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Basal application of composts prepared from agricultural by-products affected the growth, nutrient contents and yield of *Chrysanthemum indicum* L. grown organically

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ABSTRACT

This study was conducted to evaluate the influences of composts applying at different times on the growth, nutrient accumulation and yield of chrysanthemum plant. The research was conducted at Vietnam National University of Agriculture in Vietnam in 2023. Two types of compost were C3 (compost was prepared from rice straw, cow manure and elephant grass) and C4 (compost was prepared from rice straw, cow manure and cabbage leaves). The application times were T1 (20 days before transplanting), T2 (10 days before transplanting) and T3 (1 day before transplanting). The parameters of the growth, nutrient contents, yield of chrysanthemum were evaluated. The results showed that the C3 and C4 composts had similar effects on the growth and yield of chrysanthemum. Earlier application of compost caused the significantly higher values of the growth and yield parameters in comparison with later application. T1 treatment gave the highest values of experimental indicators. The combination effects of compost types and application times on the growth and yield of chrysanthemum were significantly different when comparing among the treatments. Application of C3 or C4 composts at 20 days before transplanting was both good for chrysanthemum growth with the highest values of LAI (0.911 and 0.958 of C3 and C4 treatment at bud stage), dry weight (175.85 and 163.87 g plant^{-1} of C3 and C4 treatment in harvesting stage) and yield (18.64 and 18.16 quintal ha^{-1} of C3 and C4 treatment).

Keywords: compost, agricultural by-products, application time, chrysanthemum.

INTRODUCTION

Chrysanthemum indicum L. is the flowering plant in the family Asteraceae which is the second most economically important floricultural crop in the world, following rose (Shahrajabian et al., 2019). This is a perennial herbaceous flowering crop with numerous benefits of ornamental purposes (Hatem et al., 2023; Shahrajabian et al., 2019) and for health promotion with high medicinal characteristics (Shahrajabian et al., 2019; Sharma et al., 2023). According to Shahrajabian et al. (2019), chrysanthemums is a fragrant, cool, and light herb and can be used as a food, drinkables, medicine. Shahrajabian et al. (2019) and Sharma et al. (2023) revealed the best benefits for human health from chrysanthemum tea are anti-inflammatory, boosting immune system, strengthening bones, improving eyesight, increasing metabolism rate, sustaining cardiovascular health, treating cough and cold as well as detoxify purpose. These benefits are related with the numerous biologically active compounds from Chrysanthemum flowers, such as polyphenolic compounds, flavonoids, anthocyanins (Sharma et al., 2023). Due to the high values in traditional medicine and to achieve the best quality and food hygiene and safety, the demand for the use of the edible products from Chrysanthemum flowers grown in organic farming has increased. Thus, the technique of organic fertilizer use for Chrysanthemum is the essential component to increase its growth and yield as well as the economic return for producers.

The increasing amount of agricultural by-products generated from agriculture production has been considered as a major issue that needs to be resolved due to its negative impacts on environment and cost production. Ayoo et al. (2019) reported about 140 billion metric tons of organic wastes produced in agriculture activities throughout the world. In Vietnam, the wastes from husbandry are estimated about 142 million tons year-1 in solid form and over 681 million m^3 day^{-1} in water form (Vu and Nguyen, 2019); and wastes from crop production are about 100 million tons $year^{-1}$ (Nguyen et al., 2021). These organic sources are the important nutrient resources with high content of organic matter, nitrogen, phosphorus, and other micronutrients, which can be used to meet crop nutrients (Bian et al., 2019; Delin and Engström, 2010; Sayara et al., 2020), especially in organic farming. Compost products produced by mixing different raw organic materials has been reported to give the numerous advantages on managing soil health by improving soil organic matter, reducing nutrient loss (Al-Tawarah et al., 2024; Bian et al., 2019), thereby rise crop nutrient uptakes (Bordoloi and Talukdar, 2019), and ultimately increase crop growth and yield. In addition, utilizing efficiently these sources could reduce the environmental pollution, conserve natural resources and reduce cost production (Ayoo et al., 2019; Bian et al., 2019).

