



Article

Jeevamrit: A Sustainable Alternative to Chemical Fertilizers for Marigold (*Tagetes erecta* cv. Siracole) Cultivation under Mid-Hills of Himachal Pradesh

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Abstract: Using desi-cow waste products like Jeevamrit under natural farming is widespread among farmers for improving soil biology and productivity. Jeevamrit enhances soil chemical and microbiological properties without needing a large quantity of farmyard manure (FYM) as a sustainable farming practice with a reduced carbon footprint. Despite its traditional use, Jeevamrit faces criticism due to a lack of scientific evidence. This study investigated the comparative effect of Jeevamrit and chemical fertilizers on the growth and yield of marigold cv. Siracole. The experiment employed a randomized block design (RBD) with three replications. The mother block of marigolds was raised for both the summer and winter seasons. From this mother block, three harvesting flushes were taken and propagated from cuttings. The rooted cuttings were planted at monthly intervals and evaluated for flowering parameters and compared to those treated with RDF (30:20:20 N, P, and K g/m²). Soil supplied with Jeevamrit showed enhanced bacteria (26.33%), fungi (18.92%), and actinomycetes (31.21%) populations compared to the recommended dose of fertilizers (RDF) (i.e., N–P–K @ 30:20:20 g m^{−2}). Jeevamrit-treated plants have a more marketable flower yield per square meter (3.98%) and a longer shelf life (9.93%) compared to RDF. The study concludes that Jeevamrit @ 2 liters m^{−2} is a sustainable and effective alternative to traditional fertilizers for enhancing marigold production in the mid-hills of Himachal Pradesh, where natural farming is already accepted.

Keywords: Jeevamrit; marigold; natural farming; soil biology improvement; sustainable agriculture



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1. Introduction

Marigold (*Tagetes erecta*) flower cultivation is getting increasingly popular among farmers. Marigold belongs to the Asteraceae family and is an important commercial loose flower grown for its decorative and long-lasting flowers. The genus *Tagetes* consists of approximately 40–50 species. *T. erecta* is popularly known as ‘Aztec Marigold’ or ‘Cravo de defunto’, originally from Mexico and widely used as an ornamental plant, natural dye, and source of bioactive products, especially lutein [1]. Moreover, the flowers of marigold are used as an ingredient in salads and as a natural food colorant since it is one of the most popular edible flowers all over the world [2]. Flowers play diverse roles beyond their ornamental value. They are utilized in various industries, including pharmaceuticals, processed food production, and confectionery. In agriculture, flowers serve as a valuable intercrop. For instance, plants exhibit insecticidal properties, acting as natural pest control agents. Additionally, the marigold plant effectively suppresses plant-parasitic nematodes, protecting crops from these harmful organisms [3]. The flowers of *T. erecta* have been used traditionally from ancient times and have been reported as helpful to treat stomachache and intestinal diseases and as tranquilizers and anthelmintics [4].

The ‘Siracole’ variety, also known as ‘Laddu Gainda’, has gained popularity among farmers due to its distinct characteristics, such as uniform flower size and bushy foliage. This marigold cultivar, originating from Eastern India, has gained recognition for its exceptional productivity [5]. Siracole cultivar has proven to be highly productive and has significant market demand, resulting in greater profit for farmers. This cultivar is propagated through herbaceous stem cuttings. This method ensures genetic consistency, producing plants identical to the parent plant. Utilizing stem cuttings allows for the efficient and reliable cultivation of this cultivar. In the context of scientific research, it is crucial to explore the factors contributing to the success of ‘Siracole’ to develop sustainable cultivation practices that optimize its potential for agricultural productivity and economic benefits.

Meeting the projected demand for healthy and sustainable food production is a crucial challenge. In fact, increasing crop productivity by mitigating climate change and preserving agro-ecosystems is one of the significant goals of sustainable agriculture [6]. However, meeting agricultural demand via the intensive use of synthetic fertilizers and pesticides has led to land degradation and environmental pollution in several agro-ecosystems, which has had an adverse impact on humans, animals, and aquatic ecosystems [7]. Sustainable agriculture has been identified as an alternative integrated approach that could be used to solve fundamental and applied issues related to production in an ecological way [8].

Natural organic formulations induce a multifold increase in microbial population and earthworm activity, which enhances nutrient availability in soil, leads to improving the plant’s resistance mechanism, and increases crop productivity [9–11]. Among natural farming formulations, Jeevamrit is recognized as a pillar of natural farming systems [12]. Jeevamrit application in the soil has the efficiency to improve soil fertility and plant development. The components used to prepare Jeevamrit are easily available on farms viz. cow dung, urine, legume flour, and jaggery. These preparations are rich in essential macro and micronutrients, vitamins, essential amino acids, and beneficial microorganisms. These components contribute to enhanced soil health by improving its physical, chemical, and biological properties, ultimately leading to increased crop yields [13,14].

Marigolds are valued not only for their beauty but also for their medicinal and culinary applications. Therefore, minimizing chemical residues within these plants is of paramount importance. Embracing organic amendments, such as Jeevamrit, in marigold cultivation offers a promising solution. This eco-friendly approach carries multiple benefits. By reducing reliance on chemical inputs, we can foster a more balanced ecosystem and safeguard natural resources. This shift towards sustainable agriculture aligns with the growing need to protect our environment while ensuring agricultural productivity. Our research delves into the effectiveness of Jeevamrit in marigold cultivation, specifically examining its role in reducing chemical residues. We aim to contribute valuable insights into how this organic amendment can pave the way for a more sustainable and environmentally responsible agricultural system.

2. Materials and Methods

The investigation was carried out in the Department of Floriculture and Landscape Architecture, Experimental Research Farm, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India, during the summer and winter seasons of 2023–2024. The experimental farm of the department is located in the hilly regions of the Western Himalayas at an altitude of 1276 m above mean sea level, with a latitude of 30°52′02″ N and a longitude 70°11′30″ E. Figure 1 displays the meteorological data collected during the experiment. The average mean temperature, rainfall, and humidity recorded during this period were 18.29 °C, 61.92 mm, and 48.48%, respectively. The experiment followed a factorial randomized block design comprising two fertilizer treatments (T₁: Jeevamrit @ 2 liters m^{−2} at 15-day intervals and T₂: RDF (recommended doses of fertilizers) N–P–K @ 30:20:20 g m^{−2}), three harvesting flushes (H₁, H₂, and H₃), and two seasons (S-I: summer and S-II: winter). Before the start of the experiment, the chemical characteristics of the soil were assessed (Table 1). Farmyard manure (FYM) @ 5 kg m^{−2} was

used in both treatments at the time of field preparation. RDF comprising fertilizers, i.e., urea, single super phosphate (SSP), and muriate of potash (MOP), in desired quantities were incorporated into the soil at the time of field preparation in individual plots and a split dosage of urea was applied, the first half at the time of field preparation and the other half in two splits, first one month after transplanting and the remainder one month after the first application (late vegetative stage/early flowering).

