

Original Research Article

EFFECT OF BIO-ADDITIVES AND INTEGRATED NUTRIENT MANAGEMENT ON RESIDUAL SOIL HEALTH AND YIELD IN ONION (*Allium cepa* L.)

ABSTRACT

Over a period of two Rabi seasons in 2021 and 2022, a field experiment was conducted by embracing different organic manures, inorganic fertilizers and bio-additives (*Pseudomonas fluorescens* and *Bacillus subtilis*) over growth, yield, quality and persisting soil fertility of onion in the mineralized soils of Himachal Pradesh. The study was organized in thirteen treatments with amalgamation of organic manure, bio-additives and inorganic fertilizers. The analysis unveils that lowest soil pH (6.94), electrical conductivity (0.186 dSm^{-1}), highest soil organic carbon (0.85 %), available nitrogen (257.79 kg/ha) and available phosphorus (26.14 kg/ha) were recorded with treatment T₇ [75 % RDF + 40 kg S/ha + *Bacillus subtilis* + FYM (250 q/ha)]. The highest available potassium was recorded in treatment T₁₂ [100 % RDF (125:75:60 kg/ha)] and highest available sulphur was recorded in treatment in T₁₁ [100 % RDF + 40 kg S/ha]. The maximum gross income (₹ 5,46,260 /ha), net income (₹ 3,86,350.73 /ha) and benefit: cost ratio (2.41) was obtained in treatment T₇ [75 % RDF + 40 kg S/ha + *Bacillus subtilis* + FYM (250 q/ha)]. Therefore, it is apparent that consolidation of organic manure and inorganic fertilizer along with *Bacillus subtilis* provides more balance nutrition for plants which ameliorated the vegetative phenomenon, inflated soil nutrient status and nurtured sustaining crop prolificacy, leading to 50-70 % dwindling of fertilizer usage.

KEYWORDS: Bio-additives; onion; soil nutrient status; sulphur; crop prolificacy.

1. INTRODUCTION

Onion is one of the most important commercial vegetable crops cultivated extensively in India and belongs to family Alliaceae (Sultana et al. 2007). The crop is native of Asia (Jones and Mann 1963). Onion is an indispensable item in every kitchen as condiment, therefore onion is popularly known as ‘queen of kitchen’ (Selviraj 1976). Pungency in onion is due to the presence of a volatile oil ‘allyl propyl disulphide’— an organic compound rich in sulphur (Sharma et al. 2022) Onion has a paramount effect in preventing heart diseases, diabetes (Saini 1997; Vohra et al. 1994) and also contains several anti cancerous agents which have

shown to prevent cancer (Belay et al. 2015). The beneficial compound called 'quercetin' present in onion is a powerful antioxidant (Črnivec et al. 2021). Onion is used by processing industries to greater extent for preparing dehydrated products like powder and flakes (Ramkumar and Karuppusamy 2021). India occupies second position after China in production, cultivating onion over an area of 1431 thousand ha with annual production of 26148 thousand metric tonnes and in Himachal Pradesh, onion is cultivated over an area of 3411.08 ha with annual production of 74827 metric tonnes (Anonymous 2020).

In recent years, it has been realized that judicious application of nutrients has expanded many folds with the adoption improved technology for obtaining higher yield and better quality of onion (Shedeed et al. 2014). In modern agriculture, fertilizers constitute major portion of cost of production of onion. Inorganic fertilizers application will cause deleterious effect on soil health leading to soil acidity or alkalinity (Ramesh et al. 2017). Moreover, chemical fertilizers are very expensive and sometimes unavailable to small scale farmers and therefore sole application of inorganic fertilizers deteriorates soil fertility level day by day, that affect the production, economics of production and human health (Aisha et al. 2007; Hernandez et al. 2010). This anxiety has now led farmers to devise ways and means to switch over from conventional to organic farming systems which used no synthetic fertilizer and pesticide in crop production (Colla et al. 2002). Use of chemical fertilizers supplemented with organic manures and biofertilizers will be environmentally benign (Gupta et al. 1999), indirectly it improves the physical properties of soil such as aggregation, aeration, permeability and water holding capacity (Chandramohan 2002; Yafan and Barker 2004).

