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Optimizing Agriculture: The Role of INM in Enhancing Potato (*Solanum tuberosum* L.) Production in Uttarakhand Hills

[1]Priyanka Bankoti, [2*]Mansi Nautiyal, [3]Bhagyashree Debbarma, [2]Diksha Nautiyal, [2]Neha Saini, [2]Atin Kumar, [2]Raja Joshi, [4]Jitendra Singh, [5]Deepak Kumar, [6]Ankit, [7]Vaishnavi Sharma and [8]Shani Raj

[1,7]School of Agricultural Sciences, Shri Guru Ram Rai University, Dehradun-248001, Uttarakhand, India

[2*]School of Agriculture, Uttaranchal University, Dehradun 248007, Uttarakhand, India

[3]Department of Forestry and Natural Resources, Hemwati Nandan Bahuguna Garhwal Central University, Srinagar 246174, Uttarakhand, India

[4] Department of Soil Science and Agricultural Chemistry, Veer Kunwar Singh College of Agriculture Dumraon, Bihar Agriculture University, Sabour – 802119, Bihar, India

[5]Department of Soil Science and Agricultural Chemistry, Dr. Khem Singh Gill Akal College of Agriculture, Eternal University, Baru Sahib, Sirmaur – 173101, Himachal Pradesh, India

[6]School of Agriculture, Dev Bhoomi Uttarakhand University, Dehradun 248007, Uttarakhand, India

[8]Department of Horticulture, BTC, CARS, Bilaspur, Indira Gandhi Krishi Vishwavidyalaya, Raipur-495001, Chhattisgarh, India

***Corresponding Author:** Mansi Nautiyal

Email: agrimansi06@gmail.com

Telephone No: +917830805022

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Abstract

Field study examined how INM impacted Kufri Chipsona-1 potato growth and quality. The investigation was carried out in the Uttarakhand Hills, which are characterized by sandy loam soils. The field experiment employed a randomized block design to examine the combined effects of chemical fertilizers, organic manures, and bio fertilizers (including vermicompost, FYM, PSB, and VAM as well as a control. The experiment set out to examine the quality and yield factors. According to the findings of the research, the treatment T4 (consisting of 75% RDF of NPK + FYM at 30 t/ha and PSB at 10 kg/ha) revealed in the highest overall yield (26.9 t/ha), whereas the treatment T8 (which served as the control) resulted in the lowest productivity (6.49 t/ha). In addition, the treatment had a beneficial impact on growth, quality, and several other yield related characteristics.

Keywords: *FYM, potato, growth, quality, yield.*

Introduction

An indigenous produce of tropical South America, the potato is formally classified as *Solanum tuberosum* L. It produces more dry matter, dietary fibre, protein of superior quality, vitamin and mineral content, and energy than any other crop, making it one among the most prolific food crops. In the nation, it is estimated that the area of potato cultivation is around 20.85 lakh hectares, and the output of potatoes is approximately 480.96 lakh million tonnes. About 23.07 tons of potato are produced per hectare (Anon., 2015). According to Khurana and Naik (2003), potatoes rank third in India when weighed fresh, fourth in industrialized countries, and sixth in emerging nations. This is related to the fact that potatoes are not as crucial to food production as other significant crops. At 99.2 million tons, China has surpassed all other countries as the world's largest producer of potatoes. According to FAOSTAT (1997), China and India together collect around one-third of the world's potato crop. Its composition, according to Khalid et al. (2020), was 2% carbohydrates, 0.09% lipids, 2.2% fibres, 0.25 mg vitamin C, 12 mg calcium, and 0.25 mg pyridoxine. The essential amino acids needed by human nutrition are remarkably well-composed in potato protein.

Additionally, it contains trace amounts of vitamins, minerals, and additional nutrients. Potato, which is referred to as the "Poor man’s crop" due to its high human population density and ability to provide ample protein and caloric at a low cost to meet nutritional requirements in countries like India, is undeniably a crucial crop for these regions.

