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Study on the main physicochemical characteristics of different plant cultivation substrates and their effects on standard roses

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Abstract: Standard roses are a widely used ornamental plant in urban landscapes, valued for their attractive flowers and adaptability to various environmental conditions. This study investigated how different substrate types affect the growth and development of standard roses and their potential to improve the ecology of urban landscapes. Nine substrate conditions (rotted corn stover, decomposed shiitake mushroom residue, perlite, and combinations) were compared with field soil as a control treatment. The physical and chemical characteristics of each substrate were analysed, and the growth and development of standard rose plants were observed over six months. The results indicated that the substrate T4 (70% rotted corn stover, 15% decomposed shiitake mushroom residue, 15% perlite) achieved the highest evaluation index, leading to superior plant growth compared to other substrates. This combination provided optimal water retention, aeration, and nutrient supply, making it the most effective substrate for cultivating standard roses. Additionally, the use of these substrates can improve soil quality and reduce environmental pollution, offering a sustainable option for urban landscape management.

Keywords: physicochemical properties; physiological index; principal component analysis; nutrient interactions; soilless culture

The Chinese rose stands as one of China's esteemed traditional ten renowned flowers, renowned for its unique qualities such as year-round blooming, early flowering, exotic appeal, diverse flower forms, and varied branch postures (Dorte 2010). Its remarkable adaptability, ease of propagation, extensive cultivation range, and myriad cultivars contribute to its popularity, with most cultivars boasting abundant, large flowers in a spectrum of colours and forms, have made it a ubiquitous and beloved choice in the realm of garden greening. Chinese rose is one of the traditional ten famous flowers in China, which has the characteristics of four-season flowering, early flowering, exoticism, flower type, branch posture diversity, and so on (Dorte 2010). Because of its adaptability, ease of reproduction, wide range of

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cultivation, and cultivars, most cultivars of flowers bloom all year round, with large flowers and colour and rich type by the garden greening workers around the favourite. Season in urban landscaping, cut flower production, garden landscaping, home decoration, and other aspects play an important role. Because some cultivars have the characteristics of climbing growth and can also be used for vertical greening, landscaping has a peculiar effect on the garden streetscape.

Research on Chinese rose cultivation technology has been ongoing since the 1980s and focuses on various areas, including germplasm resource classification, phenological period observation, introduction and domestication, genetic breeding, disease and pest control, cultivation and maintenance, research on gardening applications, and the development of evaluation systems (Dong et al. 2016, He et al. 2017). Standard roses, commonly referred to as Chinese roses, are significantly affected by the substrate or growing medium utilised for their cultivation. The substrate provides the roots with physical support, water, nutrients, and oxygen, essential for plant growth (Jeong et al. 2018). Different substrates have different physical and chemical properties, such as water retention, aeration, pH, and nutrient availability, which affect plant growth and development (Dorte 2010, Zhai 2017). Therefore, the selection of a suitable substrate is essential for successful plant cultivation.

Substrate cultivation refers to the cultivation mode in which the root system of flowers is deeply fixed to the substrate (medium) and from which they get the nutrients, water, and oxygen they need. According to the difference in the nature of the components, the cultivation substrate is divided into organic, inorganic and mixed (Ge et al. 2012, Pan et al. 2019). Inorganic cultivation substrates lack inherent nutrients, requiring plants to rely on facility pipelines for fertiliser and water delivery. This dependency results in significant costs for the necessary infrastructure. In contrast, organic substrates often exhibit poor physical and chemical stability, leading to potential reductions in both yield and quality. Mixed cultivation substrates offer a diverse composition and high selectivity, effectively supplying water, air, and fertilisers while providing better regulatory control than inorganic or organic substrates (Bakhmatova et al. 2022). The mixed-type cultivation substrate has diverse components, and high selectivity, and its ability to supply and regulate water, air, and fertiliser is greater than that of inorganic or organic substrates (Vallance et al. 2011, Ge et al. 2012, Lang et al. 2018). According to a large amount of research data, mixed substrates have the highest utility in the cut flower soilless culture process. Their formulation principle is to analyse and utilise the physicochemical properties of several single substrates and mix them according to a certain ratio in order to create the optimal conditions required for the growth of the plant root system (Moral et al. 1994, Perner et al. 2007, Zhang et al. 2012). Involving environmental, safety, and economic considerations, the substrate should be locally sourced to minimise costs and improve urban landscape ecology (Mostafa 2000, Zhang et al. 2016, Song et al. 2018).

