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Assessing the influence of planting time and fertilization on growth, flowering, yield and soil properties of chrysanthemum

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ABSTRACT

Objectives: To identify optimal planting time for maximizing growth and flowering, and assess the impacts of various fertilization techniques on plant growth and soil health in chrysanthemum.
Methods: The investigation was conducted at Dr. Y.S. Parmar University of Horticulture and Forestry in Nauni, Solan, Himachal Pradesh, India from 2022 to 2023. The study aimed to investigate the impact of various planting times and fertilization schedules on the yield, quality, and soil health characteristics of chrysanthemum. Different planting times from 15 June to 30 August under organic and inorganic fertilization regimes were evaluated. Data related to vegetative growth, flowering, soil chemical and biological properties were recorded.
Results: Planting on 15 June along with inorganic fertilization resulted in improved vegetative characters like plant height (74.37 cm) and plant spread (30.56 cm), flowering characters like cut flower stem length (64.07 cm), stem strength (10.40°), flower diameter (11.80 cm) and duration of flowering (22.50 days) and soil chemical properties like available N, P, K (326.53, 40.36 and 359.48 kg/ha, respectively). However, planting on June 15 combined with organic fertilization led to enhancement in soil microbiological properties, including bacterial count (138.33 cfu/g soil), fungal count (31.75 cfu/g soil), actinomycetes count (62.46 cfu/g soil), microbial biomass (52.62 μg/g soil) as well as vase life (19.70 days).
Conclusion: In the present study, it was found that planting time and fertilization significantly impacted chrysanthemum growth, yield and soil properties. The 15 June planting with inorganic fertilization boosted growth, yield and macronutrient content, while organic fertilization on the same date enhanced soil microflora. Flowering was influenced by planting time and organic fertilization showed promise as an alternative to chemical fertilization. Optimizing planting schedules and using organic fertilizers would lead to sustainability and offer economically viable alternatives to conventional crop management.

1. Introduction

Chrysanthemum is one of the most important flower crops in Asteraceae family and holds significant value for its varied forms, vibrant colors and prolonged vase life (Mekapogu et al., 2022). It occupies the second position among the top ten cut flowers after the rose (Darras, 2021). Chrysanthemum holds economic significance in India as it has a major share in the export market along with supporting the local economies of the country.

Chrysanthemum plant, classified as a qualitative short-day plant, has a restricted availability period of around 13 weeks (Van-Der Ploeg and Heuvelink, 2006). Synchronous planting of it can lead to an oversupply in the market, resulting in decreased prices. By implementing planting date scheduling, market volatility can be mitigated through controlled bloom periods, thereby, increasing demand and yielding higher market prices.

Optimal fertilizer application is crucial for plant development, growth and quality (Fageria et al., 2008). Intensive farming and use of agrochemicals cause environmental pollution, impacting human health (Mandal et al., 2020). The shift towards organic agriculture emphasizes

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ecosystem health and the demand for chemical-free products (Pandey and Singh, 2012). Organic manure provides essential nutrients and enhances the soil physico-chemical and biological properties (Yamada and Xu, 2001).

Jeevamrit, an organic amendment rich in macro and micronutrients and beneficial microorganisms, enhances soil biological activity and nutrient availability, promoting crop growth and environmental sustainability (Rathore et al., 2023). Supporting eco-friendly practices reduces the costs of chemical fertilizers and pesticides and boosts production economics, benefiting small and marginal farmers (Saharan et al., 2023).

This study analyses the impact of planting time and nutrition on chrysanthemum production and quality, hypothesizing that inorganic fertilization boosts growth and yield, while organic fertilization enhances soil microflora. Furthermore, planting time can be manipulated to regulate flowering times. Previous studies have primarily focused on the individual effects of planting time or fertilization types on chrysanthemum cultivation. However, there is a lack of comprehensive research that integrates these factors to provide a holistic understanding of their combined impact. This study addresses this gap by simultaneously examining the effects of planting time and different fertilization methods, thus contributing to a more nuanced understanding of chrysanthemum cultivation.

2. Material and methods

Experimental site: The study was carried out at the experimental farm of Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan, India in 2022 and 2023. The farm is situated at an elevation of 1,276 m above mean sea level, at coordinates 30°51′0′’ N latitude and 77°11′30′’ E longitude (Fig. 1).

Planting material: Shoot tip cuttings of chrysanthemum cv. ‘Purnima’ were prepared from a healthy mother block by following standard practices. Rooted cuttings were used for transplanting.

3. Experimental conditions

The experimental field was ploughed up to a depth of 0.30 m. Well-decomposed farmyard manure (FYM) was incorporated @ 5 kg/m^2. Raised beds, each measuring 1 m^2 and 6 in. in height, were prepared. Cuttings were planted on different dates with 15 days intervals. For inorganic fertilization, a basal dose of 30 g/m^2 NPK was applied during bed preparation (half of the dose of N, along with full doses of P and K, was applied). The remaining half dose of N (15 g/m^2) was added to the soil 45 days after planting. For organic fertilization, Jeevamrit was applied via drenching @ 30 ml/plant, beginning 30 days after transplanting, using a 1:4 dilution ratio.