Improved management of nitrogen, phosphorus, potassium, sulphur and other inputs in the soil could improve the yield and quality of onion. Availability of nitrogen is salient for growing plants as it remains the major constituent of protein and nucleic acid molecules. Application of nitrogen with different doses increases the growth and yield of onion (Patel et al. 1992). Phosphorous is desired for the transfer of energy within the plant system and is involved in several metabolic activities (Rengel and Zhang 2011). It has its favourable outcomes on early root development, plant growth, yield and quality (Williamson et al. 2001). Potassium plays prime role in plant metabolism (Ali et al. 2021) and it improves color, glossiness and dry matter accumulation besides improving keeping quality of onion (Dorias et al. 2001). Sulphur is an essential macronutrient and at an optimum concentration accelerates the plant growth (Thomas et al. 2000; Anwar et al. 2001). It also influences the taste and

pungency in the crop (Tripathy et al. 2013). Therefore, integrated nutrient management is available strategy for advocating judicious and efficient use of chemical fertilizers with matching addition of organic manures for sustainable onion cultivation.

Organic manures like FYM and Vermicompost activate many species of living organism which release phytohormones and may stimulate the plant growth and absorption of nutrients. The increase in microbial population in the presence of organic manures may also be attributed to greater availability of organic carbon and mineralized nutrients for their proliferation and further cellular development (Marathe et al. 2012). Apart from improving physical and biological properties of soil organic manures help in improving the use and efficiency of chemical fertilizers (Gedam et al. 2008). Combined use of FYM and inorganic fertilizers is of special significance under intensive cropping system as these are complementary and supplementary to each other in sustaining crop yields and soil productivity (Abid et al. 2020). FYM improves the soil physical, chemical and biological properties along-with the provision of macro and micro nutrients (Augusti 1996). Use of organic manures in combination with chemical fertilizers in an appropriate proportion improves the overall soil health for sustainable onion production (Gupta et al. 1999).

Importance of nutrients supply in integrated manner in sustaining productivity is emphasized to restore and sustain soil health and productivity in the long run which otherwise is likely to deteriorate due to continuous and intensive cultivation without adequate nutrients management. Therefore, biofertilizers are widely accepted as low cost supplements to chemical fertilizers with no deleterious effect on either soil health or environment (Bhagyaraj and Suvarna 1999). Bio-fertilizer has recently gained with momentum for affecting the sustainable increase in crop yield under various agro-climatic conditions. Biofertilizers are live carrier based microbial preparations used in agriculture as low input resources to enhance the availability of plant nutrients or promote the growth by way of synthesizing growth factors and also improve building hormones along with anti-metabolite properties (Singh et al. 2021). Role of bio-fertilizer on the crop growth and yield was documented by Vijayakumar et al. 2000 and Ramakrishnan and Thamizhiniyan 2004. A small dose of biofertilizer is sufficient to produce desirable results because each gram of carrier of biofertilizers contains at least 10 million viable cells of a specific strain (Anandaraj and Delapierre 2010). These may be helpful for increasing the crop production by enhancing the soil fertility, therefore use of

biofertilizers not only supplement the nutrient but also improve the efficiency of applied nutrients (Bayu T 2020).

Various bio-additives enhance emergence of seed, plant growth and improve crop production by residing in the rhizosphere of plants and enhancing growth by direct and indirect mechanisms such as nitrogen fixation, solubilization of nutrients (phosphorous, potassium), siderophores production and water & minerals uptake (Bhattacharya and Jha 2012; Pérez-Montaña et al. 2014). These bio-additives affect plant growth by producing growth substances such as IAA, GA and Cytokinins (Verma et al. 2010; Garcia de Salamone et al. 2001), fix nitrogen from the atmosphere and provide the plants with this element (Boddey and Dobreiner 1995) and are antagonistic towards phytopathogenic micro-organisms (Velivelli et al. 2012). Alternatively, these bio-additives supplement the role of chemical fertilizers, pesticides and other inputs by decreasing the inhibitory effects of various pathogens on plant growth and development (Lugtenberg and Kamilova 2009).

Integrated nutrient management is a viable strategy for advocating judicious and efficient use of organic manures and plant growth promoting rhizobacteria in conjunction with chemical fertilizers has been found to be promising not only in sustaining high productivity but also for good growth, improving soil fertility on long term basis and reducing fertilizer input cost. Taking into consideration, current investigation was designed and implemented to appraise the effect of bio-additives (*Bacillus subtilis* and *Pseudomonas fluorescens*) and organic manures on growth, yield, quality and persisting soil fertility of onion in the mineralized soils of Himachal Pradesh.

