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Effects of LDD1 compost and chemical fertilizer on the growth, yield and antioxidant activity of *Chrysanthemum indicum* L.

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Abstract Chrysanthemum, one of the most valuable crops and medicinal plants, is increasingly cultivated for its pharmacological benefits. The combination of LDD1 compost and chemical fertilizer showed the highest number of flowers, which was significantly greater than other treatments. Additionally, LDD1 compost alone resulted in the highest dry root weight. The antioxidant activity of bioactive compounds extracted from dried chrysanthemum flowers was evaluated by measuring total flavonoids, phenolics, and 2,2-diphenyl-1-picrylhydrazyl (DPPH) scavenging activity. Although the flavonoid and phenolic contents did not significantly differ among the treatments, fertilization led to significantly higher antioxidant activity compared to non-fertilized plants. The study highlighted the potential of using LDD1 compost, or a combination of LDD1 compost and chemical fertilizer at half the rate, to promote vigorous growth, high yields, and enhanced antioxidant activity. This approach helps to reduce the reliance on chemical fertilizers.

Keywords: LDD1 compost, Antioxidant, Free radical scavenging, Flavonoids, Phenolics

Introduction

Yellow-flowered chrysanthemum (*Chrysanthemum indicum* L.) is a flowering plant belonging to the Asteraceae family. It thrives well in the northern region of Thailand due to the cool climate (Rawdkhao, 2020). Chemical compounds found in the flowers include flavonoids, which have antioxidant properties, reduce inflammation, and have antimicrobial effects. Chrysanthemum is a popular herbal drink in China, Korea, and Japan, consumed for health benefits and as tea (Luyen *et al*., 2015). However, there is currently no research on the cultivation of yellow chrysanthemum regarding growth and yield in the eastern region of Thailand due to its potential as a new economic crop for gardeners in Chanthaburi province. Rajamangala University of Technology

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Tawan-ok, Chanthaburi Campus, also organizes an annual event where decorative flowers are planted, serving as a tourist attraction for event participants and visitors for photography. Yellow chrysanthemums also have the potential to contribute to this aspect. In addition to their ornamental use, yellow chrysanthemums can be processed into dried tea and flowers, providing an additionally source of income for the university.

Chrysanthemum is a small shrub with single, serrated leaves with deep lobes at the edges. It bears inflorescences in a head-like form comprising numerous small florets. The outer florets, called ray florets, are sterile and possess only pistils, while the inner florets, known as disc florets, are larger and fertile, clustered in the center of the flower. Chrysanthemums belong to the Asteraceae family and are commonly propagated as stem cuttings, division, and seed propagation. Stem cuttings are preferred as they maintain the original characteristics of the parent plant. Recommend conditions for cultivating chrysanthemums include loamy soil with a pH of 6.5 - 7.5 and an average temperature throughout the year of 15°C, with average maximum and minimum temperatures of 32.6 - 37.7 and 0 - 1.3°C, respectively. The length of the day affects chrysanthemum flowering; being a short-day plant, it blooms when the duration of daylight is less than 12 hours. Thus, the optimal time for flowering occurs approximately from October to March, making the suitable period for planting and harvesting flowers from June to July (Rawdkhao, 2020).

In Thailand, yellow chrysanthemums are predominantly cultivated in the northern region, where geographical constraints limit the cultivation of high-value temperate fruits. Therefore, promoting the cultivation of yellow chrysanthemums as an economic crop for local gardeners has been encouraged. Moreover, the implementation of Good Agricultural Practices (GAP) and the promotion of organic farming practices have been introduced, particularly in areas like Doi Sango in Chiang Rai province (Rungsirisakun *et al*., 2016). Chrysanthemum fields also have become tourist attractions in several provinces, including Chiang Mai, Phitsanulok, Lampang, Phetchabun, Nakhon Ratchasima, Sa Kaeo, and Saraburi.