Therefore, increasing potato yields is key to satisfying this need. Crops have a hard time getting the massive amounts of nutrients they need from soils because to potatoes' large dry matter output, which draws a lot of nutrients out of the soil per unit area and time (Morirul et al., 2013). Soil nutrition addition from outside sources becomes crucial. Potatoes mostly get their nutrition from inorganic fertilizers. As a crop that heavily consumes nutrients, potatoes have very high needs for nitrogen, phosphate, and potassium. In order to achieve optimum development and growth, plants need a well-proportioned amount of nutrients. Pervez et al. (2013) identified phosphate, potassium, and nitrogen as three essential elements that significantly impact potato productivity.

Organic and inorganic fertilizers improve soil and agricultural output. Saha et al. (2008) conducted several investigations on how organic and inorganic fertilizers affect soil properties, crop productivity, and agronomical outcomes in diverse agro-environments.

Anonymous (2004) states that organic things serve as reservoirs for plant nutrients, beneficial plant microorganisms, and organic chemicals that may prevent plant diseases. Proper nutrition management has the potential to boost the yield of potatoes by up to 50% (Grewal and Singh 1992). Exclusively relying on synthetic fertilizers makes it unfeasible to continue agricultural production due to the degradation of the soil ecosystem, including both physical and biological factors (Khan et al., 2008).

The goal of modern nutrient management is to make things last for a long time and have as little impact on the world as possible. Chemical fertilizers have caused a lot of problems because farmers only use them to get high yields. The physical and chemical qualities of soil have decreased, soil microbe activity has decreased, humus content has decreased, and pollution of the soil, water, and air has increased when chemical fertilizers are used extensively without the addition of organic manures or bio fertilizers.

To make the best use of plant nutrients for economic reasons, environmental sustainability, and the growth of soil health, it is important to use combined nutrient management systems. Chemical fertilizers are needed for current intense crop production methods, but the main idea behind this plan is to use organic manures and chemical fertilizers in the best way possible to help crops grow in a way that lasts. It was the objective of the experiment to find out how INM changed the way the potatoes flourished.

Soil Conditions

At the experimental location, the soil is referred to as "sandy loam," and it is characterized by having features such as being deep, having good drainage, having a coarse loamy cover over fragmental soils, and having a medium fertility. Five distinct soil samples obtained from upper most layer of the soil, which was between 0 and 15 centimetres deep, and then mixed together in the appropriate manner. A representative sample of the soil was obtained for the purpose of analysing its physiochemical process after it had been thoroughly mixed. Here are the specifics of the field's soil:

Physical Attributes of Soil as Measured in the Field

Particular	**Value (%)**	**Method Adopted**
Coarse Sand	0.71	Bouyoucue hydrometer method (Bouyoucus, 1962)
Find Sand	65.2	
Silt	18.6	
Clay	15.70	

Chemical Attributes of Soil as Measured in the Field

Particular	**Value (%)**	**Method Adopted**
Soil pH (1:25) soil water suspension	7.12	Glass electro pH meter method (Jackson, 1973)
Organic Carbon (%)	0.42	Walkley and Black method (Walkley and Black, 1934)
Available Nitrogen	352	Kjeldahl method (SubbiationAsija, 1956)
Available Phosphorus (kg/ha)	9.1	Olsen's method (Olsen, *et al*.2006)
Available Potassium (kg/ha)	18.1	Flame photometry method (Jackson, 1973)

Material and Method

The experiment was place on the School of Agriculture's Research Farm, Shri Guru Ram Rai University. Located at a height of 640 m above mean sea level, the university's precise geographical coordinates are as follows: Longitude 78.032188; latitude 30.316496.

The investigation was conducted utilizing the potato cultivar Kufri Chipsona-1. This cultivar of potato is resistant to late blight. The trial used an RBD design, with three replications. The experimental details are as follows:

Symbol	Treatments
T_1	100% RDF of NPK
T_2	100% RDF of NPK + FYM @ 30 t/ha
T_3	100% RDF of NPK + vermicompost @ 10 t/ha
T_4	75% RDF of NPK + FYM @ 30 t/ha + PSB @ 10 kg/ha
T_5	75% RDF of NPK + FYM @ 30 t/ha + VAM @ 10 kg/ha
T_6	50% RDF of NPK + vermicompost @ 10 t/ha + PSB @ 10 kg/ha
T_7	50% RDF of NPK + vermicompost@ 10 t/ha + VAM @ 10 kg/ha
T_8	Control

The assessment of growth, quality, and yield attributes was conducted at the designated time intervals of 30, 60, and 90 days. The one-way analysis of variance (ANOVA) was used to see whether the regimens differed significantly.

