Livestock and Poultry Waste Compost as an Amendment in Medium for Pumpkin Seedlings

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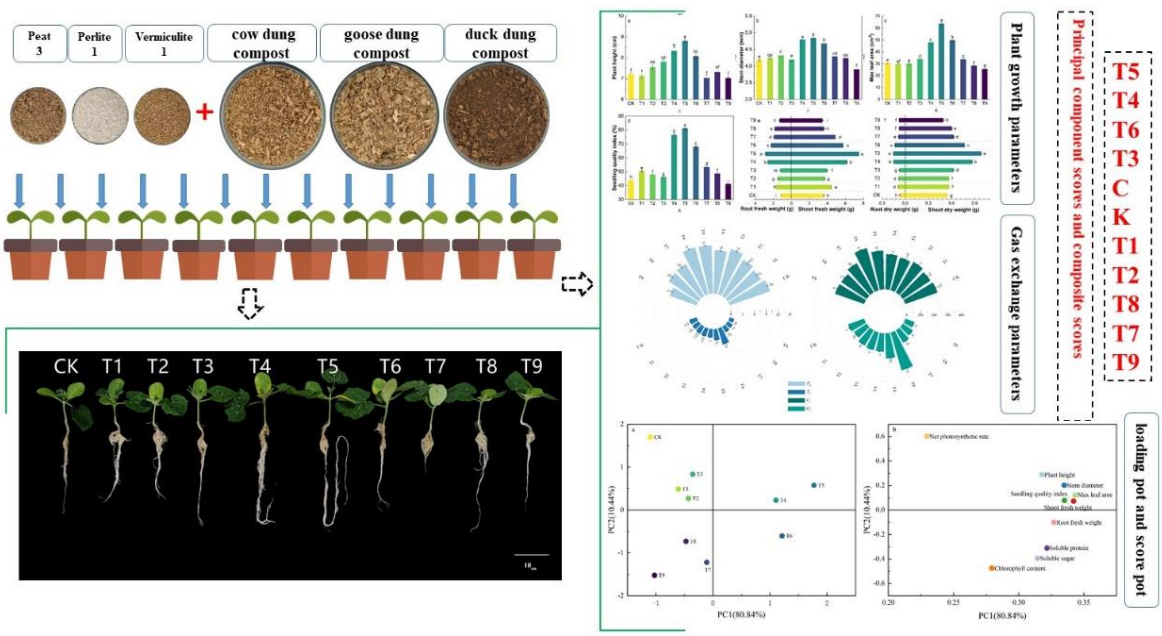
GRAPHICAL ABSTRACT



Livestock and Poultry Waste Compost as an Amendment in Medium for Pumpkin Seedlings

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This research evaluated cow dung compost (CDC), goose dung compost (GDC), and duck dung compost (DDC) as peat addition in growing media used for the production of pumpkin seedlings. Commercial substrate (peat: vermiculite: perlite=3:1:1, v/v) was used as the control (CK). The partial addition in peat of each waste compost in the mixtures were 10%, 20%, and 30% (v/v). The results showed that all compost in mixtures increased bulk density, total porosity, electrical conductivity, and mineral content, but negatively affected the pH and organic matter of the growing media compared to CK. CDC in mixture increased ventilation porosity and gas-water ratio and decreased water-holding porosity compared to CK, which was the opposite of the effect of GDC and DDC. The mixtures elaborated with GDC showed better growth, biomass, gas exchange parameters, and physiological indicators of seedling plants than other treatments in varying degrees, which depended on the additional amount of GDC. DDC inhibited plant growth and gas exchange parameters, especially in high addition rate; however, it had a slight promotion effect on chlorophyll content and quality because DDC was rich in minerals. GDC was better than CDC and DDC as a partial addition for peat in the cultivation of pumpkin seedlings.

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Keywords: Peat addition; Solid organic wastes; Cow dung compost; Goose dung compost; Duck dung compost

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INTRODUCTION

In China, the meat output of the livestock and poultry industries is an important part of the country's animal husbandry, and its annual slaughter volume has ranked first in the world for many years (Nocentini *et al.* 2021; Hou and Liu 2022). With the rapid development of the aquaculture industry, the excessive waste in the breeding process has become an important factor in restricting the development of the aquaculture industry due to environmental issues (Liu *et al.* 2020). As the largest producer and consumer country in the world of livestock and poultry products, the dung production in the breeding process exceeded the most suitable load that could be accommodate by the land (Li *et al.* 2020). The lots of stacking of feces causes a large amount of greenhouse gases and the emissions of odor gases, which has a great impact on the quality of air. If the dung wastes are not treated and instead discharged directly, they will affect soil nutrients and cause the water body and air to be polluted (Elahi *et al.* 2024). In addition, the dung wastes also contain a certain amount of pathogenic microorganisms, drug residues, and heavy metals, which threaten to the health of the people (Liu *et al.* 2020).

The area of facilities in China is about 2.5 million ha, and the annual output of vegetables is about 265 million tons, accounting for about 1/3 of the total vegetables. The demand for substrate in the seedling industry is huge and increases year by year. Peat has been used widely as a soilless potting substrate in the seedlings industry in the last decades (Gonnella and Renna 2021; Chrysargyris *et al.* 2023; Rozas *et al.* 2023). However, there have been increasing problems in the environment and ecology, which provide reasons not to use peat (Magnan *et al.* 2022). Based on the rising costs of peat, alternative high-quality and low-cost substrates for growing media in horticulture are needed (Abdel-Razzak *et al.* 2019; Adamczewska-Sowińska *et al.* 2022).

Livestock and poultry waste composts are high in organic matter and nutrients (Bustamante *et al.* 2021; Nocentini *et al*. 2021). Numerous composted organic materials derived both from livestock and poultry animal wastes have been investigated for use in soilless growing media (Libutti *et al.* 2020). Furthermore, the addition of livestock and poultry compost could reduce the potentials of single materials, such as poor physical properties and low nutrients (Li *et al.* 2020). Compost from cow manure can also be used as an addition to replace part of peat, while the same proportion of composts from horse and chicken manure were reported to be not suitable without being previously mixed with other materials (Vukobratović *et al.* 2018).