Cultivation substrate for landscaping mainly has three categories: field soil (natural soil), improved soil, and artificial mixed substrate (Pan et al. 2019). Among them, improved soil has been proposed for garden soil mixed with perlite, vermiculite, peat, and other materials. Artificial mixed substrate that is now more popular in horticulture soilless substrate, its composition includes inorganic materials and organic materials of two categories, inorganic materials can be vermiculite, perlite, ceramic grains, sand, gravel, zeolite, slag, etc. Organic materials can be used in peat, coconut husk, slag, sawdust, cotton-chip shells, rice husk ash, foam, organic resin products, rotting straw, rotting tree ash, organic resins, organic resins, and organic materials can be used to improve the quality of the soil. Organic resin products, rotting straw, rotting bark (pine scale), organic fertiliser, microbial organic fertiliser, etc. (Sun et al. 2007, Niu et al. 2016, Santoso et al. 2019). The effects of different substrate ratios on the quality of rose were studied, and finally, the treatment of peat:perlite:edible mushroom residue = 2:3:2 and peat:perlite = 3:1 were selected as the most suitable for the cultivation of rose (Zhang et al. 2012) – the effect of soilless substrate on the quality of rhododendrons. On the formulation of soilless substrate for azalea cultivation, the study results showed that peat soil:vermiculite: perlite = 3:3:3 in equal volume ratio was the optimum formulation (Yu et al. 2004). Due to the differences in physiological characteristics of different plants, the same kind of cultivation substrate may not be suitable for other plants, and the current research on the cultivation substrate materials for *s*tandard roses has not been reported.

Currently, research on Chinese rose cultivation mainly focuses on pest and disease control, introduc-

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tory cultivation, and propagation of cuttings. Still, little research has been conducted on the effects of cultivation substrates and fertilisers on the growth of potted standard roses (Sun et al. 2007). Since the goal of substrate research is to replicate natural soil as closely as possible, the key to correctly and quantitatively assessing substrate quality is to separate the various elements impacting soil quality into representative, independent, and dominating components (Xu et al. 2015, Zabel et al. 2016, Tang et al. 2023). Therefore, in this study, we used rotted corn stover, decomposed shiitake mushroom residue, perlite, and field soil as cultivation substrates to monitor the growth and development of standard rose plants over six months. Our goal was to investigate soilless cultivation methods and identify suitable substrate ratios based on their water and fertiliser retention, acid-base buffering capacity, and nutrient supply. We aimed to select locally sourced, cost-effective ratios that serve as alternatives to traditional soil. Through this research, we identified optimal substrate combinations for cultivating standard roses and explored a technical framework suitable for the factory production of these plants. This work intends to provide both theoretical insights and practical guidelines for the soilless cultivation of flowers and future factory production endeavours.

MATERIAL AND METHODS

Research area. The experimental site was within the Fuping Pilot Base of the Institute of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group Co., at coordinates 26°34'N, 106°42'E, and an elevation of 1 210 to 1 411 m a.s.l. The average annual temperature was 14 °C, with an extreme maximum temperature of 31 °C and an extreme minimum ranging from –6 °C to 4 °C. The frost-free period lasted 289 days; the average annual humidity was approximately 80%. Precipitation totalled 1 417.1 mm, and the site received an average of 1 174 sunshine hours per year, corresponding to a sunshine percentage of 27% relative to the total possible hours.

Test materials. The selection of the Rosa Mister Lincoln cultivar, a type of standard roses. Taking this rose substrate potting seedlings as the test material, plants with consistent height, stem thickness, branching structure, growth potential, and no disease or pest infection were selected and planted in 40 cm (height) × 35 cm (width) planting bags to ensure uniformity in growth and aesthetic appeal.

Soil, rotted corn stover, decomposed shiitake mushroom residue, and perlite were selected as cultivation substrates, and their physical and chemical properties are shown in Table 1. The soil type of the soil is Plaggic Anthrosols based on the field investigation and the physicochemical properties data of the soil in Table 1 (FAO 2006), and its soil texture is silt loam (67.47% silt, 16.40% clay and 16.13% sand) (USDA 2022).

Test methods. The test will be rotted corn stover, decomposed shiitake mushroom residue and perlite formulated into 9 different ratios, with the soil as a control, a total of 10 kinds of substrate, with 3 replications for each substrate formula. Substrate ratios are shown in Table 2. The substrate mixed according to the experimental design was uniformly loaded into the planting bag, and each planting bag was planted with a standard rose on April 1, 2022. The nutrient solution was all chosen from the classic Hoagland formula (potassium nitrate 607 mg/L, ammonium phosphate 115 mg/L, magnesium sulfate 493 mg/L, iron salt solution 2.5 ml/L, trace element solution

Table 1. Treatments with different substrate ratios

Material	Hydrolysed nitrogen	Available phosphorus	Available potassium	Organic matter (%)	pH	EC (mS/cm)	Bulk density (g/cm^3)	PORT (%)	Particle size/ fibre length (mm)
	(mg/kg)								
Soil	113.87	48.51	243.61	10.65	7.12	0.25	1.28	47.38	–
Rotted corn stover	145.61	310.33	420.15	–	–	–	–	–	5–10
Decomposed shiitake mushroom residue	–	–	–	92.61	5.77	0.47	0.09	57.80	–
Perlite	–	–	–	–	7.05	0.64	0.19	75.90	3–8

EC – electrical conductivity; PORT – total porosity

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Table 2. Treatments with different substrate ratios

Treatment	Rotted corn stover	Decomposed shiitake mushroom residue	Perlite	Soil
	(V, %)			
T1	75	15	10	0
T2	80	10	10	0
T3	65	20	15	0
T4	70	15	15	0
T5	60	20	20	0
T6	65	15	20	0
T7	50	25	25	0
T8	55	20	25	0
T9	60	15	25	0
CK	0	0	0	100

5 ml/L, pH = 6.0), watered once immediately after planting, and then watered every 2–3 days, relying on natural rainfall after the plants resumed growth.