At a significance level of 5%, a critical differences (CD) test was conducted to further divide the means for subsequent analysis. The calculation of the leaf area index (LAI) at different phases was performed utilizing the formula proposed by Sestak et al. (1971).

$$LAI = \frac{\text{Leaf area}}{\text{Ground area covered by the plant}} \times 100$$

Results and Discussion

Plant Height

Plant heights of 38.75 cm, 47.63 cm, and 50.52 cm were recorded for Treatment T4 (75% RDF of NPK + FYM @ 30 t/ha + PSB @ 10 kg/ha) at 30, 60, and 90 days after planting, and yielded statistically useful findings above those of the other treatments. At 30, 60, and 90 days after seeding, Treatment T8 (control) had the Shortest plant size (12.19 cm, 23.21 cm, and 26.31 cm) (Table 1).

Table 1: The Effect of INM on Potato Plant Height

Symbol	Treatments	Plant Height (cm)		
		30 Days	60 Days	90 Days
T_1	100% RDF of NPK	28.14	34.57	38.28
T_2	100% RDF of NPK + FYM @ 30 t/ha	35.24	45.71	49.34
T_3	100% RDF of NPK + vermicompost @ 10 t/ha	28.82	36.52	41.27
T_4	75% RDF of NPK + FYM @ 30 t/ha + PSB @ 10 kg/ha	38.75	47.63	50.52
T_5	75% RDF of NPK + FYM @ 30 t/ha + VAM @ 10 kg/ha	33.15	43.84	48.56

T_6	**50% RDF of NPK + vermicompost @ 10 t/ha + PSB @ 10 kg/ha**	34.37	43.34	45
T_7	**50% RDF of NPK + vermicompost@ 10 t/ha + VAM @ 10 kg/ha**	28.39	43.08	45.39
T_8	**Control**	12.19	23.21	26.31
	S. E m±	0.375	0.272	1.373
	CD @5%	1.172	0.855	4.229