In nutrient management techniques, an essential component is synchronizing the nutrient availability from fertilizers with crop nutrient demand within the critical periods in order to achieve better nutrient use efficiency, gain the maximum yields and limit nutrient losses (Delin and Engström, 2010; Kelley et al., 2022). Under application of organic amendments, the organic nutrients must be mineralized to become available to plants, however the mineralization rates of organic fertilizers are different (Delin and Engström, 2010), due to the interactive effects of the type and rate of organic amendments, the climate conditions and the crop types (Delin and Engström, 2010; Liu et al., 2009). The effect of compost application onto soil highly depends on both soil and compost intrinsic properties, along with the compost application rate. However, it is important to mention that the results of the application of compost may not be viewed within a short period due to the slow release of nutrients (Tittarelli et al., 2007). Thus, in organic farming, the type and timing application of organic amendments must be considered as the keys for consideration (Gupta and Hussain, 2014) because of its relation with the time of the nutrient release to the crop (Delin and Engström, 2010). This study was conducted to determine the suitable application time of different compost types prepared from agricultural by-products for the growth, nutrient accumulation and yield of chrysanthemum plants.

MATERIALS AND METHODS

Experiment site, plant materials and cultivation practices

The study was conducted at the research area of Vietnam National University of Agriculture in Vietnam in 2023. This region climate is tropical. During the experiment, the average air temperature and humidity in the June, July, August, September, October, November, and December in 2023 were 29.7 °C, 30.8 °C, 29.3 °C, 28.4 °C, 27.2 °C, 23.5 °C, 19.3 °C and 82.0%, 76.0%, 82.0%, 82.0%, 72.0%, 77.0%, 72.0%, respectively. The two kinds of composts were prepared from agricultural by-products including C3 (rice straw, cow manure, elephant grass) and C4 (rice straw, cow manure, cabbage leaves). The Vietnamese traditional chrysanthemum variety was used. Two and half month - seedlings with 30–35 cm of plant height were transplanted at the hill-to-hill space of 30 cm. One row was grown on the seed bed with 1.2 m of wide, 10 m of length and 40 cm of height. The composts were applied one time at basal. The application time was followed the experimental treatments. The application doses of C3 and C4 composts were the same (9.5 tons ha^{-1}) in order to ensure the N content in each treatment equally 250 kg N ha^{-1} as the common application rate for chrysanthemum in Vietnam. The organic cultivation practices was applied for chrysanthemum plant during crop season.

Experimental design, treatments and parameters

The two-factor experiment was designed according to a randomized completely block design with 3 replications. Area of an experimental plot was 10 m^2. The first experimental factor was the types of compost consisting of C3 (Compost was recycled from rice straw, cow manure and elephant grass) and C4 (Compost was recycled from rice straw, cow manure and cabbage leaves). Composting method was thermophilic method. The properties of compost (C3; C4) were pH (7.9; 7.6), OC (38.3%; 37.1%); OM (69.0%;

66.7%); Total nitrogen content (2.64%; 2.64%); Total phosphorous content (0.92%; 0.79%); Total potassium content (3.34%; 3.24%); C/N (14.5; 14.0). The second experimental factor was the application times of compost including T1 (20 days before transplanting), T2 (10 days before transplanting) and T3 (1 day before transplanting).

Five random plants were observed in each plot to record the growth (plant height, plant width, number of primary branches, SPAD value (SPAD, Soil Plant Analysis Development)) and yield parameters. The SPAD value was measured with a chlorophyll meter (SPAD–502, Konica Minolta Sensing Inc., Osaka, Japan). The leaf area index (LAI) and dry weight (DW) were measured at young stage, bub stage and harvesting stage. LAI (m^2 of leaves m^{-2} of land) was determined according to the formula:

$$LAI = \frac{A1 \times Number\ of\ plants\ m^{-2}\ of\ land}{A2 \times 100} \quad (1)$$

where: A1 is the weight of whole fresh leaves of 1 plant (g); A2 is the weight of 1 dm^2 of fresh leaves (g).

The shoots were cut at 5 cm from the base and oven-dried at 80°C until the weight was constant for determining DW. The total nitrogen content (the Kjeldahl method (Donald and Robert, 1998)), total phosphorous content (the ascorbic acid method (Murphy and Riley, 1962)), total potassium content (the flame photometer method (Donald and Dean, 1998)) of plant were measured at the young stage (30 days after transplanting), bub stage (80 days after transplanting) and harvesting stage (flowering stage, 120 days after transplanting). The average flower weight was evaluated on 5 plants on each experimental plot. The yield was calculated as the total dried flower weight of the harvests of each experimental plot.