The experiment was laid out in a randomized block design (RBD) with 12 treatments, each replicated thrice, in a factorial arrangement (Fig. 2). The factors included planting time (P_1: 15 June, P_2: 30 June, P_3: 15 July, P_4: 30 July, P_5: 15 August, P_6: 30 August) and fertilization regimes (FM_1: Jeevamrit at 30 ml plant^{-1}, FM_2: NPK at 30 g/m^2). Planting at 30 cm × 30 cm spacing included 9 plants/m^2 for June and July plantings, and 49 plants/m^2 for August plantings. Pinching was done only in plots with 9 plants/m^2, promoting multi-stemmed branching, while no pinching was done in plots with 49 plants/m^2.

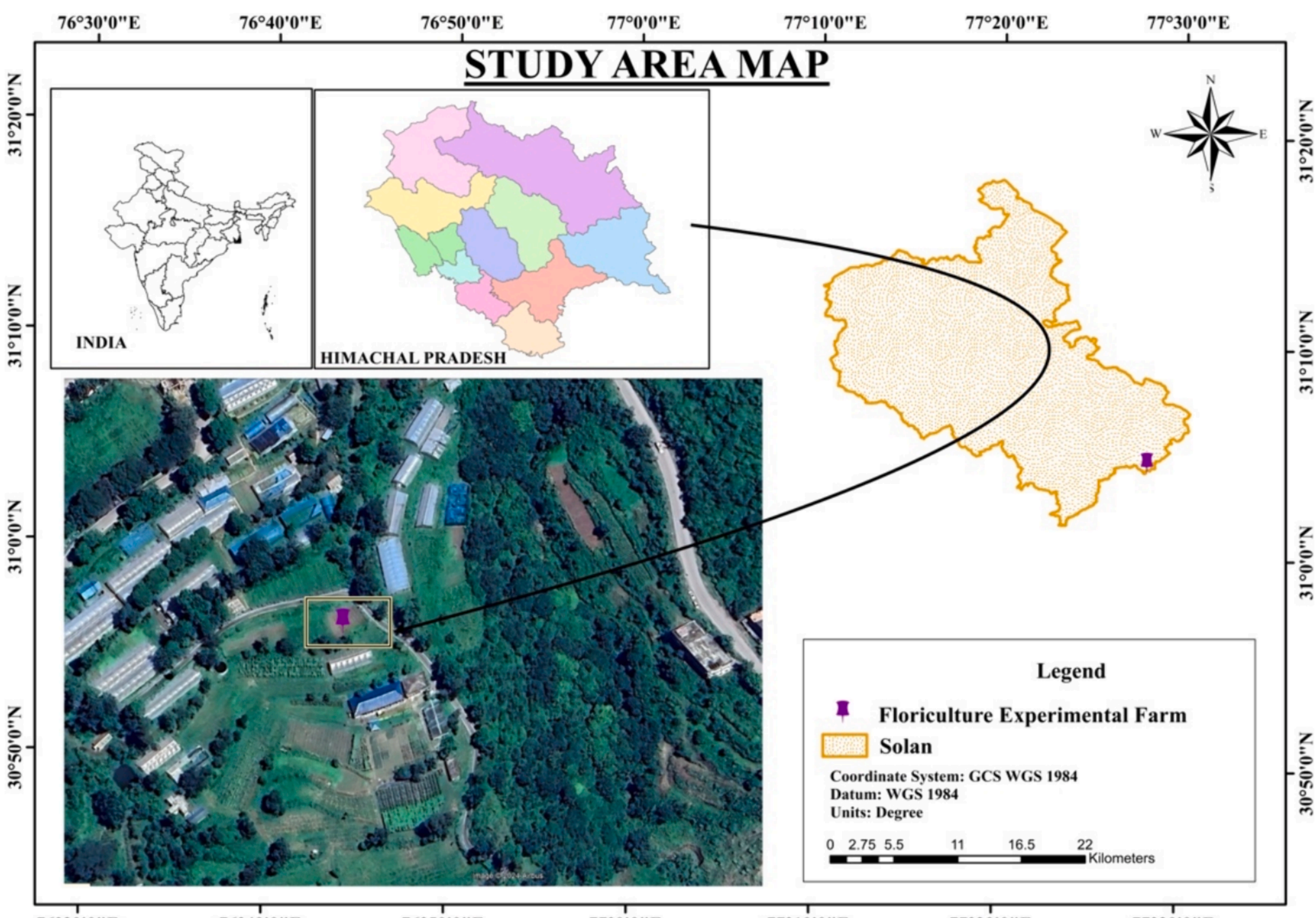

Fig. 1. Location of experimental farm where research trial was conducted.