2. MATERIALS AND METHODS

2.1 Experimental Site

During the *Rabi* season of 2020-21 and 2021-22, the field experiment on onion was carried out at the College of Horticulture & Forestry's research farm Hamirpur (Himachal Pradesh), located at a latitude of 31° 41'47.6" N and a longitude of 76° 28'06.3" E, and an elevation of 650 meters above sea level. The climate of the region is classified as subtropical, with average low to high temperatures of 20.1°C to 35.9°C and an average annual rainfall of 1225 mm. Maximum rainfall is recorded during monsoon, from June to September. The soil structure at the research location is classified as sandy clay loam. Prior to initiating the experiment, soil samples were collected from different spots of the experimental site from a depth of 0-15 cm and composite sample was prepared. After analysis, soil pH was neutral (7.04) having normal

electrical conductivity of 0.211 dSm^{-1} and organic carbon content was medium (0.70 %). The nutrient status of soil was low in available Nitrogen (197.56 kg/ha), however medium in available Phosphorous (15.73 kg/ha), available Potassium (156.78 kg/ha) and Sulphur (30.60 kg/ha).

2.2 Experimental Design and Crop management

The experiment was laid out in Randomized Complete Block Design with three replications and thirteen treatments viz., [Control], [*Bacillus subtilis* + FYM (250 q/ha)], [*Pseudomonas fluorescens* + FYM (250 q/ha)], [75 % Recommended dose of NPK+ *Bacillus subtilis* + FYM (250 q/ha)], [75 % Recommended dose of NPK + *Pseudomonas fluorescens* + FYM (250 q/ha)], [50 % Recommended dose of NPK + *Bacillus subtilis* + FYM (250 q/ha)], [50 % Recommended dose of NPK + *Pseudomonas fluorescens* + FYM (250 q/ha)], [75 % Recommended dose of NPK + 40 kg S/ha + *Bacillus subtilis* + FYM (250 q/ha)], [75 % Recommended dose of NPK + 40 kg S/ha + *Pseudomonas fluorescens* + FYM (250 q/ha)], [50 % Recommended dose of NPK + 40 kg S/ha + *Bacillus subtilis* + FYM (250 q/ha)], [50 % Recommended dose of NPK + 40 kg S/ha + *Pseudomonas fluorescens* + FYM (250 q/ha)], [100 % Recommended Dose of NPK + 40 kg S/ha] and [100 % Recommended Dose of NPK (125:75:60 kg/ha)] in a plot size of 1 m x 0.75 m spacing of 15 x 10 cm accommodating 50 plants per plot. Agrifound Dark Red variety developed by National Horticulture Research and Development Foundation, Nasik, Maharashtra of onion was employed for the study. The experimental field was thoroughly ploughed with the help of tractor followed by planking. Deep ploughing was done to bring the soil to a fine tilth and all the clods of the soil were thoroughly broken. All the stubble and weeds were removed. Plots were prepared according to the layout plan. The organic manure such as farmyard manure and recommended dose of fertilizers were applied at the time of field preparation as per the treatments in the respective plots. First irrigation was done immediately after sowing and daily irrigation is done till the plants are fully established thereafter, irrigation is done twice a week and then once in 6-7 days to retain optimum soil moisture, depending upon weather conditions. Weeding was done manually on a regular basis to keep the plot free from weeds and to keep the soil loose and airy. Two shallow weeding were done at 20 and 40 DAT to keep the field free from weeds. Harvesting was done at 60-70 % neck fall, while the leaves were still green.

➤ Application of inorganic fertilizers, organic manures and bio-additives

Calculated amount of inorganic fertilizers nitrogen, phosphorous, potassium and sulphur (125:75:60:40 kg/ha) were applied in the form of urea (203.8 kg/ha), SSP (356.25 kg/ha), MOP (75 kg/ha) and Sulphur (40 kg/ha) in respective treatments before transplanting of seedlings. One third dose of N along with the full doses of P, K and S were applied as basal dose. Remaining dose of N was given in two splits; after 30 and 60 DAT. Organic manures such as FYM (250 q/ha) were applied during field preparation in the respective treatments. Seedling roots were dipped in bio-additives viz., *Bacillus subtilis* and *Pseudomonas fluorescens* prior to sowing for 30 minutes as per the treatments and immediately transplanted in the field.