Statistical analysis

Analysis of variance was used to test for statistical differences between means of plant nutrient contents, LAI, dry weight and yield, followed by Tukey's honestly significant difference (HSD) test. The Pearson correlation coefficient was estimated to assess the potential relation between the nutrient contents, growth and yield. The statistical analyses were performed using Statistix software (version 8.0, Analytical Software, Tallahassee, FL, USA).

RESULTS

Effect of application time and types of compost on the growth of chrysanthemum

Plant height, plant width and number of primary branches

Effect of the application times and types of compost on the plant height, plant width and number of primary branches were presented in Figure 1. The number of primary branches ranged from 48.68 to 52.40 branches plant^{-1}. The plant width ranged from 118.73 cm to 127.33 cm. The plant height ranged from 37.76 cm to 42.50 cm.

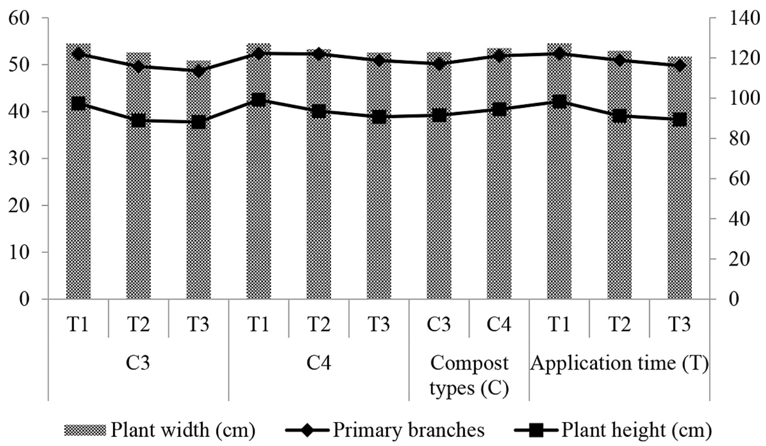

Figure 1. Effect of the application times and types of compost on the plant height, plant width and number of primary branches of chrysanthemum. C3: Compost was recycled from rice straw, cow manure and elephant grass. C4: Compost was recycled from rice straw, cow manure and elephant grass; T1:20 days before transplanting; T2:10 days before transplanting; T3: 1 day before transplanting. The right vertical axis refers to the data of plant width. The left vertical axis refers to the data of primary branch number and plant height

The C3T3 treatment gave the lowest values while the C4T1 treatment gave the highest values of these growth parameters. Chrysanthemums in the treatment fertilized with compost at 20 days before transplanting (DBT) (T1) had more primary branches, higher plant height and plant width than those in the treatment fertilized with compost at 10 days (T2) and 1 day (T3) before transplanting. The C4 compost gave higher plant height and plant width than the C3 compost.

SPAD value

Results of Table 1 show that compost types did not cause statistically significant differences in SPAD values of chrysanthemum at all three growth stages. Meanwhile, application times caused significant differences in SPAD values at the bud and harvest stages. Fertilizing with compost at 20 DBT gave higher SPAD values of chrysanthemum than the other treatments at the young stage, but lower values than the other treatments at the bud and harvest stages. This may be due to the fact that under earlier application of compost, the plants used the nutrients released from the compost earlier, so they had higher SPAD values instantly from the early growth stage. On the contrary, in the later compost application treatment, the plants used the nutrients from the compost later and gave higher SPAD values at the late growth stage. There were statistically significant differences in the interaction effects of compost and application time on SPAD value among treatments. Application of C3 or C4 compost at 20 DBT gave the highest SPAD values.