This study used different proportions of agricultural waste, such as cow dung, goose dung, and duck dung after composting, and determined the cultivation substrate suitable for pumpkin vegetable planting. The results provide new solutions for the optimal use of agricultural breeding waste compost and improving the substrate quality in seedling husbandry for pumpkin vegetable quality.

EXPERIMENTAL

Materials

The experiment was conducted in the container plant factory between February 2023 to May 2023 at Jiangsu Academy of Agricultural Sciences, which is located in Nanjing, east of China (32º07′N, 118º78′E). The long-term mean annual air temperature at this location is 17.3 °C, and mean annual precipitation is 1090 mm.

The purpose of the experiment was to explore the alternative of composting waste from different sources of waste. Three kinds of different sources of waste compost were used in this experiment, including strip aerobic cow dung compost (CDC), in-situ fermented bed goose dung compost (GDC), and fermenter duck dung compost (DDC), all of which were obtained from local farms in Jiangsu Province. Ordinary commercial substrate (S) was used as growing media and was partially replaced with different ratios of CDC, GDC and DDC, resulting in the following ten treatments(v/v): (1) ordinary commercial substrate (S)100%, (2) S: CDC 90:10(CDC 10%), (3) S: CDC 80:20(CDC 20%), (4) S: CDC 70:30(CDC 30%), (5) S: GDC 90:10(GDC 10%), (6) S: GDC 80:20(GDC 20%), (7) S: GDC 70:30(GDC 30%), (8) S: DDC 90:10(DDC 10%), (9) S: DDC 80:20(GDC 20%), (10) S: DDC 70:30(DDC 30%), labeled as CK, T1, T2, T3, T4, T5, T6, T7, T8, and T9 treatments.

Pumpkin (*Cucurbita moschata*) seeds were soaked, then cleaned and would be germinated on wet gauze and placed in a growth chamber with an air temperature of 22 ℃. After the seeds germinated, consistent pumpkin seeds were directly sown into different substrates with one seed per hole. The treatments (growing media) were established in a completely randomized plot design, using ten replicates per treatment. The sponge blocks with seedlings were moved to the plant factory, in which fluorescent lamps with a light intensity of 100 ± 10 $\mu mol \cdot m^{-2} \cdot s^{-1}$ were used as the light source based on 12 $h \cdot d^{-1}$ photoperiod. Because organic waste compost contains a large amount of nitrogen, phosphorus and potassium, the treatments were only watered after sowing.

Physical and Chemical Properties

Using the appropriate amount of raw materials and different processing samples, the ring knife method was used to determine the indicators such as bulk density, total porosity, ventilation porosity, water-holding porosity, and gas-water ratio. The measurement method was as follows: the samples for the dry wind were added into the specified size ring (ring knife weight W_0). Then the sample weight W_1 was measured. The sample was soaked in water for 24 h, after which its wet weight W_2, was recorded. The ring knife was tightened with gauze and poured until there was no water outflow, with the weight W_3 measured after removing the gauze, and calculation could be achieved according to the following formulas:

$$\text{Bulk density} = (W_1\text{-}W_2)/V \text{ (mg/cm}^3) \quad (1)$$

$$\text{Total porosity} = (W_2\text{-}W_1)/V \times 100\% \text{ (\%)} \quad (2)$$

$$\text{Ventilation porosity} = (W_2\text{-}W_3)/V \times 100\% \quad (3)$$

$$\text{Water-holding porosity} = \text{total porosity} - \text{ventilation porosity} \quad (4)$$

$$\text{Gas-water ratio} = \text{ventilation porosity/water-holding porosity} \quad (5)$$

In these equations, W_1 is weight of air-dried samples (g), W_2 is the weight of samples soaked into water for 24 h (g), W_3 is the weight of samples inverted until there was no water outflow (g), and V is volume of the ring knife (cm^3).

The pH was directly determined by using a pH meter, and the EC was measured by using the conductivity parameter analyzer. Among them, H_2SO_4-H_2O_2 digestion with semi-micro Kjeldahl method was used to determine the total nitrogen content (TN) of the sample. The molybdenum antimony anti-colorimetric method was used to determine the total phosphorus content (TP) of the sample, and the flame photometer method was used to determine the total potassium content (TK) of the sample. The content of alkaline hydrolyzed nitrogen (AHN) in the sample was determined by the alkaline hydrolysis diffusion method. The content of available phosphorus (AP) in the sample was determined by the citric acid leaching-vanadium molybdenum yellow colorimetric method. The content of available potassium (AK) in the samples was determined by a leaching-atomic absorption flame spectrophotometer (Bao 2000). The content of organic matter in the sample was determined by the potassium dichromate oxidation-external heating method.

Growth and Biomass of Pumpkin Seedlings

Six pumpkin seedlings samples with uniform growth were measured on 21 d after transplanting. Plants were cleaned and dried with absorbent paper. Each plant was separated into the shoot and root using a sharp scalpel and forceps. Plant heights were measured by a ruler. Stem diameters were measured using a vernier caliper. Max leaf areas were measured by an area meter (YMJ-A; Beijing Yaxin Inc. China). Afterward, enzymes in the samples were denatured by steaming at 105 °C for 20 min and then drying to constant weight at 70 °C for 48 h. The shoot fresh weight and shoot dry weight were measured using an electronic balance. The seedling quality index (SQI) was calculated as follows,

$$SQI = (PH/SD + SDW/RDW) \times (SDW + RDW) \tag{6}$$

where PH is plant height, SD is stem diameter, SDW is shoot dry weight, and RDW is root dry weight.

Gas Exchange Parameters of Pumpkin Seedlings

The Li-6800 portable photosynthesis system (LI-COR Inc. Lincoln, NE, USA) was used to determine gas exchange parameters of pumpkin seedlings starting from 9:00 am to 10:00 am on each measurement day. Six pots were included in each group under different substrate treatments, and one leaf of the second layer was randomly selected from each pot for measurement. Gas exchange parameters were recorded five times every 2 s. The light intensity and the temperature of the leaf chamber were set to 200 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and 22 °C, which had 6 cm^2 of measurement area. Determination parameters included: net photosynthetic rate (P_n), stomatal conductance (G_s), intercellular carbon dioxide concentration (C_i), and transpiration rate (T_r). The measurement was repeated three times.