2.3 Soil Sampling and Analysis

After completion of two-year experiment, soil samples were collected from 15 cm depth of the treatment plots. These samples were air-dried, crushed and sieved through a 2 mm mesh and stored in cloth bags for subsequent chemical analysis of parameters such as soil pH, electrical conductivity (EC), organic carbon content, and available nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) content. The pH and EC of soil samples were measured using a digital pH meter and an electrical conductivity meter, respectively. Organic carbon content of the samples was determined using the Chromic and Titration method proposed by Walkley and Black (1934). Alkaline Potassium Permanganate Method was used to determine available N (Subbiah and Asija 1956), P was measured by the method inclined by Olsen (Olsen *et al.* 1954), Available K was measured by Normal Neutral Ammonium Acetate Method (Merwin and Peech 1951) and Sulphur was determined by 0.15 % CaCl₂ Extractant and Turbidimetric Method (Chesnin and Yien 1950). The mean values of data were subjected to analysis of variance as described by Gomez and Gomez (1984) for Randomized Complete Block Design.

2.4 Statistical Analysis

The merging of data was subject to statistical analysis of variance as delineated by Gomez and Gomez (1984). The main aim of the analysis was to regulate the impact of treatments on different plant and soil parameters. Further, considering the costs associated with various treatments and the market rate of the crop an economic estimation was performed. The benefit-cost ratio (B/C ratio) was calculated by dividing the value of marketable produce by the total cost of cultivation.

3 RESULTS AND DISCUSSION

3.1 Soil pH

Application of organic manure, inorganic fertilizer and plant growth promoting rhizobacteria improved the soil pH as compared to initial status. Perusal of data presented in Table 1, revealed that minimum pH (6.94) was recorded by the treatment T₇ (75 % Recommended dose of NPK + 40 kg S/ha + *Bacillus subtilis* + FYM (250 q/ha)). The soil pH decreased moderately due to inoculation with plant growth promoting rhizobacteria like *Bacillus* and *Pseudomonas* significantly enhanced the population of soil microorganisms in the rhizosphere which increased their dehydrogenase activity and then dehydrogenase released hydrogen ions in the rhizosphere resulting in the formation of carbonic acid that decreases the pH value as reported by Khadiga et al. (2015). Decrease in pH values might be ascribed to H⁺ ion released during sulphur oxidation. When elemental sulphur is applied to soil, a biological reaction takes place carried out by sulphur oxidizing bacteria, producing sulfuric acid that reduces soil pH as stated by Nemat et al. (2011).

3.2 Electrical conductivity (dSm⁻¹)

Electrical conductivity is important trait as it indicates the availability of nutrients and provides information related to the concentration of soluble salts present in the soil. The data revealed that maximum electrical conductivity (0.202 dSm⁻¹) was observed in treatment T₀ (Control) while, the minimum electrical conductivity (0.186 dSm⁻¹) was recorded in treatment T₇ (75 % Recommended dose of NPK + 40 kg S/ha + *Bacillus subtilis* + FYM) after harvesting the crop (Table 1). This may be due to plant uptake of soluble salts through root systems by plants or leaching of cations and at the same time chloride accumulation in the surface due to capillary action can be accountable for the decrease in electrical conductivity as mentioned by Prasad (2021).

3.3 Organic carbon (%)

Organic carbon induces changes in microbial activities that affect the transformation and availability of nutrients, organic matter and overall soil health. Data revealed that highest organic carbon (0.85 %) was observed in treatment T₇ (75 % Recommended dose of NPK + 40 kg S/ha + *Bacillus subtilis* + FYM) whereas, minimum organic carbon was obtained in treatment T₀ (Control) after harvesting the crop (Table 1). This might be due to inoculation by

Bacillus subtilis and *Pseudomonas fluorescens* as plant growth promoting rhizobacteria strains which are required for maximizing the plant yield and improved soil quality by increasing the organic carbon as reported by Hosam et al. (2013). Similar findings are reported by Prasad (2022).