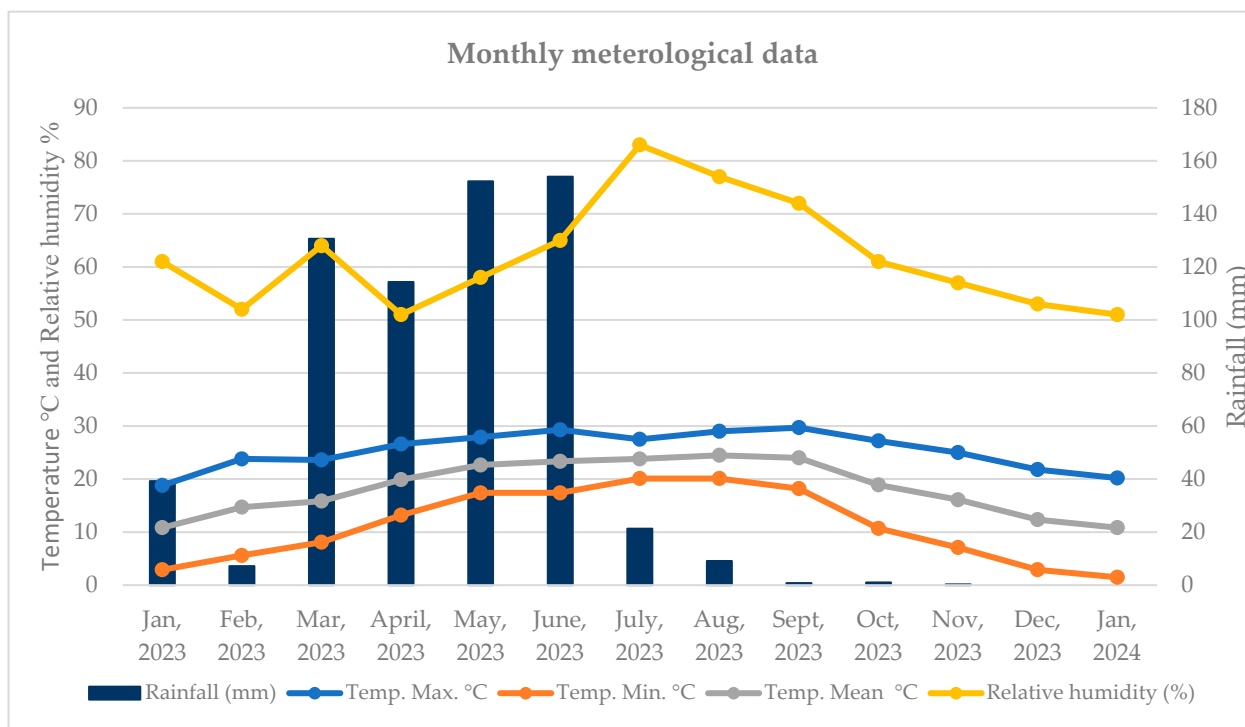


Figure 1. Metrological data during the study period.

Table 1. Initial soil characteristics.

Particular	Season-I	Season-II	References
pH	7.86	6.92	[15]
EC (dS m ⁻¹)	1.02	0.95	[15]
Organic Carbon (%)	0.78	0.91	[16]
Available N (kg/ha)	262.57	282.39	[17]
Available P (kg/ha)	52.56	57.52	[18]
Available K (kg/ha)	395.45	402.27	[19]

Rooted cuttings of three sequential harvests were planted on 15 March, 2 April, and 13 May in summer and on 28 August, 10 September, and 27 September 2023 to evaluate growth and flowering parameters. There were nine rooted cuttings planted in a one-meter square plot at a spacing of 30 × 30 cm.

2.1. Preparation of Jeevamrit

Jeevamrit was prepared by mixing 10 kg of cow dung, 10 L of cow urine, 2 kg of black jaggery, 2 kg of pulse flour (black chickpeas), and a handful of soil (100 g) as microbial inoculum, and the total volume was made up to 200 liters by adding water and stirring the mixture twice a day in a clockwise manner. On the fifth day, the solution was filtered, and the filtrate was used for soil drenching. Jeevamrit @ 2 liters m⁻² was administered to the soil at 15-day intervals. The first treatment was performed on the 20th day after planting cuttings, and the final two applications were performed at fifteen-day intervals after the

first treatment. The filtrate was applied in pure form in 1 m² plots. The nutrient status and microbial load of the Jeevamrit are given in Table 2.

Table 2. Nutrient status and microbial load in Jeevamrit.

Parameter	Nutrient Status
pH	7.5
EC (dSm ^{−1})	4.8
N (%)	1.85
P (%)	0.25
K (%)	0.30
Bacteria (cfu)	17.8 × 10 ⁵
Fungi (cfu)	13.4 × 10 ⁵
Actinomycetes (cfu)	8.5 × 10 ⁵
Mg (ppm)	45
Cu (ppm)	1.62
Zn (ppm)	4.38
Mn (ppm)	9.50
Fe (ppm)	185

2.2. Vegetative and Flowering Attributes

The vegetative (plant height and spread) and flowering attributes (days for bud formation, number of flowers per plant, and duration of flowering) were noted for each harvesting flush (H₁–H₃) at the proper stage of data collection. At each replication and treatment, five plants were randomly selected, and all the vegetative and flowering characters were recorded.

2.3. Sample Collection and Measurement of Soil Chemical Properties

The soil samples were collected from each plot to a depth of 15 cm using a soil auger before planting and after harvesting the crop. A composite sample was created by combining soil samples from several locations. The excess soil was quartered, and 500 g was kept for analysis. The remaining two-quarters of the soil were mixed once again, and the procedure was repeated until only 500 g of soil remained. To prepare soil samples for chemical analysis, they were passed through a 2 mm screen and then placed in cotton bags to dry naturally.

2.4. Soil Chemical Properties

Soil pH and electrical conductivity were estimated using a conductivity meter [15]. Organic carbon content was estimated using the Walkley–Black method [16]. To obtain the actual percentage of organic carbon by the Walkley–Black method, organic carbon should be multiplied by a factor of 100/77, i.e., 1.3 (with 77 % being the average recovery factor). To determine the available nitrogen (N) in the soil, the alkaline potassium permanganate method was employed [17]. Available P was determined using the alkaline potassium permanganate method [18]. Olsen’s method is typically used for phosphorus (P) determination [19].

2.5. Microbiological Properties of Soil

The microbiological properties of the soil were analyzed following the completion of the trial for each treatment. The quantification of viable microbes was carried out using the nutrient agar (NA) for the bacterial count, potato dextrose agar medium (PDA) for the fungal count, and Kenknight and Munaier’s medium (KNM) for the actinomycetes count, using the standard spread-plate technique with serial dilutions [20]. The population was

measured in terms of colony-forming units (cfu) per gram of soil, and the assessment of microbial biomass-C was performed using the soil fumigation extraction method [21]:

$$MB - C \mu\text{g g}^{-1} \text{ soil} = \frac{EC(F) - EC(UF)}{K} \quad (1)$$

where $K = 0.25 \pm 0.05$ (a factor that represents the efficiency of extraction of microbial biomass carbon), $EC(F)$ = Total amount of extractable carbon in fumigated soil samples, and $EC(UF)$ = Total amount of extractable carbon in unfumigated soil samples. The 2,3,5-triphenyl tetrazolium chloride (TTC) reduction method was used to estimate the dehydrogenase activity in liquid formulations [22]. The estimation of phosphatase activity was carried out using the procedure outlined by [23].