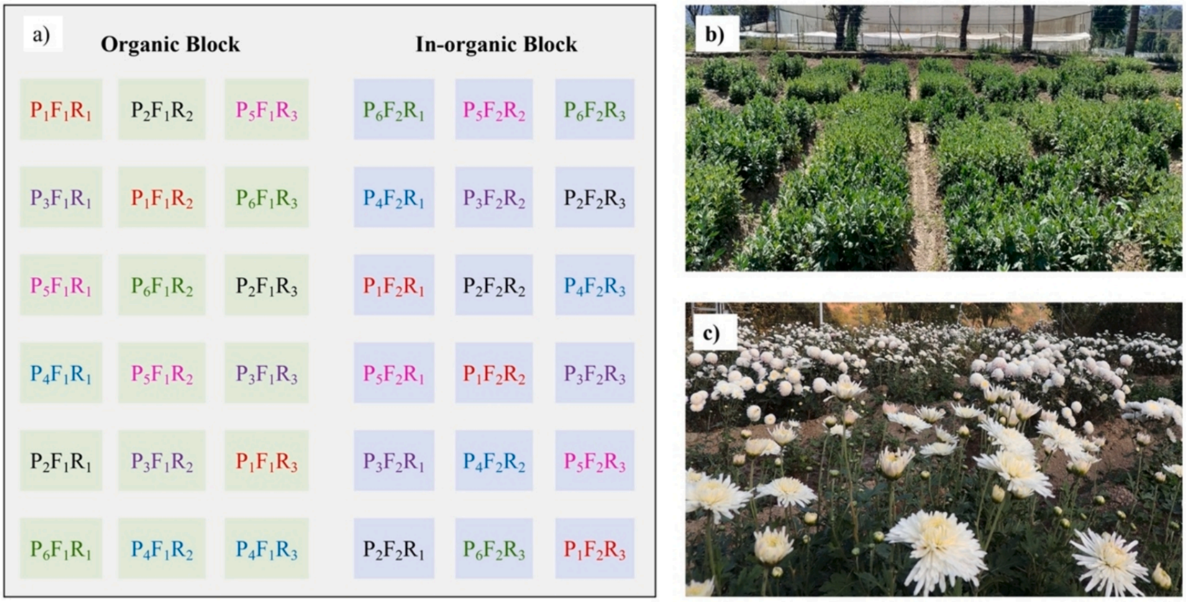

Fig. 2. **(a)** An experimental layout showing six different planting dates (P_1-P_6), two fertilization regimes (F_1 and F_2), each replicated three times (R_1-R_3). **(b)** A vegetative overview of the field. **(c)** A flowering overview of the field.

3.1. *Vegetative and flowering characteristics*

Data were collected on randomly selected five plants from each replication and different vegetative characters (such as plant height and spread, measured with a metre rod) and flowering attributes (days taken to bud formation and stage of harvesting) were observed from the date of planting. The number of cut stems per plot was counted manually, cut flower stem length using a metre rod, flower diameter using vernier calipers; stem strength as deviation angle when placed horizontally, vase life in distilled water under room temperature and duration of flowering at harvesting of 1st cut stem till the harvesting of last cut stem).

3.2. *Chemical properties*

Soil samples were taken from the study area at a depth of 0 to 15 cm before laying out the experiment. Soil pH and EC were measured using 1:2 soil water suspension and were found 6.85 and 0.34 dS/m, respectively (Jackson, 1973). Soil organic carbon was determined as per Walkley and Black (1934) which was 0.92 % (rapid titration method). Available nitrogen was found 292.76 kg/ha (Subbiah and Asija, 1956). Available phosphorus was recorded 27.48 kg/ha (Olsen et al., 1954) and available potassium was recorded 315.84 kg/ha (Merwin and Peech, 1951).

3.3. *Soil microbial attributes*

Microbial quantification was performed using the serial dilution standard spread plate technique on three different media: nutrient agar, potato dextrose agar and Kenknight and Munaier's medium, following the protocol outlined by Subbarao (1995). The microbial population was quantified as colony-forming units per gram of soil. Additionally, microbial biomass-C was assessed using the soil fumigation extraction method given by Vance et al. (1987).

$$\text{Microbial biomass} - \text{C}\ (\mu\text{g/g soil}) = \frac{\text{EC (F)} - \text{EC (UF)}}{\text{K}}$$

where, K: 0.25 ± 0.05 (a measure of the effectiveness of microbial biomass carbon extraction), EC (F): Amount of extractable carbon in soil samples post-fumigation, EC (UF): Total extractable carbon in unfumigated soil samples.

The dehydrogenase activity in liquid formulations was calculated using the 2,3,5-triphenyl tetrazolium chloride reduction method (Casida et al., 1964) and phosphatase activity was measured according to the procedure detailed by Tabatabai and Bremner (1969).

3.4. *Statistical techniques and analysis*

The data collected during the two years of experimentation in 2022 and 2023 were pooled and analyzed using SPSS statistics. Analysis of variance (ANOVA) was performed on the pooled data employing randomized block design (RBD) and the treatments were compared using the critical difference at 5 % level of significance.