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Table 1. Effect of integrated nutrient management on pH, EC (dSm⁻¹) and organic carbon (%) in soil

Treatment Code	Treatment Details	Soil pH	EC (dSm ⁻¹)	Organic carbon (%)
T ₀	Control	7.07	0.202	0.61
T ₁	<i>Bacillus subtilis</i> + FYM (250 q/ha)	7.01	0.197	0.73
T ₂	<i>Pseudomonas fluorescens</i> + FYM (250 q/ha)	7.03	0.198	0.75
T ₃	75 % Recommended dose of NPK + <i>Bacillus subtilis</i> + FYM (250 q/ha)	7.00	0.194	0.77
T ₄	75 % Recommended dose of NPK + <i>Pseudomonas fluorescens</i> + FYM (250 q/ha)	7.02	0.195	0.74
T ₅	50 % Recommended dose of NPK + <i>Bacillus subtilis</i> + FYM (250 q/ha)	7.03	0.194	0.76
T ₆	50 % Recommended dose of NPK + <i>Pseudomonas fluorescens</i> + FYM (250 q/ha)	7.02	0.196	0.78
T ₇	75 % Recommended dose of NPK + 40 kg S/ha + <i>Bacillus subtilis</i> + FYM (250 q/ha)	6.94	0.186	0.85
T ₈	75 % Recommended dose of NPK + 40 kg S/ha + <i>Pseudomonas fluorescens</i> + FYM (250 q/ha)	6.96	0.189	0.83
T ₉	50 % Recommended dose of NPK + 40 kg S/ha + <i>Bacillus subtilis</i> + FYM (250 q/ha)	6.98	0.192	0.80
T ₁₀	50 % Recommended dose of NPK + 40 kg S/ha + <i>Pseudomonas fluorescens</i> + FYM (250 q/ha)	6.99	0.193	0.79
T ₁₁	100 % Recommended Dose of NPK + 40 kg S/ha	7.04	0.198	0.70
T ₁₂	100 % Recommended Dose of NPK (125:75:60 kg/ha)	7.05	0.199	0.71
	Mean	7.00	0.194	0.75
	CD_(0.05)	0.01	0.002	0.01
	SE(m)	0.00	0.00	0.00
	C.V	0.16	0.51	1.33

3.4 Available Nitrogen (kg/ha)

The data for available nitrogen is presented in Table 2. Maximum available nitrogen (257.79 kg/ha) was recorded in treatment T₇ (75 % Recommended dose of NPK + 40 kg S/ha + *Bacillus subtilis* + FYM) and minimum available nitrogen (188.86 kg/ha) was observed in treatment T₀ (Control) after harvesting the crop. Breakdown of complex nitrogenous compounds to nitrate due to action of micro-organisms might have increased nitrogen and enhanced nitrogen uptake in plants as reported by Ramesh et al. (2017). Moreover, free-living nitrogen fixing PGPR like *Bacillus* attaches to the root and efficiently colonizes root surfaces as stated by Ahmed et al. (2017). Whereas, Saharan and Nehra (2011) reported that it might be due to the use of mixture of plant growth promoting rhizobacteria including *Bacillus spp.* which fix the atmospheric nitrogen and excretes growth promoters that increase nitrogen content in soil.

3.5 Available Phosphorus (kg/ha)

An examination of data regarding available phosphorus presented in Table 2 and depicted that maximum available phosphorus (26.14 kg/ha) in soil after harvesting of crop was recorded in treatment T₇ (75 % Recommended dose of NPK + 40 kg S/ha + *Bacillus subtilis* + FYM) while, minimum available phosphorus (14.87 kg/ha) was recorded in treatment T₀ (Control). Increase in available phosphorus over initial value might be ascribed to the role of *Bacillus* which solubilizes the insoluble phosphorus compounds and increases the plant growth as reported by Bektas and Kusek (2021). Increase in phosphorous could also be due to greater solubilization of native phosphorous from the soil due to action of various organic acids liberated due to decomposition of organics as stated by Ramesh et al. (2017). Whereas, Hosam et al. (2013) mentioned that inoculation with isolates of *Pseudomonas* had a stimulatory effect on plant growth and produces indolic compounds and siderophores, to solubilize phosphate. Plant growth promoting rhizobacteria enhance phosphorous uptake by releasing organic acids such as fumeric acid, butyric acid, citric acid etc. which improves microbial activity and increases phosphorous availability as reported by Shahzad et al. (2020); Kapoor (1995).