2.6. Plant N, P, and K

Plant N, P, and K were assessed by [24]

$$\text{Biomass (kg / ha)} = \frac{\text{Weight of dry plant} \times 10,000}{\text{Area covered by the plant} \times 1000} \quad (2)$$

$$\text{Nutrient Uptake (kg / ha)} = \frac{\text{Biomass (kg/ha)} \times \text{Nutrient content (\%)}}{100} \quad (3)$$

2.7. Chlorophyll Content

The leaf chlorophyll was estimated using the method given by [25]. The total chlorophyll content was calculated using the formula:

$$\text{Total chlorophyll (mg g}^{-1}\text{)} = \frac{20.2A_{645} + 8.02A_{663}}{a \times 1000 \times w} \times V \quad (4)$$

V—Volume of extract made

A—Length of light in cell (usually 1 cm)

W—Weight of sample

A₆₄₅—Absorbance at 645 nm

A₆₆₃—Absorbance at 663 nm

2.8. Carotenoid Content

The concentration of total carotenoids was compared using the standard curve [26]. The following formula was used to calculate the quantity of carotenoids

$$\text{Total carotenoids (ug/100 g)} = \frac{\text{Concentration from standard curve} \times \text{dilution factor} \times 100}{\text{wt of sample}} \quad (5)$$

2.9. Statistical Analysis

The field experiment was conducted with three replications and nine plants in each replication and was laid out in a Randomized Complete Block Design (RBD). The analysis of variance using a three-way ANOVA was conducted between treatments, seasons, and harvesting flushes, and the treatments were compared at 0.05% significance. The data recorded during the experiment were statistically analyzed using Microsoft Excel 2010 and SPSS version 16.0 software.

3. Results

3.1. Effect of Seasons Nutritional Modules and Plants Raised from the Cuttings of Different Harvesting Flushes

The maximum plant height (124.66 cm), plant spread (62.51 cm), chlorophyll content (2.52 mg g^{-1}), minimum days taken for flowering (53.67 days), size of flower (11.00 cm), marketable flower yield per square meter (8.00 kg), and minimum number of days for

flowering (53.67 days) was obtained during summer season (S-I) as compared to winter season (Tables 3 and 4). The shelf life of flowers was observed to be significantly longer during the winter season, lasting an average of 5.76 days compared to the summer season. This extended shelf life can be attributed to the reduced ethylene production and slowed-down senescence process that occurs due to the low temperatures during winter.

Table 3. Effect on plant height, plant spread, chlorophyll content, and days taken for flowering.

	S-I	S-II	Mean	T ₁	T ₂	Interactions	CD	SE
Plant height (cm)								
H ₁	124.62	94.68	109.65	109.88	109.42	Seasons	0.86	0.29
H ₂	124.88	92.13	108.51	108.83	108.18	Nutritional modules	NS	0.29
H ₃	124.47	90.70	107.58	107.77	107.40	Season × Nutritional modules	NS	0.42
Mean	124.66	92.56	-			Harvesting flushes	1.06	0.36
T ₁	124.96	92.70	108.90			Season × Harvesting flushes	1.49	0.51
T ₂	124.36	92.31	108.34			Nutritional modules × Harvesting flushes	NS	0.51
Plant spread (cm)								
H ₁	62.38	52.31	57.35	57.56	57.13	Seasons	1.65	0.56
H ₂	62.92	51.82	57.37	57.55	57.18	Nutritional modules	NS	0.56
H ₃	62.23	48.47	55.35	55.52	55.18	Season × Nutritional modules	NS	0.79
Mean	62.51	50.87	-			Harvesting flushes	NS	0.69
T ₁	62.72	51.03	56.88			Season × Harvesting flushes	NS	0.97
T ₂	62.30	50.70	56.50			Nutritional modules × Harvesting flushes	NS	0.97
Chlorophyll content of leaves (mg g ⁻¹)								
H ₁	2.65	2.17	2.41	2.55	2.27	Seasons	0.04	0.01
H ₂	2.54	1.78	2.16	2.21	2.10	Nutritional modules	0.04	0.01
H ₃	2.38	1.49	1.94	2.06	1.81	Season × Nutritional modules	NS	0.02
Mean	2.52	1.81	-			Harvesting flushes	0.05	0.02
T ₁	2.62	1.93	2.28			Season × Harvesting flushes	0.07	0.02
T ₂	2.42	1.70	2.06			Nutritional modules × Harvesting flushes	0.07	0.02
Days taken for flowering (days)								
H ₁	54.22	62.87	58.54	58.45	58.63	Seasons	0.32	0.11
H ₂	53.18	65.65	59.42	59.42	59.42	Nutritional modules	NS	0.11
H ₃	53.60	67.05	60.33	60.32	60.33	Season × Nutritional modules	0.46	0.16
Mean	53.67	65.19	-			Harvesting flushes	0.39	0.13
T ₁	53.46	65.33	59.39			Season × Harvesting flushes	0.56	0.19
T ₂	53.88	65.04	59.46			Nutritional modules × Harvesting flushes	NS	0.19

S-I: summer, S-II: winter, H₁: first harvesting flushes, H₂: second harvesting flushes, H₃: third harvesting flushes T₁: Jeevamrit @ 2 liters m⁻², T₂: RDF N-P-K @30:20:20 g m⁻², CD: critical difference, SE: standard error, NS: no-significant.

The results of the study revealed that nutritional module T₁ significantly improved the growth and quality of flowers. Specifically, the treatment led to a notable increase in chlorophyll content (2.28 mg g⁻¹), yield of marketable flower per square meter (7.29 kg), and shelf life of flowers (5.54 days). The optimum nutrients are required for the growth and development of plants. However, there was no significant effect of treatments on plant height, plant spread, days taken for flowering, and size of flowers. Plants raised from the cuttings of the first harvesting flush (H₁) exhibited maximum plant height (109.65 cm), chlorophyll content (2.41 mg g⁻¹), size of flower (8.86 cm), and marketable flower yield per square meter (7.27 kg) and took the minimum number of days for flowering (58.54 days), while the effect of harvesting flushes on plant spread was non-significant.

Table 4. Effect on size of flower, marketable flower yield per square meter, and shelf life.

	S-I	S-II	Mean	T ₁	T ₂	Interactions	CD	SE
Size of flower (cm)								
H ₁	10.97	6.76	8.86	8.90	8.82	Seasons	0.16	0.05
H ₂	11.17	5.69	8.43	8.47	8.39	Nutritional modules	NS	0.05
H ₃	10.88	5.24	8.06	8.10	8.02	Season × Nutritional modules	NS	0.08
Mean	11.00	5.89				Harvesting flushes	0.19	0.07
T ₁	11.04	5.94	8.49			Season × Harvesting flushes	0.27	0.09
T ₂	10.97	5.85	8.41			Nutritional modules × Harvesting flushes	NS	0.09
Marketable flower yield m ⁻² (kg)								
H ₁	8.11	6.42	7.27	7.41	7.13	Seasons	0.07	0.02
H ₂	8.10	6.28	7.19	7.28	7.10	Nutritional modules	0.07	0.02
H ₃	7.79	6.17	6.98	7.18	6.78	Season × Nutritional modules	0.10	0.03
Mean	8.00	6.29	-			Harvesting flushes	0.08	0.03
T ₁	8.19	6.39	7.29			Season × Harvesting flushes	NS	0.04
T ₂	7.81	6.19	7.00			Nutritional modules × Harvesting flushes	0.12	0.04
Shelf life (days)								
H ₁	4.77	5.13	4.98	5.33	4.62	Seasons	0.21	0.07
H ₂	4.93	5.98	5.46	5.65	5.27	Nutritional modules	0.21	0.07
H ₃	4.62	6.12	5.37	5.65	5.08	Season × Nutritional modules	NS	0.10
Mean	4.77	5.76	-			Harvesting flushes	0.25	0.09
T ₁	5.02	6.07	5.54			Season × Harvesting flushes	0.36	0.12
T ₂	4.52	5.46	4.99			Nutritional modules × Harvesting flushes	NS	0.12

S-I: summer, S-II: winter, H₁: first harvesting flushes, H₂: second harvesting flushes, H₃: third harvesting flushes
T₁: Jeevamrit @ 2 liters m⁻², T₂: RDF N-P-K @30:20:20 g m⁻², CD: critical difference, SE: standard error, NS: non-significant.