LAI

It is clear that leaf area index of chrysanthemum reached the highest at the bud stage, then gradually reduced at the harvest stage (Table 2). Concerning the individual effects of experimental factors, statistically significant differences in LAI among treatments were not recorded under applying different types of compost, but recorded under the different times of application at all three growth stages. Applying compost at 20 DBT gave the highest LAI values (0.319, 0.934 and 0.852 at young, bud and harvest stages). Regarding the interaction effect of compost types and application times, the statistically significant differences in LAI values were recorded at all growth stage when comparing among treatments. LAI at the young, bud and harvest stages was highest in C4T1 (0.317, 0.958 and 0.855) and C3T1 (0.321, 0.911 and 0.848) following by C4T2, C3T2. The lowest

Table 1. Effect of types and application times of compost on SPAD of chrysanthemum plant

Treatments		SPAD value		
		Young stage	Bud stage	Harvesting stage
C3	T1	48.65[a]	53.09[bc]	50.53[a]
	T2	45.46[a]	53.93[abc]	51.59[a]
	T3	44.21[a]	56.19[a]	54.96[a]
C4	T1	46.29[a]	52.47[c]	50.70[a]
	T2	45.21[a]	54.65[abc]	53.20[a]
	T3	44.83[a]	55.14[ab]	54.57[a]
Compost type (C)	C3	46.11[a]	54.40[a]	52.36[a]
	C4	45.44[a]	54.08[a]	52.82[a]
Application time (T)	T1	47.47[a]	52.78[b]	50.62[b]
	T2	45.33[a]	54.29[a]	52.39[ab]
	T3	44.52[a]	55.66[a]	54.76[a]
Tukey $HSD_{0.05}$	(C*T)	5.45	2.47	5.56
	(C)	2.02	1.38	3.11
	(T)	3.05	0.91	2.06
CV (%)		4.19	1.61	3.74

Note: values with different letters in the same column of individual or interactive factors indicate significant differences in the Tukey HSD test at the 5% significance level. CV% – Coefficient of variation. C3 – Compost was recycled from rice straw, cow manure and elephant grass. C4 – Compost was recycled from rice straw, cow manure and elephant grass; T1 – 20 days before transplanting; T2 – 10 days before transplanting; T3 – 1 day before transplanting.

Table 2. Effect of types and application times of compost on LAI of chrysanthemum plant (m^2 of leaves m^{-2} of land)

Treatments		LAI		
		Young stage	Bud stage	Harvest stage
C3	T1	0.321[a]	0.911[a]	0.848[a]
	T2	0.304[ab]	0.863[ab]	0.780[ab]
	T3	0.297[ab]	0.789[bc]	0.679[bc]
C4	T1	0.317[a]	0.958[a]	0.855[a]
	T2	0.307[ab]	0.787[bc]	0.738[abc]
	T3	0.282[b]	0.760[c]	0.630[c]
Compost type (C)	C3	0.308[a]	0.854[a]	0.769[a]
	C4	0.302[a]	0.835[a]	0.741[a]
Application time (T)	T1	0.319[a]	0.934[a]	0.852[a]
	T2	0.305[ab]	0.825[b]	0.759[b]
	T3	0.290[b]	0.774[b]	0.654[c]
Tukey $HSD_{0.05}$	(C*T)	0.0373	0.0947	0.1257
	(C)	0.0138	0.0352	0.0467
	(T)	0.0209	0.053	0.0704
CV (%)		4.32	3.96	5.89

Note: values with different letters in the same column of individual or interactive factors indicate significant differences in the Tukey HSD test at the 5% significance level. CV% – Coefficient of variation. C3 – Compost was recycled from rice straw, cow manure and elephant grass. C4 – Compost was recycled from rice straw, cow manure and elephant grass; T1 – 20 days before transplanting; T2 – 10 days before transplanting; T3 – 1 day before transplanting.

LAI values were recorded in C3T3 (0.297, 0.789 and 0.679) and C4T3 (0.282, 0.760 and 0.630).

Dry weight

It can be seen from Table 3 that chrysanthemum produced the higher dry weight in stems than in leaves through the growth stages. Applying different types of compost had statistically significant effects on dry weight. C4 compost did not gave higher dry weight of chrysanthemum than C3 compost at the young and bud stages, but showed statistically significantly higher dry weight at the harvest stage. Different application times also brought statistically significant effects on dry weight at different growth stages of chrysanthemum. T1 gave the highest dry weight, following by T2 and T3. The interaction between compost type and application time had statistically significant effects on the dry weight when comparing among treatments. C3T3 gave the lowest dry weight at the young and harvest stages (11.98, 113.83 g $plant^{-1}$ at the young and harvest stages, respectively). C4T3 had the lowest plant dry weight at the bud stages. C3T1 and C4T1 treatments had higher plant dry weight at young and bud stages than other treatments. C3T1 gave the highest dry weight at harvest stages (175.85 g $plant^{-1}$).