3.6 Available Potassium (kg/ha)

Maximum available potassium (174.59 kg/ha) in soil after harvesting was recorded in treatment T₁₂ (100 % Recommended dose of NPK + FYM) whereas, minimum available

potassium (142.13 kg/ha) was recorded in treatment T₀ (Control) after harvesting the crop (Table 2). Overall mean for available potassium was 157.76 kg/ha. Increase in available potassium could be ascribed to the improved soil properties due to the action of organics, leading to better penetration of roots, thereby resulting to greater uptake of potassium as reported by Ramesh et al. (2017). Similar results on conjunctive application of both organic and inorganic fertilizers were documented by Ramesh et al. (2011). Greater availability of nutrients from inorganic sources might have increased available potassium in soil. Similar results are in conformity with Nainwal et al. (2015) and Behairy et al. (2015).

3.7 Available Sulphur (kg/ha)

Data pertaining to available sulphur (Table 2) depicted that maximum available sulphur (53.45 kg/ha) was recorded in treatment T₁₁ (100 % Recommended dose of NPK + 40 kg S/ha + FYM) however, minimum available sulphur (29.31 kg/ha) was recorded in treatment T₀ (Control) in soil after harvesting of crop. Overall mean value was 42.66 kg/ha. Sulphur application enhances the population of sulphur consuming microorganisms leading to oxidation of S to SO₄²⁻ producing sulfuric acid that reduces the soil pH and increase the concentration of available sulphur in soil. The results are in line with the findings of Nemat et al. (2011), Jaggi (2005) and Sankaran et al. (2005).

3.8 Economics of Onion Cultivation

Data for economics of onion cultivation is presented in Table 3. Maximum gross income (₹ 5,46,260 /ha) was recorded by treatment T₇ (75 % Recommended dose of NPK + 40 kg S/ha + *Bacillus subtilis* + FYM) whereas, minimum gross income (₹ 2,90,120 /ha) was obtained with treatment T₀ (Control). Highest net income (₹ 3,86,350.73 /ha) was obtained with treatment T₇ (75 % Recommended dose of NPK + 40 kg S/ha + *Bacillus subtilis* + FYM) however, minimum net income (₹ 1,82,900 /ha) was observed by treatment T₂ (*Pseudomonas fluorescens* + FYM). Maximum B: C ratio (2.41) was observed by treatment T₇ (75 % Recommended dose of NPK + 40 kg S/ha + *Bacillus subtilis* + FYM) while, lowest B: C ratio (1.21) was recorded by treatment T₂ (*Pseudomonas fluorescens* + FYM).

Table 2. Effect of integrated nutrient management on available N (kg/ha), P (kg/ha), K (kg/ha) and S (kg/ha) in soil

Treatment Code	Treatment Details	Available N in soil (kg/ha)	Available P in soil (kg/ha)	Available K in soil(kg/ha)	Available S in soil (kg/ha)
T ₀	Control	188.86	14.87	142.13	29.31
T ₁	<i>Bacillus subtilis</i> + FYM (250 q/ha)	215.46	17.57	148.01	36.62
T ₂	<i>Pseudomonas fluorescens</i> + FYM (250 q/ha)	212.53	16.41	145.77	35.68
T ₃	75 % Recommended dose of NPK+ <i>Bacillus subtilis</i> + FYM (250 q/ha)	240.52	19.50	156.12	42.76
T ₄	75 % Recommended dose of NPK + <i>Pseudomonas fluorescens</i> + FYM (250 q/ha)	237.27	18.17	154.18	41.36
T ₅	50 % Recommended dose of NPK + <i>Bacillus subtilis</i> + FYM (250 q/ha)	228.76	17.95	153.01	40.70
T ₆	50 % Recommended dose of NPK + <i>Pseudomonas fluorescens</i> + FYM (250 q/ha)	226.53	17.71	150.61	39.55
T ₇	75 % Recommended dose of NPK + 40 kg S/ha + <i>Bacillus subtilis</i> + FYM (250 q/ha)	257.79	26.14	167.89	48.72
T ₈	75 % Recommended dose of NPK + 40 kg S/ha + <i>Pseudomonas fluorescens</i> + FYM (250 q/ha)	254.54	24.70	165.74	46.59
T ₉	50 % Recommended dose of NPK + 40 kg S/ha + <i>Bacillus subtilis</i> + FYM (250 q/ha)	251.42	23.82	162.91	44.42
T ₁₀	50 % Recommended dose of NPK + 40 kg S/ha + <i>Pseudomonas fluorescens</i> + FYM (250 q/ha)	249.24	22.66	159.78	43.86
T ₁₁	100 % Recommended Dose of NPK + 40 kg S/ha	246.38	21.82	170.17	53.45
T ₁₂	100 % Recommended Dose of NPK (125:75:60 kg/ha)	242.52	20.53	174.59	41.64
	Mean	234.75	20.14	157.76	41.89
	CD_(0.05)	1.35	1.14	0.71	0.52
	SE(m)	0.46	0.39	0.24	0.17
	C.V	0.34	3.35	0.26	0.73

