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Impact of Various *Jeevamrut* Formulations and Biofertilizers on Growth and Yield of Potato (cv. Kufri Bahar)

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ABSTRACT

The beneficial microbes are boon for agriculture as they are source of plant growth regulators, acting as buffering agent in soil, playing the role of soil enhancer and are essential component of bio-geochemical cycle. This enables the ecofriendly approach of plant nutrient management. Among various natural formulations, *Jeevamrut* is traditional nutrient management approach which is rich in beneficial microbes. The present study was aimed at understanding the effect of various combinations of *Jeevamrut* formulations and biofertilizers (*Azotobacter*, VAM and PSB) on growth and yield of potato. Applications of *Jeevamrut* formulations containing vermitea or neem cake improved germination, plant height, number of stems per plant and yield of potato tubers. The co-inoculation of PSB with *Azotobacter* or VAM improved the growth and yield of potato. The significant germination of tubers, plant height, stem counts and tuber yield was improved due to interaction between these two factors (*Jeevamrut* formulations and biofertilizers) and highest value was noticed after combined application of *Jeevamrut* + vermitea and PSB along with *Azotobacter* (J_2B_3) which produced highest tuber yield (350.00 and 354.20 q/ha) followed by *Jeevamrut* + vermitea and PSB along with VAM (J_2B_4) (343.00 and 342.00 q/ha) during 2021-22 and 2022-23, respectively.

Key words: *Azotobacter*, biofertilizers, *Jeevamrut*, microbial inoculation, neem cake, vermitea

INTRODUCTION

Organic vegetable production has become necessity of the present scenario due to health consciousness of consumers. The use of excessive chemicals to ensure higher crop productivity in modern agricultural practices has led to health problems and environmental pollution including soil and consumer health, drinking and irrigation water contamination, air pollution etc. Organic production is the only option to eliminate the ill effects of these agrochemicals where all nutrients and crop production inputs are provided through biological sources. Though yield reduction in crops has been reported due to organic approach in agriculture but health and environmental risk has been reduced considerably. The major challenges reported by many authors are reduction in crop productivity which has led another area of research where standardization of organic inputs can be done to find out the best combinations of organic crop management including the inputs from biofertilizers and natural formulations.

There are many organic sources of nutrients which are applied to improve crop productivity and soil health, some of which are: farm yard manure, vermicompost or vermitea, green manuring, biofertilizers, biodynamic formulations, organic liquid formulations, plant extracts etc (Sharma *et al.*, 2018; Yadav *et al.*, 2020). Among various natural formulations, liquid organic formulations like *Jeevamrut*, *Beejamrut*, *Panchagavya*, Vermitea and *Amritpani* are traditional nutrient management approach which have bio-pesticidal and plant growth enhancer role as they are rich in beneficial microflora and are effective component of biodynamic farming (Somdutt *et al.*, 2021). These formulations help in building the soil fertility by enhancing the activities of soil microflora and fauna.

Jeevamrut is a fermented product of mixture of cow urine and dung with water enriched with pulses flour, soil and jaggery. It is used as traditional source of nutrients and biopesticides (Patel *et al.*, 2019). It is also an integral component of natural and biodynamic farming system. Jeevamrut is cost effective and eco-friendly approach and acts as buffering

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agent in soil and so maintains the soil pH (6.5 to 7.8), improves aeration and improves the count of beneficial soil microbes like Rhizobateria and *Bacillus* (Kulkarni and Gargelwar, 2019). It is rich source of nitrogen, phosphorus and potassium with significant level of micronutrients as well. Cow urine is one of the important ingredients which act as soil enhancer and plant growth promoter (Pradhan *et al.*, 2018; Bhattacharjee and Uppaluri, 2023). *Jeevamrut* is rich source of microbial biomass which promotes the biological and enzymatic activities of soil (Patel *et al.*, 2021a).

