only nutrient-rich but also contains high-quality humus, plant growth hormones, enzymes and substances which can protect plants against pests and diseases.

Rhizobium are living microbes that enhance plant nutrition either by mobilizing or increasing nutrient availability in soils. Since they may effectively colonize the rhizosphere, rhizoplane, or root interior, a variety of microbial organisms, including beneficial bacteria and fungus, are being used as *Rhizobium*. Microorganisms found in *Rhizobium* increase the plant's availability of vital nutrients, thereby aiding in the growth of trees and other plants. *R. japonica* biofertilizer is commonly used in soybean crop. According to Meshram et al. [14], the main component of *Rhizobium* is helpful microorganisms that have the ability to liberate nutrients from plant wastes and raw materials in the soil and make them commercially available in situations when particular strains of the microorganism are employed as biological fertilizers. *Rhizobium* contain microorganisms which promotes the adequate supply of nutrients to the host plants and ensure their proper growth and regulation in their physiology. With the help of *Rhizobium*, soil fertility can be increased and different resources can be used more effectively, leading to a sustained increase in crop yield.

2. MATERIALS AND METHODS

The field experiment was carried out at the Research Farm of the School of Agriculture, Abhilashi University, Chail Chowk, Mandi (H.P.) during *kharif* of 2023. The experimental farm is situated at 30^0 32' N latitude and 74^0 53' E longitudes, with an elevation of 1391 m above mean sea level. The pH of the experimental field was slightly acidic in reaction (5.60) with electrical conductivity of 0.008 dS m^{-1}, high in organic carbon (0.80%), low in nitrogen (215.49 kg ha^{-1}), low in phosphorus (8.67 kg ha^{-1}) and medium in potassium (246.03 kg ha^{-1}). The experiment was laid out in a randomized block design (RBD) with nine treatments and three replications. The treatments which were used during experiment are- T_1= Absolute control, T_2= 100% RDF, T_3= 100% RDF + *Rhizobium*, T_4=75% RDF + 25% N by FYM, T_5= 75% RDF + 25% N by Vermicompost, T_6= 50% RDF + 50% N by FYM, T_7= 50% RDF + 50% N by Vermicompost, T_8= 50% RDF + *Rhizobium* + 25% N by FYM + 25 % N by Vermicompost and T_9= 100% RDF + *Rhizobium* + 25% N by FYM + 25% N by Vermicompost. The nutrients were applied according to the various integrated nutrient management treatments. The recommended doses of nitrogen, phosphorus and potassium for crop were 20:40:20 which were applied through Urea, DAP and MOP. The seeds were treated with *Rhizobium* before the sowing of the crop. The vermicompost and FYM were applied two weeks prior to the sowing of the seeds of the soybean crop. After the harvest of the crop, the samples were collected from every net plot and were cleaned and dried under the shade. After the drying of the samples under shade, the samples were oven-dried at 60 ± 2°C for 24 to 48 hours until their weight was constant and the samples were finely powdered with a mixer grinder. After the grinding process, the samples were used for the analysis of nitrogen, phosphorus and potassium content and their uptake by soybean crop. The Kjeldahl digestion and distillation method was used to determine the nitrogen content described by [15]. The venadomolybdate phosphoric yellow color method was used for determining the phosphorus content given by [15]. The flame photometer method was used for determining the potassium content given by [15]. The nitrogen, phosphorus and potassium (kg ha^{-1}) uptake by grains and straw of soybean crop in each treatment was calculated by multiplying the N, P and K content (%) with yields of grains and straw (q ha^{-1}). The total uptake of different nutrients was calculated after summing their uptake by grains and straw of soybean crop.

3. RESULTS

Nitrogen (N) content (%) and uptake (kg ha^{-1}): The nitrogen content in grains and straw and uptake by soybean crop are presented in Table 1 and Fig. 1. The study of the data showed a non-significant effect of integrated nutrient management on the content of nitrogen in the grains and straw of the soybean crop during the experiment. However, treatment T_9 (100% RDF + *Rhizobium* + 25% N by FYM + 25% N by Vermicompost) recorded the highest nitrogen content in grains (6.39 %) and straw (2.48%) of soybean crop. While, treatment T_1 (Absolute control) noted the lowest nitrogen content in grains (6.26 %) and straw (2.42 %) of soybean crop during the field experiment.