Physiological Indicators of Pumpkin Seedlings

The fully expanded second young leaves were ground and mixed with 95% ethanol. The samples were kept in dark conditions until they turned white. Absorbances of the extraction at 665 and 649 nm were separately measured by a spectrophotometer (ultraviolet-1800; Shimadzu, Kyoto, Japan), and the contents of chlorophyll (Chl) were calculated through absorbance. The content of soluble sugar in leaves was determined by the Anthrone sulfate method, and the content of soluble protein in leaves was determined by Coomassie brilliant blue colorimetry (Gao 2005).

Statistical Analyses

The statistical analysis was based on the one-way analysis of variance (ANOVA) of the mean values of each parameter for each treatment (substrate), in order to test the statistically significant differences. Microsoft Excel 2016 and SPSS 2022 software were used to conduct statistical data analysis. Origin 2020 was used to make function plots and Microsoft Word 2016 was used to elaborate the tables.

RESULTS AND DISCUSSION

Physical Properties of Raw Materials and Substrate Treatments

Table 1 shows that the density of DDC was the highest, which was 555 mg/cm^3, and the perlite density was the lowest, which was significantly reduced by 80.9% compared with that of DDC. Therefore, DDC was the heaviest in the raw material of the unit volume. The total porosity of GDC was the highest, which was 81.9%. There was no significant difference between the total porosity of GDC and DDC. The total porosity of peat and perlite were the minimum, which was 59.3% and 58.1%, and there was a significant reduction of 27.7% and 29.1% compared with that of CDC; the ventilation porosity of CDC was the highest, 35.4%, followed by perlite, 26.3%. The ventilation porosity of DDC was the lowest, 1.54%, which was significantly reduced by 95.6% compared with that of CDC. The water-holding porosity of GDC and DDC were the highest, 67.4% and 67.5%, and there was no significant difference between them. The water-holding porosity of perlite was a minimum of 31.8%. The gas-water ratio of perlite was a maximum of 0.82, and there was no significant difference in the gas-water ratio between peat and vermiculite. There was no significant difference in the gas-water ratio between GDC and DDC. The pH of CDC and DDC were highest, followed by GDC, and there was no significant difference between the vermiculite and perlite, and the pH of peat was the lowest. The EC value of GDC was the maximum, followed by DDC and the EC of perlite was the minimum.

Table 2 shows that the density of T9 was the maximum, the minimum capacities of treatments were CK and T1, and the difference between them was not significant. The total porosity of T3 was the highest and the total porosity of CK was the lowest. The total porosity of T3 was significantly increased by 5.60% compared with that of CK. The maximum ventilation porosity was T3, which was significantly increased by 40.8% compared to CK. The ventilation porosity of the T9 was the minimum, a significant decrease of 6.88% compared to CK. The water pores of T6 was the maximum, which was significantly increased by 4.36% compared to CK. The water-gas ratio of T3 was the highest, which was significantly increased by 43.6% compared to CK. The gas-water ratio of T9 was the lowest, which was significantly decreased by 10.8% compared to CK. The pH of T9 was the highest, which was significantly increased by 3.1% compared to CK, which was the lowest. The EC of T6 was the highest, which was significantly increased by 23.4% compared to CK. The EC of T7 was the lowest, which was significantly decreased by 5.6% compared to CK.

The physical properties of seedling matrix have a vital impact on the growth of plant seedlings. A suitable physical property was an important indicator for measuring seedling substrate characteristics and could provide good environmental conditions for plants. The suitable total porosity for seedlings was 60% to 90%, the suitable degree of ventilation porosity was 15% to 30%, the suitable degree of water was 40% to 75%, and the suitable gas-water ratio was 0.25 to 0.5 (Jankauskienė *et al.* 2019). The tested raw materials and treatments were rich in minerals and beneficial to the physical and chemical properties of seedlings mixtures combined on various substitute addition rates (Table 2 and Table 4). Generally, the results of this study showed that adding different proportions of organic waste compost improved the total porosity, representing the capacity of air and water in the substrate, which not only meets the crop growth and creation of good water and gas condition but also was conducive to the absorption of nutrients in the root system of the crops (Zapałowska *et al.* 2023; Bustamante *et al.* 2021). There was a negative relationship between ventilation porosity and water-holding porosity of the seedling matrix (Chrysargyris *et al.* 2023). However, the pH of DDC was too high, and the pH of DDC related treatments T7, T8, and T9 became higher than other treatments, affecting negatively the growth of the plants, which was consistent with the research results of relevant scholars (Adamczewska-Sowińska *et al.* 2022). The EC value of the ideal substrate is 0.75 mS/cm to 3.49 mS/cm (Abdel-Razzak *et al.* 2019). The EC of treatments with GDC were higher than other treatments, which was positive to the growth of treatments.

Table 1. Physical Properties of Raw Materials

Materials	Bulk Density (mg/cm^3)	Total Porosity (%)	Ventilation Porosity (%)	Water-holding Porosity (%)	Gas-water Ratio	pH	EC (mS/cm)
Peat	150.71 ± 2.03e	59.27 ± 1.25d	6.43 ± 0.55d	52.84 ± 0.70c	0.12 ± 0.01c	7.08 ± 0.08d	4.13 ± 0.12c
Vermiculite	355.82 ± 7.84b	67.95 ± 0.93c	7.73 ± 0.44c	60.22 ± 0.70b	0.13 ± 0.01c	7.47 ± 0.12bc	0.91 ± 0.03e
Perlite	106.19 ± 7.30f	58.11 ± 0.89d	26.26 ± 0.44b	31.85 ± 0.69e	0.82 ± 0.02a	7.36 ± 0.11c	0.58 ± 0.03f
Cow dung compost	175.87 ± 7.73d	81.96 ± 0.70a	35.42 ± 0.79a	46.54 ± 1.04d	0.76 ± 0.03b	8.59 ± 0.09a	3.09 ± 0.05d
Goose dung compost	243.94 ± 9.55c	70.17 ± 0.77b	2.76 ± 0.67e	67.41 ± 0.15a	0.04 ± 0.01d	7.61 ± 0.04b	8.45 ± 0.07a
Duck dung compost	555.07 ± 13.64a	69.08 ± 0.72bc	1.54 ± 0.08f	67.54 ± 0.72a	0.02 ± 0.00d	8.43 ± 0.13a	6.45 ± 0.07b
Different letters after data in the same columns indicate significant differences at 0.05 level, the same below.							