3.2. Interaction Effect of Seasons and Plants Raised from the Cuttings of Different Harvesting Flushes

The interactions between seasons and harvesting flushes of cuttings revealed that the cuttings taken from H₂ (i.e., plants raised from second harvesting flush) and planted during summer season resulted in the maximum plant height (124.88 cm) and size of flower (11.17 cm) and took the minimum number of days for flowering (53.18 days), whereas the chlorophyll content of leaves (2.65 mg g⁻¹) and marketable flower yield per square meter (8.11 kg) were observed to reach maximum values under H₁ (Tables 3 and 4). The maximum shelf life (6.12 days) was recorded during the winter season (S-I) from the cuttings of the third flush (H₃), whereas the interaction effect of seasons and harvesting flushes on plant spread and marketable flower yield per square meter was found to be non-significant.

3.3. Interaction Effects of Seasons and Nutritional Modules

The interactions between seasons and nutritional modules indicate that the minimum number of days taken for flowering (53.46 days) and maximum marketable flower yield per square meter (8.19 kg) were recorded under T₁ during the summer season, whereas the interaction effect on plant height, plant spread, chlorophyll content, size of flower, and shelf life was found to be non-significant.

3.4. Interaction Effect of Nutritional Modules and Plants Raised from the Cuttings of Different Harvesting Flushes

The interaction between nutritional modules and harvesting flushes revealed that the maximum chlorophyll content (2.55 mg g⁻¹) was recorded in the plants fed Jeevamrit (T₁) and produced from the first harvesting flush (H₁), whereas a non-significant effect was observed on plant height, plant spread, days taken for flowering, and shelf life.

3.5. Interaction Effect of Seasons, Nutritional Modules, and Plants Raised from the Cuttings of Different Harvesting Flushes

The data presented in Table 5 show that the maximum chlorophyll content (2.68 mg g⁻¹) from the leaves of marigolds was obtained during the summer season (S-I) from plants

supplied with Jeevamrit (T_1) from the first harvesting flush of cuttings (H_1), whereas the flower size was observed at maximum values (11.20 cm) under $S\text{-I} \times T_1 \times H_2$.

Table 5. Three-way table (season, treatment, and harvesting flush interactions).

	Seasons			
	S-I		S-II	
	T_1	T_2	T_1	T_2
	Plant height (cm)			
H_1	124.87	124.37	94.90	94.47
H_2	125.33	124.43	92.33	91.93
H_3	124.67	124.27	90.87	90.53
$CD_{0.05}$	NS		SE	0.72
	Plant spread (cm)			
H_1	62.67	62.10	52.45	52.17
H_2	63.10	62.73	52.00	51.63
H_3	62.40	62.07	48.65	48.30
$CD_{0.05}$	NS		SE	1.37
	Chlorophyll content of leaves (mg g^{-1})			
H_1	2.68	2.61	2.42	1.92
H_2	2.62	2.45	1.80	1.75
H_3	2.57	2.20	1.56	1.42
$CD_{0.05}$	0.10		SE	0.03
	Days taken for flowering			
H_1	53.90	54.53	63.00	62.73
H_2	53.03	53.33	65.80	65.50
H_3	53.43	53.77	67.20	66.90
$CD_{0.05}$	NS		SE	0.27
	Size of flower (cm)			
H_1	11.00	10.93	6.80	6.71
H_2	11.20	11.13	5.73	5.64
H_3	10.92	10.85	5.28	5.19
$CD_{0.05}$	NS		SE	0.13
	Marketable flower yield $\text{m}^{-1}(\text{kg})$			
H_1	8.25	7.97	6.56	6.29
H_2	8.24	7.96	6.33	6.23
H_3	8.08	7.50	6.28	6.06
$CD_{0.05}$	NS		SE	0.06
	Shelf life (days)			
H_1	5.17	4.37	5.50	4.87
H_2	5.07	4.80	6.23	5.73
H_3	4.83	4.40	6.47	5.77
$CD_{0.05}$	NS		SE	0.17

Kg: kilogram, cm: centimeters, S-I: summer, S-II: winter, H_1 : first harvesting flushes, H_2 : second harvesting flushes, H_3 : third harvesting flushes T_1 : Jeevamrit @ 2 liters m^{-2} , T_2 : RDF N-P-K @ 30:20:20 g m^{-2} , CD: critical difference, SE: standard error, NS: non-significant.

A non-significant effect of nutritional modules and plants produced from different flushes of cuttings during two different seasons was observed on plant height, plant spread, chlorophyll content of leaves, days taken for flowering, marketable flower yield per square meter, and shelf life of flowers.

3.6. Effect of Seasons, Nutritional Modules, and Plants Raised from the Cuttings of Different Harvesting Flushes

The summer season enhanced the total carotenoids (2.36 mg g^{-1}) of flowers and viable bacteria ($18.27 \times 10^5 \text{ cfu g}^{-1}$), fungal ($3.87 \times 10^3 \text{ cfu g}^{-1}$), and actinomycete ($2.73 \times 10^3 \text{ cfu g}^{-1}$) populations in the soil (Table 6). In contrast, the highest availability of nutrients in soil was observed during the winter season, with maximum amounts of available nitrogen ($300.39 \text{ kg ha}^{-1}$), phosphorus (61.57 kg ha^{-1}), and potassium ($417.60 \text{ kg ha}^{-1}$)

being recorded (Table 6). Low temperatures during winter reduced plant metabolism, which in turn decreased nutrient uptake. This led to a higher availability of nutrients such as nitrogen (N), phosphorus (P), and potassium (K) in the soil.

Table 6. Effect on total carotenoids, viable bacteria, fungi, and actinomycetes.

	S-I	S-II	Mean	T ₁	T ₂	Interactions	CD	SE
Total carotenoids (mg g ⁻¹)								
H ₁	2.30	2.20	2.25	2.32	2.17	Seasons	0.04	0.01
H ₂	2.53	2.07	2.30	2.40	2.20	Nutritional modules	0.04	0.01
H ₃	2.25	1.80	2.02	2.10	1.95	Season × Nutritional modules	0.05	0.02
Mean	2.36	2.02	-			Harvesting flushes	0.04	0.02
T ₁	2.48	2.07	2.28			Season × Harvesting flushes	0.06	0.02
T ₂	2.23	1.98	2.10			Nutritional modules × Harvesting flushes	NS	0.02
Bacterial count (×10 ⁵ cfu g ⁻¹ Soil)								
H ₁	17.97	13.65	15.81	18.17	13.44	Seasons	0.15	0.05
H ₂	18.38	13.82	16.10	18.58	13.63	Nutritional modules	0.15	0.05
H ₃	18.45	13.93	16.19	18.63	13.74	Season × Nutritional modules	NS	0.07
Mean	18.27	13.80	-			Harvesting flushes	0.18	0.06
T ₁	20.74	16.18	18.46			Season × Harvesting flushes	NS	0.09
T ₂	15.79	11.42	13.60			Nutritional modules × Harvesting flushes	NS	0.09
Fungal count (×10 ³ cfu g ⁻¹ Soil)								
H ₁	3.54	2.79	3.17	3.57	2.77	Seasons	0.11	0.04
H ₂	3.80	3.05	3.43	3.83	3.03	Nutritional modules	0.11	0.04
H ₃	4.28	3.53	3.90	4.30	3.50	Season × Nutritional modules	NS	0.05
Mean	3.87	3.12	-			Harvesting flushes	0.14	0.05
T ₁	4.27	3.52	3.90			Season × Harvesting flushes	NS	0.07
T ₂	3.47	2.72	3.10			Nutritional modules × Harvesting flushes	NS	0.07
Actinomycetes count (×10 ³ cfu g ⁻¹ Soil)								
H ₁	2.37	1.69	2.03	2.46	1.60	Seasons	0.08	0.03
H ₂	2.75	2.05	2.40	2.84	1.96	Nutritional modules	0.08	0.03
H ₃	3.06	2.35	2.70	3.15	2.26	Season × Nutritional modules	NS	0.04
Mean	2.73	2.03	-			Harvesting flushes	0.09	0.03
T ₁	3.16	2.47	2.82			Season × Harvesting flushes	NS	0.05
T ₂	2.29	1.59	1.94			Nutritional modules × Harvesting flushes	NS	0.05

cfu: colony-forming unit, mg: milligrams S-I: summer, S-II: winter, H₁: first harvesting flushes, H₂: second harvesting flushes, H₃: third harvesting flushes T₁: Jeevamrit @ 2 liters m⁻², T₂: RDF N-P-K @30:20:20 g m⁻², CD: critical difference, SE: standard error, NS: non-significant.

