Natural Farming: A Sustainable Alternative to Chemical Fertilizers for Marigold (*Tagetes erecta* cv. Siracole) Cultivation under Mid-Hills of Himalayan Region

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Article

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Abstract: Using desi-cow waste products like Jeevamrit, natural farming is widespread among farmers for improving soil biology and productivity. Jeevamrit enhances soil chemical and microbiological properties without needing large quantities 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. In this study mother block of marigold was raised for both summer and winter seasons. The cuttings were harvested from the mother block and then kept for rooting. 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/m^2). Soil supplied with Jeevamrit enhanced bacteria (26.33%), fungi (18.92%), and actinomycetes (31.21%) populations compared over the recommended dose of fertilizers (RDF) (i.e., N:P: K @ 30:20:20 g m^{-2}). Jeevamrit-treated plants have marketable flower yield per square meter (3.98 %) and shelf life (9.93 %) compared to RDF. The study concludes that Jeevamrit @ 2 liter m^{-2} is a sustainable and effective alternative to traditional fertilizers for enhancing marigold production in the mid-hills of the Himalayan region, where natural farming is already accepted.

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

1. Introduction

Marigold (*Tagetes erecta*) flower cultivation is getting increasingly popular among farmers. Marigold, belonging to the family Asteraceae, is an important commercial loose flower grown for its highly decorative and long lasting flowers. The genus *Tagetes* consists of approximately 40–50 species and belongs to family Asteraceae (Composite). *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, its flowers 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 are also used in drugs and pharmaceutical products, processed food, confectionery and in the poultry industry; one of the most important effects of the plant is their use as very valuable intercrop for controlling plant parasitic nematodes and insecticidal activity [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 tranquillizers and anthelmintic [4].

In marigold crop, 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

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marigold cultivar, originally identified in Eastern India, has proven to be highly productive and holds a significant market demand, resulting in higher prices for farmers. The propagation of 'Siracole' primarily relies on herbaceous stem cuttings, which ensure the production of true-to-type plants. This method allows for efficient and effective cultivation of this valuable marigold variety. In the context of scientific research, it is crucial to explore the factors contributing to the success of 'Siracole' and to develop sustainable cultivation practices that optimize its potential for agricultural productivity and economic benefits. This cultivar is used for cultural and social occasions as loose flowers or as garlands [5].

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 by intensive use of synthetic fertilizer and pesticides has led to land degradation and environmental pollution in several agro ecosystems which has had an adverse effect 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 strengthening the plants resistance mechanism and increases crop productivity [9–11]. Among natural farming formulations, Jeevamrit is recognized as pillar of natural farming system [12]. Jeevamrit application in the soil has the efficiency to improve soil fertility and plant development. The components used to prepare liquid organic fermented manures like Jeevamrit are easily available in farm viz. cow dung, urine, legume flour and jaggery. There is presence of essential macronutrients, micro nutrients, many vitamins, essential amino acids and beneficial microorganisms in these preparations [13,14] which helps in increasing yield.