The study of the data showed a significant effect on the nitrogen uptake by grains, straw as well as total uptake by soybean crop. During the investigation, the application of treatment T_9 (100% RDF + *Rhizobium* + 25% N by FYM + 25% N by Vermicompost) recorded maximum nitrogen uptake by grains, straw and total uptake by soybean crop (138.02 kg ha^{-1}, 88.60 kg ha^{-1} and 226.62 kg ha^{-1}, respectively), which was statistically at par with treatments T_3 (100% RDF + *Rhizobium*) (132.22 kg ha^{-1}, 86.03 kg ha^{-1} and 218.25 kg ha^{-1}, respectively) and T_2 (100% RDF) (127.76 kg ha^{-1}, 84.24 kg ha^{-1} and 211.67 kg ha^{-1}, respectively). However, under treatment T_1 (Absolute control), the lowest uptake of nitrogen by grains, straw and total uptake by soybean crop was noted (52.02 kg ha^{-1}, 35.32 kg ha^{-1} and 87.34 kg ha^{-1}, respectively) during the study.

Phosphorus (P) content (%) and uptake (kg ha^{-1}); The content of phosphorus in grains and straw of soybean crop and phosphorus uptake by soybean crop are presented in Table 2 and depicted in Fig. 2. The study of data of results revealed that the concentrations of phosphorus in the grains and straw of the soybean crop did not significantly change due to the application of the different integrated nutrient management treatments. However, treatment T_9 (100% RDF + *Rhizobium* + 25% N by FYM + 25% N by Vermicompost) noted the highest phosphorus content in grains (0.28 %) and straw (0.16 %) of the soybean crop, while treatment T_1 (Absolute control) recorded the minimum content of phosphorus in grains (0.24 %) and straw (0.10 %) of soybean crop.

The further analysis of the data showed that there is significant effect on the phosphorus uptake by grains, straw as well as total uptake by soybean crop. Application of treatment T_9 (100% RDF + *Rhizobium* + 25% N by FYM + 25% N by Vermicompost) recorded the highest uptake of phosphorus by grains, straw and total uptake (6.65 kg ha^{-1}, 5.72 kg ha^{-1} and 11.77 kg ha^{-1}, respectively) by soybean crop, which was statistically on par with treatment T_3 (100% RDF + *Rhizobium*) (5.82 kg ha^{-1}, 5.22 kg ha^{-1} and 11.04 kg ha^{-1}, respectively) and T_2 (100% RDF) (5.43 kg ha^{-1}, 4.77 kg ha^{-1} and 10.53 kg ha^{-1}, respectively). Whereas, the minimum uptake of phosphorus uptake by grains, straw as well as total uptake by soybean crop was found under treatment T_1 (Absolute control), (1.99 kg ha^{-1}, 1.46 kg ha^{-1}and 3.45 kg ha^{-1}, respectively) during the field experiment.

Potassium (K) content (%) and uptake (kg ha^{-1}): The potassium content in grains and straw of soybean crop and uptake of potassium by soybean crop are presented in Table 3 and Fig. 3. The potassium content in grains and straw of soybean crop was found non-significant due to application of different integrated nutrient management practices. While, the application of treatment T_9 (100% RDF + *Rhizobium* + 25% N by FYM + 25% N by Vermicompost) observed the highest potassium content in grains (1.32 %) and straw (2.44 %) of the soybean crop. Whereas, treatment T_1 (Absolute control) noted the lowest potassium content in grains (1.07 %) and straw (2.11 %) of soybean crop during the field study.

Table 1. Effect of integrated nutrient management on nitrogen content (%) and their uptake (kg ha^{-1}) by soybean crop

S.N.	Treatments	Nitrogen content (%)		Nitrogen uptake (kg ha^{-1})		
		Grain	Straw	Grain	Straw	Total
T_1	Absolute control	6.26	2.42	52.02	35.32	87.34
T_2	100% RDF	6.35	2.47	127.76	84.24	211.67
T_3	100% RDF + *Rhizobium*	6.36	2.47	132.22	86.03	218.25
T_4	75% RDF + 25% N by FYM	6.31	2.46	118.82	76.28	195.10
T_5	75% RDF + 25% N by Vermicompost	6.33	2.46	122.61	78.77	201.38
T_6	50% RDF + 50% N by FYM	6.27	2.43	91.67	60.09	151.76
T_7	50% RDF + 50% N by Vermicompost	6.28	2.44	97.15	62.87	160.02
T_8	50% RDF + *Rhizobium* + 25% N by FYM + 25% N by Vermicompost	6.29	2.45	105.73	68.49	174.22
T_9	100% RDF + *Rhizobium* + 25% N by FYM + 25% N by Vermicompost	6.39	2.48	138.02	88.60	226.62
	SEm±	0.18	0.08	3.59	2.33	5.68
	CD (*P* = .05)	NS	NS	10.54	7.05	17.20