Seedlings were subjected to routine maintenance and observation of biological characteristics every three days. Some studies have shown that the main factors affecting soil quality include organic matter, total nitrogen (TN), total phosphorus (TP), total potassium (TK), pH, and other factors, and there is a large degree of correlation between the factors (Tang et al. 2022, 2023). In this study, pH, bulk density, total porosity (PORT), organic matter content, TK, TP, TN, total nutrients, electrical conductivity (EC), plant height, stem diameter, leaf area, number of leaves, number of flowers, and other indicators were selected as the main factors affecting the performance of the substrate. A comprehensive evaluation was carried out using the principal component analysis method to screen out ecological substrate formulations that are more effective, easier to formulate, and lower cost.

According to the experimental setting, samples of different substrate cultivation samples were taken and measured on April 1, 2022, with 30 samples. Changes in physiological indexes of standard roses under different substrate cultivation were observed in the fall of 2022 and 2023. Morphological indicators of plants were recorded and counted on days 30, 60, 90, 120, 150 and 180. Morphological indicators of plants included plant height, stem diameter, leaf area, number of leaves, and number of flowers. Repeat this process in 2023.

Methods of analysis for tests of physical and chemical properties of substrates. The physical and chemical properties of each substrate were analysed before planting. Water holding capacity (WHC) was determined by saturating the substrate with water and measuring the weight difference before and after draining. Aerated porosity (AFP) was determined by filling the substrate into a cylinder and measuring the volume of air space after applying a vacuum. Pure water is used as the extraction solution; the pH of pure water is 6.95, EC is 0.07 μS/cm, and the substrate/pure water ratio is 1:5. EC and pH were measured using an EC meter and a pH meter, respectively. Bulk density, aeration porosity, non-capillary porosity, and PORT were determined by the ring knife method (Xu et al. 2015); organic matter content was determined by the volumetric method using potassium dichromate (100 °C water bath); pH was determined by the glass electrode method; TK was determined by alkali fusion – flame photometry method, TP by alkali fusion – ammonium molybdate spectrophotometric method, TN by the semi-micro-volumetric Kjeldahl method, and total nutrients (TN + TP + TK) by the volumetric method using potassium dichromate (Yu et al. 2019). EC was determined by the water conservation and leaching method (Zabel et al. 2016).

Methodology of data statistics. The data were analysed using Excel 2020 (Microsoft Corp., Redmond, USA) and SPSS 24.0 (IBM Corp., Armonk, USA). Multiple comparisons were performed using Duncan's method. One-way analysis of variance (ANOVA) followed by Tukey's multiple comparison test (P < 0.05) was used to analyse the data. All treatments in this experiment were set to replicate (n = 3) for statistical analysis. SPSS statistical software was used to analyse the data by ANOVA and multiple comparisons were made between the means of different treatments. Statistically significant differences were determined based on the criteria of P < 0.05.

RESULTS AND DISCUSSION

Physical properties of different treatment formulations. The physical properties of the substrates varied significantly with different material ratios. The bulk density of the substrates of the nine treatments ranged from 0.57–0.74 g/cm^3 and were significantly smaller than those of CK (Table 3). As can be seen from Figure 1, except for the pH of CK, which was weakly acidic, the pH of the other treatments ranged from 7.77 to 7.90, and all of them were weakly alkaline. The EC reflected the salt content of the treatments, in

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Table 3. Comparison of the bulk density (g/cm^3) of different combinations of substrates

Treatment	1	2	3
T1	0.672 ± 0.014^b	0.617 + 0.014^c	0.729 ± 0.035^c
T2	0.689 ± 0.018^a	0.693 + 0044^a	0.703 ± 0.011^a
T3	0.692 + 0.013^a	0.738 ± 0008^a	0.721 + 0.011^b
T4	0.666 ± 0.005^c	0.604 ± 0.040^d	0.6736 ± 0.023^b
T5	0.687 ± 0.005^{ab}	0.639 ± 0.036^c	0.669 ± 0.019^a
T6	0.687 ± 0.006^a	0.681 ± 0.044^b	0.657 ± 0.007^a
T7	0.692 + 0.006^a	0.739 ± 0.042^a	0.693 ± 0.011^a
T8	0.683 ± 0.006^a	0.573 ± 0.025^e	0.644 ± 0.017^a
T9	0.691 + 0.008^a	0.649 ± 0.034^b	0.685 ± 0.012^a
CK	1.293 + 0.014^d	1.301 ± 0.026^d	1.274 ± 0.021^d