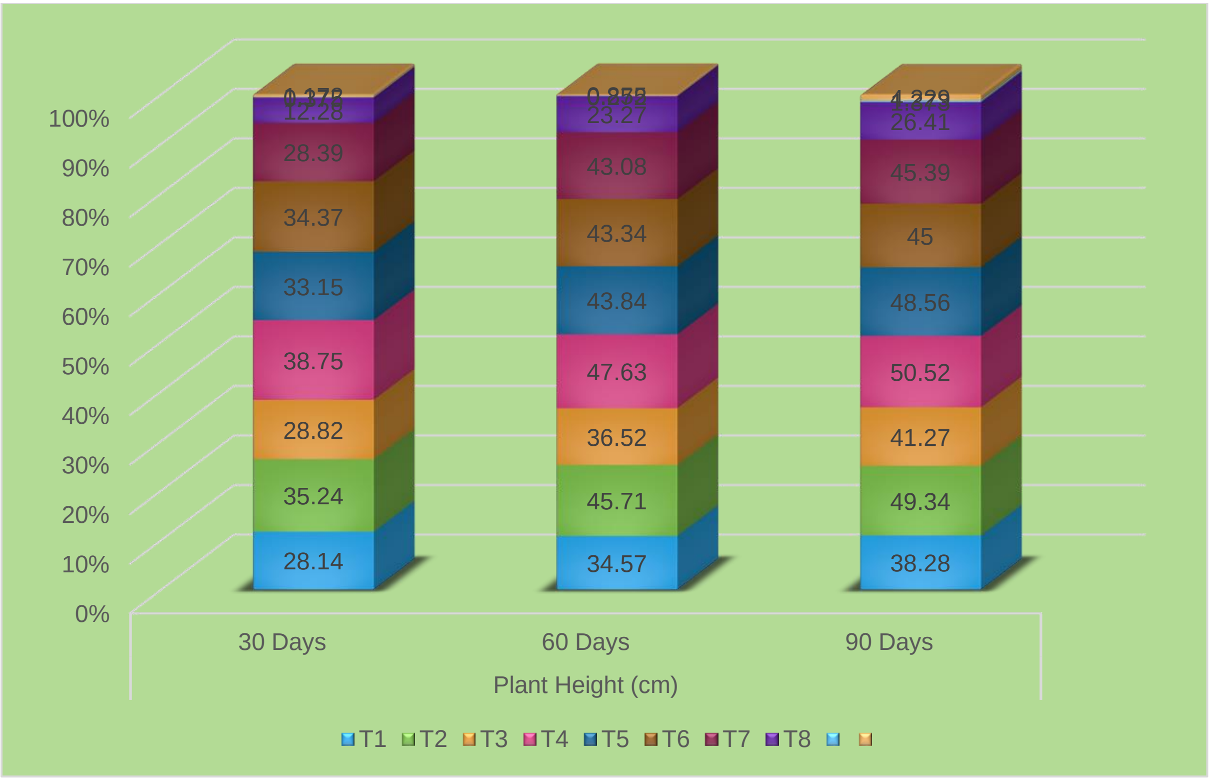

Fig. 1. Mean data of plant height (cm)

Compound leaves

In contrast to the other treatments, Treatment T4 (75% RDF of NPK + FYM @ 30 t/ha + PSB @ 10 kg/ha) produced the most compound leaves (40.73, 45.35, and 48.38) at 30, 60, and 90 days post-planting. The number of compound leaves was lowest in treatment T8 (control) at the same time points, with 29, 14, 34, and 37.49. T4, which consisted of 75% RDF of NPK, FYM at 30 t/ha, and PSB at 10 kg/ha, produced the tallest plants and the most complex leaves. Raghav et al. (2008) attributed this phenomenon to the enhanced nitrogen utilization of the plant resulting from the bio-fertilizers, organic manures, and synthetic fertilizers when mixed together. As demonstrated in Table 2, microorganisms present in bio-fertilizers such as PSB enhance plant growth through the rhizosphere of the soil, where they deliver vital nutrients to crops.

Table 2: Effect of INM on the No. of Compound leaves per plant of potato.

Symbol	Treatments	No. of Compound Leaves		
		30 Days	60 Days	90 Days
T_1	100% RDF of NPK	36.74	42.64	45.53
T_2	100% RDF of NPK + FYM @ 30 t/ha	39.57	44.82	47.94
T_3	100% RDF of NPK + vermicompost @ 10 t/ha	37.41	43.81	46.72
T_4	75% RDF of NPK + FYM @ 30 t/ha + PSB @ 10 kg/ha	40.73	45.35	48.38
T_5	75% RDF of NPK + FYM @ 30 t/ha + VAM @ 10 kg/ha	39.23	45.64	47.62
T_6	50% RDF of NPK + vermicompost @ 10 t/ha + PSB @ 10 kg/ha	38.41	43.61	46.69

T_7	**50% RDF of NPK + vermicompost@ 10 t/ha + VAM @ 10 kg/ha**	39.04	44.82	47.83
T_8	**Control**	29.14	34.75	37.49
	S. E m±	0.13	0.148	0.111
	CD @5%	0.421	0.476	0.361