The biofertilizers like *Azotobacter*, Vesicular Arbuscular Mycorrhizae (VAM) and Phosphate Solubilizing Bacteria (PSB) are important constituents of organic crop management system to improve the availability and uptake of nutrients by the plants. *Azotobacter* utilizes atmospheric nitrogen for their cell protein synthesis which is then mineralized in soil after the death of *Azotobacter* cells thereby contributing towards the nitrogen availability of the plants. *Azotobacter* has beneficial effects on crop growth and yield through biosynthesis of biologically active substances, stimulation of rhizospheric microbes, producing phytopathogenic inhibitors. Vesicular arbuscular mycorrhizae (VAM) can improve plant acquisition of soil minerals by soil exploration and can better enable a plant to withstand environmental stresses. Phosphate solubilizing bacteria (PSB) are a group of beneficial bacteria capable of hydrolysing organic and inorganic phosphorus from insoluble compounds. Considering the significance of *Jeevamrut* and biofertilizers for plant growth and yield, the present investigation was carried out to standardize the various combinations of *Jeevamrut* formulations and biofertilizers (*Azotobacter*, VAM and PSB).

MATERIALS AND METHODS

The experiment was performed at the crop research centre of agriculture at ITM University, Gwalior, India located under humid and subtropical climatic condition in the gird region of north Madhya Pradesh. The experiment was carried out in two consecutive years 2021-22 and 2022-23. Kufri Bahar, a commercially grown variety of potato released by Central Potato Research Institute, Shimla was used for experimentation.

The treatments consisted of two factors: Factor-J (*Jeevamrut*) of three different formulations and control; Factor-B (Biofertilizers) of four combinations and control. The treatment details were: J_0: No *Jeevamrut* (control), J_1: *Jeevamrut*, J_2: *Jeevamrut* + Vermitea, J_3: *Jeevamrut* + Neem cake, B_0: No biofertilizers (control), B_1: Azotobacter, B_2: VAM (Vesicular Arbuscular Mycorrhiza), B_3: PSB (Phosphate Solubilizing Bacteria) + *Azotobacter*, B_4: PSB + VAM. The planting was done at the spacing of 10 cm between plants in the ridges at the spacing of 45 cm. The control plots (J_0B_0) received complete fertilizers through urea, DAP and MOP as per recommended dose (N:P:K as 180:80:120 kg/ha) by ICAR-CPRI, Gwalior, while rest of the plots received 50% of the mentioned dose.

The observations on various growth and yield parameters were carried out to understand the impact of application of various *Jeevamrut* formulations and biofertilizers. The emergence of the tuber sprouts was recorded after 30 days of planting. The height of the main stem from the ground level to the apical bud (leaf apex) was measured with the meter scale at 30, 60 and 75 days after planting. At 30, 60 and 75 days after planting, the number of haulms/m was recorded on the plants which were randomly selected and tagged. The average number of haulms/m was calculated by dividing total number of shoots by five. The weight of tubers from each plot was taken after harvesting and was expressed as kg/plot. The yield of tubers/ha was estimated by using the recorded yield in kg/plot as:

$$\text{Estimated yield of potato (q/ha)} = \frac{\text{Yield of potato (kg)}}{\text{450 (in sq.m)}} \times \frac{\text{10000 (sq. m./ha)}}{\text{100 (kg/q)}}$$

Where, 450 sq. m. (square meter) was the size of experimental plot and yield of potato was from one plot.

The data were statistically analyzed for factorial randomized block design by using two way ANOVA through data analysis tools of excel sheet. The analyzed data were presented as through tables (individual effect) and graphically (interaction effect) where mean value was presented as mean ± SD values of three replications. The correlation study and

the principal component analysis were carried out by using SPSS software to understand the correlation of total microbial count of soil under various treatments with the different variables.

RESULTS AND DISCUSSION

The germination of potato tubers was observed at 25 days after planting (Table 1) and it was found that germination per cent increased significantly after application of *Jeevamrut* fortified with vermitea (J_2) which was at par with J_3 (*Jeevamrut* fortified with neem cake). Among various biofertilizer combinations, all biofertilizers reflected positive response in comparison to control (B_0). However, B_3 (PSB + *Azotobacter*) was best followed by B_4 (PSB + VAM) and resulted in maximum germination of tuber during both the years of experiment. The significant interaction between *Jeevamrut* formulation and the biofertilizers was noticed with highest germination per cent (95.60 and 95.70) in J_2B_3 followed by J_2B_4 (95.30 and 95.20) during 2021-22 and 2022-23, respectively, in comparison to other combinations and control (J_0B_0) (Fig. 1). The possible reason behind the enhanced sprouting after application of *Jeevamrut* and biofertilizers might be the improvement in α-amylase activities and sugar content of tuber under the influence of plant growth promoting substances like gibberellin (Zhang *et al.*, 2022) released from *Azotobacter* and PSB. This could also be associated with