The implementation of organic amendments like Jeevamrit in marigold cultivation is crucial due to its medicinal and culinary uses, as it helps minimize chemical residues within the plant. This eco-friendly practice promotes environmentally sustainable agriculture by reducing chemical inputs, fostering a balanced ecosystem and ultimately preserving natural resources while enhancing overall agricultural sustainability. Our research aims to explore the effectiveness of Jeevamrit in marigold cultivation, focusing on its impact on reducing chemical residues and contributing to a more sustainable 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 summer and winter seasons of 2023–24. The Experimental farm of the department is located in the hilly regions of Western Himalayas at an altitude of 1276 m above mean sea level having latitude of 30° 52′02″ N and longitude 70°11′30″E. About 75% of the region's average rainfall (1115 mm) occurs during the monsoon, which runs from mid-June to mid-September. Fig. 1 displays the meteorological data collected during the experiment. The experiment was laid out in RBD factorial design comprising two fertilizer treatments (T_1: Jeevamrit @ 2 liter m^{-2} at 15 days interval and T_2: RDF (recommended doses of fertilizers) N:P:K @ 30:20:20 g m^{-2}), three harvesting flushes (H_1, H_2 and H_3) and two seasons (S-I: summer and S-II: winter). Before the start of the experiment, chemical characteristics of soil were assessed (Table 1). Farm yard manure (FYM) @ 5 kg m^{-2} was used in both the treatments at the time of field preparation. RDF (recommend does of fertilizers) comprising of fertilizers i.e., urea, single super phosphate (SSP) and muriate of potash (MOP) in desired quantities were incorporated to the soil at the time of field preparation in individual plots and split dosage of urea was applied; first half at the time of field preparation and the other half in two splits, first one month of transplanting and remaining after one month of first application (late vegetative stage/early flowering). The first application of Jeevamrit was started after 30 days of planting.

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

Table 1. Initial soil characteristics.

Particular	Season-I	Season-II	References
pH	7.86	6.92	[15]
EC	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]

Preparation of Jeevamrit

Jeevamrit was prepared by mixing 10 kg cow dung, 10 liter cow urine, 2 kg black jaggery, 2 kg pulse (blackchickpeas) flour and a handful of soil (100 g) as microbial inoculum, and the total volume was made up to 200 liters by adding water and stir 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 liter m^{-2} was administered to the soil at 15 days interval. The first treatment was made on the 20th day after planting of cuttings, and the final two applications was made at fifteen days interval after the first treatment. The filtrate was applied in pure form in 1 m^2 plots. The ingredients are shown in Figure 1.

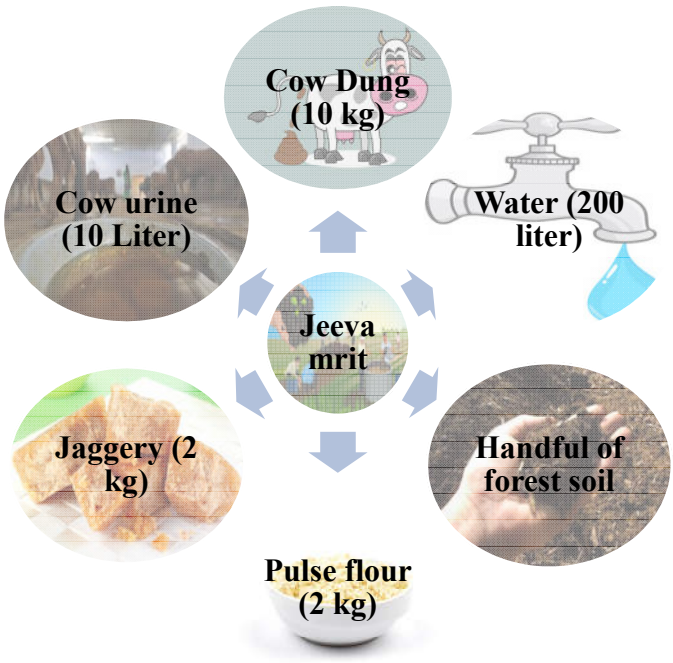

Figure 1. Elements used for preparation of Jeevamrit.