The chrysanthemum flower is used as an herbal remedy in China and Korea to treat infections, reduce fever, alleviate pain, reduce inflammation, and lower blood pressure. Important compounds found in chrysanthemum flowers include phenolic compounds and flavonoids. Extraction of these compounds involves soaking dried flowers in methanol, followed by methanol evaporation and subsequent dissolution of the extract with dichloromethane, ethanol, and water. Studies have shown that extracts dissolved in the ethanol layer have the highest total phenolic and flavonoid content and exhibit the highest peroxyl radical scavenging activity (Luyen *et al*., 2015), consistent with research on extracting compounds from dried flowers using ethanol, which yields higher flavonoid content compared to aqueous extraction (Ruenwai, 2020).

The microbial activator called "Super LDD1", which contains 8 strains of microorganisms, was isolated and developed by Land Development Department, Ministry of Agriculture and Cooperatives, Thailand. These microorganisms show high growth rates and enzymatic decomposition activity which includes 4 strains of aerobic cellulose-decomposing fungi (*Corynascus* sp., *Scytalidium* sp., *Chaetomium* sp., and *Scopulariopsis* sp.), 2 strains of cellulose-decomposing actinomycete bacteria (*Streptomyces* sp.), and 2 strains of fat-decomposing bacteria (*Bacillus* sp.) (Leaungvutiviroj *et al*., 2007). Super LDD1 contains a highly efficient microorganisms that can decompose plant residues which contain high cellulose and fats. They are also highly resistant to heat and help shorten the fermentation and decomposition process of plant and animal residues in the compost, resulting in better compost quality. Compost using Super LDD1 usually made from plant residues or agricultural by-products such as rice straw, rice husks, peanut shells, corn cobs, coconut coir, sugarcane bagasse, oil palm bunches, coffee husks, and leaf litter, mixed with animal manure. This mixture undergoes decomposition through microbial activity, transforming the original materials into a soft, and crumbly substance that is brownish black in color. Using compost benefits soil quality improvement, both physically and chemically. It makes the soil loose, well-aerated, and better at retaining water. Compost serves as a source of nutrients for plants, providing both macronutrients and micronutrients. The nutrients bind to the soil, preventing them from being easily washed away, and they are gradually slowly released for plant use throughout the growing season. Compost also enhances resistance to pH fluctuations, increases the food supply for soil microorganisms, and boosts the quantity and beneficial activity of microbes in the soil (Land Development Department, 2015).

Research on organic fertilization involves using chicken manure mixed with soil before and after transplanting at a rate of 1,000 kg per rai. This resulted in greater stem height in asiatic pennyworth compared to chemical fertilizer alone and organic fertilizer combined with chemical fertilizer. However, the highest concentration of the phytochemical asiaticoside found in asiatic pennyworth leaves was obtained when organic fertilizer was used in combination with chemical fertilizer (Buakum and Sanprasert, 2017). Additionally, applying chicken manure at a rate of 31.95 kg N per rai resulted in the highest fresh weight yield per rai compared to chemical fertilizer alone (Thepsilvisut, 2017). The application of organic fertilizer, or organic fertilizer combined with Super LDD1, can promote plant growth and yield, showing no significant difference compared to chemical fertilizer application, as seen in tomato (Rattananoppanun, 2013).

Since organic fertilizer is less costly than chemical fertilizer, it can be recommended to reduce chemical fertilizer usage. The combined application of Super LDD1 organic and chemical fertilizers resulted in greater plant growth and yield, as seen in potatoes, compared to using either fertilizer alone. This combination also increased exchangeable potassium levels and soil pH (Puttajunyawong, 2013). Organic fertilizer can increase the production of phytochemical compound in plants. For example, in *Oryza sativa* L. var. *indica* 'Suphan Buri 1', the amount of 2-acetyl-1-pyrroline was significantly higher in treatments with organic fertilizer compared to those with chemical fertilizer or the control (Poomipan *et al*., 2015).

This study examined the effects of different fertilizer methods (LDD1 compost, chemical fertilizers, and their combination) on the growth, flower yield, and antioxidant properties of yellow chrysanthemum flowers.