Table 1. Germination (%) of potato tubers as influenced by application of *Jeevamrut* and Biofertilizers

Factors	Year 1	Year 2
J_0 (control)	90.26 ± 0.86^b	90.10 ± 1.51^c
J_1	92.02 ± 0.93^b	92.72 ± 1.24^b
J_2	94.30 ± 1.50^a	94.52 ± 1.03^a
J_3	92.82 ± 0.94^{ab}	93.80 ± 1.10^{ab}
C. D. (P=0.05)	1.900	1.488
S. Em±	0.935	0.732
P value	1.46 x 10^{-07}**	1.55 x 10^{-11}**
B_0 (control)	90.93 ± 1.36^b	91.15 ± 2.14^b
B_1	92.03 ± 1.35^{ab}	92.68 ± 1.99^{ab}
B_2	92.18 ± 2.20^{ab}	92.18 ± 2.16^b
B_3	93.45 ± 1.84^a	94.15 ± 1.65^a
B_4	93.18 ± 1.79^a	93.78 ± 1.75^{ab}
C. D. (P=0.05)	1.661	1.663
S. Em±	1.045	0.819
P value	5.75 x 10^{-05}**	5.95 x 10^{-09}**

All values are mean ± SD of three replications. Different superscripts are significantly different. *P=0.05 and **P=0.01.

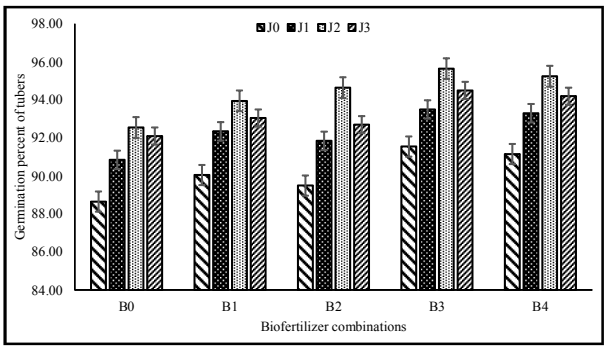

Fig. 1. Germination (%) of potato tubers as influenced by interaction of *Jeevamrut* and Biofertilizers.

higher carbon: nitrogen ratio (Lei *et al.*, 2019) in the tubers supplied with *Jeevamrut* and biofertilizers (*Azotobacter* and PSB) which were source of plant growth promoting substances. Similar findings were reported by Rohith *et al.* (2022) after application of *panchagavya*, neemcake and vermicompost in *Capsicum*.

The average plant height recorded at different stages of crop viz., 30, 45, 60 and 75 days after planting (Tables 2 and 3) showed that plant height increased progressively with the age of plant. At all stages of plant growth, the average plant height was highest after application of *Jeevamrut* fortified with vermitea (J_2) followed by J_3 (*Jeevamrut* fortified with neem cake). Further, application of PSB in combination with *Azotobacter* (B_3) resulted in highest plant height in potato followed by B_4 (PSB and VAM combination). However, at 75 days after planting these treatments were at par with each other for plant height in potato. The significant interaction between *Jeevamrut* formulation and the biofertilizers was noticed with highest plant height in J_2B_3 followed by J_2B_4 during 2021-22 and 2022-23 in comparison to other combinations and control (Fig. 2). *Jeevamrut* is a natural source of nutrients containing most of the essential plant nutrients (carbon, nitrogen, phosphorus, potassium and the micronutrients including zinc, copper, manganese, etc.) which are necessary for the plants to complete life cycle (Somdutt *et al.*, 2021). Patel *et al.* (2021a) reported significant effect of foliar spray of *Jeevamrut* and *Panchagavya* on plant height and dry matter content of pearl millet.