The available N (299.81 kg ha⁻¹), P (61.82 kg ha⁻¹), and K (419.80 kg ha⁻¹) in the soil were observed at maximum values under T₂ as shown in Table 6. The application of Jeevamrit enhanced the viable bacterial (18.46×10^5 cfu g⁻¹), fungal (3.90×10^3 cfu g⁻¹), and actinomycetes (2.82×10^3 cfu g⁻¹) counts (Table 5).

Our analysis revealed higher viable bacterial (16.19×10^5 cfu g⁻¹), fungal (3.90×10^3 cfu g⁻¹), and actinomycete (2.70×10^3 cfu g⁻¹) counts in the soil where marigold plants were raised from cuttings taken from the third harvesting flush (H₃). The maximum available phosphorus (59.97 kg ha⁻¹) was recorded under H₁, whereas the effect of harvesting flushes on available N and K in soil was found to be non-significant.

3.7. Interaction Effect of Seasons and Plants Raised from the Cuttings of Different Harvesting Flushes

The cuttings planted during summer and taken from H₂ (i.e., second harvesting flush) exhibited the maximum total carotenoids in flowers (2.53 mg g⁻¹) (Table 6). A significant effect on available nitrogen was observed, which was found to reach maximum values under H₃ during the winter season, whereas the interaction effect of seasons and harvesting flushes was non-significant on bacteria, fungus, actinomycetes, and available P and K.

3.8. Interaction Effects of Seasons and Nutritional Modules

Total carotenoid content in flowers (2.48 mg g^{-1}) was significantly enhanced by the application of Jeevamrit during the summer season, while available nitrogen ($306.74 \text{ kg ha}^{-1}$) and potassium ($423.90 \text{ kg ha}^{-1}$) were observed to reach maximum values under T_2 during the winter season. The interaction effect was non-significant on bacteria, fungus, actinomycetes, and available P.

3.9. Interaction Effect of Treatments and Plants Raised from the Cuttings of Different Harvesting Flushes

The effect of treatments and harvesting flushes on total carotenoids, bacterial, fungal, and actinomycetes counts (Table 6), and available N, P, and K (Table 7) was found to be non-significant.

Table 7. Effect on available N, P, and K of soil.

	S-I	S-II	Mean	T_1	T_2	Interactions	CD	SE
					N kg ha^{-1}			
H_1	290.87	295.65	293.26	286.93	299.58	Seasons	0.82	0.28
H_2	285.67	300.92	293.29	286.97	299.62	Nutritional modules	0.82	0.28
H_3	283.20	304.62	293.91	287.58	300.23	Season $\times$ Nutritional modules	1.16	0.40
Mean	286.58	300.39	-			Harvesting flushes	NS	0.34
T_1	280.28	294.04	287.16			Season $\times$ Harvesting flushes	1.42	0.49
T_2	292.88	306.74	299.81			Nutritional modules $\times$ Harvesting flushes	NS	0.49
					P kg ha^{-1}			
H_1	57.51	62.43	59.97	57.14	62.80	Seasons	0.79	0.27
H_2	56.64	61.27	58.95	56.48	61.42	Nutritional modules	0.79	0.27
H_3	55.41	61.00	58.20	55.17	61.23	Season $\times$ Nutritional modules	NS	0.38
Mean	56.52	61.57	-			Harvesting flushes	0.97	0.33
T_1	53.92	58.61	56.27			Season $\times$ Harvesting flushes	NS	0.47
T_2	59.11	64.52	61.82			Nutritional modules $\times$ Harvesting flushes	NS	0.47
					K kg ha^{-1}			
H_1	408.82	417.02	412.92	406.62	419.22	Seasons	5.00	1.70
H_2	408.25	416.45	412.35	406.05	418.65	Nutritional modules	5.00	1.70
H_3	411.12	419.32	415.22	408.92	421.52	Season $\times$ Nutritional modules	7.05	2.40
Mean	409.40	417.60	-			Harvesting flushes	NS	2.08
T_1	403.10	411.30	407.20			Season $\times$ Harvesting flushes	NS	2.95
T_2	415.70	423.90	419.80			Nutritional modules $\times$ Harvesting flushes	NS	2.95

Kg ha^{-1} : kilogram per hectare, N: Nitrogen; P: Phosphorus; K: Potassium, S-I: summer, S-II: winter, H_1 : first harvesting flushes, H_2 : second harvesting flushes, H_3 : third harvesting flushes T_1 : Jeevamrit @ 2 liters m^{-2} , T_2 : RDF N-P-K @30:20:20 g m^{-2} , CD: critical difference, SE: standard error, NS: non-significant.

3.10. Interaction Effect of Seasons, Nutritional Modules, and Plants Raised from the Cuttings of Different Harvesting Flushes

As shown in Table 8, the highest concentration of carotenoids (2.70 mg g^{-1}) was found under $T_1 \times H_2 \times \text{S-I}$. However, the interaction did not show statistically significant effects on the levels of bacteria, fungus, and actinomycetes or the availability of essential nutrients like nitrogen (N), phosphorus (P), and potassium (K).

Table 8. Three-way table (season, treatment, and harvesting flush interactions).

	Seasons			
	Season-I		Season-II	
	T_1	T_2	T_1	T_2
	Total carotenoids (mg g^{-1})			
H_1	2.40	2.20	2.25	2.15
H_2	2.70	2.35	2.10	2.04
H_3	2.35	2.14	1.85	1.75

Table 8. Cont.

	Seasons			
	Season-I		Season-II	
	T ₁	T ₂	T ₁	T ₂
CD_{0.05}	0.02	SE		0.03
		Bacteria count ($\times 10^5$ cfu g ⁻¹)		
H ₁	20.33	15.60	16.01	11.28
H ₂	20.93	15.83	16.23	11.42
H ₃	20.97	15.93	16.30	11.55
CD_{0.05}	NS	SE		0.13
		Fungal count ($\times 10^3$ cfu g ⁻¹)		
H ₁	3.94	3.14	3.19	2.39
H ₂	4.20	3.40	3.45	2.65
H ₃	4.68	3.88	3.93	3.13
CD_{0.05}	NS	SE		0.09
		Actinomycetes count ($\times 10^3$ cfu g ⁻¹)		
H ₁	2.80	1.94	2.12	1.26
H ₂	3.20	2.29	2.48	1.63
H ₃	3.49	2.63	2.81	1.89
CD_{0.05}	NS	SE		0.06
		N kg ha ⁻¹		
H ₁	284.57	297.17	289.30	302.00
H ₂	279.37	291.97	294.57	307.27
H ₃	276.90	289.50	298.27	310.97
CD_{0.05}	NS	SE		0.66
		P kg ha ⁻¹		
H ₁	54.69	60.32	59.59	65.27
H ₂	54.67	58.60	58.30	64.24
H ₃	52.39	58.42	57.96	64.04
CD_{0.05}	NS	SE		
		P kg ha ⁻¹		
H ₁	402.52	415.12	410.72	423.32
H ₂	401.95	414.55	410.15	422.75
H ₃	404.82	417.42	413.02	425.62
CD_{0.05}	NS	SE		4.16

Kg ha⁻¹: kilogram per hectare, N: Nitrogen; P: Phosphorus; K: Potassium, cfu: colony-forming unit, S-I: summer, S-II: winter, H₁: first harvesting flushes, H₂: second harvesting flushes, H₃: third harvesting flushes T₁: Jeevamrit @ 2 liters m⁻², T₂: RDF N-P-K @30:20:20 g m⁻², CD: critical difference, SE: standard error, NS: non-significant.