Materials and methods

The yellow-flowered chrysanthemum was propagated by stem cutting in 105-cells seedling tray using peatmoss and then transplanted in soil bed at the Department of Plant Production Technology and Landscape, Faculty of Agro-Industrial Technology, Rajamangala University of Technology Tawan-ok, Chanthaburi Campus from December 2022 to May 2023 during the dry season. The mean temperature in December 2022 to May 2023 was 26.2, 26.3, 27.8, 28.7, 29.7, and 29.6 celcius, respectively. The precipitation in December 2022 to May 2023 was 0.6, 3.3, 62.0, 7.5, 168.3, and 439.6 mm, respectively. The soil type is sandy loam soil comprised of soil pH 4.77, electrical conductivity of 0.05 dS/m, organic matter of 1.95%, 70.84 mg P/kg, 42.09 mg K/kg, 237.81 mg Ca/kg, and 20.84 mg Mg/kg (Office of Agricultural Research and Development Region 6, 2022). The experiment was conducted in a randomized complete block design (RCBD) consisting of four treatments with triplication, which consisted of the following: 1) No fertilizer (control) 2) LDD1 compost (developed by Land Development Department of Thailand) at the rate of 25,000 kg/ha 3) Chemical fertilizer 15-15-15 (15% N, 15% P_2O_5, and 15% K_2O) at the rate of 208.75 kg/ha. 4) LDD1 compost at the rate of 12,500 kg/ha combined with chemical fertilizer 15-15-15 at the rate of 104.38 kg/ha. LDD1 compost was applied once during soil preparation before planting while chemical fertilizer was applied every month after transplanting for a total duration of 3 months. The bed plot size was 0.6×1.5 m^2 and a planting distance was 30 cm with 10 plants per treatment. The plants were irrigated using a hose, weeds were manually removed regularly, and no chemical insecticides were used throughout the experiment.

Table 1. Analysis of LDD1 compost

Content	Value	Test method
1. pH	8.5	(2) p 5
2. Moisture (%)	3.8	(2) p 7
3. Nitrogen (%)	0.5	(1)1.05.02
4. Phosphorus (%)	0.6	(2) p 24-27
5. Potassium (%)	1.1	(2) p 29-32
6. EC (dS/m)	3.8	(2) p 33
7. Organic matter (%)	19.4	(1)1.28.01
8. C/N ratio	21:1	(1)1.28.01
9. Calcium (%)	1.1	(1)1.13.01
10. Magnesium (%)	0.3	(1)1.14.01

Testing methods:

(1) According to the announcement of the Department of Agriculture on the specification of methods for analyzing chemical fertilizers (2016),

(2) Organic Fertilizer Analysis Manual, Agricultural Chemistry Group, Agricultural Production Science Research and Development Office, Department of Agriculture (2008)

Table 2. The rate of fertilizer applied to the chrysanthemum plants in each treatment

Fertilization rate	T2 LDD1 compost	T3 Chemical fertilizer	T4 LDD1+chemical fertilizer
LDD1 compost (kg/ha)	25,000	NA	12,500
Chemical fertilizer (kg/ha)	NA	626.25	313.125
Kg N/ha	125	93.75	109.375
Kg P/ha	150	93.75	121.875
Kg K/ha	275	93.75	184.375

The plant growth parameters were measured including plant height, canopy diameter, number of flowers per plant, diameter of fully bloomed flowers at 60 and 90 days after transplantation. Additionally, dry weight of aboveground parts, roots, and flowers were collected at 120 days after transplantation.

Sample extraction

Fresh flowers were collected and washed with water and then dried using a Universal oven UF110 (Memmert, Germany) at 65 °C for 12 hours. The dried flowers were then packed in plastic bags and stored in the dark at room temperature. 0.3 grams of dried flowers were ground and macerated with 5 mL 95% ethanol in 15 mL centrifuge tube for 24 hours in the dark at room temperature. Subsequently, the mixture was centrifuged at 6,000 rpm at room temperature for 10 minutes. Supernatant was transferred to a new centrifuge tube for further analysis.

