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Effect of herbaceous plant cultivation on soil fertility, rose growth and leaf photosynthetic characteristics in rose gardens

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Abstract

Soil management is an important task in the daily management and maintenance of plants, adopting scientific and reasonable soil management methods and soil improvement measures is of great significance in improving the growing environment of trees and promoting their growth and development. Herbaceous cultivation is a soil management method of planting grasses in the whole garden or between the rows of plants, and it has achieved good ecological and economic benefits in related practices. In order to explore the application effect of herbaceous cultivation in rose garden, and to provide a reference for guiding the ecological and scientific cultivation and management of roses, we proposed this study to carry out herbaceous cultivation experiments in the rose garden of the West Campus of Changjiang University in Jingzhou City. Alfalfa and clover were planted separately in the rose garden, with clean tillage as the control, and evaluating the soil water content, soil pH, alkaline dissolved nitrogen, effective phosphorus, quick-acting potassium content, and rose plant height, stem diameter, and photosynthetic gas exchange parameters of the rose plants after grassing in the soil layer of 0cm-30cm in each treatment area. The study showed that herbaceous cultivation affected soil nutrients and plant growth, and the correlation analysis revealed that there was a certain correlation between each soil fertility factor and rose growth and photosynthetic indexes under each herbaceous cultivation, and that the soil fertility factor had a closer relationship with plant photosynthetic characteristics. planting clover and alfalfa improved the fertility level of rose garden soil, effectively enhanced the growth of roses and the photosynthetic performance of leaves, and had a positive effect on soil improvement and sustainable production of rose garden.

Keywords: rose, grass cultivation, soil fertility, growth, photosynthetic properties

Introduction

Grass cultivation is an efficient soil management method of planting grasses in the whole orchard or between the rows of plants,[1] it is effective in improving soil physicochemical properties, regulating the ecological environment of the orchard, promoting the growth and development of the main planted crops,[2-3] and improving the comprehensive benefits of the orchard, [4] and is one of the important measures to ensure the sustainable development of agricultural production in China. In recent years, scholars at home and abroad that work in the orchard grass on the orchard soil physical properties, fruit quality and other aspects of the impact of this topic, gradually increased. Hu Pan et al. [5] using integrated analysis (meta-analysis) quantitative study of the orchard grass, found that grass planting can reduce the titratable acid content of the fruit and soil temperature. Tang Jun et al.[6] showed that grass intercropping can promote the growth and development of *pomelo (Honey pomelo)*, improve fruit quality, and improve the ecological environment in the garden. Li Jian et al.[7] found that grass mulching for 3-5 consecutive years can increase the organic matter content of *kiwifruit (Actinidia chinensis)* orchard soil, improve the capacity of fertilizer supply, maintain soil moisture in the orchard, regulate and improve the microclimate of the orchard, improve the soil pH value, and loosen the orchard soil. Orchard grass in the relevant practice has achieved good ecological and economic benefits; therefore, the selection and cultivation of suitable grass species, for a more scientific and efficiently economic plant cultivation, has a positive significance.

Rose is a deciduous shrub of Rosaceae family, with rich flower fragrance, and source of food and medicine,[8] it not only has important economic value, but also can beautify the environment, heal the body and mind, and has a wider application prospect in the garden green space. With the rapid and stable development of China's economy, the development of roses is also changing, and the rose industry has become an important industry for farmers in some areas to increase their income and become rich.[9] Differences in soil management practices affect soil physicochemical properties and soil fertility and crop yield.[10] Currently, frequent clearing of domestic rose garden soils and the improper use of long-term chemical fertilizers and herbicides lead to soil sloughing, poor air permeability, low water- and fertilizer-retaining capacity, and lowered soil quality, which in turn affects the growth and development of roses, the quality of flowers, and the quality of people's lives. It seriously impedes the development of China's agroforestry industry and the construction of green ecological landscape. Raw grass planting can increase soil basic fertility, enhance soil ecological service function and microbial diversity, which is important for promoting the growth and development of main plants.[11]

Theoretically, the composite cultivation of roses with different herbaceous plants helps to form an effective ground cover under the rose shrubs, improves the soil physical properties of the rose garden, and contributes to the formation of a benign material and energy cycle above and below the ground in the rose garden.

So far, there are few research reports on grassing in rose gardens, and the effect of grassing is not yet known. Therefore, this study was carried out in the rose garden of Changjiang University to investigate the effects of alfalfa and clover on the soil nutrient status and photosynthetic performance of the rose garden, in order to provide theoretical basis and technical support for the three-dimensional planting of roses in the garden green space in the middle reaches of the Yangtze River.