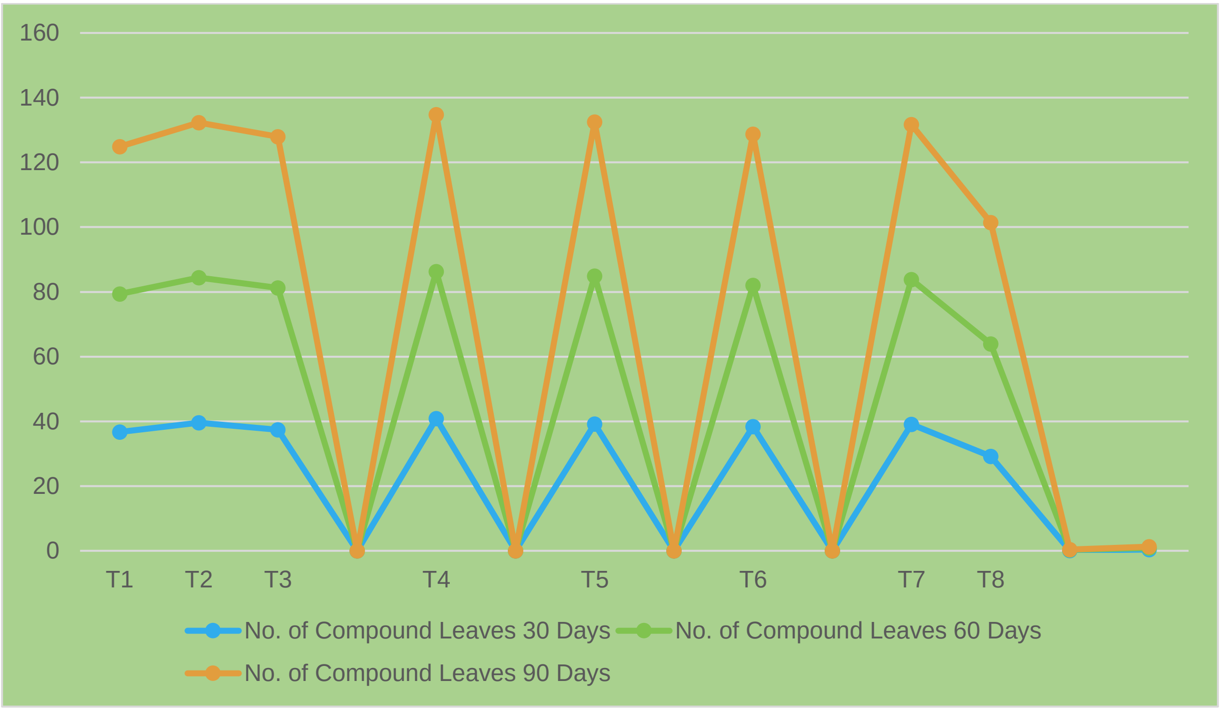

Fig. 2. Mean data of No. of Compound Leaves/Plant

Leaf Area Index (LAI)

A large amount of variance in leaf area index was seen between the treatments at the time of harvest (Fig. 3). The implementation of 75% RDF of NPK + FYM @ 30 t/ha + PSB @ 10 kg/ha (T4) led in a leaf area index of 4.25, which was greater than that of Control (T8). These results were seen due to the fact that the leaf area index was greater than that of the control. The leaf area index is a component that plays a significant role in determining the efficiency of photosynthetic activity. It also has a positive influence on the growth and production of crops. Chopra et al. (2006) discovered that an increase in the quantities of nitrogen led to a corresponding rise in the leaf area index (0, 125, 187). This research was published in the journal Plant Physiology.