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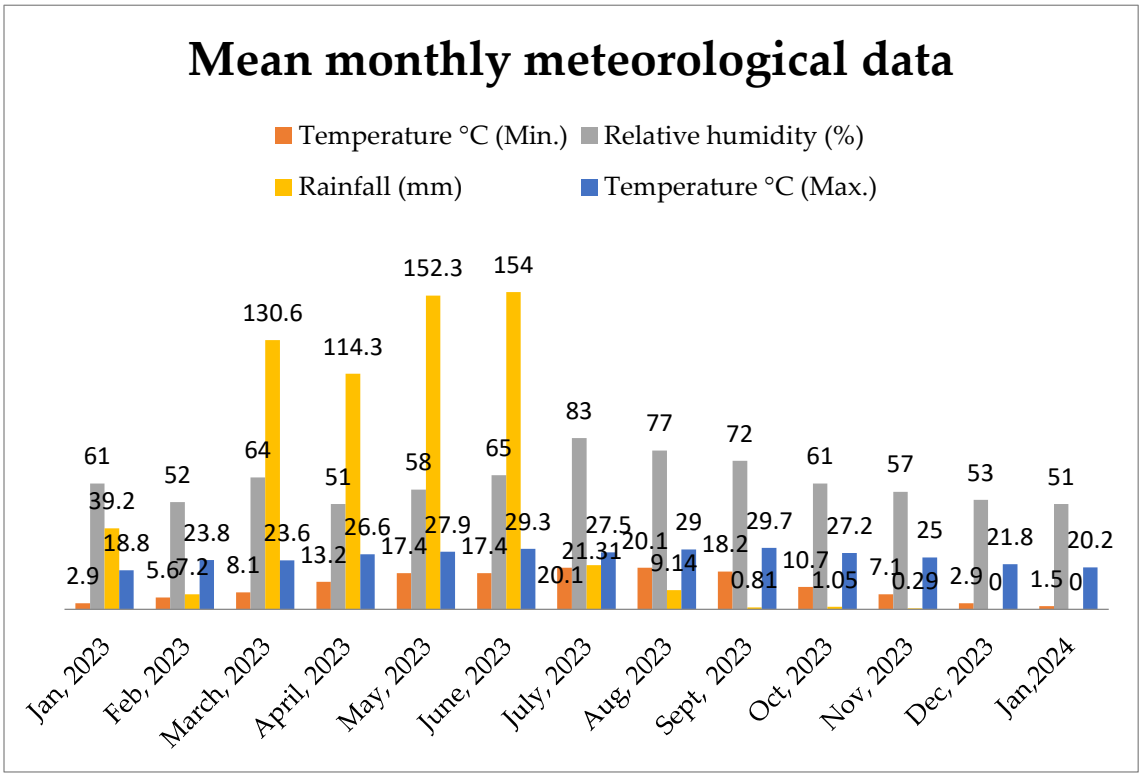

Figure 2. Metrological data during the study period.

Vegetative and Flowering Attributes

For every replication and treatment, nine plants were randomly selected and all the vegetative parameters (plant height and spread) and flowering parameters (days for bud formation, number of flowers per plant and duration of flowering) were noted from each harvesting flushes (H_1-H_3) at proper stage of data collection. At each replication and treatment, nine plants were randomly chosen, and all the vegetative and flowering characters were measured at each harvesting flush from H_1 to H_3. Plant attributes that were determined included; height and spread, days to bud initiation, number of flowers produced per plant and days to flowering.

Sample Collection and Measurement of Soil Chemical Properties

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

Soil Chemical Properties

Soil pH and EC were estimated using a conductivity metre [15]. Organic carbon content was estimated using the Walkley-Black method [16]. To obtain actual percentage of organic carbon by Walkley and Black method, organic carbon should be multiplied by a factor 100/77 i.e., 1.3 (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 for available K was determined using the standard neutral ammonium acetate method [19].

Microbiological Properties of Soil

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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 bacterial count, potato dextrose agar medium (PDA) for fungal count, and Kenknight and Munaier's medium (KNM) for 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 done using the soil fumigation extraction method [21]:

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

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

Plant N, P and K

Plant N, P and K was assessed by [24].

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

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

Chlorophyll Content

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

$$\text{Total chlorophyll (mg g}^{-1}) = \frac{\mathbf{20.2}A645\mathbf{+8.02}A663}{a\ x\ \mathbf{1000}\ x\ w}\mathbf{x\ V}$$

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

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:

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

Statistical Analysis

Field experiment was conducted having three replications with nine plants in each replications and was laid out in Randomized Complete Block Design (RBD). The analysis of variance using three-way ANOVA was conducted between treatments, growing seasons and planting dates. The data recorded during the experiment was statistically analyzed by using the Microsoft-Excel and SPSS.