The average number of stems recorded at different stages of crop *viz.*, 30, 45, 60 and 75 days after planting (DAP) showed significant impact of both, *Jeevamrut* formulations and

Table 2. Average plant height of potato after application of *Jeevamrut* formulation and biofertilizers (30 and 45 days after planting)

Factors	30 DAP		45 DAP	
	Year 1	Year 2	Year 1	Year 2
J_0 (control)	17.54 ± 0.57^{d}	18.04 ± 1.02^{d}	30.06 ± 0.97^{d}	30.18 ± 1.63^{d}
J_1	19.16 ± 1.08^{c}	19.80 ± 0.95^{c}	32.00 ± 1.28^{c}	32.74 ± 1.27^{c}
J_2	20.74 ± 0.85^{a}	21.30 ± 0.88^{a}	34.00 ± 1.24^{a}	34.80 ± 1.23^{a}
J_3	20.12 ± 0.93^{b}	20.66 ± 0.94^{b}	33.10 ± 1.24^{b}	33.94 ± 1.31^{b}
C. D. (P=0.05)	0.407	0.402	0.448	0.627
S. Em±	0.200	0.198	0.220	0.308
P value	5.73 x 10^{-10}**	2.46 x 10^{-11}**	1.66 x 10^{-10}**	2.49 x 10^{-10}**
B_0 (control)	18.20 ± 1.17^{d}	18.65 ± 1.57^{e}	30.65 ± 1.58^{e}	30.97 ± 2.46^{d}
B_1	19.32 ± 1.40^{b}	19.83 ± 1.32^{c}	32.20 ± 1.61^{c}	32.85 ± 1.77^{b}
B_2	19.02 ± 1.47^{c}	19.58 ± 1.43^{d}	31.80 ± 1.65^{d}	32.42 ± 1.87^{c}
B_3	20.30 ± 1.50^{a}	20.98 ± 1.38^{a}	33.55 ± 1.84^{a}	34.33 ± 2.00^{a}
B_4	20.10 ± 1.49^{a}	20.73 ± 1.41^{b}	33.25 ± 1.87^{b}	34.00 ± 1.98^{a}
C. D. (P=0.05)	0.455	0.449	0.501	0.701
S. Em±	0.224	0.221	0.246	0.345
P value	2.74 x 10^{-07}**	5.06 x 10^{-09}**	2.08 x 10^{-08}**	4.45 x 10^{-08}**

All values are mean ± SD of three replications. Different superscripts are significantly different. *P=0.05 and **P=0.01.

Table 3. Average plant height of potato after application of *Jeevamrut* formulation and biofertilizers (60 and 75 days after planting)

Factors	Average plant height at 60 DAP		Average plant height at 75 DAP	
	Year 1	Year 2	Year 1	Year 2
J_0 (control)	43.56 ± 2.11^{d}	42.86 ± 1.97^{d}	46.36 ± 1.80^{d}	46.42 ± 1.53^{d}
J_1	47.12 ± 2.05^{c}	46.40 ± 2.13^{c}	49.44 ± 1.58^{c}	49.16 ± 1.46^{c}
J_2	50.28 ± 1.82^{a}	49.54 ± 1.89^{a}	51.90 ± 1.39^{a}	51.46 ± 1.36^{a}
J_3	48.92 ± 1.85^{b}	48.22 ± 2.15^{b}	50.96 ± 1.39^{b}	50.50 ± 1.43^{b}
C. D. (P=0.05)	0.714	0.884	0.852	0.723
S. Em±	0.301	0.435	0.419	0.342
P value	7.86 x 10^{-13}**	6.86 x 10^{-11}**	2.90 x 10^{-11}**	1.66 x 10^{-13}**
B_0 (control)	44.70 ± 3.24^{e}	43.90 ± 3.14^{e}	47.50 ± 2.92^{d}	47.37 ± 2.38^{c}
B_1	47.38 ± 2.74^{c}	46.58 ± 2.62^{c}	49.60 ± 2.18^{b}	49.23 ± 2.13^{b}
B_2	46.68 ± 2.88^{d}	46.00 ± 2.69^{d}	49.03 ± 2.30^{d}	48.80 ± 2.11^{b}
B_3	49.55 ± 2.89^{a}	48.90 ± 3.11^{a}	51.28 ± 2.34^{a}	50.93 ± 2.15^{a}
B_4	49.05 ± 2.83^{b}	48.40 ± 3.02^{b}	50.93 ± 2.41^{a}	50.60 ± 2.20^{a}
C. D. (P=0.05)	0.911	0.988	0.953	0.914
S. Em±	0.448	0.486	0.469	0.450
P value	1.50 x 10^{-10}	8.28 x 10^{-09}**	1.08 x 10^{-08}**	4.03 x 10^{-11}**