Table 2. Physical Properties of Different Substrate Treatments

Treatments	Bulk Density (mg/cm^3)	Total Porosity (%)	Ventilation Porosity (%)	Water-holding Porosity (%)	Gas-water Ratio	pH	EC (mS/cm)
CK	182.83 ± 1.00i	60.77 ± 1.04f	10.65 ± 0.48d	50.12 ± 0.59d	0.21 ± 0.01d	7.22 ± 0.02h	2.78 ± 0.07g
T1	184.08 ± 1.17hi	61.91 ± 1.00d	12.10 ± 0.49c	49.81 ± 0.54e	0.24 ± 0.01c	7.35 ± 0.02d	2.89 ± 0.07f
T2	185.34 ± 1.37gh	63.04 ± 0.95b	13.55 ± 0.50b	49.49 ± 0.51f	0.27 ± 0.01b	7.29 ± 0.01e	3.01 ± 0.06d
T3	186.60 ± 1.61fg	64.18 ± 0.91a	15.00 ± 0.52a	49.17 ± 0.49g	0.31 ± 0.01a	7.27 ± 0.01f	2.99 ± 0.07e
T4	187.49 ± 0.45f	61.32 ± 0.94e	10.47 ± 0.42e	50.85 ± 0.55c	0.21 ± 0.01e	7.24 ± 0.02g	3.12 ± 0.05c
T5	192.15 ± 0.13e	61.86 ± 0.84d	10.29 ± 0.36f	51.58 ± 0.52b	0.20 ± 0.01f	7.30 ± 0.01e	3.21 ± 0.06b
T6	196.81 ± 0.66d	62.41 ± 0.74c	10.10 ± 0.30g	52.31 ± 0.48a	0.19 ± 0.00g	7.28 ± 0.02ef	3.42 ± 0.06a
T7	203.04 ± 1.27c	61.26 ± 1.02e	10.41 ± 0.45e	50.86 ± 0.59c	0.20 ± 0.01e	7.37 ± 0.01c	2.62 ± 0.06j
T8	223.26 ± 1.71b	61.75 ± 0.99d	10.16 ± 0.42g	51.59 ± 0.59b	0.20 ± 0.01f	7.42 ± 0.03b	2.67 ± 0.06i
T9	243.48 ± 2.22a	62.24 ± 0.96c	9.92 ± 0.40h	52.33 ± 0.59a	0.19 ± 0.01h	7.44 ± 0.01a	2.72 ± 0.07h

Table 3. Chemical Properties of Raw Materials

Materials	Total Nitrogen (g/kg)	Total Phosphorus (g/kg)	Total Potassium (g/kg)	Alkaline Nitrogen (g/kg)	Available Phosphorus (g/kg)	Available Potassium (g/kg)	Organic Matter (%)
Peat	11.320 ± 1.101d	2.360 ± 0.125d	3.140 ± 0.075e	0.816 ± 0.020d	0.527 ± 0.022d	0.025 ± 0.001e	88.183 ± 0.679a
Vermiculite	0.703 ± 0.025e	1.567 ± 0.035e	7.703 ± 0.916d	0.013 ± 0.000e	0.010 ± 0.000e	0.009 ± 0.000d	3.110 ± 0.046e
Perlite	0.713 ± 0.025e	0.877 ± 0.060f	0.513 ± 0.065f	0.017 ± 0.001e	0.089 ± 0.002e	0.008 ± 0.000d	1.613 ± 0.038f
Cow dung compost	24.801 ± 0.289c	12.997 ± 0.147c	20.491 ± 0.914b	1.206 ± 0.031c	0.993 ± 0.040c	1.793 ± 0.045b	64.393 ± 0.767b
Goose dung compost	35.903 ± 0.560a	35.837 ± 0.588a	18.737 ± 0.258c	1.379 ± 0.023a	2.957 ± 0.070a	1.959 ± 0.064c	47.991 ± 0.692c
Duck dung compost	28.502 ± 0.448b	22.637 ± 0.715b	23.373 ± 0.540a	0.996 ± 0.061b	1.230 ± 0.085b	1.593 ± 0.055a	45.503 ± 0.567d

Table 4. Chemical Properties of Different Substrate Treatments

Treatments	Total Nitrogen (g/kg)	Total Phosphorus (g/kg)	Total Potassium (g/kg)	Alkaline Nitrogen (g/kg)	Available Phosphorus (g/kg)	Available Potassium (g/kg)	Organic Matter (%)
CK	7.332 ± 0.224j	1.913 ± 0.079j	3.446 ± 0.087j	0.500 ± 0.006g	0.335 ± 0.014i	0.019 ± 0.000j	53.708 ± 0.198a
T1	7.987 ± 0.206i	2.447 ± 0.072i	4.321 ± 0.114h	0.519 ± 0.005e	0.358 ± 0.013h	0.106 ± 0.001h	52.524 ± 0.161b
T2	8.642 ± 0.190f	2.982 ± 0.065g	5.197 ± 0.150e	0.537 ± 0.005c	0.381 ± 0.013f	0.194 ± 0.002e	51.340 ± 0.130e
T3	9.297 ± 0.174d	3.516 ± 0.057f	6.073 ± 0.189b	0.556 ± 0.005b	0.403 ± 0.013e	0.281 ± 0.003b	50.156 ± 0.113f
T4	9.855 ± 0.181b	3.595 ± 0.094e	4.232 ± 0.083i	0.528 ± 0.004d	0.458 ± 0.014c	0.115 ± 0.003g	51.701 ± 0.168c
T5	9.767 ± 0.202c	5.276 ± 0.110b	5.017 ± 0.080f	0.555 ± 0.003b	0.581 ± 0.014b	0.211 ± 0.006d	49.694 ± 0.143g
T6	10.984 ± 0.193a	6.958 ± 0.125a	5.803 ± 0.077c	0.583 ± 0.003a	0.704 ± 0.014a	0.308 ± 0.009a	47.687 ± 0.125i
T7	8.173 ± 0.207h	2.940 ± 0.080h	4.460 ± 0.105g	0.510 ± 0.005f	0.369 ± 0.011g	0.096 ± 0.001i	51.585 ± 0.161d
T8	9.014 ± 0.192e	3.967 ± 0.083d	5.474 ± 0.127d	0.519 ± 0.005e	0.403 ± 0.009e	0.173 ± 0.003f	49.462 ± 0.128h
T9	8.550 ± 0.213g	4.995 ± 0.087c	6.488 ± 0.152a	0.529 ± 0.006d	0.436 ± 0.008d	0.251 ± 0.004c	47.339 ± 0.102j