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), minimum number of days for flowering (53.67 days), minimum days taken for flowering (53.67 days), size of flower (11.00 cm) and marketable flower yield per square meter (8.00 kg) was obtained during summer season (S-I) as compared to winter season (Tables 2 and 3). Whereas, the shelf life of flowers

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was observed more (5.76 days) during winter season due to low temperature during winters reduce ethylene production and slow down the senescence process.

Table 2. 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)								
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, H_1: first harvesting flushes, H_2: second harvesting flushes, H_3: third harvesting flushes T_1: Jeevamrit @ 2 liter m^{-2}, T_2: RDF N:P:K @30:20:20 g m^{-2}, CD: critical difference, SE: standard error, NS: no-significant.

Table 3. 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^{-1} (kg)								
H_1	8.11	6.42	**7.27**	7.41	7.13	**Seasons**	0.07	0.02

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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, H_1: first harvesting flushes, H_2: second harvesting flushes, H_3: third harvesting flushes T_1: Jeevamrit @ 2 liter m^{-2}, T_2: RDF N:P:K @30:20:20 g m^{-2}, CD: critical difference, SE: standard error, NS: non-significant.

Nutritional modules significantly promoted the chlorophyll content (2.28 mg/g), yield of marketable flower per square meter (7.29 kg) and shelf life (5.54 days) which was observed more from the plants which were supplied with Jeevamrit. The optimum nutrients are required for plant growth and development. 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 first harvesting flush (H_1) exhibited maximum plant height (109.65 cm), chlorophyll content (2.41 mg/g), size of flower (8.86 cm), marketable flower yield per square meter (7.27 kg) and took minimum number of days for flowering (58.54 days), while the effect of harvesting flushes on plant spread was 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 H_2 (i.e., plants raised from second harvesting flush) and planted during summer season resulted into maximum plant height (124.88 cm), size of flower (11.17 cm) and minimum number of days taken for flowering (53.18 days), whereas chlorophyll content of leaves (2.65 mg/g) and marketable flower yield per square meter (8.11 kg) was observed maximum from first harvesting flush of cuttings (H_1) (Tables 2 and 3). The maximum shelf life (6.12 days) was recorded during winter season (S-I) from the cuttings of third flush (H_3) and the interaction effect of seasons and harvesting flushes on plant spread and marketable flower yield per square meter was non significant.

3.3. Interaction Effects of Seasons and Nutritional Modules

The interactions between seasons and nutritional modules indicates that the minimum number of days taken for flowering (53.46 days) and maximum marketable flower yield per square meter (8.19 kg) was recorded in nutritional modules T_1 during 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

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The interaction between nutritional modules and harvesting flushes revealed that maximum chlorophyll content (2.55 mg/g) was observed from the plants fed with Jeevamrit (T_1) and the plants produced from first harvesting flush (H_1); whereas, 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

Data presented in Table 4 shows that the maximum chlorophyll content (2.68 mg/g) from the leaves of marigold was obtained during summer season (S-I), from the plants supplied with Jeevamrit (T_1) from first harvesting flush of cuttings (H_1); whereas, the flowers size was observed maximum (11.20 cm) from second harvesting flush (H_2).

Table 4. Three way table (seasons, treatments and harvesting flushes 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			
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 m^{-1} (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**

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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 liter m^{-2}, T_2: RDF N:P:K @ 30:20:20 g m^{-2}, CD: critical difference, SE: standard error, NS: non significant.