4. Results

4.1. *Vegetative and flowering characteristics*

Planting time and fertilization regimes had a significant effect on vegetative characteristics of chrysanthemum (Table 1). Among different planting times, highest plant height (71.06 cm) and spread (29.06 cm) were observed in P_1 as compared to other planting dates. FM_2 recorded the higher plant height (53.93 cm) and spread (20.57 cm) over FM_1 which recorded plant height of 47.79 cm and plant spread of 18.46 cm. Under the interaction effect, highest plant height (74.37 cm) and spread (30.56 cm) were recorded under P_1xFM_2.

Data embodied in Table 1 show that the earliest bud formation (32.45 days) and time to reach the harvesting stage (79.58 days) were recorded in P_6. Maximum cut stems/plot (49.00) were recorded under P_5 and P_6. Maximum stem length of cut flower (61.00 cm), flower diameter (11.03 cm), stem strength (10.83°), flowering duration (21.50 days) and vase life (18.92 days) were observed under P_1.

Earlier bud formation (61.85 days), lesser period taken to reach the harvesting stage (110.20 days) and more cut stems/plot (41.18), stem length of cut flower (46.09 cm), flower diameter (9.95 cm), stem strength (13.53°) and flowering duration (19.58 days) were observed in FM_2. FM_1 recorded higher vase life (17.97 days).

The interaction effect of dates of planting and fertilization regimes

Table 1
Impact of planting time and fertilization regimes on vegetative and flowering characteristics (Pooled Data: 2022 & 2023).

Treatments	Plant height (cm)	Plant Spread (cm)	Days to bud formation (days)	Days taken to harvesting (days)	Cut stems/ plot	Cut flower stem length (cm)	Flower Diameter (cm)	Stem Strength (°)	Flowering duration (days)	Vase Life (days)
Planting time										
P_1	71.06^{a}	29.06^{a}	95.33^{a}	142.93^{a}	41.55^{b}	61.00^{a}	11.03^{a}	10.83^{c}	21.50^{a}	18.92^{a}
P_2	65.71^{b}	26.32^{b}	81.78^{b}	130.95^{b}	38.25^{c}	55.56^{b}	10.47^{b}	11.25^{c}	20.50^{ab}	18.27^{b}
P_3	57.59^{c}	22.95^{c}	68.73^{c}	117.33^{c}	33.75^{d}	48.26^{c}	9.79^{c}	12.47^{bc}	20.08^{ab}	17.37^{c}
P_4	45.70^{d}	20.84^{d}	56.02^{d}	105.53^{d}	32.25^{d}	38.97^{d}	9.06^{d}	12.9^{b}	18.00^{bc}	16.43^{d}
P_5	35.59^{e}	9.19^{e}	43.88^{e}	92.76^{e}	49.00^{a}	29.72^{e}	8.45^{e}	15.72^{a}	17.17^{c}	15.70^{e}
P_6	29.51^{f}	8.76^{f}	32.45^{f}	79.58^{f}	49.00^{a}	24.10^{f}	7.77^{f}	16.2^{a}	16.17^{c}	15.05^{f}
Significance	0.45	0.42	0.64	1.04	1.69	1.45	0.23	1.05	1.91	0.24
Fertilization										
FM_1	47.79^{a}	18.46^{a}	64.22^{a}	112.83^{a}	40.08^{a}	39.79^{a}	8.90^{a}	12.92^{a}	18.22^{a}	17.97^{a}
FM_2	53.93^{b}	20.57^{b}	61.85^{b}	110.20^{b}	41.18^{b}	46.09^{b}	9.95^{b}	13.53^{b}	19.58^{b}	15.94^{b}
Significance	0.77	0.72	0.37	0.60	0.98	0.84	0.13	0.60	1.10	0.14
Interaction										
P_1xFM_1	67.76b	27.56^{b}	96.97^{a}	143.80	40.80	57.93	10.26^{c}	11.27	20.50	19.7^{a}
P_2xFM_1	63.52c	25.40^{c}	83.33^{c}	132.63	37.20	53.03	9.9^{d}	11.87	19.50	19.27^{b}
P_3xFM_1	54.90e	21.22^{e}	70.17^{e}	118.97	33.00	45.66	9.26^{e}	12.60	19.00	18.6^{c}
P_4xFM_1	42.19 g	19.42^{f}	57.1^{g}	106.93	31.50	35.96	8.82^{f}	13.10	17.33	17.4^{e}
P_5xFM_1	31.83i	8.69^{gh}	44.7^{i}	94.37	49.00	25.97	7.93^{h}	15.97	16.83	16.73^{f}
P_6xFM_1	26.52j	8.49^{h}	33.03^{k}	80.27	49.00	20.17	7.27^{i}	16.40	16.17	16.1^{g}
P_1xFM_2	74.37a	30.56^{a}	93.7^{b}	142.07	42.30	64.07	11.8^{a}	10.40	22.50	18.13^{d}
P_2xFM_2	67.91b	27.24^{b}	80.23^{d}	129.27	39.30	58.09	11.03^{b}	10.63	21.50	17.27^{e}
P_3xFM_2	60.29d	24.68^{c}	67.3^{f}	115.70	34.50	50.86	10.31^{c}	12.33	21.17	16.13^{g}
P_4xFM_2	49.20f	22.26^{d}	54.93^{h}	104.13	33.00	41.98	9.31^{e}	12.70	18.67	15.47^{h}
P_5xFM_2	39.34 h	9.68^{g}	43.07^{j}	91.14	49.00	33.47	8.98^{ef}	15.47	17.50	14.67^{i}
P_6xFM_2	32.50i	9.02^{gh}	31.87^{l}	78.90	49.00	28.04	8.28^{g}	16.00	16.17	14^{j}
Significance	1.09	1.02	0.91	NS	NS	NS	0.32	NS	NS	0.34