3.11. Effect of Season Nutritional Modules and Plants Raised from the Cuttings of Different Harvesting Flushes

Cuttings planted during the summer season (Tables 9 and 10) resulted in higher uptake of N (17.21 kg ha⁻¹), P (9.32 kg ha⁻¹), and K (14.71 kg ha⁻¹) compared to the winter season. Soil collected during Season II (winter season) exhibited more organic carbon (1.01%) than Season I (0.87%). The higher temperature promotes microbial activity in the soil, resulting in nutrient release and making them more available to the plant.

Marigold plants treated with Jeevamrit exhibited enhanced nutrient uptake by plants, i.e., nitrogen (N) at 16.62 kg ha⁻¹, phosphorus (P) at 6.87 kg ha⁻¹, and potassium (K) at 13.19 kg ha⁻¹. Furthermore, the Jeevamrit application positively influenced soil health, as evidenced by the increased organic carbon content, reaching 1.00%. Interestingly, the soil analysis presented in Table 9 reveals that Jeevamrit-treated plots had lower pH (6.27) and electrical conductivity (0.41 dS m⁻¹) values compared to other treatments.

Table 8 illustrates that marigold plants demonstrated the highest uptake of essential nutrients during the first harvest (H₁). Specifically, nitrogen (N) uptake reached 15.92 kg ha⁻¹, phosphorus (P) uptake was 5.71 kg ha⁻¹, and potassium (K) uptake was recorded at 13.10 kg ha⁻¹. Conversely, the soil analysis presented in Table 9 indicates that the second

harvest (H₂) yielded soil with lower electrical conductivity (0.57 dS m⁻¹) and a higher percentage of organic carbon (0.96%).

Table 9. Effect on N, P, and K uptake.

	S-I	S-II	Mean	T ₁	T ₂	CD _{0.05}	CD	SE
N uptake (kg ha ⁻¹)								
H ₁	16.07	15.77	15.92	17.31	14.52	Seasons	0.27	0.09
H ₂	17.25	14.39	15.82	16.72	14.92	Nutritional modules	0.27	0.09
H ₃	18.33	11.43	14.88	15.84	13.93	Season × Nutritional modules	0.38	0.13
Mean	17.21	13.86	-			Harvesting flushes	0.33	0.11
T ₁	18.73	14.52	16.62			Season × Harvesting flushes	0.47	0.16
T ₂	15.70	13.21	14.46			Nutritional modules × Harvesting flushes	0.47	0.16
P uptake (kg ha ⁻¹)								
H ₁	6.72	4.71	5.71	6.64	4.79	Seasons	0.10	0.03
H ₂	7.12	4.19	5.66	6.45	4.86	Nutritional modules	0.10	0.03
H ₃	8.80	3.61	6.20	7.52	4.89	Season × Nutritional modules	0.14	0.05
Mean	9.32	5.77	-			Harvesting flushes	0.12	0.04
T ₁	9.32	4.42	6.87			Season × Harvesting flushes	0.17	0.06
T ₂	5.77	3.92	4.85			Nutritional modules × Harvesting flushes	0.02	0.06
K uptake (kg ha ⁻¹)								
H ₁	14.27	11.94	13.10	14.13	12.08	Seasons	0.26	0.09
H ₂	14.71	10.22	12.47	13.32	11.61	Nutritional modules	0.26	0.09
H ₃	15.15	7.54	11.34	12.11	10.58	Season × Nutritional modules	0.36	0.12
Mean	14.71	9.90	-			Harvesting flushes	0.31	0.11
T ₁	15.81	10.56	13.19			Season × Harvesting flushes	0.44	0.15
T ₂	13.61	9.23	11.42			Nutritional modules × Harvesting flushes	NS	0.15

Kg ha⁻¹: kilogram per hectare, N: Nitrogen; P: Phosphorus; K: Potassium, S-I: summer, S-II: winter, H₁: first harvesting flushes, H₂: second harvesting flushes, H₃: third harvesting flushes T₁: Jeevamrit @ 2 liters m⁻², T₂: RDF N-P-K @30:20:20 g m⁻², CD: critical difference, SE: standard error, NS: non-significant.

Table 10. Effect on pH, EC, and OC of soil.

	S-I	S-II	Mean	T ₁	T ₂	CD _{0.05}	CD	SE
pH								
H ₁	6.50	6.49	6.49	6.29	6.70	Seasons	NS	0.01
H ₂	6.45	6.48	6.46	6.26	6.67	Nutritional modules	0.04	0.01
H ₃	6.46	6.49	6.47	6.26	6.69	Season × Nutritional modules	NS	0.02
Mean	6.47	6.49	-			Harvesting flushes	NS	0.02
T ₁	6.28	6.26	6.27			Season × Harvesting flushes	NS	0.03
T ₂	6.66	6.71	6.68			Nutritional modules × Harvesting flushes	NS	0.04
EC (dS m ⁻¹)								
H ₁	0.65	0.65	0.64	0.44	0.84	Seasons	NS	0.02
H ₂	0.60	0.54	0.57	0.40	0.74	Nutritional modules	0.05	0.02
H ₃	0.61	0.54	0.58	0.41	0.75	Season × Nutritional modules	NS	0.02
Mean	0.62	0.57	-			Harvesting flushes	0.06	0.02
T ₁	0.43	0.40	0.41			Season × Harvesting flushes	NS	0.03
T ₂	0.81	0.74	0.78			Nutritional modules × Harvesting flushes	0.02	0.03
OC (%)								
H ₁	0.84	0.98	0.91	0.96	0.86	Seasons	0.02	0.01
H ₂	0.88	1.03	0.96	1.03	0.88	Nutritional modules	0.02	0.01
H ₃	0.88	1.02	0.95	1.01	0.89	Season × Nutritional modules	0.03	0.01
Mean	0.87	1.01	-			Harvesting flushes	0.03	0.01
T ₁	0.93	1.07	1.00			Season × Harvesting flushes	NS	0.01
T ₂	0.81	0.95	0.88			Nutritional modules × Harvesting flushes	NS	0.01

pH: negative logarithm of H⁺ (concentration power of hydrogen), dS m⁻¹: deciSiemens per meter, EC: electrical conductivity, OC: A quantifiable part of soil organic matter is called soil organic carbon, S-I: summer, S-II: winter, H₁: first harvesting flushes, H₂: second harvesting flushes, H₃: third harvesting flushes T₁: Jeevamrit @ 2 liters m⁻², T₂: RDF N-P-K @30:20:20 g m⁻², CD: critical difference, SE: standard error, NS: non-significant.