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

Summer season enhanced the total carotenoids of flower (2.36 mg/g) and viable bacteria (18.27 × 10^5 cfu g^{-1}), fungal (3.87 × 10^3 cfu g^{-1}), actinomycetes (2.73 × 10^3 cfu g^{-1}) in soil (Table 5); whereas, available N (300.39 kg/ha), P (61.57 kg/ha) and K (417.60 kg/ha) was obtained maximum during winter season (Table 6). Low temperatures during winter reduce plant metabolism, which in turn decreases nutrient uptake. This leads to a higher availability of nutrients such as nitrogen (N), phosphorus (P), and potassium (K) in the soil.

Table 5. Effect on total carotenoids, viable bacterial, fungal 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

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H3	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
T1	3.16	2.47	**2.82**			**Season × Harvesting flushes**	NS	0.05
T2	2.29	1.59	**1.94**			**Nutritional modules × Harvesting flushes**	NS	0.05

cfu: colonies 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 liter m^{-2}, T2: RDF N:P:K @30:20:20 g m^{-2}, CD: critical difference, SE: standard error, NS: non significant.

Table 6. Effect on available N, P and K of soil.

	S-I	S-II	Mean	T1	T2	Interactions	CD	SE
					N kg ha^{-1}			
H1	290.87	295.65	**293.26**	286.93	299.58	**Seasons**	0.82	0.28
H2	285.67	300.92	**293.29**	286.97	299.62	**Nutritional modules**	0.82	0.28
H3	283.20	304.62	**293.91**	287.58	300.23	**Season × Nutritional modules**	1.16	0.40
Mean	**286.58**	**300.39**	**-**			**Harvesting flushes**	NS	0.34
T1	280.28	294.04	**287.16**			**Season × Harvesting flushes**	1.42	0.49
T2	292.88	306.74	**299.81**			**Nutritional modules × Harvesting flushes**	NS	0.49
					P kg ha^{-1}			
H1	57.51	62.43	**59.97**	57.14	62.80	**Seasons**	0.79	0.27
H2	56.64	61.27	**58.95**	56.48	61.42	**Nutritional modules**	0.79	0.27
H3	55.41	61.00	**58.20**	55.17	61.23	**Season × Nutritional modules**	NS	0.38
Mean	**56.52**	**61.57**	**-**			**Harvesting flushes**	0.97	0.33
T1	53.92	58.61	**56.27**			**Season × Harvesting flushes**	NS	0.47
T2	59.11	64.52	**61.82**			**Nutritional modules × Harvesting flushes**	NS	0.47
					K kg ha^{-1}			
H1	408.82	417.02	**412.92**	406.62	419.22	**Seasons**	5.00	1.70
H2	408.25	416.45	**412.35**	406.05	418.65	**Nutritional modules**	5.00	1.70
H3	411.12	419.32	**415.22**	408.92	421.52	**Season × Nutritional modules**	7.05	2.40
Mean	**409.40**	**417.60**	-			**Harvesting flushes**	NS	2.08
T1	403.10	411.30	**407.20**			**Season × Harvesting flushes**	NS	2.95
T2	415.70	423.90	**419.80**			**Nutritional modules × Harvesting flushes**	NS	2.95

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 liter 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), P (61.82 kg/ha) and K (419.80 kg/ha) in soil was reported higher under T2 (Table 6). Application of Jeevamrit enhanced the viable bacterial (18.46 × 10^5 cfu g^{-1}), fungal (3.90 x 10^3 cfu g^{-1}) and actinomycetes (2.82 x 10^3 cfu g^{-1}) count (Table 5).

Soil collected from the plants, raised from cuttings of third harvested flush (H3) tends to have more viable bacterial (16.19 × 10^5 cfu g^{-1}), fungal (3.90 × 10^3 cfu g^{-1}) and actinomycetes (2.70 × 10^3 cfu

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g^{-1}) count. In contrast, minimum fungal count (3.17×10^3 cfu g^{-1}) was observed in H_1. Available phosphorus (59.97 kg ha^{-1}) was noted maximum under H_1; 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 H_2 (i.e., second harvesting flush) enhanced total carotenoids in flowers (2.53 mg/g), (Table 5). The significant effect on available nitrogen was observed which was maximum under H_3 during winter season; whereas, the interaction effect was non significant on bacteria, fungus, actinomycetes, available P and K.