Chemical Properties of Raw Materials and Substrate Treatments

Table 3 shows that the total nitrogen content of GDC was the highest, which was 35.903 g/kg, followed by DDC, and there was no significant difference between perlite and vermiculite, the total nitrogen content of which were the lowest, reduced significantly by 98.0% and 98.0% compared with that of GDC. The total phosphorus content of GDC was the highest, which was 35.8 g/kg, followed by DDC and the total phosphorus content of vermiculite was the lowest, which was significantly decreased by 97.6% compared with that of GDC. The total potassium content of DDC was the highest, which was 23.4 g/kg, followed by CDC and the total potassium content of vermiculite was the lowest, which was significantly decreased by 97.8% compared with that of DDC. The alkaline nitrogen content of GDC was the highest, which was 1.38 g/kg, followed by DDC, and the alkaline nitrogen of perlite and vermiculite were the lowest, 0.013 g/kg and 0.017 g/kg, which were significantly decreased by 99.0% and 98.8% compared with that of GDC, respectively.

The available phosphorus content of GDC was the highest, which was 2.96 g/kg, followed by DDC, and the available phosphorus of perlite and vermiculite was the lowest, 0.010 g/kg and 0.089 g/kg, which were significantly decreased by 99.7% and 97.0% compared with that of GDC, respectively.

The available potassium content of DDC was the highest, which was 1.59 g/kg, followed by CDC, and the available potassium of perlite and vermiculite were the lowest, 0.009 g/kg and 0.008 g/kg, which were significantly decreased by 99.4% and 96.5% compared with that of DDC, respectively.

Table 4 shows that in terms of total nitrogen content, the performance of T6 was the highest and the performance of CK was the lowest. T6 was significantly increased by 49.8% compared to CK. In terms of total phosphorus content, the performance of T6 was the highest and the performance of CK was the lowest. T6 was significantly increased by 263.8% compared to CK. In terms of total potassium content, the performance of T9 was the highest and the performance of CK was the lowest. T9 was significantly increased by 88.3% compared to CK. In terms of the alkaline nitrogen content, the performance of T6 was the highest and the performance of CK was the lowest. T6 was significantly increased by 16.4% compared to CK. In terms of the available phosphorus, T6 was the highest which was increased by 109.9% compared to CK. In term of the available potassium, T6 was the highest, which was increased by 15.59 times higher than CK. CK had the highest organic matter content.

Breeding residues compost provides many minerals and organic matter to soil (Abdel-Razzak *et al.* 2019; Bustamante *et al.* 2021; Libutti *et al.* 2020). The amount of organic compost could also significantly affect the nutritional content in the matrix, so finding a suitable proportion is a good balance between cost and efficiency (Adamczewska-Sowińska *et al.* 2022). The nutrients contained in the seedling matrix, especially nitrogen, phosphorus, potassium, *etc*., are the basis for the normal growth and development of seedlings (Vukobratović *et al.* 2018; Abdel-Razzak *et al.* 2019). The vast majority of the matrix formula meets the requirements of the physical and chemical properties as the requirements of the seedling matrix, and the appropriate matrix formula could be further selected through growth performance and other parameters (Nocentini *et al.* 2021).

Growth Index of Pumpkin Seedlings

Pumpkin seedlings grow mainly in the seedling period. The plant height of seedlings, stem diameter, fresh and dry weight of shoot, and fresh and dry weight of root were important indicators to measure whether the seedlings was strong. As shown in Fig.

1, after germination and seeding for 3 weeks, the plant height of each treatment group was between 7.02 and 8.81 cm. As the proportion of organic fertilizers increased, the height of each treatment plant was increased to varying degrees. Among them, T5 performed best in terms of plant height; it was significantly increased by 22.1% compared to CK. This was followed by T4 and T6, which was significantly increased by 15.5% and 11.8% compared to CK; there were no significant differences in plant height among T1, T7, T8, T9, and CK. In terms of stem diameters, T5 and T4 performed best, which were significantly increased by 15.8% and 14.5% compared to CK. The differences between them was not significant. They were followed by T6 and T2, which were significantly increased by 11.7% and 3.1% compared to CK, respectively, and the differences between them was significantly different. The differences among T1, T3, T8, and CK were not significant; T9 was the lowest, a significant decrease of 6.85% compared to CK. In terms of max leaf area, T5 performed best, an increase of 108.2% compared to CK; followed by T6 and T4, which were significantly increased by 62.5% and 57.3% compared to CK, respectively. Significantly, the max leaf area of T8 and T9 leaves were the lowest, which were significantly reduced by 7.2% and 16.8% compared to CK, and there was no significant difference between them. In terms of fresh weight of shoot part, the performance of T5 was the best, which was increased significantly by 107.7% compared to CK, followed by T4 and T6, which were significantly increased by 71.2% and 59.3% compared to CK, respectively. The lowest was T9, which was significantly reduced by 4.8% compared to CK. In terms of fresh weight of underground part, T5 performed best, an increase of 144.9% compared to CK; followed by T4 and T6, which were significantly increased by 122.0% and 91.4% compared to CK. The difference between T3 and CK was not significant, which was the lowest. In terms of seedlings quality index, T5 performed best, with a significant increase of 85.4% compared to CK, followed by T4 and T6, which were significantly increased by 74.9% and 55.3% compared to CK; the lowest was T9, which was significantly decreased by 5.9% compared to CK. Above all, the effect of adding GDC was the most significant, followed by CDC, and the third was DDC.