Total flavonoid content

Determination of total flavonoid content was performed as described by Zhishen *et al*. (1999) with minor modifications. Briefly, 0.1 mL of sample extraction was mixed with 4 mL of distilled water. Then, 0.3 mL of 5% sodium nitrite was added and left for 5 minutes, followed by the addition of 0.3 mL of 10% aluminum chloride and left for 6 minutes. Subsequently, 2 mL of 1 M sodium hydroxide was added, and the mixture was made up to 10 mL with distilled water. After incubating for 10 minutes in the dark at room temperature, the absorbance was measured at 510 nm using a UV/VIS spectrophotometer (Lambda 365, PerkinElmer, USA). The total flavonoid content was calculated using a quercetin standard solution ranging from 5 to 400 µg/mL using UV Express 4.1.1 software and reported as milligrams of quercetin equivalent per gram of dry weight (mg QE/g DW).

Total phenolic content

The total phenolic content was determined using a modified Folin-Ciocalteu colorimetric method (Singleton and Rossi, 1965). A 0.05 mL of sample extraction was mixed with 2 mL of 10% Folin-Ciocalteu reagent and 2 mL of 7% sodium carbonate and left for 60 minutes in the dark at room temperature. The absorbance was then measured at 765 nm using a UV/VIS spectrophotometer. The total phenolic content was calculated against a gallic acid standard solution ranging from 50 to 1000 µg/mL and reported as milligrams of gallic acid equivalent per gram of dry weight (mg GAE/g DW).

Antioxidant activity assay

The antioxidant activity was evaluated using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity method, modified from Zhu *et al*. (2006). A 0.1 mL of sample extraction was mixed with 2.9 mL of 0.1 mM DPPH solution and left for 30 minutes in the dark at room temperature. The absorbance was then measured at 517 nm using a UV/VIS spectrophotometer. The antioxidant activity was calculated against an ascorbic acid standard solution ranging from 0.06 to 0.12 mg/mL, reported as micrograms of ascorbic acid equivalent per gram of dry weight (µgAAE/g), and the percentage of DPPH scavenging activity was calculated as equation:

$$(\%)\ \text{DPPH radical scavenging activity} = [\,(A_0 - A_1\ \text{sample}) / A_0\,] \times 100$$

where A_0 = The absorbance of ethanol (control)

A_1 = The absorbance of sample

Statistical analysis

A one-way analysis of variance (ANOVA) was performed using R software. Statistical differences were tested using Duncan's New Multiple Range Test at significance levels of $\alpha = 0.05$.

Results

Plant growth

The effects of different fertilizer types (LDD1 compost, chemical, and combined) on chrysanthemum growth and development were evaluated by measuring key growth parameters, as shown in Table 3. At 60 days after transplanting, there were no significant difference in plant height, canopy size, and flower number among the fertilization treatments. However, flower size, as measured in flower diameter, was significantly larger in plants treated with LDD1 compost (3.24 cm), followed by those treated with chemical fertilizer (2.96 cm) and the control group (2.86 cm). At 90 days after transplanting, the canopy diameter from plants treated with all three fertilizer treatments showed significantly larger than the control. Additionally, plants treated with combined fertilizers yielded significantly more flowers than other treatments. Overall, our results suggest that LDD1 compost tends to promote plant growth. A representative photo of chrysanthemums grown in our experimental field is shown in Figure 1. The plants developed healthy and produced numerous flowers, with only minor insect infestations, such as aphids, occurring during the early stages after transplanting.