Values are means ± standard error (n = 3); the same lowercase letters labelled in each column indicate no significant difference between combinations (P < 0.05)

which the EC of CK was significantly lower than that of the other treatments, and the highest EC was that of the treatment T9. The pH values of the nine substrate treatments of the present experiment, which were set up with different proportions of rotting mushroom sludge, perlite, and corn stover, ranged from 6.51 to 7.10, and the pH values of the nine treatments of the present experiment were significantly lower than that of CK (Figure 1C). The PORT of the nine treatments ranged from 54.33% to 71.48%, and the aeration porosity, water-holding porosity and were all greater than that of CK, indicating that the water and air regulation ability of the cultivation substrates of each treatment was better than that of CK.

Chemical properties of different treatment formulations. The total phosphorus, potassium, and nitrogen contents were similar or significantly higher than CK in all treatments, as shown in Figure 1E–F. In the T1–T9 treatment, total nitrogen, potassium, and phosphorus contents were significantly higher than CK. Additionally, the organic matter content in these treatments' substrate combinations was significantly greater than that in CK (Figure 1H).

Indicators of agronomic traits of the standard roses. The growth and development of standard rose plants differed among the nine substrate combinations (Figure 2). T4 and T5 were the most suitable substrates for the cultivation of standard roses because they resulted in significantly higher plant height, stem diameter, leaf area, number of leaves, and number of flowers as compared to the other substrate combinations. The growth and development of the plants in T4 and T5 were faster. Plants grown in T4 and T5 substrates had similar growth and development, indicating that these substrates could provide optimal conditions for the cultivation of standard roses (Figure 2).

Analysis of substrate physical and chemical properties. The physical properties of the substrate have a direct impact on the growth of standard roses roots. The physical properties that have been studied more on the growth of standard roses mainly include acidity, alkalinity, bulkiness, porosity, etc. It is generally believed that the pH of the soil is suitable for the growth of the roses. The pH values of the nine substrate treatments set up in this experiment with varying ratios of decomposed shiitake mushroom residue, perlite, and rotted corn stover ranged from 6.51 to 7.10, all of which were weakly acidic-neutral and did not exhibit any phenomena of poor growth or alkaline inhibition. It is generally believed that soil suitable for the flower's growth has a pH value between 5.5 and 7.0. The root growth of standard roses requires the soil to have a loose physical state, and the bulk density can measure the looseness and solidity of the substrate, which is also an important index for evaluating the advantages and disadvantages of soilless culture substrates. The best root growth and development was achieved when the bulk density was 0.85–0.95 g/cm^3, followed by 0.95–1.0 g/cm^3. When the bulk density exceeded 1.0 g/cm^3, the root development was limited, which indicated that too large bulk density would inhibit root growth and affect yield and quality. Related experimental research found that in the bulk density of 0.92–1.0 g/cm^3 farmland soil, the seedling emergence rate of the flower is more than 70%. When the bulk density is greater than 1.2 g/cm^{3,} the seedling emergence