Table3. Effect of integrated nutrient management on economics of onion cultivation

Treatment Code	Treatment Details	Total Bulb Yield(q/ha)	Total cost of Cultivation (₹/ha)	Gross Income (₹/ha)	Net Income (₹/ha)	B: C Ratio
T ₀	Control	145.06	1,04,800	2,90,120	1,85,320	1.76
T ₁	<i>Bacillus subtilis</i> + FYM (250 q/ha)	168.86	1,50,200	3,37,720	1,87,520	1.24
T ₂	<i>Pseudomonas fluorescens</i> + FYM (250 q/ha)	166.60	1,50,300	3,33,200	1,82,900	1.21
T ₃	75 % Recommended dose of NPK+ <i>Bacillus subtilis</i> + FYM (250 q/ha)	226.66	1,58,909.27	4,53,320	2,94,410.73	1.85
T ₄	75 % Recommended dose of NPK + <i>Pseudomonas fluorescens</i> + FYM (250 q/ha)	224.40	1,59,009.27	4,48,800	2,89,790.73	1.82
T ₅	50 % Recommended dose of NPK + <i>Bacillus subtilis</i> + FYM (250 q/ha)	221.00	1,56,006.14	4,42,000	2,85,993.86	1.83
T ₆	50 % Recommended dose of NPK + <i>Pseudomonas fluorescens</i> + FYM (250 q/ha)	218.73	1,56,106.14	4,37,460	2,81,353.86	1.80
T ₇	75 % Recommended dose of NPK + 40 kg S/ha + <i>Bacillus subtilis</i> + FYM (250 q/ha)	273.13	1,59,909.27	5,46,260	3,86,350.73	2.41
T ₈	75 % Recommended dose of NPK + 40 kg S/ha + <i>Pseudomonas fluorescens</i> + FYM (250 q/ha)	265.20	1,60,009.27	5,30,400	3,70,390.73	2.31
T ₉	50 % Recommended dose of NPK + 40 kg S/ha + <i>Bacillus subtilis</i> + FYM (250 q/ha)	258.40	1,57,006.14	5,16,800	3,59,793.86	2.29
T ₁₀	50 % Recommended dose of NPK + 40 kg S/ha + <i>Pseudomonas fluorescens</i> + FYM (250 q/ha)	255.00	1,57,106.14	5,10,000	3,52,893.86	2.24
T ₁₁	100 % Recommended Dose of NPK + 40 kg S/ha	247.06	1,62,412.34	4,94,120	3,31,707.66	2.04
T ₁₂	100 % Recommended Dose of NPK (125:75:60 kg/ha)	243.66	1,62,312.34	4,87,320	3,25,007.66	2.00

CONCLUSION

Treatment T₇ was found superior for majority soil parameters. Highest gross income (₹ 5,46,260 /ha), net income (₹ 3,86,350.73 /ha) and B: C ratio (2.41) was observed by treatment T₇ (75 % Recommended dose of NPK + 40 kg S/ha + *Bacillus subtilis* + FYM). Hence, it can be concluded that combined application of organic manure and inorganic fertilizer along with *Bacillus subtilis* provides more balanced nutrition for plants which improve the vegetative phenomenon, nutrient uptake, residual soil fecundity and results in better production of onion by minimizing the usage of inorganic fertilizers by more than 50%.

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