Plant yields

To evaluate the effect of different fertilizer treatments on chrysanthemum yield, the dry weights of flowers, roots, aboveground plants, and whole plants were recorded at 120 days after transplanting, as listed in Table 4. Notably, LDD1 compost-treated plants produced significantly higher dry root weight at 31.37 g, compared to other treatments, followed by plants treated with chemical and combined fertilizers at 18.43 g and 15.03 g, respectively, with no significant difference between them. Control plants, which did not receive any fertilizers, had the lowest dry root weight at 9.65 g. There were no significant differences in the mean dry weights of flowers, aboveground plants, and whole plant weights across all fertilization treatments. A representative photo of the chrysanthemum plants sampled for dry weight measurements is shown in Figure 2.

Table 3. Mean plant height, canopy diameter, flower number, and flower diameter of chrysanthemum plants under different fertilizer treatments at 60 and 90 days after transplanting

Days	Treatment	Plant height (cm)	Canopy diameter (cm)	Flower number	Flower diameter (cm)
60	No fertilizer	34.00 ± 3.0	34.32 ± 1.8	4.17 ± 0.7	2.86 ± 0.2^{b}
	LDD1 compost	38.02 ± 5.2	40.15 ± 0.8	4.03 ± 2.1	3.24 ± 0.1^{a}
	Chemical fertilizer	35.63 ± 6.1	35.02 ± 4.8	3.87 ± 1.7	2.96 ± 0.3^{ab}
	LDD1+Chemical fertilizer	35.08 ± 2.3	38.57 ± 5.0	3.80 ± 1.7	2.77 ± 0.1^{b}
	F-test	ns	ns	ns	*
	C.V. (%)	11.39	10.79	35.41	8.19
90	No fertilizer	36.87 ± 2.4	35.47 ± 5.2^{b}	5.93 ± 1.2^{b}	1.93 ± 0.2
	LDD1 compost	38.40 ± 4.7	40.23 ± 4.8^{a}	6.23 ± 0.9^{b}	1.90 ± 0.0
	Chemical fertilizer	38.07 ± 5.0	38.45 ± 3.2^{a}	6.06 ± 1.4^{b}	2.01 ± 0.2
	LDD1+Chemical fertilizer	39.77 ± 4.7	38.85 ± 3.3^{a}	11.73 ± 1.0^{a}	1.91 ± 0.3
	F-test	ns	*	**	ns
	C.V. (%)	10.06	10.54	36.61	9.42

[1/]**Significant at $p \leq 0.01$, *significant at $p \leq 0.05$, ns: not significant

[2/]Mean±SD are shown. Different letters indicate a significant difference by DMRT ($p<0.05$)

Figure 1. A representative photo of chrysanthemum plants at 56 days after transplantation

Table 4. Mean dry weights of flowers, roots, aboveground plants, and whole plants from chrysanthemums treated with different fertilization methods at 120 days after transplanting

Treatment	Dry weight (g)			
	Flower	Root	Aboveground plant	Whole plant
No fertilizer	0.75 ± 0.1	9.65 ± 6.8[c]	81.91 ± 34.2	91.57 ± 40.5
LDD1 compost	0.82 ± 0.4	31.37 ± 10.0[a]	138.38 ± 63.2	169.75 ± 73.1
Chemical fertilizer	0.67 ± 0.4	18.43 ± 1.9[b]	92.38 ± 21.4	110.82 ± 19.8
LDD1+Chemical fertilizer	0.75 ± 0.6	15.03 ± 4.1[bc]	126.65 ± 39.5	141.68 ± 37.8
F-test	ns	**	ns	ns
C.V. (%)	48.31	53.70	39.69	39.46

1/**Significant at $p \leq 0.01$, ns: not significant

2/Mean±SD are shown. Different letters indicate a significant difference by DMRT ($p<0.05$)

Figure 2. A representative photo of chrysanthemum plants at 120 days, showing the effects of different fertilization treatments as follows: A, plants without fertilizer (T1); B, plants treated with LDD1 compost (T2); C, plants treated with chemical fertilizer (T3); D, plants treated with a combination of LDD1 and chemical fertilizer (T4)

Total flavonoid content and total phenolic content

The total flavonoid content (TFC) extracted from dried chrysanthemum flowers was quantified using the equation $y = 0.00010x + 0.00052$ ($R^2=0.998$), as shown in Table 6. The results indicated no significant difference in TFC across all fertilization methods, with values ranging from 41.788 to 47.584 mg QE/g DW**.** Plants treated with LDD1 compost had the lowest TFC, while those receiving the combined fertilizer yielded the highest TFC.