All values are mean ± SD of three replications. Different superscripts are significantly different. *P=0.05 and **P=0.01.

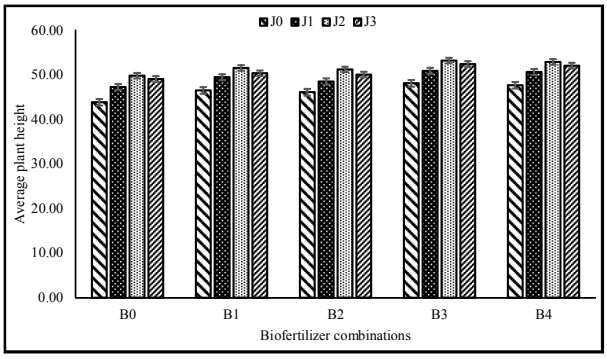

Fig. 2. Average plant height of potato after interaction of *Jeevamrut* formulation and biofertilizers at 75 days after planting.

biofertilizers application (Tables 4 and 5). In case of *Jeevamrut* formulations; *Jeevamrut* fortified with vermitea (J_2) was significantly superior in comparison to other treatments and control (J_0) and was at par with *Jeevamrut* fortified with neem cake (J_3) and produced maximum number of stem (3.53 and 3.54 at 30 DAP, 3.91 and 4.08 at 45 DAP, 4.78 and 5.90 at 60 DAP and 5.84 and 5.86 at 75 DAP) during 2021-22 and 2022-23, respectively. At all stages of plant growth (30, 45, 60 and 75 DAP), B_3 (PSB + *Azotobacter*) and B_4 (PSB + VAM) were at par with each other and produced maximum number of stems, while minimum number of

Table 4. Average number of stems of potato after application of *Jeevamrut* formulation and biofertilizers (30 and 45 days after planting)

Factors	Average number of stems at 30 DAP		Average number of stems at 45 DAP	
	Year 1	Year 2	Year 1	Year 2
J_0 (control)	1.90 ± 0.76^{d}	1.93 ± 0.66^{d}	2.70 ± 0.80^{d}	2.89 ± 1.19^{c}
J_1	2.48 ± 0.55^{c}	2.50 ± 0.53^{c}	3.15 ± 0.75^{c}	3.39 ± 1.01^{b}
J_2	3.53 ± 0.75^{a}	3.54 ± 0.80^{a}	3.91 ± 0.68^{a}	4.08 ± 0.83^{a}
J_3	2.93 ± 0.18^{b}	3.06 ± 0.31^{b}	3.57 ± 0.39^{b}	3.96 ± 0.21^{a}
C. D. (P=0.05)	0.403	0.368	0.407	0.354
S. Em±	0.198	0.171	0.200	0.174
P value	0.00037**	0.00043**	0.030**	0.010**
B_0 (control)	2.17 ± 0.84^{c}	2.23 ± 0.77^{c}	3.23 ± 0.88^{b}	3.09 ± 0.84^{d}
B_1	2.27 ± 0.69^{c}	2.31 ± 0.71^{c}	2.58 ± 0.92^{c}	2.62 ± 0.90^{e}
B_2	2.74 ± 0.76^{b}	2.80 ± 0.79^{b}	3.52 ± 0.46^{a}	3.58 ± 0.48^{c}
B_3	3.14 ± 1.14^{a}	3.20 ± 1.17^{a}	3.70 ± 0.88^{a}	4.00 ± 0.83^{b}
B_4	3.23 ± 0.19^{a}	3.24 ± 0.25^{a}	3.64 ± 0.30^{a}	4.62 ± 0.28^{a}
C. D. (P=0.05)	0.449	0.412	0.455	0.487
S. Em±	0.221	0.197	0.224	0.232
P value	0.011*	0.014*	0.005**	0.001**

All values are mean ± SD of three replications. Different superscripts are significantly different. *P=0.05 and **P=0.01.