Effect of the application times and types of compost on the nutrient accumulation in chrysanthemum plant

Concerning the effects of single experimental factors, different compost types did not effect on nitrogen contents at all growth stages while they brought the significant differences on phosphorous and potassium contents (Table 4). C4 compost gave higher phosphorous and potassium contents in plant than C3 compost. Different application time significantly affected nutrient contents in plant, T1 showed higher nutrient contents in chrysanthemum than T2 and T3. The significant interaction effects of the application times and types of compost on the nutrient accumulation in chrysanthemum plant were recorded. C3T3 gave the lowest N, P_2O_5, K_2O contents (except P_2O_5 content at young stage), while C4T1 and C3T1 brought the highest values of these nutrient contents at all growth stages.

Effect of the application times and types of compost on yield and yield components

Table 5 reveals the chrysanthemum yield and yield components affected by different application times and compost types. The results indicate

Table 3. Effect of types and application times of compost on dry weight of chrysanthemum plant *(Unit:g plant^{-1})*

Treatments		Young stage			Bud stage			Harvest stage		
		Stem	Leaves	Plant	Stem	Leaves	Plant	Stem	Leaves	Plant
C3	T1	8.45	6.72	15.18^{a}	26.71	18.78	45.49^{ab}	153.84	22.02	175.85^{a}
	T2	6.38	5.96	12.34^{a}	27.06	15.99	43.05^{bc}	121.89	19.27	141.16^{c}
	T3	6.72	5.26	11.98^{a}	21.25	14.27	35.51^{cd}	98.46	15.37	113.83^{d}
C4	T1	9.01	6.31	15.32^{a}	30.74	20.81	51.55^{a}	146.23	17.64	163.87^{b}
	T2	8.29	5.27	13.56^{a}	20.37	18.50	38.86^{bc}	142.91	14.57	157.48^{b}
	T3	8.02	5.43	13.45^{a}	15.80	14.23	30.03^{d}	106.01	15.03	121.04^{d}
Compost type (C)	C3	7.18	5.98	13.17^{a}	25.01	16.34	41.35^{a}	124.73	18.88	143.61^{b}
	C4	8.44	5.67	14.11^{a}	22.30	17.84	40.15^{a}	131.72	15.74	147.46^{a}
Application time (T)	T1	8.73	6.52	15.25^{a}	28.73	19.79	48.52^{a}	150.03	19.83	169.86^{a}
	T2	7.34	5.62	12.95^{ab}	23.71	17.24	40.96^{b}	132.40	16.92	149.32^{b}
	T3	7.37	5.35	12.71^{b}	18.52	14.25	32.77^{c}	102.24	15.20	117.43^{c}
Tukey $HSD_{0.05}$	(C*T)	-	-	4.4796	-	-	8.3165	-	-	8.2870
	(C)	-	-	1.6629	-	-	3.0873	-	-	3.0763
	(T)	-	-	2.5069	-	-	4.6541	-	-	4.6376
CV (%)		-	-	11.6	-	-	7.21	-	-	2.01

Note: values with different letters in the same column of individual or interactive factors indicate significant differences in the Tukey HSD test at the 5% significance level. CV% – Coefficient of variation. C3 – Compost was recycled from rice straw, cow manure and elephant grass. C4 – Compost was recycled from rice straw, cow manure and elephant grass; T1 – 20 days before transplanting; T2 – 10 days before transplanting; T3 – 1 day before transplanting.

Table 4. Effects of compost types and application times on nutrient contents in chrysanthemum plant (Unit: %)