The basic indicators of the growth quality of pumpkin seedlings included plant height, stem diameters, max leaf area, fresh aboveground weight, and fresh underground weight. This trial showed that different compost treatments of seedlings had a significant impact on the growth of pumpkin seedlings, and the overall manifestation of the seedlings of GDC was better, which could be explained that there were higher organic matter and availability of minerals of fermented bed goose dung compost (Testani *et al*. 2020). Best pumpkin plant growth was observed in treatment with GDC addition at 20%, which was most likely because of its high total nitrogen content, which satisfied the nitrogen needs of plant (Nocentini *et al.* 2021). These observed findings were strongly consistent with the private research conclusions. However, the fresh weight of T9 was the lowest, indicating that the highest amount of compost applied did not necessarily mean the highest biomass weight, and it was also consistent with that the dry weight of lettuce decreased with increasing amounts of compost in certain treatments (Adekiya *et al*. 2020). The root system of plants is the main organ that absorbs water and stores nutrients. Many researchers have found that organic compost exhibits a strong effect on root growth and development in cucumber (Vukobratović *et al.* 2018; Zapałowska *et al*. 2023), tomato (Aydi *et al*. 2023) and *Lactuca sativa* seedlings (Rozas *et al*. 2023).

Physiological Indicators of Pumpkin Seedlings

Figure 2 shows that the chlorophyll a content of T6 was the highest, which was increased by 18.0% compared to CK, followed by T5, which was significantly increased by 14.6% compared to CK. There were no significant differences among T7, T8, and T9. The chlorophyll a content of CK was the lowest. The chlorophylls b content of T6 was the highest, which was increased by 209.1% compared to CK. This was followed by T5, which was significantly increased by 150.9% compared to CK. The chlorophyll b content of CK content was the lowest. The chlorophyll content of CK was the lowest. The chlorophyll content of T6 was the highest, which was increased by 35.8% compared to CK, followed by T5, which was significantly increased by 27.3% compared to CK. The chlorophyll content of CK content was the lowest. The first three highest soluble sugars of treatments were T3, T6, and T7, which were increased by 29.9%, 78.6%, and 55.6% compared with that of CK, which was the lowest. The first three highest soluble proteins of treatments were T6, T7, and T3, which were increased by 92.3%, 49.9%, and 45.8% compared with that of CK, which was the lowest.

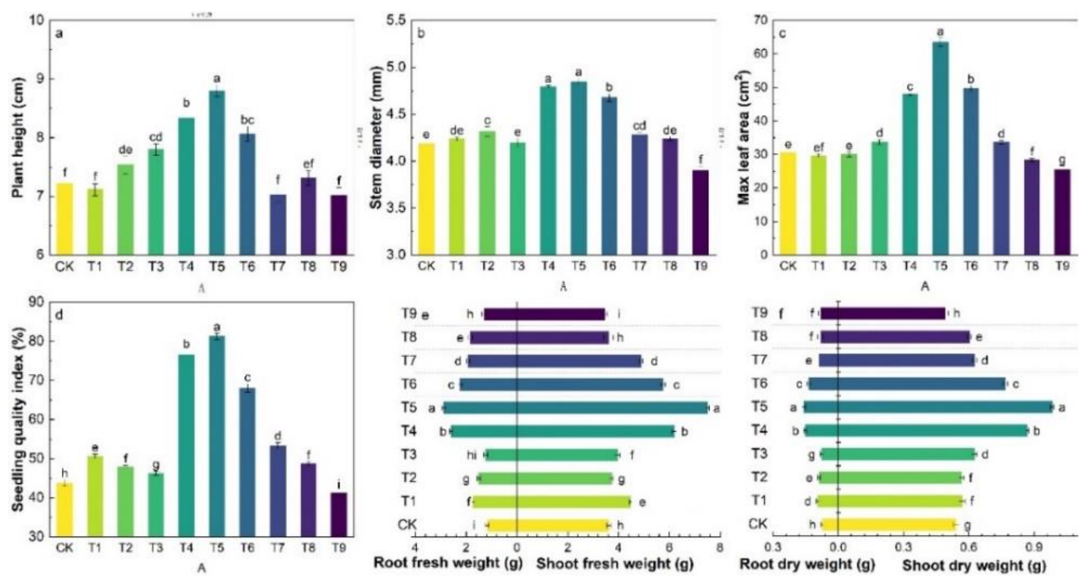

Fig. 1. Effect of different seedling substrates on the growth index of pumpkin seedlings

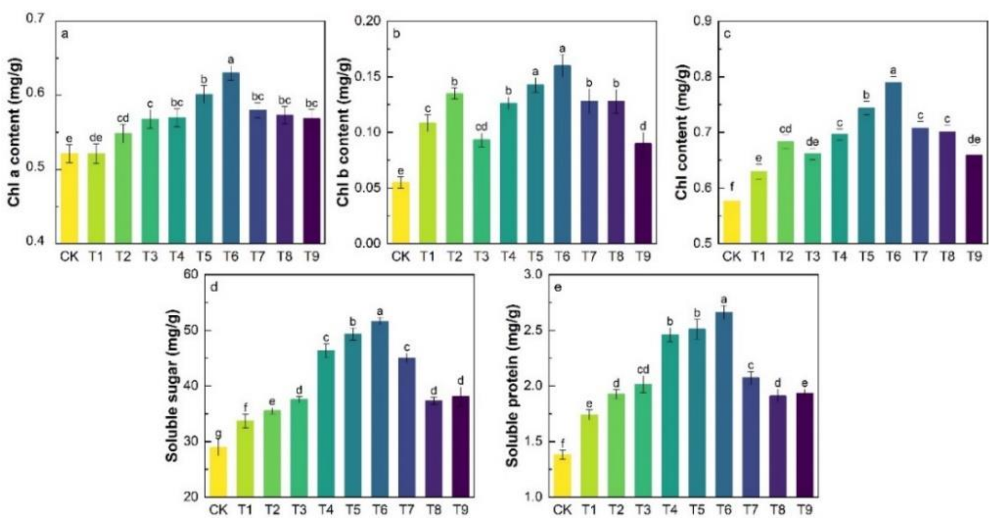

Fig. 2. Effect of different seedling substrates on physiological indicators of pumpkin seedlings