Table 5. Average number of stems of potato after application of *Jeevamrut* formulation and biofertilizers (60 and 75 days after planting)

Factors	Average number of stems at 60 DAP		Average number of stems at 75 DAP	
	Year 1	Year 2	Year 1	Year 2
J_0 (control)	3.99 ± 0.46^{c}	4.59 ± 0.35^{c}	4.79 ± 0.15^{c}	4.84 ± 0.18^{b}
J_1	4.23 ± 1.04^{b}	5.23 ± 0.82^{b}	4.58 ± 0.24^{d}	4.83 ± 0.57^{b}
J_2	4.78 ± 1.38^{a}	5.90 ± 1.00^{a}	5.84 ± 1.26^{a}	5.86 ± 1.30^{a}
J_3	4.82 ± 0.52^{a}	5.87 ± 0.82^{a}	5.36 ± 1.22^{b}	5.96 ± 1.41^{a}
C. D. (P=0.05)	0.412	0.402	0.407	0.383
S. Em±	0.206	0.198	0.200	0.176
P value	0.013*	0.025*	0.038*	0.012*
B_0 (control)	3.78 ± 0.21^{c}	4.91 ± 0.27^{c}	4.52 ± 0.41^{d}	4.87 ± 0.19^{c}
B_1	3.85 ± 0.66^{bc}	5.35 ± 0.55^{b}	4.64 ± 0.27^{cd}	4.60 ± 0.35^{d}
B_2	4.07 ± 0.57^{b}	5.07 ± 0.57^{c}	4.82 ± 0.15^{c}	5.57 ± 1.56^{b}
B_3	5.21 ± 1.13^{a}	5.78 ± 1.59^{a}	6.10 ± 1.35^{a}	6.12 ± 1.38^{a}
B_4	5.38 ± 0.46^{a}	5.88 ± 1.01^{a}	5.64 ± 1.10^{b}	5.69 ± 0.85^{b}
C. D. (P=0.05)	0.455	0.416	0.473	0.449
S. Em±	0.224	0.198	0.242	0.221
P value	0.005**	0.005**	0.018*	0.016*

All values are mean ± SD of three replications. Different superscripts are significantly different. *P=0.05 and **P=0.01.

stems was reported in B_0 (control) during both years of experimentation. In case of interactions, it was noticed that at all stages of growth (30, 45, 60 and 75 DAP), combination J_2B_3 produced highest number of plant stem followed by J_2B_4 during 2021-22 and 2022-23 (Fig. 3).

Jeevamrut is activator of metabolic enzymes (acid phosphatase, alkaline phosphatase, dehydrogenase, etc.) and soil microbes (bacteria, fungi, actinomycetes, free living nitrogen fixers and phosphorus solubilizing organisms), which directly enhance plant metabolism resulting better growth and development (Somdutt *et al.*, 2021).

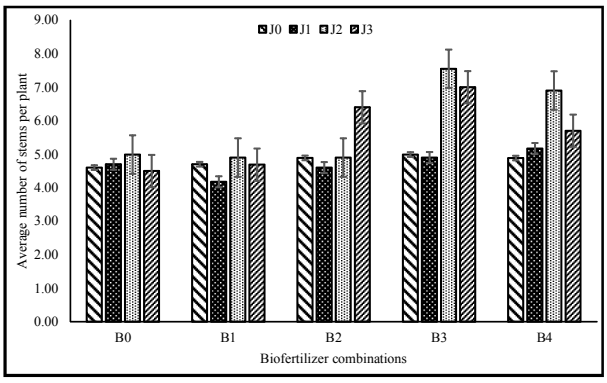

Fig. 3. Average number of stems of potato after interaction of *Jeevamrut* formulation and biofertilizers at 75 days after planting.