Table 2. Effect of integrated nutrient management on phosphorus content (%) and their uptake (kg ha^{-1}) by soybean crop

S.N.	Treatments	Phosphorous content (%)		Phosphorous uptake (kg ha^{-1})		
		Grain	Straw	Grain	Straw	Total
T_1	Absolute control	0.24	0.10	1.99	1.46	3.45
T_2	100% RDF	0.27	0.14	5.43	4.77	10.53
T_3	100% RDF + *Rhizobium*	0.28	0.15	5.82	5.22	11.04
T_4	75% RDF + 25% N by FYM	0.26	0.13	4.90	4.03	8.93
T_5	75% RDF + 25% N by Vermicompost	0.27	0.14	5.23	4.48	9.71
T_6	50% RDF + 50% N by FYM	0.25	0.11	3.66	2.72	6.38
T_7	50% RDF + 50% N by Vermicompost	0.25	0.11	3.87	2.83	6.70
T_8	50% RDF + *Rhizobium* + 25% N by FYM + 25% N by Vermicompost	0.26	0.12	4.37	3.35	7.72
T_9	100% RDF + *Rhizobium* + 25% N by FYM + 25% N by Vermicompost	0.28	0.16	6.05	5.72	11.77
	SEm±	0.09	0.01	0.23	0.33	0.60
	CD (*P* = .05)	NS	NS	0.69	0.99	1.83

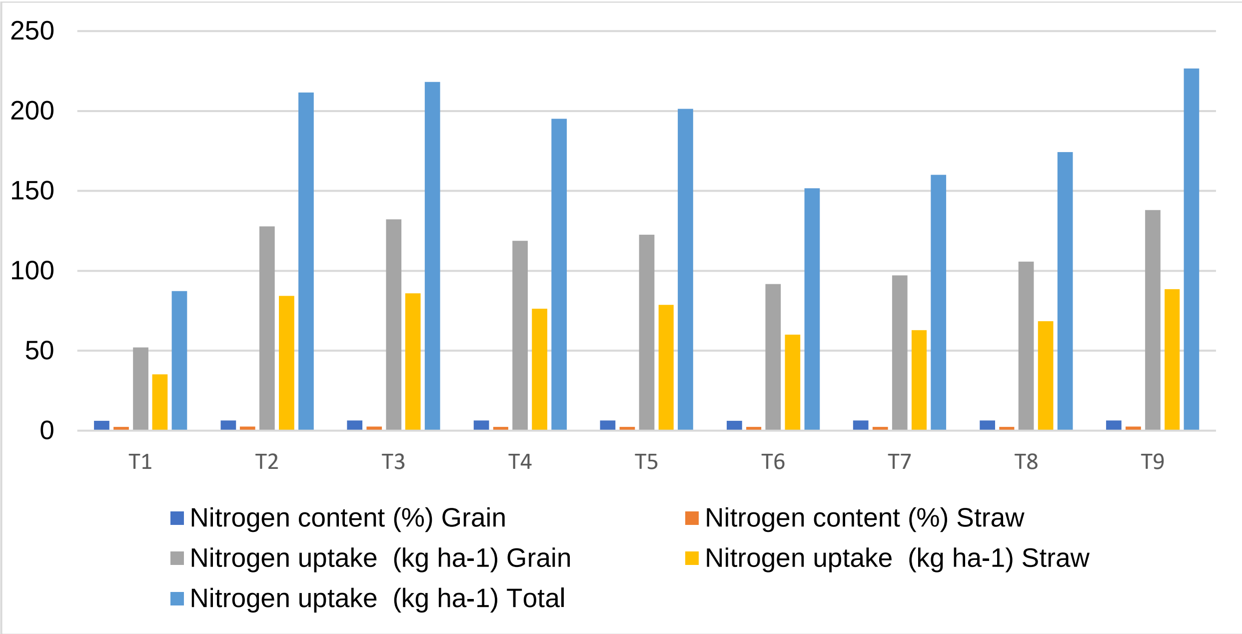

Fig. 1. Effect of integrated nutrient management on nitrogen content (%) and their uptake (kg ha^{-1}) by soybean crop