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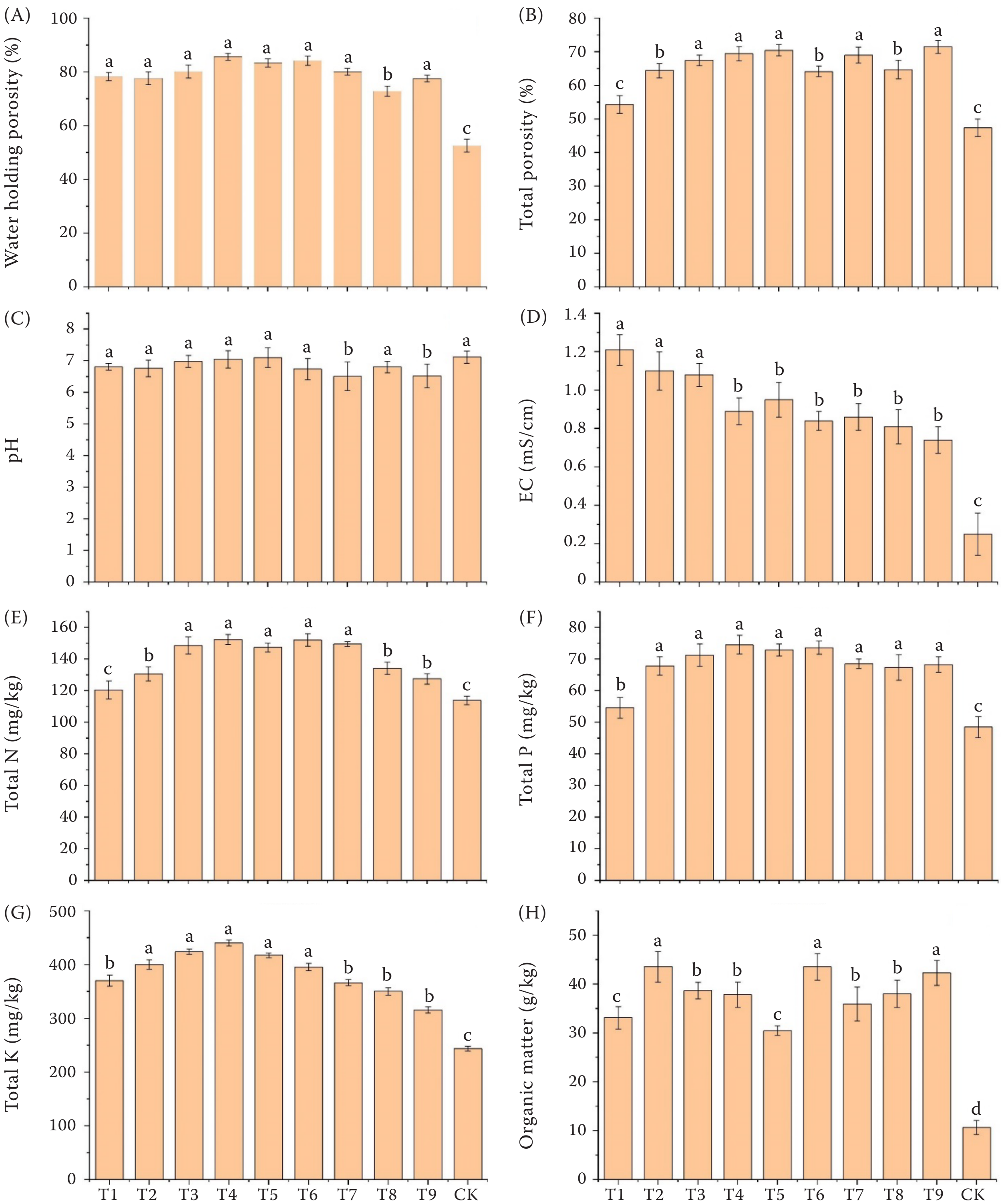

Figure 1. Physical and chemical properties of different substrate combinations. (A) Water holding porosity; (B) total porosity; (C) pH; (D) electrical conductivity (EC); (E) total nitrogen; (F) total phosphorus; (G) total potassium, and (H) organic matter

is very small, which suggests that the bulk density would also affect the seedling emergence rate of the Chinese rose (Zhang et al. 2016).

The bulk density of the nine substrate treatments in this experiment ranged from 0.57–0.74 g/cm^3, smaller than that of farmland soil. In future experi-

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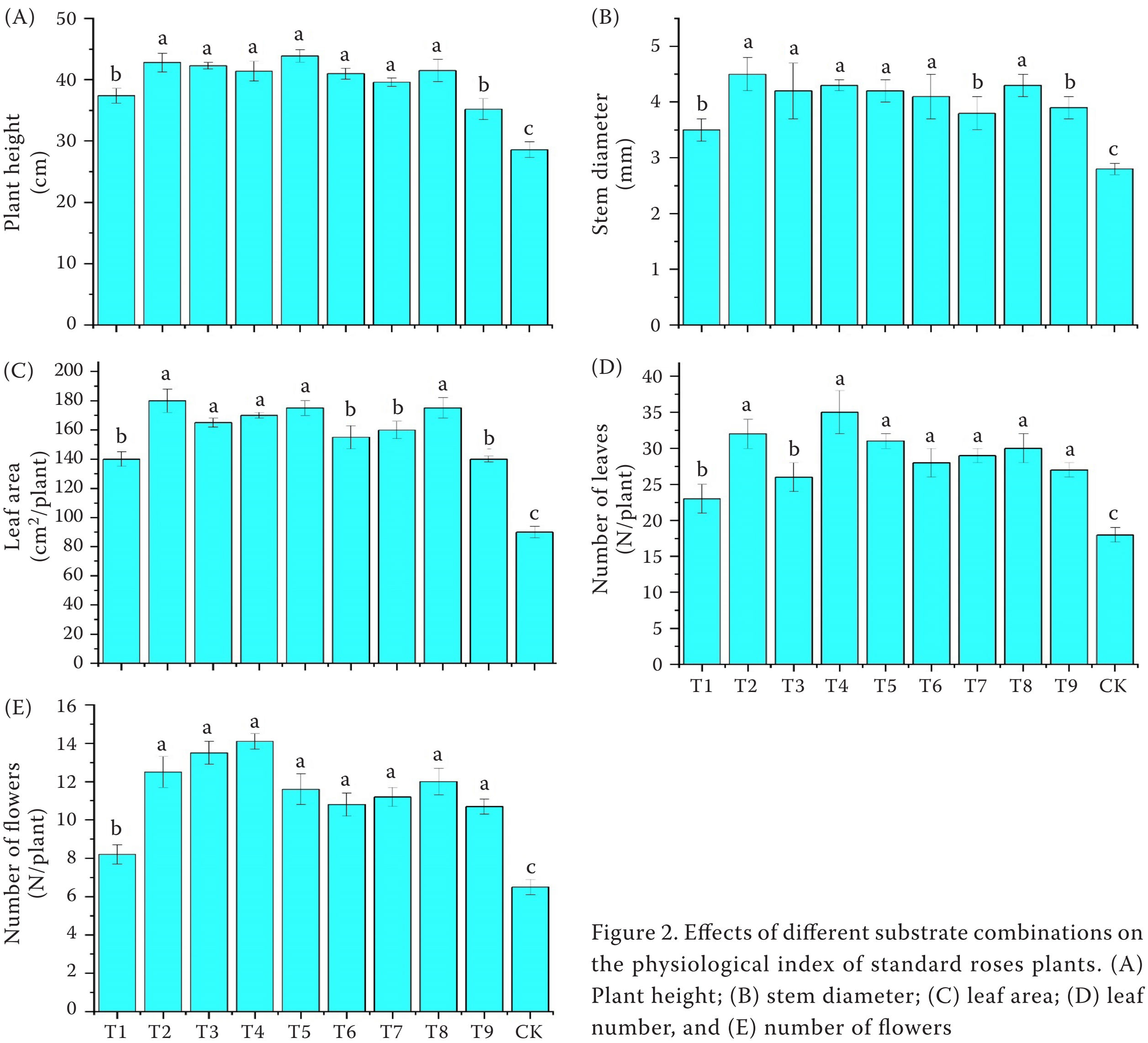