3.12. Interaction Effects of Seasons and Nutritional Modules

The interaction between season and nutritional modules (Tables 9 and 10) revealed that higher uptake of N (18.73 kg ha^{-1}), P (9.32 kg ha^{-1}), and K (15.81 kg ha^{-1}) was recorded under $T_1 \times S-I$. Furthermore, the organic carbon in the soil was observed to reach maximum values (0.93%) during the summer season when the soil was treated with Jeevamrit.

3.13. Interaction Effect of Seasons and Plants Raised from the Cuttings of Different Harvesting Flushes

The data in Table 8 reveal that the maximum uptake of N (18.33 kg ha^{-1}), P (8.80 kg ha^{-1}), and K (15.15 kg ha^{-1}) was observed from the third harvesting flush of cuttings (H_3) during the summer season. The interaction effect of nutritional modules and plants raised from the cuttings of different harvesting flushes on the uptake of K, pH, and OC was found to be non-significant.

3.14. Interaction Effect of Nutritional Modules and Plants Raised from the Cuttings of Different Harvesting Flushes

Table 8 also reveals that the maximum uptake of N (17.31 kg ha^{-1}) and P (6.64 kg ha^{-1}) was observed under $T_1 \times H_1$, whereas the lowest electrical conductivity (0.40%) of soil was observed in the soil samples collected from the plots treated with Jeevamrit (T_1) during the second harvesting flush (H_2).

3.15. Interaction Effect of Seasons, Nutritional Modules, and Plants Raised from the Cuttings of Different Harvesting Flushes

The data presented in Table 11 show the significant effect of seasons, nutritional modules, and harvesting flushes on N (19.45 kg ha^{-1}), P (11.09 kg ha^{-1}), and K (16.34 kg ha^{-1}) uptake by plants. The maximum N, P, and K values were observed in the plant samples collected from plots supplied with Jeevamrit (T_1) in plants produced from the third harvesting flush of cuttings (H_3) during the summer season (S-I).

Table 11. Three-way table (season, treatment, and harvesting flush interactions).

	Seasons			
	Season-I		Season-II	
	T_1	T_2	T_1	T_2
	N uptake (kg ha^{-1})			
H_1	18.00	14.13	16.02	14.91
H_2	18.72	15.77	14.72	14.06
H_3	19.45	17.21	12.22	10.64
$CD_{0.05}$	0.67			0.23
	P uptake (kg ha^{-1})			
H_1	8.39	5.04	4.89	4.54
H_2	8.47	5.77	4.42	3.96
H_3	11.09	6.51	3.96	3.26
$CD_{0.05}$	0.24			0.08
	K uptake (kg ha^{-1})			
H_1	15.23	13.30	13.02	10.86
H_2	15.84	13.57	10.80	9.64
H_3	16.34	13.96	7.87	7.20
$CD_{0.05}$	0.63			0.21
	pH of soil			
H_1	6.29	6.70	6.29	6.69
H_2	6.26	6.63	6.26	6.71
H_3	6.28	6.63	6.24	6.74

Table 11. Cont.

	Seasons			
	Season-I		Season-II	
	T ₁	T ₂	T ₁	T ₂
CD _{0.05}	NS	SE		0.04
	EC (dS m ⁻¹) of soil			
H ₁	0.44	0.85	0.44	0.83
H ₂	0.41	0.78	0.38	0.70
H ₃	0.43	0.78	0.38	0.71
CD _{0.05}	NS	SE		0.04
	OC (%)			
H ₁	0.89	0.79	1.03	0.93
H ₂	0.96	0.81	1.10	0.95
H ₃	0.94	0.82	1.08	0.96
CD _{0.05}	NS	SE		0.02

pH: negative logarithm of H⁺ (concentration power of hydrogen), dS m⁻¹: deciSiemens per meter, EC: electrical conductivity, OC: A quantifiable part of soil organic matter is called soil organic carbon, Kg ha⁻¹: kilogram per hectare, N: Nitrogen; P: Phosphorus; K: Potassium, S-I: summer, S-II: winter, H₁: first harvesting flushes, H₂: second harvesting flushes, H₃: third harvesting flushes T₁: Jeevamrit @ 2 liters m⁻², T₂: RDF N-P-K @30:20:20 g m⁻², CD: critical difference, SE: standard error, NS: non-significant.

4. Discussion

The data presented in Tables 3–5 show that the marketable flower yield and plant spread were equivalent in T₁ (Jeevamrit @ 2 L/m²) and RDF (recommended dose of fertilizer N–P–K @ 30:20:20 g m⁻²). The application of Jeevamrit in broccoli previously enhanced the soil properties, resulting in better nutrient absorption and more yield [27]. Chandrakala et al. [28] suggested that organic fertilizers might increase nutrient availability in soil during the early stages of plant growth and release native soil nutrients at later stages. They also revealed an increase in the number of fruits per plant due to the presence of IAA, GA₃, and other nutrients in fermented liquid manures, which improve the yield of plants. The foliar application of organic manures with soil application stimulates growth regulator production in plant cells and results in enhanced plant growth [29]. As reported by Boraiah et al. [30], the yield of plants greatly depends on the plant morphological traits, including plant height, leaf area index, branch number, and leaf density. In their study, Jeevamrit was found to increase the vitality of capsicum plants and thereby increase the translocation of nutrients between various parts of the plants. This finding is consistent with the results of the present study, underscoring the importance of morphology in determining yield.

Tables 4 and 5 also show that flowers harvested from plants that were treated with Jeevamrit had a longer shelf life compared to those treated with chemical fertilizers. Natural farming systems increase plant immunity and disease resistance, resulting in 50% fewer mycotoxins in crops and resulting in increased shelf life [31].

In the present study on marigolds, we found that the application of Jeevamrit resulted in better foliage with dark green leaves, resulting in higher chlorophyll in plants (Tables 3 and 5). The application of Jeevamrit enhances photosynthate production and their translocation to vegetative parts of plants [32]. Similarly, a study on sweet basil under NaCl-induced salt stress concluded that plants supplied with Jeevamrit displayed increases in chlorophyll ‘a’, ‘b’, and total carotenoids. These findings suggest that the organic liquid formulation, i.e., Jeevamrit is effective in promoting optimum plant growth and development by increasing photosynthesis in plants [33].

In Table 4, higher values for plant height, plant spread, marketable flowers per square meter, flower size, yield of marketable flowers per square meter, and chlorophyll content are observed in summer plantings when supplied with Jeevamrit (Tables 3 and 5). This can be attributed to increased vegetative growth in summer-planted crops, likely due to higher photosynthetic rates and carbon assimilation during the summer [34]. Our findings demonstrate a significantly higher microbial load in the Jeevamrit field compared to the

chemical fertilizers, corroborating the positive impact of Jeevamrit application on soil microbiology. This aligns with previous studies where organic manure, similar in composition to Jeevamrit, exhibited significant improvements in the soil's physical and chemical properties, surpassing the efficacy of NPK treatments. Furthermore, the application of Jeevamrit enhanced the soil's organic carbon content, contributing to its overall chemical health. Conversely, the field characterized by chemical fertilizer usage exhibited a diminished microbial load, indicating compromised soil biology and properties [35]. Saharan et al. [36] also reported that cow dung manure increases the soil organic matter significantly when compared with other manures and improves the soil chemical properties, i.e., N, P, K, Ca, and Mg.