3.8. Interaction Effects of Seasons and Nutritional Modules

Total carotenoid content in flowers (2.48 mg/g) was significantly enhanced by application of Jeevamrit during summer season, while available nitrogen (306.74 kg ha^{-1}) and potassium (423.90 kg ha^{-1}) was observed maximum under T_2 during 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, actinomycetes count (Table 5) and available N, P, K (Table 6) was non significant.

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

The more carotenoid content (2.70) was observed (Table 7) in the flowers from those plants which were treated with Jeevamrit at second harvesting flush during summer ($T_1 \times H_2 \times$ S-I). Non significant results were obtained on bacteria, fungus, actinomycetes and, available N, P, K.

Table 7. Three way table (seasons, treatments and harvesting flushes 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
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}			

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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: colonies forming uni, 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 liter m^{-2}, T_2: 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 summer season (Tables 8 and 9) resulted into more uptake of N (17.21 kg ha $^{-1}$), P (9.32 kg ha $^{-1}$) and K (14.71 kg ha $^{-1}$) over winter season. Soil collected during Season-II (winter season) exhibited more organic carbon (1.01 %) over Season-II (0.87) i.e., summer season. As the higher temperature promotes microbial activity in soil resulting into release nutrients and make them in more available form to the plant.

Table 8. 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

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H3	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
T1	15.81	10.56	**13.19**			**Season × Harvesting flushes**	0.44	0.15
T2	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 liter m^{-2}, T2: RDF N:P:K @30:20:20 g m^{-2}, CD: critical difference, SE: standard error, NS: non significant.

Table 9. effect on pH, EC and OC of soil.

	S-I	S-II	Mean	T1	T2	CD 0.05	CD	SE
					pH			
H1	6.50	6.49	**6.49**	6.29	6.70	**Seasons**	NS	0.01
H2	6.45	6.48	**6.46**	6.26	6.67	**Nutritional modules**	0.04	0.01
H3	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
T1	6.28	6.26	**6.27**			**Season × Harvesting flushes**	NS	0.03
T2	6.66	6.71	**6.68**			**Nutritional modules × Harvesting flushes**	NS	0.04
					EC (dS m^{-1})			
H1	0.65	0.65	**0.64**	0.44	0.84	**Seasons**	NS	0.02
H2	0.60	0.54	**0.57**	0.40	0.74	**Nutritional modules**	0.05	0.02
H3	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
T1	0.43	0.40	**0.41**			**Season × Harvesting flushes**	NS	0.03
T2	0.81	0.74	**0.78**			**Nutritional modules × Harvesting flushes**	0.02	0.03
					OC (%)			
H1	0.84	0.98	**0.91**	0.96	0.86	**Seasons**	0.02	0.01
H2	0.88	1.03	**0.96**	1.03	0.88	**Nutritional modules**	0.02	0.01
H3	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
T1	0.93	1.07	**1.00**			**Season × Harvesting flushes**	NS	0.01
T2	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 liter m^{-2}, T2: RDF N:P:K @30:20:20 g m^{-2}, CD: critical difference, SE: standard error, NS: non significant.

Plants of marigold drenched with Jeevamrit enhanced the uptake of N (16.62 kg ha $^{-1}$), P (6.87 kg ha $^{-1}$) and K (13.19 kg ha $^{-1}$) similar effect of Jeevamrit was observed on organic carbon (1.00 %) in soil. The minimum values of pH (6.27) and EC (0.41 dS m^{-2}) was observed (Table 9) from the soil samples collected from the plots treated with Jeevamrit.