* Non-significant differences (DMRT, 5% significance) are denoted by identical letters within each column.

revealed that the earliest bud formation (31.87 days) was observed in P_6xFM_2. Maximum flower diameter (11.80 cm) was recorded in P_1xFM_2 and vase life (19.70 days) in P_1xFM_1.

4.2. Soil chemical properties

Maximum available N, P and K (318.81, 38.08 and 352.47 kg/ha, respectively) was observed in P_1 in comparison to all other planting times (Fig. 3). FM_2 resulted in maximum available N, P and K (321.71, 38.48 and 353.29 kg/ha, respectively) (Fig. 4). The interaction was found non-significant (Fig. 5).

During both study years, fertilizer regimes and planting days had non-significant effects on soil pH and EC (Figs. 6-8). Among different planting time, maximum OC (1.14 %) was observed in P_1 planting compared with all other planting time (Fig. 6). Organic fertilization recorded maximum OC (1.13 %) (Fig. 7). The interaction effect on OC was found to be non-significant (Fig. 8).

4.3. Soil microbiological properties

Data presented in Table 2 show that planting time had a non-significant effect on all the soil microbiological properties. Among different planting times, maximum dehydrogenase enzyme was recorded in P_1 (3.69 mg TPF/h/g/soil, respectively). Maximum phosphatase enzyme (24.20 mmole PNP/h/g/soil, respectively) was recorded under P_1.

Fertilization had a significant effect on soil microbial properties and data reveal that more bacterial, actinomycetes and fungal counts (133.09, 61.58 and 31.26 cfu/g soil, respectively), microbial biomass (51.85 µg/g soil) and, dehydrogenase and phosphatase enzymes (3.81 mgTPF/h/g soil, 22.52 mmole PNP/h/g soil, respectively) were recorded in FM_1. The interaction effect had no significant effect on all the soil microbiological properties.

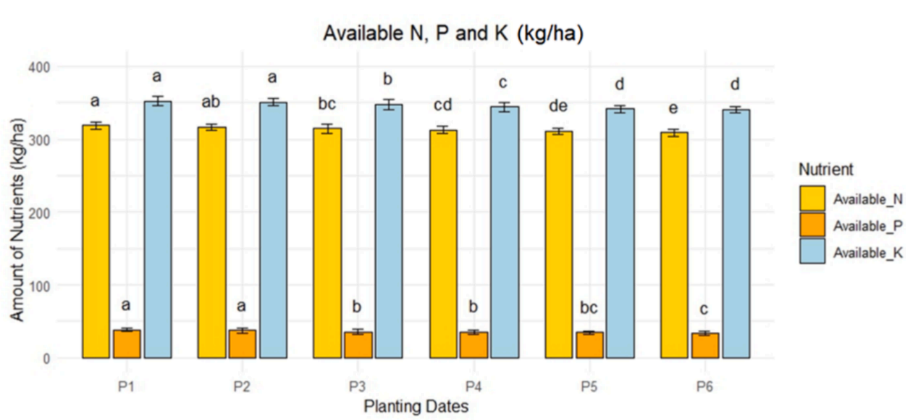

Fig. 3. Impact of planting time on soil available NPK.

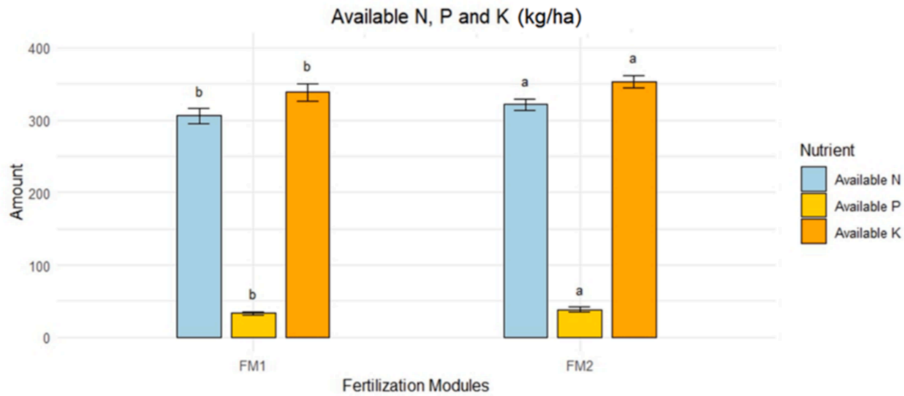

Fig. 4. Impact of fertilization regimes on soil available NPK (Pooled Data: 2022 & 2023).