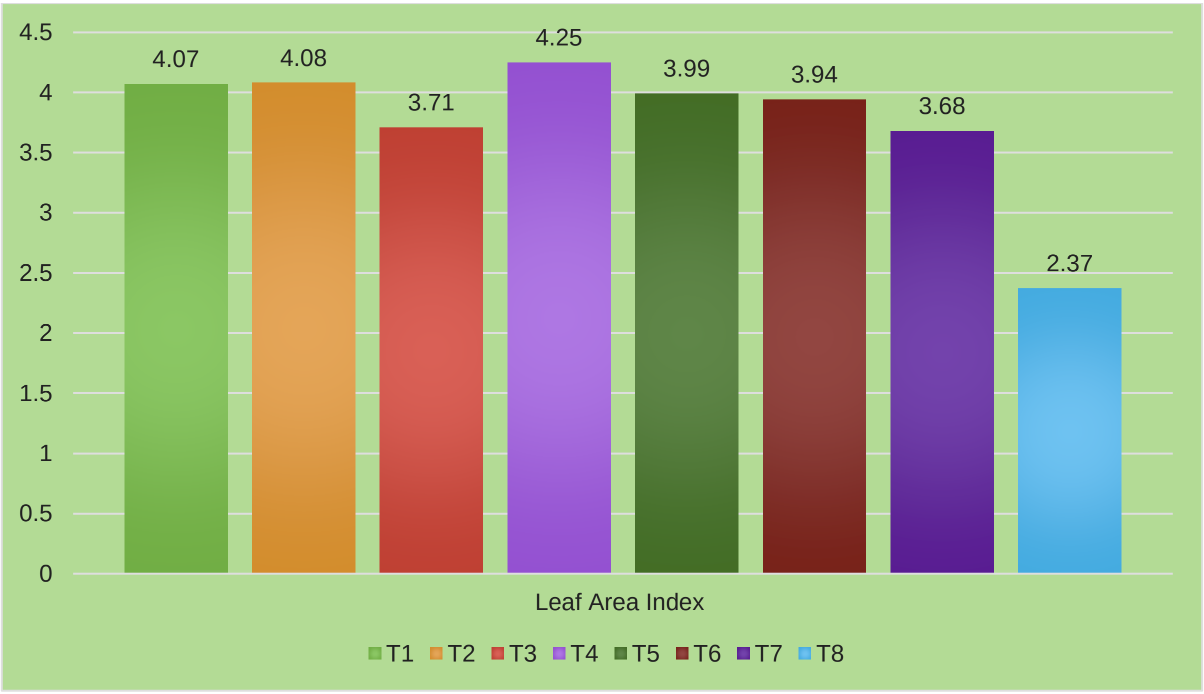

Fig. 4. Effect of INM on LAI of Potato at harvest

Yield

The treatment T4 (75% RDF of NPK + FYM @ 30 t/ha + PSB @ 10 kg/ha) produced the greatest overall yield (26.9 t/ha), whereas the treatment T8 (control) produced the minimum results (6.49 t/ha) (Table 3). Furthermore, it was observed that augmenting the tuber bulking rate with FYM in conjunction with the appropriate quantity of NPK ultimately resulted in a rise in potato yield per hectare. Moreover, the rise in crop productivity per hectare can be ascribed to the increased availability of nutrients, specifically phosphorus and nitrogen, facilitated by bio-fertilizers. This is due to the enhanced biological nitrogen fixation, phosphorus solubilization, establishment of a more robust root system, and secretion of plant hormones.

Table 3: Effect of INM on the yield of potato.

Symbol	Treatments	Yield (t/ha)
T_1	100% RDF of NPK	23.01
T_2	100% RDF of NPK + FYM @ 30 t/ha	23.36
T_3	100% RDF of NPK + vermicompost @ 10 t/ha	19.25
T_4	75% RDF of NPK + FYM @ 30 t/ha + PSB @ 10 kg/ha	26.9
T_5	75% RDF of NPK + FYM @ 30 t/ha + VAM @ 10 kg/ha	22.96
T_6	50% RDF of NPK + vermicompost @ 10 t/ha + PSB @ 10 kg/ha	21.44
T_7	50% RDF of NPK + vermicompost@ 10 t/ha + VAM @ 10 kg/ha	17.92
T_8	Control	6.49
	S. E m±	2.128
	CD @5%	6.44