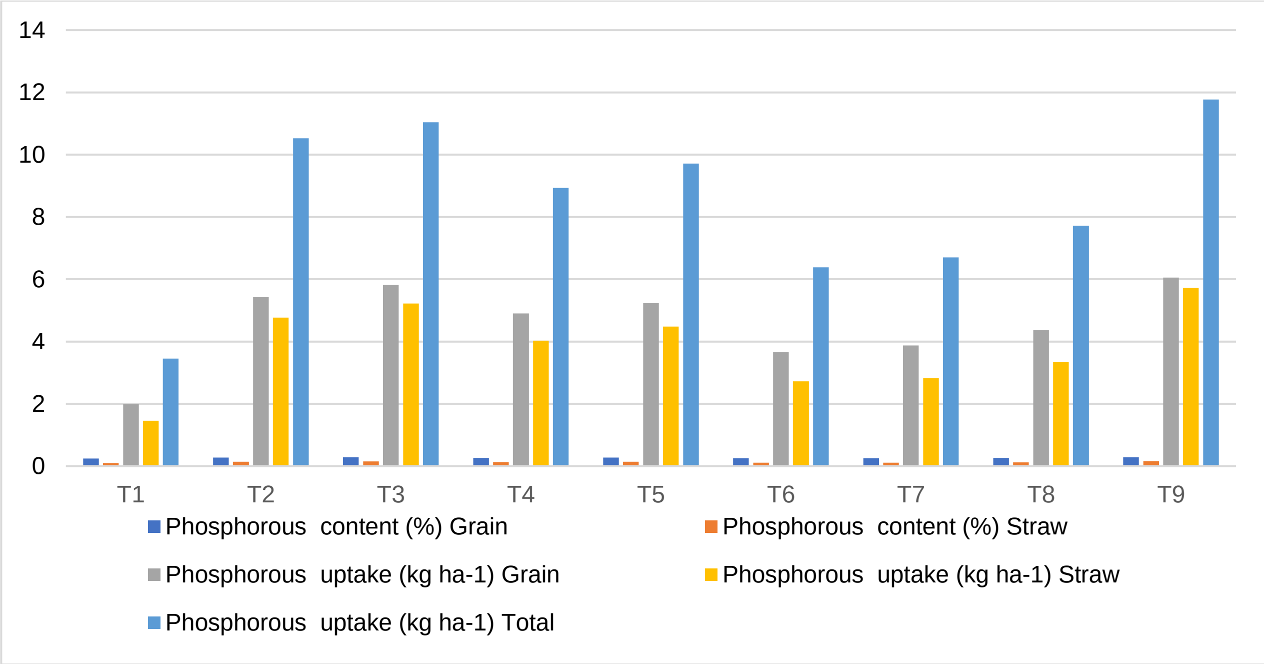

Fig. 2. Effect of integrated nutrient management on phosphorus content (%) and their uptake (kg ha^{-1}) by soybean crop

Table 3. Effect of integrated nutrient management on potassium content (%) and their uptake (kg ha^{-1}) by soybean crop

S.N.	Treatments	Potassium content (%)		Potassium uptake (kg ha^{-1})		
		Grain	Straw	Grain	Straw	Total
T_1	Absolute control	1.07	2.11	8.89	30.80	39.69
T_2	100% RDF	1.29	2.36	25.95	80.49	106.43
T_3	100% RDF + *Rhizobium*	1.30	2.41	27.03	83.94	110.97
T_4	75% RDF + 25% N by FYM	1.26	2.28	23.73	70.70	94.43
T_5	75% RDF + 25% N by Vermicompost	1.27	2.32	24.60	74.29	98.89
T_6	50% RDF + 50% N by FYM	1.18	2.18	17.25	53.91	71.16
T_7	50% RDF + 50% N by Vermicompost	1.20	2.21	18.56	56.94	75.50
T_8	50% RDF + *Rhizobium* + 25% N by FYM + 25% N by Vermicompost	1.22	2.24	20.51	62.62	83.13
T_9	100% RDF + *Rhizobium* + 25% N by FYM + 25% N by Vermicompost	1.32	2.44	28.51	87.17	115.68
	SEm±	0.05	0.09	0.91	2.30	3.36
	CD (*P* = .05)	NS	NS	2.79	6.96	10.17