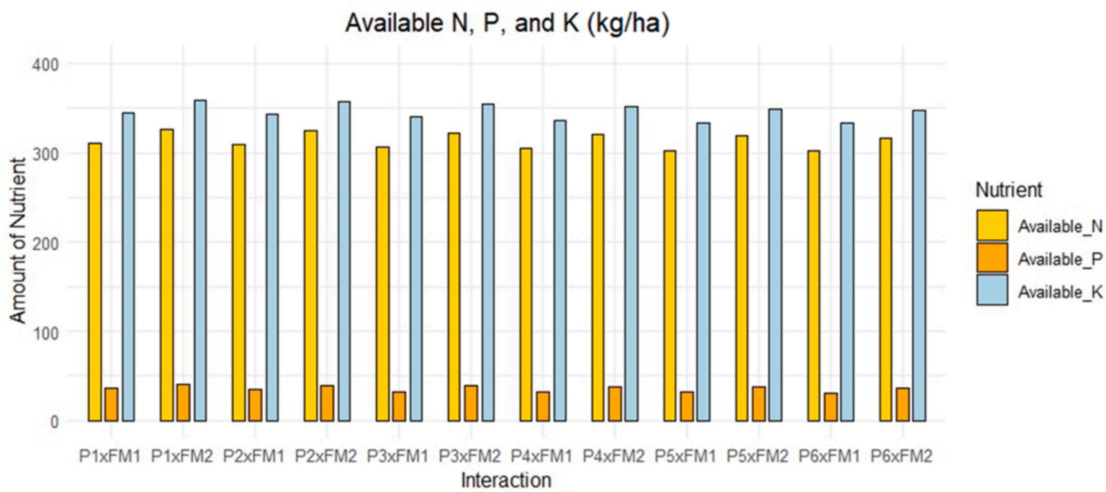

Fig. 5. Interaction impact of planting time and fertilization regimes on soil available NPK (Pooled Data: 2022 & 2023).

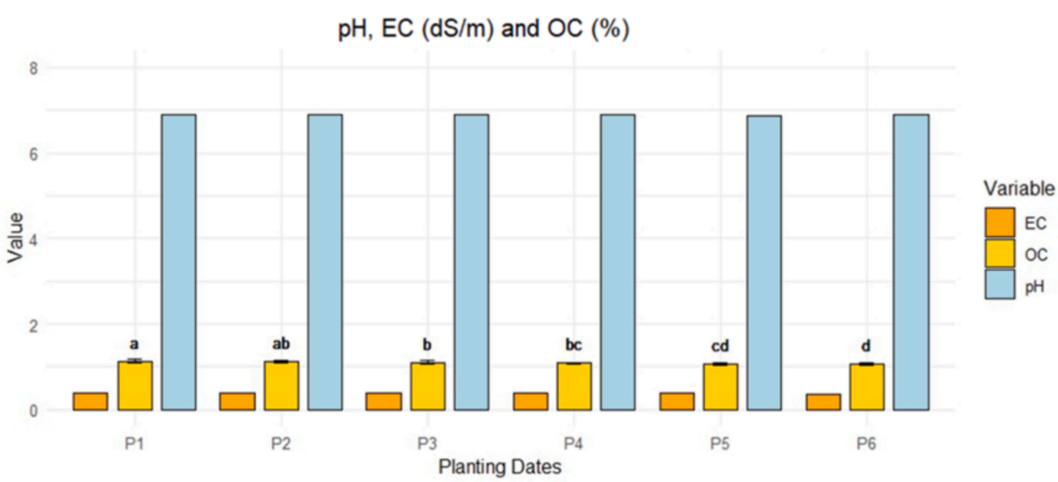

Fig. 6. Impact of planting time on soil pH, EC and OC (Pooled Data: 2022 & 2023).

5. Discussion

5.1. Vegetative and flowering characteristics

Delayed planting in chrysanthemums shortened the bud formation and flowering period, whereas, early planting extended the juvenile phase, delaying flower initiation. Early-planted crop benefited from prolonged optimal long-day conditions, enhancing vegetative growth, compared to those planted later. A study on chrysanthemum cv. Aparajita found that early plantings enhanced vegetative growth (Kishore et al., 2023).

Differences in fertilization effects lead to a rise in rapid nutrient

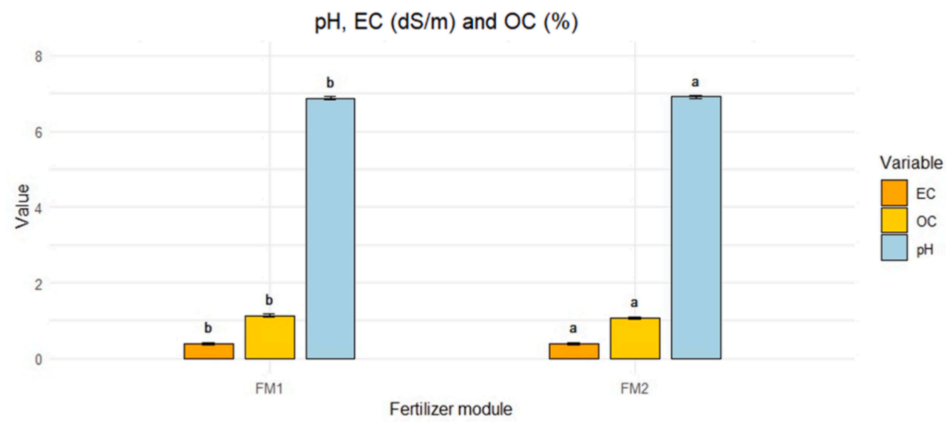

Fig. 7. Impact of fertilization regimes on soil pH, EC and OC (Pooled Data: 2022 & 2023).