Figure 2. Effects of different substrate combinations on the physiological index of standard roses plants. (A) Plant height; (B) stem diameter; (C) leaf area; (D) leaf number, and (E) number of flowers

ments, we may consider increasing the bulk density of the substrate appropriately. The bulk density of CK was 1.27 g/cm^3, which may be due to the large bulk density that hindered the growth of the root system of the standard roses, resulting in the reduction of seedling emergence rate, yield, and quality of the CK. Standard roses prefer a loose and aerated soil environment, and suitable soil porosity is conducive to maintaining good water holding capacity and aeration in the bed soil, which is favourable for the regulation of nutrients and the extension and activity of the standard roses root system. The PORT of the nine substrate treatments in this experiment ranged from 54.33% to 71.48%, which can meet the requirements of pore properties in the process of flower cultivation and is conducive to the growth and development of the flower's root length. Research revealed that the total soil porosity of 56.92–73.52% is favourable to the growth of standard roses (Zhai 2017). Standard roses prefer fertile and nutrient-rich soil, and the contents of organic matter, total nitrogen, quick-acting nitrogen, effective phosphorus, and quick-acting potassium in the treatments with the addition of decomposed shiitake mushroom residue and organic fertiliser were significantly higher than those in the test site soil (CK), which could provide the required nutrients for the growth and development of standard roses.

In conclusion, the standard roses cultivation substrate, crafted primarily from decomposed shiitake mushroom residue and enhanced with organic fertiliser and perlite, demonstrated a significantly superior capacity to regulate soil porosity and water transport, surpassing conventionally modified Chinese rose soil performance. Additionally, the substrate's organic

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Table 4. Results of principal component analysis

Index	PC1	PC2	PC3	PC4	PC5
pH	–0.474	0.589	0.124	0.112	0.475
Total porosity	0.647	0.171	–0.168	0.299	0.165
Organic matter	0.342	–0.708	0.246	0.152	0.013
Bulk density	–0.743	–0.245	0.327	–0.154	–0.014
Total nutrients (TN + TP + TK)	0.105	0.411	0.653	0.232	0.602
Total potassium	0.451	0.365	0.542	–0.359	0.178
Total phosphorus	0.469	–0.155	0.717	–0.106	–0.294
Total nitrogen	0.545	0.619	0.305	–0.023	–0.266
Electrical conductivity	–0.847	0.244	0.179	–0.058	–0.024
Cation exchange capacity	–0.537	0.434	0.209	–0.138	–0.046
Stem diameter	–0.637	0.274	0.159	–0.106	–0.069
Plant height	0.752	–0.119	–0.365	–0.146	–0.079
Eigenvalue	3.213	2.572	2.1	1.812	1.234
Contribution rate (%)	32.015	14.578	14.326	13.854	10.542
Cumulative contribution rate (%)	32.015	46.593	60.919	74.773	85.315

TN – total nitrogen; TP – total phosphorus; TK – total potassium

matter content, effective nitrogen, effective phosphorus, and quick-acting potassium were all increased. After the evaluation and analysis of the principal component model, treatment T4 performed better in the indicators of the flower seedling emergence rate, seedling retention rate, and agronomic traits, and the yield was higher than that of CK and other cultivation substrate treatments.