Treatments		Young stage			Bud stage			Harvest stage		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
C3	T1	2.25^{a}	0.1000^{ab}	2.23^{ab}	2.60^{ab}	0.1100^{ab}	2.46^{a}	2.77^{a}	0.1200^{ab}	2.58^{a}
	T2	2.11^{ab}	0.0933^{b}	2.15^{abc}	2.51^{ab}	0.1067^{ab}	2.37^{ab}	2.58^{bc}	0.1067^{bc}	2.45^{cd}
	T3	1.99^{b}	0.1033^{ab}	2.07^{c}	2.43^{b}	0.0967^{b}	2.25^{b}	2.50^{c}	0.0967^{c}	2.41^{d}
C4	T1	2.27^{a}	0.1167^{a}	2.28^{a}	2.64^{a}	0.1233^{a}	2.51^{a}	2.79^{a}	0.1267^{a}	2.62^{a}
	T2	2.12^{ab}	0.1067^{ab}	2.20^{abc}	2.56^{ab}	0.1133^{ab}	2.47^{a}	2.62^{b}	0.1100^{abc}	2.54^{b}
	T3	2.03^{b}	0.1000^{ab}	2.12^{bc}	2.47^{ab}	0.1133^{ab}	2.41^{ab}	2.56^{bc}	0.1100^{abc}	2.50^{bc}
Compost type (C)	C3	2.12^{a}	0.0989^{b}	2.15^{a}	2.51^{a}	0.1044^{b}	2.36^{b}	2.62^{a}	0.1078^{b}	2.48^{b}
	C4	2.14^{a}	0.1078^{a}	2.20^{a}	2.56^{a}	0.1167^{a}	2.46^{a}	2.66^{a}	0.1156^{a}	2.55^{a}
Application time (T)	T1	2.26^{a}	0.1083^{a}	2.26^{a}	2.62^{a}	0.1167^{a}	2.49^{a}	2.78^{a}	0.1233^{a}	2.60^{a}
	T2	2.11^{b}	0.1017^{a}	2.18^{a}	2.54^{ab}	0.1100^{ab}	2.42^{ab}	2.60^{b}	0.1083^{b}	2.49^{b}
	T3	2.01^{b}	0.1000^{a}	2.09^{b}	2.45^{b}	0.1050^{b}	2.33^{ab}	2.53^{c}	0.1033^{b}	2.46^{b}
Tukey $HSD_{0.05}$	(C*T)	0.2037	0.0207	0.1455	0.1939	0.0205	0.1606	0.1045	0.0171	0.0684
	(C)	0.0756	0.0076	0.0540	0.0720	0.0075	0.0596	0.0388	0.0063	0.0254
	(T)	0.1140	0.0116	0.0814	0.1085	0.0114	0.0899	0.0585	0.0096	0.0383
CV (%)		3.38	7.07	2.36	2.70	6.54	2.35	1.40	5.42	0.96

Note: values with different letters in the same column of individual or interactive factors indicate significant differences in the Tukey HSD test at the 5% significance level. CV% – Coefficient of variation. C3 – Compost was recycled from rice straw, cow manure and elephant grass. C4 – Compost was recycled from rice straw, cow manure and elephant grass; T1 – 20 days before transplanting; T2 – 10 days before transplanting; T3 – 1 day before transplanting.

that two types of compost did not cause the differences in yield parameters. However, compost application at different times showed significant differences in flower number plant^{-1}, weight of 100 flowers (g), flower weight plant^{-1} (g) and yield (quintal ha^{-1}). This could be the main reason contributing to the statistically significant differences being given by combination effect of application

Table 5. Effects of compost types and application times on yield of chrysanthemum plant

Treatments		Flower number plant^{-1}	Weight of 100 flowers (g)	Flower weight plant^{-1} (g)	Yield (quintal ha^{-1})
C3	T1	1463^{a}	6.16^{a}	79.03^{a}	18.64^{a}
	T2	1331^{abc}	5.82^{a}	71.24^{ab}	17.00^{ab}
	T3	1248^{abc}	5.60^{a}	67.74^{b}	16.51^{ab}
C4	T1	1427^{ab}	5.81^{a}	78.66^{a}	18.16^{ab}
	T2	1217^{bc}	5.57^{a}	65.57^{b}	17.52^{ab}
	T3	1131^{c}	5.52^{a}	63.79^{b}	16.11^{b}
Compost type (C)	C3	1347^{a}	5.86^{a}	72.67^{a}	17.25^{a}
	C4	1258^{b}	5.63^{a}	69.34^{a}	17.39^{a}
Application time (T)	T1	1445^{a}	5.98^{a}	78.85^{a}	18.40^{a}
	T2	1274^{b}	5.69^{a}	68.40^{b}	17.26^{ab}
	T3	1190^{b}	5.56^{a}	65.76^{b}	16.31^{b}
Tukey $HSD_{0.05}$	(C*T)	232.39	0.93	11.725	2.4818
	(C)	86.268	0.3452	4.3524	0.9213
	(T)	130.05	0.5205	6.5614	1.3889
CV(%)		6.3	5.72	5.83	5.06