The chlorophyll content and soluble sugar content on the leaves of plant seedlings can reflect the optical metabolic level of the plant (Aydi *et al.* 2023). The present results showed that chlorophyll content and soluble sugar of T6 were the highest, consistent with the highest P_n of T6. Higher plant growth and leaf pigment content of Swiss chard were observed when the soil was treated with compost from animal wastes (Libutti *et al.* 2020). These observed values in soluble sugar and protein strongly followed the research findings in cucumber treated with compost compared to the control (Jankauskienė *et al.* 2019), okra (Adekiya *et al.* 2020), and lettuce (Xu *et al*. 2021). The decrease in soluble sugar content in T8 and T9 might be due to the significant decrease in their biomass and the dilution of soluble sugar. It also had been reported that the relationship between nitrogen application amounts and levels of soluble proteins was positively correlated (Testani *et al.* 2020), which could explain why the soluble protein of higher amount compost was higher compared with that of lower amount compost in treatment. The results could also showed that organic compost had a better promotion effect on the quality of plants, based on the appropriate addition amount (Testani *et al.* 2020; Zapałowska *et al.* 2023).

Gas Exchange Parameters of Pumpkin Seedlings

Figure 3 shows that different substrate treatments had a varying degree of impact on the photosynthesis of pumpkin leaves. In terms of net photosynthesis rate P_n, the treatments giving the highest values were T6, T5, and T3, which was significantly increased by 14.8%, 13.3%, and 10.0% compared to CK, respectively. These findings indicated that the addition of GDC in substrate treatment was helpful to the promotion on P_n. There were not any significant differences among T4, T2, T1, and CK. T7, T8, and T9 were decreased by 13.1%, 14.7%, and 32.9% compared to CK, respectively. In terms of transpiration rate T_r, the highest treatment was T6, which was significantly increased by 119.1% compared to CK, followed by T5 and T4, which were increased by 43.1% and 10.6%, respectively. There were no significant differences among T1, T2, T3, and CK. T7, T8, and T9 were decreased by 14.6%, 24.1%, and 40.5% compared to CK, respectively. In terms of intercellular carbon dioxide concentration C_i, the highest treatment was T6, which was significantly increased by 27.8% compared to CK, followed by T5, which was increased by 12.9% compared to CK. There were no significant differences among T1, T2, T3, T4, T7, and CK. T8 and T9 decreased by 10.9% and 9.5% compared to CK, respectively. In terms of stomatal conductance G_s, the highest treatment was T6, which was significantly increased by 132.1% compared to CK, followed by T5, which was increased by 48.2% compared to CK. There were no significant differences among T2, T3, T4, and CK. T1, T7, T8, and T9 were decreased significantly by 10.8%, 14.9%, 28.6%, and 43.0% compared to CK, respectively.

The effect of different compost addition in peat on the photosynthesis of pumpkin plants showed significant variation in all parameters (Pn, Tr, Ci, and Gs). The results of this study were similar to earlier research on photosynthesis parameters in lettuce plants (Xu et al. 2021). The Pn was positively correlated with Tr, because stomatal opening is associated with the photosynthetic process from gas exchange, and the result was consistent with the previous findings on tomato (Aydi et al. 2023). Ci was the most important in plant growth, which could assess limitations to plant photosynthesis potential. Ci was the final balance result of various driving forces and resistance of external CO2 gas entering mesophyll cells as well as photosynthesis and respiration in leaves (Liu et al. 2020). In this study, Ci varied to different degrees depending on the treatments, and it was positively correlated with the growth of plants and was the key factor of Tr. In conclusion, adding compost to the substrate could improve the photosynthetic performance of pumpkin, but excessive compost would cause stress damage to the root system and hinder the growth of seedlings.

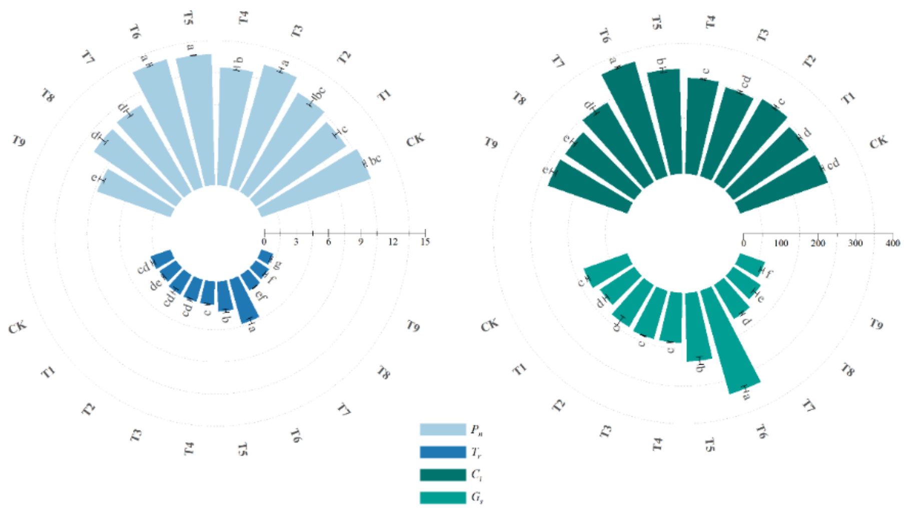

Fig. 3. Effect of different seedling substrates on gas exchange parameters of pumpkin seedlings

Comprehensive Evaluation

Main component analysis was performed with the plant height of pumpkin seedlings, stem diameters, max leaf area, fresh shoot weight, fresh underground root weight, seedling quality index, net photosynthesis rate, total chlorophyll content, soluble sugar, and soluble protein as the evaluation indicators. Then the main component score was obtained and a comprehensive score was found.