The data of tuber yield per plot and estimated yield (q/ha) recorded at harvesting of crop reflected significant difference in crop yield of potato after application of *Jeevamrut* formulations and biofertilizer combinations (Table 6). Among various formulations of *Jeevamrut*, the tuber yield was significantly better (337.20 and 338.32 q/ha) in J_2 (*Jeevamrut* + vermitea) followed by J_3 (*Jeevamrut* + neem cake: 328.00 and 328.03 q/ha) and J_1 (*Jeevamrut* alone) and produced maximum tuber yield/ha. Contrarily, minimum tuber yield/ha was reported in J_0 during both years of trial. Among various biofertilizer combinations, the highest tuber yield (307.50 and 309.95 q/ha) was estimated after application of PSB along with *Azotobacter* (B_3) followed by PSB along with VAM (B_4: 304.50 and 305.03 q/ha). The interaction effect between both the factors *Jeevamrut* based formulations and biofertilizer combinations was reported to be significant for tuber yield at harvesting and highest yield was estimated after combined application of *Jeevamrut* + vermitea and PSB along with *Azotobacter* (J_2B_3) which produced highest tuber yield (350.00 and 354.20 q/ha) followed by J_2B_4 (343.00 and 342.00 q/ha) during 2021-22 and 2022-23, respectively (Fig. 4).

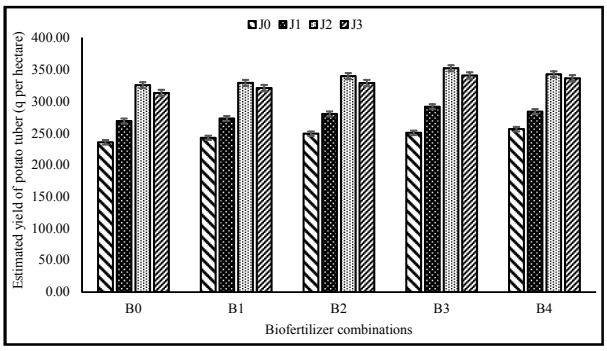

Fig. 4. Estimated yield of potato after interaction of *Jeevamrut* formulation and biofertilizers.

The organic liquid formulations like *Jeevamrut* have ability to stimulate the plant growth and enhance the biological efficiency of crops resulting in improvement in soil microbial population which could be helpful in phosphate solubilization, nitrogen fixation, nutrient uptake and utilization. This also ensures gradual conversion and mineralization of organic matters, solubilization of phosphorus and potassium in available form which results in steady and continuous supply of nutrients to plants bringing positive influence during the growth phase to ensure greater yield attributes (Chongre *et al.*, 2020). Similar findings were described by Patel *et al.* (2021b).

The correlation study of total microbial population in soil with different variables was significant and positive between all components including the estimated yield (Table 7). The variables which were mostly influenced due to microbial population of soil were plant height follwed by germination percentage and estimated yield. Between plant height the correlation value was heighest for plant height at 60 days after planting followed by 45, 30 and 75 days. The eperimental

Table 6. Average yield of potato after application of *Jeevamrut* formulation and biofertilizers