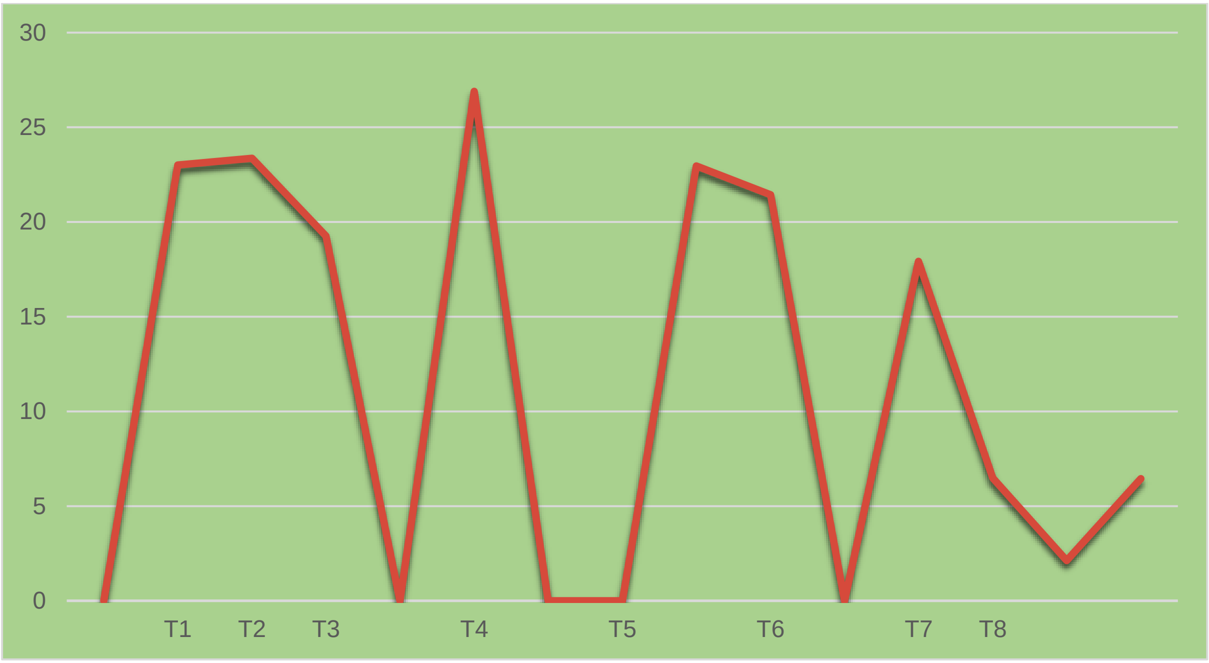

Fig. 4. Mean data of Yield of Potato

Tuber shape, size and depth of eyes

The morphology of the tubers was checked during each treatment on the basis of the findings of the eye examination. The development of oval, round, and oblong shapes was seen. All tuber sizes were recorded when the weights and readings were acquired. The readings were reported using the size categories of large, medium, and tiny. Table 4 demonstrates that the depth of the tuber eyes in each treatment was classified as shallow, fleet (medium deep), or deep based on eyesight testing throughout the storage period.

Table 4: Effect of INM on tuber characteristics of potato

Symbol	Treatments	Tuber shape	Tuber size	Depth of eyes
T_1	**100% RDF of NPK**	Round	Medium	Moderate
T_2	**100% RDF of NPK + FYM @ 30 t/ha**	Round	Big	Moderate
T_3		Round	Medium	Moderate

	100% RDF of NPK + vermicompost @ 10 t/ha			
T_4	**75% RDF of NPK + FYM @ 30 t/ha + PSB @ 10 kg/ha**	Round	Big	Moderate
T_5	**75% RDF of NPK + FYM @ 30 t/ha + VAM @ 10 kg/ha**	Round	Big	Moderate
T_6	**50% RDF of NPK + vermicompost @ 10 t/ha + PSB @ 10 kg/ha**	Round	Medium	Moderate
T_7	**50% RDF of NPK + vermicompost@ 10 t/ha + VAM @ 10 kg/ha**	Round	Medium	Moderate
T_8	**Control**	Round	Small	Moderate

Conclusion

Consequently, it can be concluded that the use of integrated nutrients, which included 75% RDF of NPK, FYM at 30 t/ha, and PSB at 10 kg/ha, was beneficial for the growth and yield of potatoes. Out of all the integrated nutrition management approaches tested. The implementation of 75% RDF of NPK, 30 t/ha of FYM, and 10 kg/ha of PSB produced the greatest tuber features of potatoes and the highest Leaf Area Index recorded at harvest. Fertilizing the potato crop cv. Kufri Chipsona-1 with 75% RDF of NPK, 30 t/ha FYM, & 10 kg/ha of PSB would enhance output and growth significantly. The findings of the trial formed the basis for this suggestion.

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Authors Contributions

The research was planned and formulated by Priyanka Bankoti, Mansi Nauityal, and Diksha Nautiyal, who also offered a study title and carried out the study. Vaishnavi Sharma, Raja Joshi, Ankit Pant, and Shani Raj supervised the collection of soil samples and the collecting of data on numerous parameters. All writers helped review the paper, write the entire work, and give their final approval on the content.

Conflict of Interest

All other authors state that they have no conflicts of interest in this study.

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