Principal component analysis. This study applied principal component analysis (PCA) to evaluate the advantages and disadvantages of nine substrate formulations by calculating composite scores and ranking the formulations accordingly. PCA combines the original 12 traits into principal components, which are linear combinations of these traits. To ensure the analysis's validity, components with eigenvalues greater than 1 and a cumulative contribution rate exceeding 85% were selected (Tang et al. 2023).

Five of the 12 components in this analysis met these criteria and were chosen as principal components. As shown in Table 4, all five components had eigenvalues greater than 1, and their cumulative contribution rate was 85.31% (> 85%), indicating that they captured the relevant information from the original evaluation indices. This suggests that these components effectively represent the overall condition of the substrates, providing a comprehensive assessment of their relative advantages and disadvantages.

Table 5 summarises the results of a comprehensive analysis of all substrate formulations using the

Table 5. Comprehensive evaluation score of each substrate

Treatment	PC1	PC2	PC3	PC4	PC5	Aggregate score	Ranking
T1	–0.485	1.119	–1.696	–1.458	0.457	–1.127	9
T2	0.175	2.654	–1.705	0.6	–0.465	0.184	3
T3	–0.343	–0.905	1.007	1.522	0.954	0.231	2
T4	3.968	1.693	1.77	–0.572	0.852	2.041	1
T5	2.099	–1.965	–0.541	–0.351	–1.875	0.082	4
T6	–0.261	–0.422	–0.752	2.411	0.305	0.035	5
T7	–1.561	0.301	1.564	0.202	–1.08	–0.324	6
T8	–0.548	–3.024	–1.096	–1.321	1.314	–0.892	8
T9	–3.042	0.547	1.45	–1.033	–0.461	–0.83	7
CK	–2.523	–1.686	–0.958	0.528	–0.676	–2.358	10

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principal component synthesis model. This model calculates and ranks each formulation's composite score, representing its overall performance across all tested indices. A higher composite score indicates superior performance, suggesting the substrate is more effective in the evaluated categories. Based on this analysis, the substrate formulations were ranked as follows: T4 > T3 > T2 ≥ T5 > T6 > T7 > T9 > T8 > T1 > CK, with T4 showing the best overall performance.

Different cultivation substrates significantly affect the growth and physiology of the Chinese rose, making substrate selection crucial for optimising plant development. Among the substrates tested, the T3 and T4 treatments, composed of corn stover, decomposed shiitake mushroom residue, and perlite, were the most favourable for standard roses growth. However, while T3 provided good growing conditions, it resulted in fewer flowers, making T4 the better choice for ornamental purposes.

In addition to substrate selection, other factors such as light, water, and temperature influence plant growth, highlighting the need for further research to optimise environmental conditions for standard roses growth. Moreover, the use of alternative substrates like rotted corn stover, mushroom residue, and perlite offers several advantages over traditional soil, including improved water retention, aeration, nutrient supply, and reduced environmental impact. These substrates enhance plant growth and contribute to better soil quality, reduced erosion, and less pollution, making them ideal for sustainable urban landscape management. Further research is needed to explore their long-term effects and potential to improve urban ecological systems.

In conclusion, the substrate T4 (70% corn stover, 15% rotted shiitake mushroom residue, 15% perlite) was the most suitable for cultivating standard roses due to its superior water retention, aeration, and nutrient supply. Rotted corn stover exhibited the highest water-holding capacity and aerated porosity, enabling it to retain more water and enhance root aeration. Additionally, its slightly higher pH and lower EC compared to decomposed shiitake mushroom residue suggest that it offers a more stable environment for plant growth. While perlite has lower WHC and higher AFP than rotted corn stover, it provides better drainage and aeration for roots. Furthermore, perlite contains a higher phosphorus content than the other substrates, essential for plant growth and development. Based on these findings, the experimental substrates were prioritised for suitability as follows: T4 > T3 > T2 ≥ T5 > T6 > T7 > T9 > T8 > T1 > CK. Additionally, using these substrates can improve soil quality and reduce environmental pollution, offering a sustainable option for urban landscape management.

REFERENCES

Bakhmatova K.A., Matynyan N.N., Sheshukova A.A. (2022): Anthropogenic soils of urban parks: a review. Eurasian Soil Science, 55: 64–80.

Dong X.M., Wang Y.F., Shi L., Wang J.H., Pan C.L. (2016): Application of black fungus residue organic fertiliser in maize cultivation. Forest By-Product and Speciality in China, 6: 4–6.

Dorte B.D. (2010): Effect of growing media composition, compaction and periods of anoxia on potted roses' quality and keeping quality (*Rosa* sp.). Scientia Horticulturae, 126: 52–63.

FAO (2006): Guidelines for Soil Description. 4th Edition. Rome, Food and Agriculture Organization of the United Nations. ISBN 9789251055212-97.

Ge M., Gang C., Hong J., Xiang H., Wang X. (2012): Screening for formulas of complex substrates for seedling cultivation of tomato and marrow squash. Procedia Environmental Sciences, 16: 606–615.