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Higher uptake (Table 8) of N (15.92 kg ha $^{-1}$), P (5.71 kg ha $^{-1}$) and K (13.10 kg ha $^{-1}$) by plant was noted under H_1; whereas, lesser electrical conductivity (0.57 dS m^{-1}) and more organic carbon (0.96 %) from the soil samples was observed under H_2 (Table 9).

3.12. Interaction Effects of Seasons and Nutritional Modules

The interaction between season and nutritional modules (Table 8 and Table 9) revealed that the maximum N uptake (18.73 kg ha $^{-1}$), P (9.32 kg ha $^{-1}$), K (15.81 kg ha $^{-1}$) and organic carbon (0.93 %) in soil samples was observed when plants were drenched with Jeevamrit (T_1) during summer season (S-I).

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

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

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

From Table 8 the maximum uptake of N (17.31 kg ha $^{-1}$) and P (6.64 kg ha $^{-1}$) was observed in interaction $T_1 \times H_1$ whereas, the minimum electrical conductivity (0.40 %) of soil was observed from the samples collected from the plots which were supplied with Jeevamrit (T_1) during second harvesting flush (H_2).

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

Data presented in Table 10 shows 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}) content of plant samples. The maximum N, P and K was observed from the plant samples collected from the plots supplied with Jeevamrit (T_1), plants produced from third harvesting flush of cuttings (H_3), during summer season (S-I).

Table 10. Three way table (seasons, treatments and harvesting flushes 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**		**SE**	**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**		**SE**	**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**		**SE**	**0.21**

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		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
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, H_1: first harvesting flushes, H_2: second harvesting flushes, H_3: third harvesting flushes T_1: Jeevamrit @ 2 liter m^{-2}, T_2: RDF N:P:K @30:20:20 g m^{-2}, CD: critical difference, SE: standard error, NS: non significant.

4. Discussion

Data presented in Tables 2–4 shows that the marketable flower yield, plant spread and plant spread were equivalent in T_1 (Jeevamrit @ 2 L/m^2) and RDF (recommended dose of fertilizer N:P:K @ 30:20:20 g/m^2) [27]. Observed that the application of organic manures in broccoli enhanced the soil properties, resulting into better nutrient absorption and more yield. Chandrakala et al. (2011) [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 attributed the increase the number of fruits per plant due to the presence of IAA, GA_3 and other nutrients in fermented liquid manures like Jeevamrit, which improve the yield of plant [29]. Revealed that foliar application of organic manures with soil application stimulates growth regulator production in plant cells and resulted into enhanced plant growth. According to [30], yield depends on the morphology of the plant; including vegetative characteristics i.e., plant height, leaf area index, number of branches and leaves. They reported increased vigor in capsicum with the use of Jeevamrit, resulting in better distribution of nutrients to different plant parts, which ultimately increased yield.

Table 3 and Table 4 also shows that flowers harvested from plants which were treated with Jeevamrit had a longer shelf life compared to those treated with chemical fertilizers. Natural farming systems increases plant immunity and disease resistance, resulting in 50 % fewer mycotoxins in crops resulting into more shelf life [31].

In the present study on the marigold crop found that the application of Jeevamrit resulted in better foliage with dark green leaves, indicating higher chlorophyll content (Table 2 and Table 4). Application of Jeevamrit enhances photosynthate production and their translocation to vegetative buds and fruits [32]. Similarly, a study on sweet basil under NaCl-induced salt stress they concluded that plants supplied with Jeevamrit increases the 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 [33].

In Table 4, more plant height, plant spread, marketable flowers per square meter, flower size, and yield of marketable flowers per square meter are observed in summer plantings. More chlorophyll content was also observed in summer planted crop when supplied with Jeevamrit (Tables 2 and 4). 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]. Nitrogen is crucial for the biosynthesis of proteins, chlorophyll and other organic compounds of plants, and it is a

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primary component of the energy molecules ATP and ADP [35]. Phosphorus affects photosynthesis, synthesis of protein and nucleic acid, membrane transport and cytoplasmic streaming. Potassium aids in osmotic and ionic regulation and activates enzymes involved in protein and carbohydrate metabolism. Similar results were reported by [36] on growth characteristics of soybean.