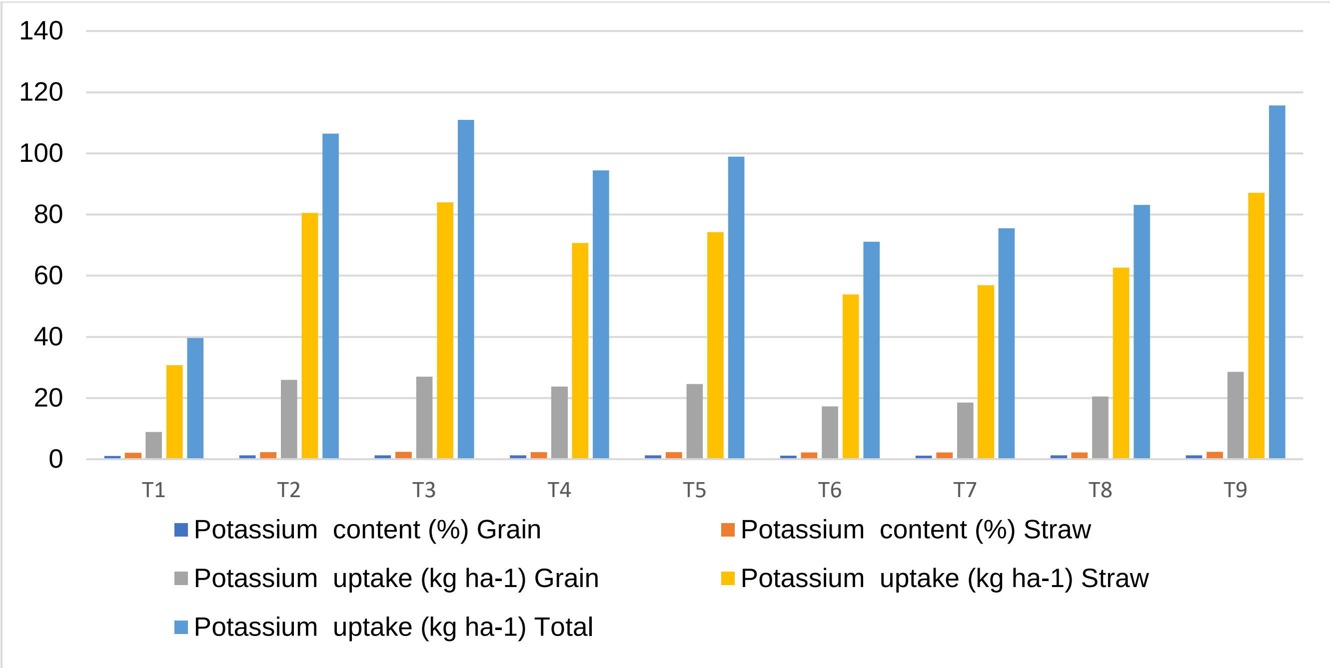

Fig. 3. Effect of integrated nutrient management on potassium content (%) and their uptake (kg ha^{-1}) by soybean crop

The analysis of the data revealed that the uptake of the potassium by grains, straw as well as their total uptake by soybean crop were significantly affected by the application of the various integrated nutrient management treatments during the field experiment. Further analysis of data showed that the treatment T_9 (100% RDF + *Rhizobium* + 25% N by FYM + 25% N by Vermicompost) recorded the maximum potassium uptake by grains, straw and total uptake (28.51 kg ha^{-1}, 87.17 kg ha^{-1} and 115.68 kg ha^{-1}, respectively) by soybean crop, which was statistically at par with treatment T_3 (100% RDF + *Rhizobium*) (27.03 kg ha^{-1}, 83.94 kg ha^{-1} and 110.97 kg ha^{-1}, respectively) and T_2 (100% RDF) (25.95 kg ha^{-1}, 80.49 kg ha^{-1} and 106.43 kg ha^{-1}, respectively). However, treatment T_1 (Absolute control) noted the lowest potassium uptake by grains, straw as well as total uptake by soybean crop (8.89 kg ha^{-1}, 30.80 kg ha^{-1}, 39.69 kg ha^{-1}, respectively) during the field experiment.