Note: values with different letters in the same column of individual or interactive factors indicate significant differences in the Tukey HSD test at the 5% significance level. CV% – Coefficient of variation. C3 – Compost was recycled from rice straw, cow manure and elephant grass. C4 – Compost was recycled from rice straw, cow manure and elephant grass; T1 – 20 days before transplanting; T2 – 10 days before transplanting; T3 – 1 day before transplanting

time and compost types among treatments. Application of C4 compost at 1 day before transplanting (C4T3) showed the lowest values of yield and yield components (flower number plant^{-1}, weight of 100 flowers (g), flower weight plant^{-1} (g) and yield (quintal ha^{-1}) were 1131, 5.52, 63.79, 16.11 respectively). Application of compost C3 or C4 at 20 day before transplanting (C3T1, C4T1) showed the highest values of those parameters. The flower number plant^{-1}, weight of 100 flowers (g), flower weight plant^{-1} (g) and yield (quintal ha^{-1}) of C3T1 and C4 T1 were 1463 and 1427, 6.16 and 5.81, 79.03 and 78.66, 18.64 and 18.16, respectively.

Pearson correlation matrix of recorded parameters

Relationships among observation parameters were analysed to understand the physiological characteristics of chrysanthemum affected by the different application times and types of compost through growth stage (Table 6). At the young stage, the N content was positively and highly correlated with the K content, LAI, DW and yield; The K content, LAI, DW were also positively and highly correlated with the yield. At the bud stage, the N content was positively and very highly correlated with the P content; LAI was positively and very highly correlated with DW. At the harvest stage, the N content was positively and very highly correlated with the K and P contents; DW was positively and very highly correlated with the yield.

DISCUSSION

Composts prepared from agricultural by-products bring good effects on the growth and yield of *Chrysanthemum indicum* L.

Recently, agricultural by-products may become useful organic fertilizers (compost) for plants through the composting process. Compost holds high organic matter content as well as abundance in macro- and micronutrients, which supplies for the nutrient needs of plant (Kaboré et al., 2010; Waqas et al., 2023; Al-Tawarah et al., 2024; Thieu and Nguyen, 2024). The positive effects of compost made from agricultural by-products on the agricultural crops have been recorded by many researches. Zhang and Sun (2016) demonstrated that compost application for three years resulted in increasing grain yield by approximately 7–15%, particularly in the second and third years. The growth and yield of corn improved when applying compost of sewage sludge, sawdust,

Table 6. Pearson correlation matrix of nutrient contents and growth, yield parameters of chrysanthemum plant in response to the different application times and types of compost

Young stage					
	N	P_2O_5	K_2O	LAI	DW
P_2O_5	0.39^{ns}				
K_2O	0.65^{**}	0.19^{ns}			
LAI	0.72^{***}	0.07^{ns}	0.56^{*}		
DW	0.68^{**}	0.52^{*}	0.39^{ns}	0.43^{ns}	
Yield	0.80^{***}	0.12^{ns}	0.70^{**}	0.71^{**}	0.54^{*}
Bub stage					
	N	P_2O_5	K_2O	LAI	DW
P	0.83^{***}				
K_2O	0.64^{**}	0.73^{***}			
LAI	0.59^{*}	0.36^{ns}	0.42^{ns}		
DW	0.60^{**}	0.32^{ns}	0.33^{ns}	0.93^{***}	
Yield	0.53^{*}	0.39^{ns}	0.41^{ns}	0.56^{*}	0.54^{*}
Harvest stage					
	N	P_2O_5	K_2O	LAI	DW
P_2O_5	0.86^{***}				
K_2O	0.89^{***}	0.81^{***}			
LAI	0.66^{**}	0.59^{**}	0.51^{*}		
DW	0.71^{***}	0.58^{*}	0.63^{**}	0.80^{***}	
Yield	0.58^{*}	0.54^{*}	0.49^{*}	0.58^{**}	0.70^{**}

Note: ns: non-significant; *: P-value < 0.05; **: P-value < 0.01; ***: P-value < 0.001; N, P_2O_5, and K_2O: total nitrogen content, total phosphorous content and total potassium content of chrysanthemum plant; LAI: leaf area index; DW: dry weight.

garden and part waste (Anita and Waclaw, 2024). Aunkamol et al. (2022) reported that the growth and yield of lettuce were increased when applying of 10% food waste compost. The farmyard manure (10 tons ha^{-1}) increased significantly cucumber yield in Nigeria (Eifediyi and Remison, 2010). Thieu and Nguyen (2024) indicated that application of compost from agricultural residues gave the positive effects on the growth and yield of cucumber.