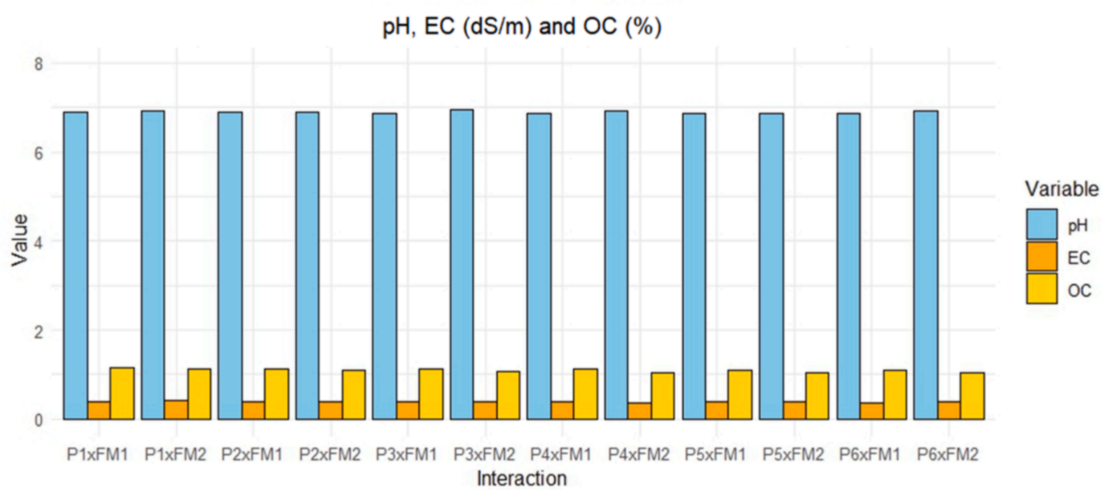

Fig. 8. Interaction impact of planting time and fertilization regimes on soil pH, EC and OC.

availability in inorganic fertilizers, particularly NPK which are quickly utilized by the plants. In contrast, organic fertilization with Jeevamrit had slower nutrient release, slightly affecting plant growth.

Chrysanthemums planted early had a longer vegetative growth phase, which might have allowed more energy to be stored and directed to the development of the flowers, leading to improved flowering attributes. Strong flower bud differentiation and expansion are encouraged by a prolonged time frame, which results in bigger flowers, longer stems, better vase life, longer flowering time and stronger stems. On the other hand, later plantings perceive a more rapid transition to flowering due to shorter day length which might restrict the amount of time available for optimal development of the stem and flowers, leading to less desirable floral characteristics. The highest stem count was attained despite the late planting (5^{th} and 6^{th}), which might be due to the higher plant density. Sharma et al. (2015) have also reported similar outcomes.

NPK fertilizers enhanced flowering in chrysanthemums by promoting essential physiological processes. Nitrogen aids protein and enzyme synthesis, phosphorus supports energy transfer and cell division and potassium regulates water uptake and nutrient transport. These nutrients collectively improve flowering characteristics, as also reported by Yang et al. (2003).

The beneficial microbes and organic substances that improve nutrient uptake, physiological activities and defensive mechanisms in plants treated with Jeevamrit might be responsible for the plants' longer vase life. Comparably, Thakur et al. (2023) reported the application of Jeevamrit extended the vase life in iris.

5.2. *Chemical properties of soil*

A significant influence of different fertilizers and planting dates on soil chemical properties was observed except for soil pH and EC. Earlier planting extends the vegetative phase, promoting enhanced root development and, thereby, improving nutrient uptake from the soil. As a consequence, this leads to higher levels of available NPK compared to late plantings (Abaza et al., 2023).

Inorganic fertilizers significantly increased soil NPK levels which might be due to their immediate and concentrated nutrient release, providing highly soluble forms of NPK for swift plant uptake which leads to a quick boost in soil nutrient availability. Both fertilization methods improved soil NPK levels, affirming the positive impact on nutrient availability. Similar results were reported with NPK application @ 100:150:100 kg/ha/year in chrysanthemum (Choudhary et al., 2022).

The organic fertilization regime led to a modest increase in OC content. This can be attributed to Jeevamrit, an organic input rich in organic matter, which enhanced soil microbial activity and fostered the accumulation of OC. Yadav et al. (2022) also reported increased OC in soil with the application of Jeevamrit in garden peas.