He R., Yang X., Liu Q.L. (2017): Domestic status and international trend for rose breeding. Chinese Landscape Architecture, 33: 35–41.

Jeong D.H., Lee D.Y., Jang I.B., Yu J., Park K.C., Lee E.H., Kim Y.J., Park H.W. (2018): Growth and ginsenoside content of one year old ginseng seedlings in hydroponic culture over a range of days after transplanting. The Korean Journal of Internal Medicine, 26: 464–470.

Lang B., Fu M.J., Yan H., Zhu S.M., Chen Y. (2018): Effects of seedbed substrate matched by different black fungus residue on the quality of tobacco seedlings. Journal of Agricultural Science Yanbian University, 40: 83–88.

Moral R., Gomez I., Pedreno, Navarro J., Mataix J. (1994): Effects of cadmium on nutrient distribution, yield, and growth of tomato grown in soilless culture. Journal of Plant Nutrition, 17: 953–962.

Mostafa M.M. (2000): Effect of cycocel and potassium on the growth and flowering of *Senecio cruentus* plant. Alexandria Journal of Agricultural Sciences, 3: 149–164.

Niu W.H., Xu J., Dong L.L., Li X.W., Zhang L.J. (2016): A research progress on the vantage of cultivation of ginseng in farmlands. World Science and Technology, 18: 1981–1987.

Pan X., Wang X.H., Ding H.W. (2019): Investigation and reflection on ginseng industry. Ginseng Research, 31: 55–58.

Perner H., Dietmar S., Christian B., Paul M., Eckhard G. (2007): Effect of arbuscular mycorrhizal colonization and two levels of compost supply on nutrient uptake and flowering of pelargonium plants. Mycorrhiza, 17: 469–474.

https://doi.org/10.17221/258/2024-PSE

Santoso S.P., Kurniawan A., Soetaredjo F.E., Cheng K.C., Putro J.N., Ismadji S., Ju Y.H. (2019): Eco-friendly cellulose-bentonite porous composite hydrogels for adsorptive removal of azo dye and soilless culture. Cellulose, 26: 3339–3358.

Song S., Sun H., Han Z.X. (2018): Soilless cultivation facility agriculture and its economic benefit analysis. Agriculture Devlopment and Equipment, 12: 142–148.

Sun Y.T., Zhang M., Xu Z., Kong D.X., Sun L.L. (2007): Effects of controlled release compound fertilizers on soil nutrient and growth of potted rosa Chinensis. Journal of Soil and Water Conservation, 21: 65–68.

Tang Y.K., Shen Y.Z., Ai W.D., Wu Z.Q., Mao R.X., Wu H., Hu W., Feng H.Q. (2022): Effects of different particle sizes on the bulk density, porosity character, water suction of substrates. Chinese Journal of Space Science, 42: 1161–1170.

Tang Y.K., Shen Y.Z., Feng H.Q., Wu H., Mao R.X., Ai W.D., Wu Z.Q. (2023): Study on primary physicochemical characteristics and nutrient adsorption of four plant cultivation substrates. Life Sciences in Space Research, 36: 78–85.

USDA (2022): Keys to Soil Taxonomy. 13th Edition. Washington, Natural Resources Conservation Service.

Vallance J., Déniel F., Le Floch G., Guerin-Dubrana L., Blancard D., Rey P. (2011): Pathogenic and beneficial microorganisms in soilless cultures. Agronomy for Sustainable Development, 31: 191–203.

Xu Q., Zhang P.D., Tu Z. (2015): Research progress of substrate culture of plant. Shandong Agricultural Sciences, 47: 131–137.

Yu S.J., Li Z.Z., Yu F.Z. (2004): Studies on media formula for pot azalea subirrigated by ebb and flow bench systems with hydroponics. Acta Horticulturae Sinica, 31: 210–214.

Yu X.N., Feng X.G., Zhang J.M., Huang J.J., Zhang Q. (2019): Research progress on chemical constituents and pharmacological effects of *Panax ginseng*. Ginseng Research, 31: 47–51.

Zabel P., Bamsey M., Schubert D., Tajmar M. (2016): Review and analysis of over 40 years of space plant growth systems. Life Sciences in Space Research, 10: 1–16.

Zhai T. (2017): Effects of cultivation substrate and fertilizer on growth of potted ginseng. [Master Thesis.] Jilin, Jilin Agricultural University. (In Chinesse)

Zhang J.Y., Shu B., Pan H.F., Zhou X.F., Wang G.F., Li M. (2012): The different ratio of matrix influence on the quality of cut lily. Chinese Agricultural Science Bulletin, 28: 188–191.

Zhang P.Q., Dai X.D., Han Z.H., Ma Q.F., Kong X.H., Liu J.N., Chen H., Ma Y.P. (2016): Experiment on cultivation of *Auricularia auricula* by reusing fungus residue. Edible Fungi, 38: 24–25.

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