Our experiment results showed that both two kinds of compost brought good effects on the chrysanthemum growth and yield. The results of growth, physiological and yield indicators in this study were higher to the results of these parameters of some studies such as the studies of Phan et al. (2020), Doan et al. (2022) and Md Ehsanullah et al. (2023). Although these two composts were made from different green materials (elephant grass and cabbage leaves were composted for C3 and C4, respectively), they did not show the different effects on the growth or yield of chrysanthemum. This could be due to the similar chemical properties (pH, OM, OC, C/N) and nutrient contents (N and K contents) of those two composts. Therefore, the results of our research indicated that the agricultural by-products should be converted into highly-valuable and nutritious composts for plant growth, improving soil health and contributing to environmental protection. Agricultural by-products can be the residues of vegetable growing areas, other field-available grasses and plants. The compost prepared from these sources supports plant growth well to produce safety agricultural product for human.

Apply compost early before transplanting to promote the chrysanthemum growth

Compost is the result of incomplete (partial) decomposition of organic materials which are then accelerated by certain types of bacteria or microbes under certain conditions. According to Liu et al. (2009) and Sánchez et al. (1997), the timing of compost application clearly affected the nutrient availability for crops. Liu et al. (2009) reported the application time of organic amendments significantly affected on soil microbial properties and soil nutrient status, thereby influenced plant nutrient uptake and soil nutrient retention. According to Sánchez et al. (1997), at the initial stage, the mineralization of compost was very slow, so late application of compost could lead to the shortage of available nutrients to the crop at the critical period of crop nutrient demand. On the other hand, some types of organic fertilizers, such as chicken manure, can mineralized rapidly and may cause nutrient leaching if applied in inappropriate time, because the nutrients from these organic sources are already in the available forms (Delin and Engström, 2010). Our study results clearly showed that different compost application times significantly affected the growth and yield of chrysanthemum. The growth and yield of chrysanthemum under different application time and types of compost were affected right from the young stage. The N content was positively and highly correlated with the K content (0.65), LAI (0.72), DW (0.68) and yield (0.80) at the young stage (Table 6). Combining with the results of the influence of application time on growth, physiological and yield parameters, it showed that early compost application supports plant growth well from the initial stage, leading to better crop yield. The application of C3 or C4 compost at 20 DBT gave higher results than the other treatments (10 or 1 DBT) in terms of LAI, DW, nutrient contents and yield. This could be due to the fact that, 20 DBT was enough to mineralize organic compositions of compost into readily available nutrients to meet the chrysanthemum nutrient requirement immediately after transplanting. This indicates that to increase the effectiveness of compost prepared from agricultural by-products for plants in general and chrysanthemums in particular, it should be applied 20 days before transplanting.

CONCLUSIONS

Agricultural by-products should be converted into organic fertilizers (compost) which have a positive effect on the growth and yield of chrysanthemum. C3 (compost was prepared from rice straw, cow manure and elephant grass) and C4 (compost was prepared from rice straw, cow manure and cabbage leaves) composts had the similar effects on the growth, nutrient contents and yield of chrysanthemum. In addition, earlier application time of compost caused the differences on the growth, nutrient contents and yield of chrysanthemum. T1 (applying compost at 20 days before transplanting) gave the highest values of experimental parameters. The interactive effects of compost types and application times on the nutrient accumulation, growth, yield of chrysanthemum were significantly different among treatments. Application of C3 or C4 compost at 20 days before transplanting was both good for chrysanthemums with the highest values of LAI (0.911 and 0.958 of C3 and C4 treatment at the bud stage), dry weight (175.85 and 163.87 g plant^{-1} of C3 and C4 treatment in harvesting stage) and yield (18.64 and 18.16 quintal ha^{-1} of C3 and C4 treatment). The results of this research show up promising prospects for organic farming of medicinal crops in general and *Chrysanthemum indicum* L in particular by applying compost prepared from various agricultural by-products.

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