Similarly, the total phenolic content (TPC) extracted from dried chrysanthemum flowers was quantified using the equation y = 0.00040x + 0.11747 (R^2=0.999), as shown in Table 6. Results showed that there was no significant difference in TPC across all fertilization methods. The TPC ranged from 8.742 to 10.421 mg GAE/g DW, with the lowest TPC found in chemical fertilizer-treated plants and the highest TPC observed in LDD1-treated plants.

Table 6. Total flavonoid content (TFC) and total phenolic content (TPC) extracted from dried chrysanthemum flowers under different fertilization treatments. TFC is expressed as milligrams of quercetin equivalent per gram of dry weight (mg QE/g DW), and TPC is expressed as milligrams of gallic acid equivalent per gram of dry weight (mg GAE/g DW)

Treatment	**TFC (mg QE/g DW)**	**TPC (mg GAE/g DW)**
No fertilizer	43.273 ± 3.86	8.916 ± 0.55
LDD1 compost	41.788 ± 2.15	10.421 ± 0.70
Chemical fertilizer	44.926 ± 4.76	8.742 ± 0.22
LDD1+Chemical fertilizer	47.584 ± 3.16	9.713 ± 0.80
F-test	ns	ns
C.V. (%)	8.58	9.23

[1/]ns: not significant, *significant at $p \leq 0.05$
[2/]Mean±SD are shown

Antioxidant activity

To assess the impact of different fertilizer types on antioxidant activity of bioactive compounds in chrysanthemum flowers, a DPPH assay was performed for all treatments. The DPPH assay uses a stable free radical agent that can accept an electron or hydrogen radical, leading to a visible change in color. This discoloration is used to measure the antioxidant capacity. The antioxidant activity and free radical scavenging percentages from flower extracts are listed in Table 7. The unit of antioxidant activity is expressed as micrograms of ascorbic acid equivalent per gram of dry weight (μg AAE/g DW). Fertilizer application resulted in significantly higher antioxidant activity compared to non-fertilized plants. However, there were no significant differences among the plants treated with different fertilization methods (LDD1 compost, chemical, and combined), with antioxidant activity ranging from 1.466 to 1.554 μg AAE/g DW. These results align with the radical scavenging percentage, where all fertilizer-treated plants exhibited significantly higher radical scavenging percentages than those without fertilizers.

Table 7. Antioxidant activity and DPPH scavenging percentage of chrysanthemum flower extracts under different fertilization treatments. Antioxidant activity is reported in micrograms of ascorbic acid equivalent per gram of dry weight (µg AAE/g DW)

Treatment	Antioxidant activity (µg AAE/g DW)	% radical scavenging activity
No fertilizer	1.124 ± 0.29^{b}	47.789 ± 12.90^{b}
LDD1 compost	1.466 ± 0.04^{a}	62.793 ± 1.65^{a}
Chemical fertilizer	1.442 ± 0.10^{a}	61.717 ± 4.31^{a}
LDD1+Chemical fertilizer	1.554 ± 0.17^{a}	66.648 ± 7.43^{a}
F-test	*	*
C.V. (%)	16.30	16.72

[1/]*significant at $p \leq 0.05$. [2/]Mean±SD are shown. Different letters indicate a significant difference by DMRT ($p<0.05$)