Factors	Average yield (kg/plot)		Estimated yield (q/hectare)	
	Year 1	Year 2	Year 1	Year 2
J_0 (control)	18.45 ± 0.58^{d}	18.58 ± 0.61^{d}	246.00 ± 7.71^{d}	247.71 ± 8.21^{d}
J_1	20.89 ± 0.63^{c}	21.03 ± 0.70^{c}	278.60 ± 8.44^{c}	280.49 ± 9.33^{c}
J_2	25.29 ± 0.75^{a}	25.37 ± 0.86^{a}	337.20 ± 9.98^{a}	338.32 ± 11.51^{a}
J_3	24.60 ± 0.80^{b}	24.60 ± 0.88^{b}	328.00 ± 10.70^{b}	328.03 ± 11.74^{b}
C. D. (P=0.05)	0.425	0.455	5.662	6.058
S. Em±	0.209	0.224	2.786	2.981
P value	2.27 x 10^{-15}**	2.13 x 10^{-13}**	2.71 x 10^{-11}**	1.06 x 10^{-13}**
B_0 (control)	21.45 ± 3.14^{d}	21.43 ± 3.07^{e}	286.00 ± 41.84^{d}	285.70 ± 40.90^{e}
B_1	21.83 ± 3.10^{c}	21.89 ± 3.03^{d}	291.00 ± 41.33^{c}	291.88 ± 40.40^{d}
B_2	22.37 ± 3.17^{b}	22.54 ± 3.18^{c}	298.25 ± 42.27^{b}	300.64 ± 42.36^{c}
B_3	23.06 ± 3.48^{a}	23.24 ± 3.55^{a}	307.50 ± 46.46^{a}	309.95 ± 47.34^{a}
B_4	22.83 ± 3.20^{a}	22.87 ± 3.04^{b}	304.50 ± 42.63^{a}	305.03 ± 40.56^{b}
C. D. (p=0.05)	0.475	0.508	6.33	6.773
S. Em±	0.234	0.25	3.115	3.333
P value	3.31 x 10^{-07}**	3.07 x 10^{-07}**	3.32 x 10^{-05}**	3.73 x 10^{-06}**

All values are mean ± SD of three replications. Different superscripts are significantly different. *P=0.05 and **P=0.01.

Table 7. Correlation study of various parameters with total microbial count (TMC)

	TMC	GP	PH30	PH45	PH60	PH75	SN30	SN45	SN60	SN75	EY
TMC	1										
GP	.914**	1									
PH30	.925**	.990**	1								
PH45	.926**	.988**	.996**	1							
PH60	.927**	.988**	.997**	.999**	1						
PH75	.919**	.989**	.995**	.997**	.998**	1					
SN30	.809**	.882**	.857**	.856**	.858**	.856**	1				
SN45	.632**	.688**	.662**	.662**	.667**	.674**	.881**	1			
SN60	.755**	.717**	.743**	.747**	.747**	.733**	.734**	.684**	1		
SN75	.735**	.638**	.656**	.659**	.657**	.643**	.651**	.584**	.855**	1	
EY	.819**	.897**	.902**	.889**	.889**	.896**	.830**	.667**	.646**	.636**	1

** P= 0.01. TMC–Total microbial count, GP–Germination percentage, PH–Plant height at different days after planting, SN–Number of stems at different days after planting and EY–Estimated yield.

findings confirmed that application of *Jeevamrut* and bifertilizers had resulted in greater availablity of nutrients to the plants due to mineralization of organic matters prasent in soil (Fitriatin *et al.*, 2021; Reddy and Menon, 2021).

The scree plot of all PCs confirmed that the PC1 (9.165) alone explained 83.31% of the total variance with all attributes under study (Fig. 5). This reflected the strong relationship between the parameters under study and microbial activities in soil. The positive loading of this parameter indicated significant improvement in microbial community after application of *jeevamrut* and biofertilizers.

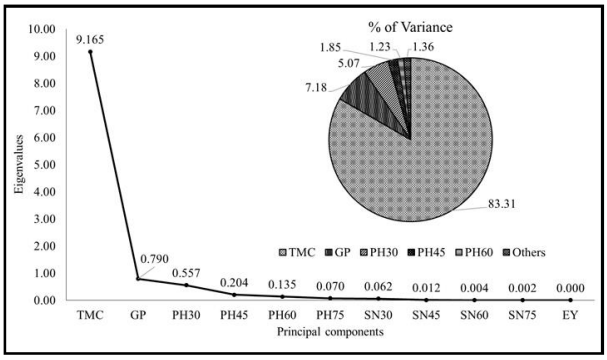

Fig. 5. The scree plot of all principal components explaing the percentage of variance explained by each component.

CONCLUSION

The present study confirmed that application of *Jeevamrut* fortified with vermitea or neem cake and consortia of biofertilizers including PSB and *Azotobacter* or VAM was one of the most successful approaches for getting sustainable yield in potato. Further, application of these natural sources of nutrients improved soil health by increasing the nutrient availability and reducing the requirement of chemical fertilizers.

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