In Tables 6 and 8, the total carotenoids are higher in flowers harvested from plants treated with FYM and Jeevamrit than those treated with chemical fertilizers. This is due to the improved nutritional status of plants; more specifically, the higher availability of nitrogen is a crucial part of carotenoids, chlorophyll molecules, amino acids, nucleic acids, phosphatides, alkaloids, enzymes, hormones, and vitamins [37] reported by the plants under Jeevamrit treatment. More carotenoid content was observed during the summer season due to more sunlight and higher temperatures, which enhance biosynthesis and result in increasing the carotenoid concentration. The present study found support from the findings of de Azevedo [38] in Kale.

Microbes present in the rhizosphere produce various metabolites, bioactive compounds, enzymes, and phytohormones (i.e., cellulase, catalase, siderophores, and indole acetic acid), which not only enhance the microbial community but also promote plant growth and improve soil fertility [39,40]. Additionally, the secretion of enzymes, antibiotics, and various organic compounds suppresses phytopathogens and neutralizes toxic compounds and microbes [40]. Diverse and rich microbes are crucial for maintaining soil bioavailability. Our study shows that Jeevamrit helps to improve the abundance and diversity of soil microflora (Table 5). The bacteria and fungi identified from the natural farming field exhibit strong plant growth-promoting properties, indicating their role in enhancing soil chemistry and biology. Our study also suggests that the plants supplied with organic amendments make nutrients more available, resulting in improved nutrient uptake by plants [41].

The significantly highest available potassium (K) under T₂ may be due to the acidifying action of FYM on applied K during decomposition, making more K available by reducing K fixation (Table 7). The higher available K in the soil under T₂ may be due to the fact that, with time, the K held in the interlayer spaces of minerals becomes mobile through the decomposition of FYM. These results are consistent with the findings of [42] in potato and jute.

Natural farming has been reported to enhance the soil's microbial, physical, and chemical properties [43], supporting our study. Hartmann et al. [44] demonstrated that organic manure-based products not only boost bacterial diversity but also enhance nutrient uptake by plants. Proteobacteria and actinobacteria play crucial roles in nitrogen fixation, carbon recycling, disease and pathogen suppression, soil remediation, phosphate dissolution, and many other biological activities that directly or indirectly improve plant growth [45]. Metagenomic analysis of ZBNF soil conducted by Saharan et al. [46] revealed a microbial community dominated by Proteobacteria, followed by Actinobacteria, Firmicutes, and Cyanobacteria. This diverse community plays a crucial role in soil health and plant growth. Proteobacteria, adept at utilizing excess moisture and nutrients, play a key role in nutrient cycling [47–50] while exhibiting resilience to agricultural pressure [51]. Actinobacteria, on the other hand, help in nitrogen fixation and organic matter decomposition [52]. They further contribute to plant health by producing beneficial metabolites like enzymes and antibiotics that suppress pathogens and stimulate growth [53]. Meanwhile, Firmicutes, with their chitinolytic bacteria, offer a robust defense against fungal pathogens. Finally, Cyanobacteria round out this ecological team by exhibiting plant growth-promoting prop-

erties and acting as biocontrol agents against phytopathogens through their production of various enzymes [54].

At the genus level, *Streptomyces*, *Bacillus*, *Pseudomonas*, and *Rhizobium* dominated the ZBNF soil. These genera are known for their significant roles in the nitrogen cycle, organic matter degradation, carbon cycling, and shaping the soil microbial community [43].

The positive impact of organic manures on soil properties, including microbial, physical, and chemical aspects, is well documented [55]. Hartman et al. [56] specifically demonstrated that organic manure-based products not only boost bacterial populations but also enhance soil nutrient content.

Our study further strengthens these findings by observing the maximum microbial diversity under Jeevamrit treatment. This aligns with the known roles of Proteobacteria and Actinobacteria in nitrogen fixation, carbon recycling, disease suppression, soil remediation, phosphate dissolution, and other activities that directly or indirectly enhance plant growth [45,57,58]. The application of Jeevamrit, rich in beneficial microbes, demonstrably enhances bacterial abundance and promotes a thriving soil ecosystem. This diverse bacterial community, with its multifaceted physiological functions, plays a pivotal role in stabilizing the soil's physical, chemical, and biological properties.

A study by Saharan et al. revealed that the metabolism cluster dominated the functional annotation of microbial reads, surpassing information storage and processing, cellular processing, and signaling clusters. Notably, the increased relative abundance of metabolism-related genes, such as hydrolases, isomerases, and ligases, suggests their potential roles in facilitating decomposition, growth, pathogen suppression, and nutrient recycling, ultimately contributing to improved soil fertility [10].

The rhizosphere and soil microbes exhibited remarkable contributions by producing a diverse array of metabolites, bioactive compounds, enzymes, and phytohormones, including cellulase, catalase, siderophores, and indole acetic acid. These products not only reshaped the surrounding microbial community but also played a crucial role in promoting plant growth, enhancing soil fertility, and reducing the heavy metals in soil and plants. Furthermore, the use of organic fertilizers led to a significant reduction in heavy metals such as cadmium (32.5%), chromium (50.25%), lead (44.50%), and manganese (42.25%) by plants and improved the growth of radish, food quality, and reduced human health risk associated with heavy metals [40]. In conclusion, the Jeevamrit application significantly reshaped the soil microbial community, fostering the proliferation of bacterial and fungal groups known for their direct and indirect contributions to both soil health and plant growth.

The increase in available nitrogen (N) in the FYM-amended plot with RDF (Table 7) can be attributed to the accumulation of higher organic N due to the addition of more organic carbon to the soil [59]. This might be due to the residual effects of fertilizers and manures and the increase in inorganic N fractions in the soil due to biochemical degradation and mineralization. The addition of FYM with inorganic fertilizers under T₂ would have acidified the soil by releasing H⁺ ions, thereby increasing phosphorus availability [60].

From Tables 9 and 11, the highest NPK content in the leaves of marigold plants with the incorporation of organic manure and Jeevamrit may be due to the proper nutrition of the crop and the enhanced efficiency of organic amendments. These findings align with those of [61] in onion. Higher temperatures extend the growing season of plants and enhance mineralization, resulting in an increase in available nutrients to plants and, thus, an increase in the uptake [62]. Higher temperatures promote microbial activity, consequently releasing nutrients, making them more available, and decreasing nutrient restriction [63,64].

The increased levels of organic carbon (Table 10) might be attributed to a decrease in bulk density, likely due to the application of Jeevamrit [65]. Similar results were reported by Sharma and Chadak, who found that incorporating Jeevamrit and farmyard manure not only boosted the soil's nutritional content but also influenced the composition of the microbial community and enhanced the soil structure, water-holding capacity, and soil organic carbon [66].

5. Conclusions

In summary, it can be concluded that the cuttings planted during the summer season enhanced plant height (25.75%), plant spread (18.62%), chlorophyll content (28.17%), yield of marketable flower per square meter (21.38%), and flower size (46.46%). Nutritional module T₁, i.e., Jeevamrit @ 2 liters m⁻², enhanced the uptake of N (13.00%), P (29.40%), and K (13.42%), resulting in a higher yield of marketable flower per square meter (3.97%) compared to the recommended dose of fertilizers. The plants produced from the first flush of cuttings taken from the mother block effectively increased the marketable flower yield per square meter (7.27 kg). This study demonstrates the potential of Jeevamrit to replace chemical fertilizers in marigold cultivation, underscoring its significance in sustainable agriculture. Further research should be directed toward the extension of this study to other crops and areas, especially in the mid-hill agro-climatic zone of Himachal Pradesh. Extending the research on Jeevamrit to other areas or crops will assist in establishing its effectiveness and use in agriculture. Further studies can also investigate the optimal formulation and application methods of Jeevamrit to maximize its impact on crop yields and environmental sustainability.

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