In Tables 5 and 7, the total carotenoids were higher in flowers from plants treated with amendments from animal wastes (FYM + Jeevamrit) over those treated with chemical fertilizers. This is due to improved nutritional status of plant, more specifically the higher availability of nitrogen is an crucial part of carotenoids, chlorophyll molecules, amino acids, nucleic acids, phosphatides, alkaloids, enzymes, hormones and vitamins [37], experienced by the plants in the Jeevamrit treatment. More carotenoid content was observed during summer season due to the more sunlight and high temperature which enhances the biosynthesis resulting into increasing the carotenoid concentrations. Present study got support from the findings of [38].

Microbes present in the rhizosphere produce various metabolites, bioactive compounds, enzymes and phytohormones (i.e., cellulase, catalase, siderophores, indole acetic acid) which not only enhance the microbial community but also promote the 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 suggest that the plants supplied with organic amendments makes nutrients in more available form resulting into improved nutrient uptake of plant by plants [41].

The significantly highest available potassium (K) under T_2 may be due to the acidifying action of FYM on applied K during decomposition, making more K available by reducing K fixation (Table 6). The higher available K content in the soil under T_2 may be due to the fact that, with time, the K held in the interlayer spaces of minerals becomes mobile through the decomposition of applied FYM. Similar results were observed by [42] in potato and jute cultivation.

Natural farming has been reported to enhance soil microbial, physical and chemical properties [43–47], supporting our study [48]. Demonstrated that organic manure based products not only boost bacterial populations but also enhance nutrient uptake by plant. 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 [49–54]. Our findings confirm that Jeevamrit application enhances bacterial abundance and boosts the soil ecosystem.

In Table 6, the increase in available nitrogen (N) in the FYM amended plot (T_2) can be attributed to the accumulation of higher organic N due to the addition of more organic carbon to the soil [55]. This might be due to the residual effects of fertilizers and manures and the increase of inorganic N fractions in the soil due to biochemical degradation and mineralization. The addition of FYM with inorganic fertilizers under T_2 would have acidified the soil by releasing H^+ ions, thereby increasing phosphorus (P) availability [56].

From Tables 8 and 10, the highest NPK content in the leaves of marigold plant 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 [57] in onion.

Higher temperature extends the growing season of plant and enhances mineralization resulting into increase available nutrients to plants and increase the uptake [58]. Higher temperature promotes microbial activity in consequently release nutrients and make them more available and decrease nutrient restriction [59,60].

The increased levels of organic carbon (Table 9) might be attributed to a decrease in bulk density, likely due to the application of Jeevamrit [61]. Similar results were reported by Sharma & 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, enhanced soil structure, water-holding capacity and soil organic carbon [62].

5. Conclusions

In summary, it can be concluded that the cuttings planted during the summer season enhanced plant height (124.66 cm), plant spread (62.51 cm), chlorophyll content (2.52 mg g^{-1}), yield of marketable flower per square meter (8.00 kg), flower size (11.00 cm). Nutritional module T_1 i.e., Jeevamrit @ 2 liter m^{-2} enhanced uptake of N (16.62 kg ha^{-1}), P (6.87 kg ha^{-1}), K (13.19 kg ha^{-1}) by plant, resulting into higher yield of marketable flower per square meter (7.29 kg) over the recommended dose of fertilizers. The plants produced from the first flush of cuttings taken from the mother block effectively increased marketable flower yield per square meter (7.27 kg). From the present findings, it can be concluded that drench application of Jeevamrit @ 2 liter m^{-2} at an interval of 15-day can be recommended as an alternative to chemical fertilizers for quality flower production in marigold cultivar 'Siracole'.

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