The score plot shows that each group presented the form of gathering between groups, indicating that the data conformed to the grouping rule and had a certain degree of stability and reliability. The loading plot shows correlation between the characteristic vectors and the main component and the closer the distance indicates the more the correlation. The most positive correlation with PC1 was max leaf area, followed by seedling quality index. The most positive correlation with PC2 was net photosynthetic rate, and the most negative correlation with PC2 was chlorophyll content. Table 5 shows that scores of T3, T4, T5 and T6 were higher than that of CK. The ranking order was T5, T4, T6, T3, CK, T1, T2, T8, T7, and T9, of which the comprehensive score of T5 was 2.35, indicating that the pumpkin seedlings were optimal after addition of goose dung organic fertilizer into substrate treatments.

Table 5. Principal Component Scores and Composite Scores

Treatments	Principal Component Score(F1)	Principal Component Contribution Rate	Principal Component Score(F2)	Principal Component Contribution Rate	Overall Ratings (F)	Ranking
CK	-0.3540	80.84%	0.8319	10.44%	0.4778	5
T1	-0.6060		0.4883		-0.1177	6
T2	-0.4276		0.2686		-0.1590	7
T3	-1.0991		1.6987		0.5996	4
T4	1.1057		0.2274		1.3331	2
T5	1.7718		0.5743		2.3461	1
T6	1.2128		-0.6077		0.6051	3
T7	-0.1073		-1.2229		-1.3302	9
T8	-0.4718		-0.7324		-1.2041	8
T9	-1.0246		-1.5262		-2.5508	10

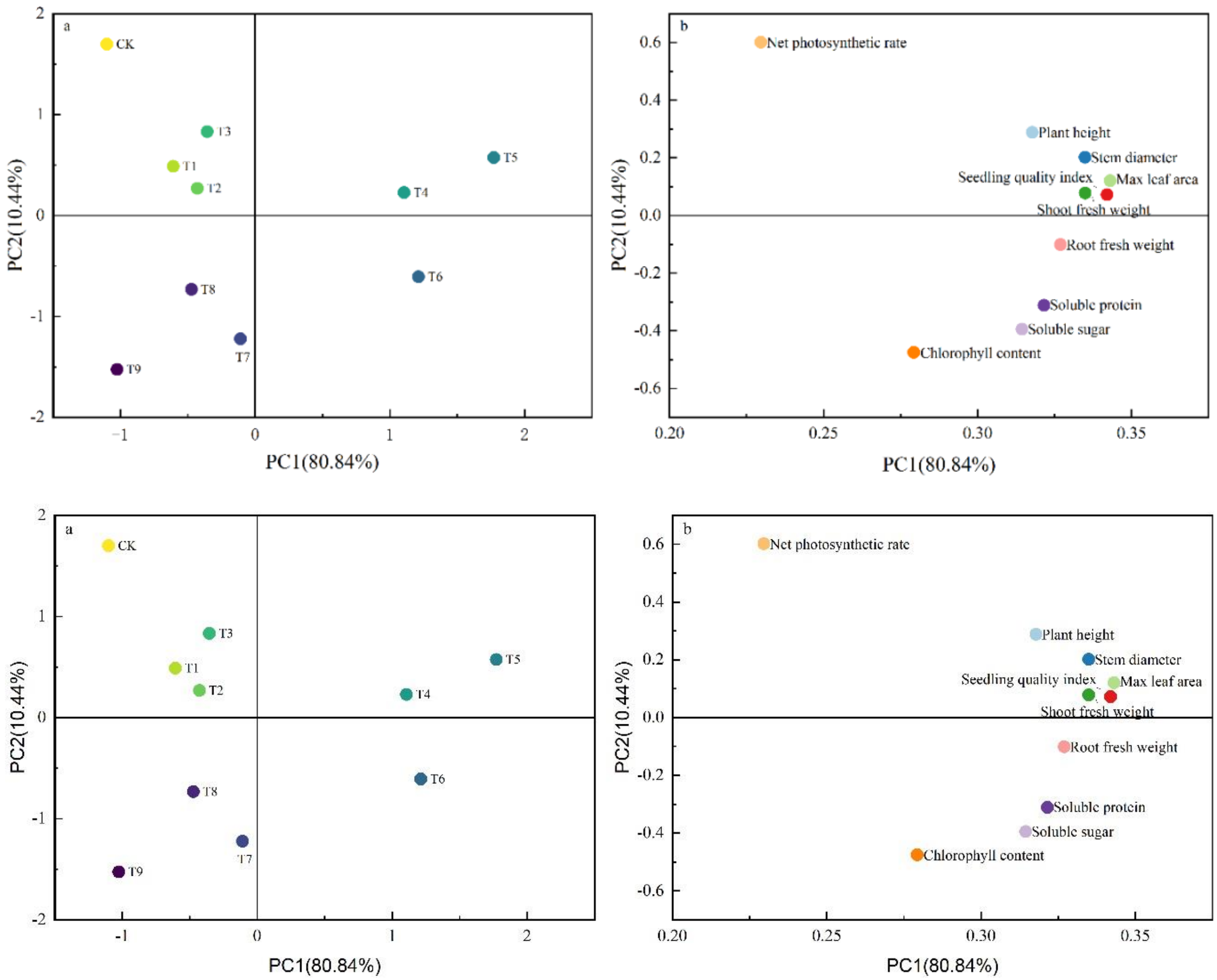

Fig. 4. Score plot and loading plot of different substrates on growth of pumpkin seedlings

CONCLUSIONS

1. The physical and chemical properties of the treatments were statistically influenced by the type and the proportion of compost in the substrates. Cow dung compost (CDC), goose dung compost (GDC), and duck dung compost (DDC) addition in mixtures increased bulk density, total porosity, electrical conductivity, and mineral content, but negatively affected the plant height (PH) and organic matter of the growing media compared to the control condition (CK).
2. Application of GDC significantly promoted the growth, biomass, gas exchange parameters, and physiological indicators of seedlings plants relative to other composts in varying degrees, which depended on the addition amount of GDC.
3. GDC was a good alternative to the peat-based substrate for seedling production, especially at the addition rate of 20% and 30% of GDC, which had shown beneficial effects on the seedling production of pumpkin compared to the control.
4. CDC could also be used as an addition to replace part of peat related with an addition amount, while the same proportion of DDC was not always adequately used to replace expensive peat, and the chemical properties of substrates elaborated with duck compost were not satisfying, since pH was high and electrical conductivity (EC) was low.

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