Discussion

The microbial activator super LDD1 compost, developed by Land Development Department, Thailand, consists of four fungal species, two *Streptomyces* species, and two *Bacillus subtili*s species, which promote the degradation of cellulose compounds and lipids. This study compared the effects of LDD1 compost with chemical fertilizer on the growth, yield, and antioxidant properties of chrysanthemum plants. Our data indicate that most aboveground plant parameters showed no significant difference among fertilizer treatments. However, certain parameters, such as canopy diameter and flower traits showed significant improvement with fertilizer application, particularly with LDD1 compost. In this experiment, LDD1 compost was mixed with soil during plot preparation, allowing transplanted seedlings to access nutrients immediately. In contrast, chemical fertilizer was applied every 30 days after transplanting, which may have delayed nutrient availability for seedlings and contributed to slower stem and flower growth in the early stages compared to the LDD1 compost method. However, during later growth stages, there was no significant difference in growth between plants treated with compost and chemical fertilizers, potentially due to the fact that chemical fertilizer supplied adequate nutrients at this point. In stevia cultivation, plants grown with organic fertilizer showed the highest dry weight of roots, shoots, and the whole plant, which was similar to our study. This may be due to the ability of organic fertilizer to enhance root activity (Liu *et al*., 2011). Furthermore, our fertilizer analysis revealed that LDD1 compost supplied comparable levels of N, P, and K to those in mineral fertilizer, resulting in similar plant growth and yield. Our study supports the use of organic fertilizers as a sustainable approach to reduce chemical fertilizer usage in chrysanthemum cultivation.

Notably, fertilization with LDD1 compost resulted in the highest dry root weight. Our results align with several previous studies that reported the positive effects of organic fertilizer or manure on the root growth, including in stevia (Liu *et al*., 2011), maize (Wen *et al*., 2016), and rice (Yang *et al*., 2004). Root growth is strongly influenced by the soil environment, and LDD1 fertilization introduces beneficial microorganisms that enhances soil organic matter and nutrient availability, primarily through microbial activity in the crop rhizosphere (Wen *et al*., 2016). These microbes in organic compost can also suppress soil-borne pathogens and produce antimicrobial compounds, promoting root growth and beneficial organisms in soil (Thepsilvisut, 2017; Taneja *et al*., 2024). A previous study on *Chrysanthemum morifolium* showed that the application of microbial inoculants enhanced root growth, improved root morphology, and increased soil microbial biomass carbon compared to uninoculated soil (Prasanna *et al*., 2016). Microbial inoculants likely promoted nutrient availability (N, P and C) in the rhizosphere by solubilizing nutrients and facilitating their transport into plant roots.

Chrysanthemum flowers are rich in bioactive compounds, particularly phenolics, and flavonoids, which offer various pharmacological benefits, such as antioxidant, anti-inflammatory, anti-microbial, and anti-cancer properties (Wu *et al*., 2010; Sharma *et al*., 2023). Chemical analysis of *C. indicum* flowers revealed the presence of 10 flavonoids, with quercitrin being the most abundant (Wu *et al*., 2018). Other bioactive compounds found in chrysanthemum flowers include anthocyanins, carotenoids, caffeoylquinic acids, and terpenoids (Sharma *et al*., 2023).

Although the total flavonoid and phenolic content did not differ significantly across treatments and the control, fertilizers—particularly LDD1 compost combined with chemical fertilizer—tended to yield higher total flavonoid content in dried chrysanthemum flowers compared to other methods. Moreover, our results suggest that fertilizers promote antioxidant activity in the chrysanthemum extracts. This observation is in line with previous studies that report the positive effects of fertilizers in increasing bioactive compound levels in medicinal plants. For instance, Lee *et al*. (2005), demonstrated that fertilizer supplemented with lime increased terpene, monoterpenoid, and sesquiterpenoid levels in *Chrysanthemum boreale*. Similar effects have been reported in other medicinal plants, including saffron (Ghanbari *et al*., 2019), damask rose (Hamedi *et al*., 2022), and chicory (Gholami *et al*., 2018), where compost application improved total phenolic and flavonoid content. Fertilizers provide enriched nutrients compared to non-fertilized soil, serving as building blocks for biosynthesis of plant secondary metabolites, including phenolics, flavonoids, and other bioactive compounds (Gholami *et al*., 2018).

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