5.3. *Soil micro-biological properties*

Micro-biological properties are enhanced by the application of Jeevamrit by acting as a stimulant, promoting robust microbial activity and supporting a significant microbial population that proliferates in the

Table 2
Impact of planting time and fertilization regimes on soil microbiological properties (Pooled Data: 2022 & 2023).

Treatments	Bacterial Count (cfu/g soil)	Actinomycetes Count (cfu/g soil)	Fungal Count (cfu/g soil)	Microbial Biomass (μg/g soil)	Dehydrogenase enzyme (mgTPF/h/g soil)	Phosphatase enzyme (mmole PNP/h/g soil)
Planting time						
P_1	116.94	61.12	31.11	49.57	3.69	24.20
P_2	124.28	61.01	31.08	49.15	3.57	22.78
P_3	122.41	60.72	30.91	48.97	3.47	21.08
P_4	119.59	60.41	30.55	48.71	3.31	20.36
P_5	117.79	59.18	30.49	48.20	3.18	19.02
P_6	116.42	59.16	29.59	47.99	3.01	17.43
Significance	NS	NS	NS	NS	0.22	3.17
Fertilization						
FM_1	133.09[a]	61.58[a]	31.26[a]	51.85[a]	3.81[a]	22.52[a]
FM_2	106.06[b]	58.96[b]	29.98[b]	45.68[b]	2.94[b]	19.10[b]
Significance	6.89	1.52	0.66	0.65	0.13	1.83
Interaction						
P_1xFM_1	138.33	62.46	31.75	52.62	4.07	26.04
P_2xFM_1	136.27	62.06	31.72	52.21	3.98	24.67
P_3xFM_1	134.57	61.85	31.56	52.09	3.89	22.43
P_4xFM_1	131.07	61.44	31.19	51.70	3.67	22.02
P_5xFM_1	129.40	60.91	31.14	51.36	3.64	20.64
P_6xFM_1	128.88	60.78	30.23	51.14	3.61	19.33
P_1xFM_2	95.54	59.79	31.75	46.52	3.31	22.36
P_2xFM_2	112.30	59.96	30.46	46.09	3.17	20.90
P_3xFM_2	110.26	59.60	30.45	45.86	3.05	19.74
P_4xFM_2	108.11	59.39	30.26	45.72	2.96	18.69
P_5xFM_2	106.18	57.42	29.92	45.05	2.73	17.39
P_6xFM_2	103.96	57.59	29.84	44.84	2.42	15.52
Significance	NS	NS	NS	NS	NS	NS

* Non-significant differences (DMRT, 5% significance) are denoted by identical letters within each column.

soil. Jeevamrit comprises a variety of beneficial microorganisms, such as fungi, methylotrophs, actinomycetes, *Azotobacter*, phospho-bacteria, *Pseudomonas*, lactic acid bacteria etc. An increase in soil microbiological properties by Jeevamrit application has also been reported by Rathore et al. (2023).

5.4. Future prospect

Nano fertilizers enhance nutrient release efficiency, improving plant growth and yield (Singh et al., 2023a). They also mitigate abiotic stresses by activating physiological pathways (Singh et al., 2024). Jeevamrit can complement these advanced technologies. Combining Jeevamrit with nano fertilizers can create a synergistic effect, enhancing soil health and nutrient availability while promoting sustainable agricultural practices. In the context of climate change, nanotechnology combined with Jeevamrit and advanced fertilization strategies is crucial for sustainable crop production (Rajput et al., 2023). Overall, integrating nanotechnological approaches, Jeevamrit and advanced fertilization techniques holds significant potential for enhancing chrysanthemum growth, flowering and yield, while improving soil properties and effectively managing abiotic stresses (Singh et al., 2023b). Continued research and development in this field are essential to fully harness these technologies for sustainable and resilient chrysanthemum production.

6. Conclusion

Planting time and fertilization significantly influenced the growth, yield and soil properties of the chrysanthemum crop in the present study. A significant increase in growth, yield and macronutrient content was observed under both, 15th June planting and inorganic fertilization, while the soil microflora was enhanced under organic fertilization. Additionally, the findings suggest that flowering can be regulated by the planting date and organic fertilization emerges as a promising alternative amidst rising concerns about chemical fertilizers.

Further, integrating nanotechnological approaches, Jeevamrit and advanced fertilization techniques holds significant potential for enhancing chrysanthemum growth, flowering and yield while improving soil properties and effectively managing abiotic stresses. Continued research and development in this field are essential to fully harness these technologies for sustainable and resilient chrysanthemum production.

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CRediT authorship contribution statement

Sabhya Pathania: Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation. **Sita Ram Dhiman:** Supervision, Project administration, Methodology, Conceptualization. **Bharati Kashyap:** Supervision, Methodology. **Anshul Kumar:** Writing – review & editing, Writing – original draft, Software, Formal analysis, Data curation. **Rajesh Kaushal:** Methodology. **Rakesh Kumar Gupta:** Methodology. **Jawaher Alkahtani:** . **Bandar M. AlMunqedhi:** .

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jksus.2024.103418.

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