4. DISCUSSION

The nutrient content and uptake of nitrogen, phosphorus, and potassium by the grains and straw of the soybean crop were improved during the field experiment by applying different integrated nutrition management treatments at varying doses. Organic manures caused a slow and steady release of nutrients into the soil, which helped the crop growth continuously throughout the experiment. This could be the reason for the increase in nutrient content and uptake by the soybean crop as compared to the control treatment. Integrated nutrient management practices also enhanced nutrient release and promoted growth and yield. This might be because nitrogen is also a component of chlorophyll, which allows the plant to absorb sunlight energy through photosynthesis, driving vegetative growth and higher yield and ultimately higher nitrogen uptake. These factors may contribute to an increase in the nitrogen content and uptake in crop plants. Stable nitrogen availability at earlier needed stages is provided by inorganic stages and slower availability through organic manure. This result is closely related with the findings of the results of the field studies of Singh et al., [16], Vibielie Mere [17], Meshram [18], Singh et al. [3] and Akbari et al. [19]. The implementation of integrated nutrient management treatments increased the content and uptake of phosphorus which might be due to the integration of the organic manures and inorganic fertilizers improved the efficiency of phosphorus absorbing mechanisms and stimulating root growth, both of which increased phosphorus uptake. Additionally, the addition of organic manures may have contributed to higher soil microbial activity, which in turn increased phosphorus uptake. The application of phosphorus by inorganic and organic sources aids in the synthesis of DNA and RNA, the genetic building blocks, as well as the development, maintenance and repair of all tissues and cells of the crop plants, which enhances the absorption and uptake of phosphorus by crop plants. This might account for the increase in phosphorus content and uptake. Morshed et al. [20], Ved Prakash et al. [21] and Singh et al. [3] also found similar findings of phosphorus uptake in their separate experiments. The potassium content and uptake were also increased with the application of various integrated nutrient management treatments. This might be caused by improvements in photosynthesis, energy transfer, and nutrient movement within the plants as a result of appropriate fertilization with both organic and inorganic sources of nutrients. Both organic and inorganic sources are used to apply nutrients like- nitrogen, phosphorus, potassium, and other micronutrients. This might improve the absorption of the various minerals and increased crop plant mineralization of carbohydrates, which is connected with potassium levels in plants. Similar results were also observed by Arbad *et al.* [22] Ved Prakash et al. [21] and Singh et al. [3] from their experiments. The application of organic sources of nutrients, such as organic manures, may accelerate the mineralization process in soils, which makes various nutrients available to crop plants in absorbable forms and aids in the higher uptake of nutrients by crop plants from the soils. This improves the growth and structure of roots as well as the population and activities of microorganisms in the soil. Jawhara and Owied, [23] also found the close results from their study as to this finding.

5. CONCLUSION

The application of different integrated nutrient management treatment failed to show the significant effects on the content of nutrients *i.e*. nitrogen, phosphorus and potassium in grains and straw of soybean crop. However, the maximum nitrogen, phosphorus and potassium content in grains and straw of soybean crop were recorded with the application of recommended dose of nutrients through 100% RDF + *Rhizobium* + FYM + Vermicompost (treatment T_9), however, minimum content of these nutrients in grains and straw of soybean crop was noted under treatment T_1 (Absolute control) during the field experiment. Whereas, the various integrated nutrient management practices significantly affected the uptake of nitrogen, phosphorus and potassium by grains, straw as well as total uptake by soybean crop. The highest uptake of these nutrients by grains, straw and total uptake were recorded under treatment T_9 (100% RDF + *Rhizobium* + FYM + Vermicompost), which was statistically at par with treatment T_3 (100% RDF + *Rhizobium*) and T_2 (100% RDF). The minimum uptake of nitrogen, phosphorus and potassium by grains, straw as well as total uptake was found under treatment T_1 (Absolute control) during the field experiment. In conclusion, this field study shows that the alteration of the nutrient application to the soybean crop through the inorganic fertilizers and organic manures are significant to gain the higher nitrogen, phosphorus and potassium content in grains and straw as well as their uptake by the grains, straw and total uptake by soybean crop.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to everyone who helped to make this research work successful. Above all, I would want to express my gratitude to Dr. Jay Nath Patel, my major adviser, for his invaluable advice, encouragement and support during this entire study. The course of this research has been greatly influenced by their knowledge and helpful guidance. Additionally, I am thankful to the Dr. Mohd Shah Alam for their valuable helps. The Department of Agronomy, School of Agriculture, Abhilashi University is acknowledged by the authors for providing the required field and laboratory facilities. I want to express my heartfelt appreciation to everyone who has provided thoughtful feedback on how to improve the manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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