Material and methods

Location

The study site was located in the rose garden of the College of Horticulture and Landscape Architecture, Changjiang University, Jingzhou City, Hubei Province, which has a subtropical monsoon climate. The local average annual temperature is 16.2-16.6°C, the average annual precipitation is 1100-1300 mm, the frost-free period is long, and the soil of the experimental garden is dominated by brown loam.

Experimental materials and design

This experiment begins in April 2022, and the selected rose variety was 'Fung Hwa' with an age of 2 years. The selected raw grass species were alfalfa (*Trifolium repens*) and clover (*Trifolium repens*). There were three treatments in the experiment, namely S1: planting alfalfa, grass seed amount of 2 kg per acre; S2: planting white clover, grass seed amount of 2 kg per acre; CK: control treatment (keep clear tillage, plant no grass between the roses). Each treatment had an area of 30 square meters, the treatment area was between the roses, and there were three replications for each treatment. The basal application of compound fertilizer was 70 kg per acre (N-P_2O_5-K2O=15:15:15). No fertilizer was applied during the growth of raw grass, and field management measures such as rose pruning and watering were consistent with previous years.

Variables evaluated and methods

For determination of basic soil properties, in late April 2023,soil samples were collected from the alfalfa-rose planting area, the clover-rose planting area, and the rose clear-cutting area during the rose harvesting period, and soil samples were taken from the 0~30 cm layer of the sampling site according to the "S"-shaped five-point method; soil samples from the same treatment were mixed well and brought back to the laboratory for timely processing. Soil water content (SWC) was determined by drying method; soil PH was determined by PH meter; soil physicochemical properties were determined by the method of Bao Shidan.[12] Soil organic matter (SOM) was determined by external heating method with potassium dichromate and concentrated sulfuric acid; soil alkaline nitrogen (AN) was determined by alkaline diffusion method; available phosphorus (AP) was determined by sodium bicarbonate leaching method; and quick-acting potassium (AK) was determined by flame photometric method with ammonium acetate leaching.

For determination of aboveground growth of rose plants, five rose plants with relatively uniform growth were selected and listed, and stem diameter and plant height were measured by vernier calipers and scales at 3, 6 and 12 months of herbage, and each treatment was measured five times.

The photosynthetic characteristics of roses were determined in late April 2023 for this, on a sunny morning during the rose flower harvesting period, the photosynthetic gas exchange parameters of rose leaves of different roses under the grass-growing intercropping mode were determined using a Li-6400 portable photosynthesizer. Three roses were selected from each of the alfalfa planting area, the clover planting area, and the clean tillage treatment area, and the functional leaves in the middle of the rose were selected from each plant to determine the net photosynthetic rate, intercellular CO_2 concentration, transpiration rate and stomatal conductance of the roses.

Data analysis

The experimental data were analyzed using Microsoft Excel software for data processing and graphing, SPSS26.0 for one-way ANOVA (Duncan test) with the significance level set at 0.05, and GraphPad Prism 8 for charting. The correlation between the indicators was analyzed by Pearson's correlation analysis. Pearson's correlation coefficient is often used to measure the degree of correlation between two variables, and its value ranges from -1 to 1, of which -1 indicates that the variables are completely negatively correlated, 0 indicates that they are not correlated, and 1 indicates that they are completely positively correlated.

Results

Soils

The results of the analysis of the soil in the 0 cm~30 cm soil layer in the rose garden after the raw grass treatment are shown in Table 1, and the soil of all three treatments was alkaline, with pH values ranging from 7.52 to 7.77. The soil pH of both raw grass treatments was lower than that of the clear-tillage treatment (CK), and the soil pH of the clover treatment (S2) was significantly lower than that of the other two groups ($P<0.05$), which suggests that the planting of clover has a positive effect on reducing the alkalinity of the soil in rose gardens. In terms of soil water content data, the S2 treatment had the highest soil water content of 20.73 %, which was significantly higher than that of the alfalfa treatment (S1) and the CK treatment ($P<0.05$), and the magnitude of soil water content of the three treatments was shown as S2>CK>S1. Soil organic matter, alkaline dissolved nitrogen and quick-acting potassium content increased in alfalfa treatment and clover treatment compared with CK treatment. Soil organic matter content and soil quick potash content in S1 treatment significantly increased by 24.75% and 44.98% compared with CK treatment; soil organic matter content and soil quick potash content in S2 treatment significantly increased by 42.46% and 9.97% compared with CK treatment; S1 treatment increased soil alkaline dissolved nitrogen content by 18.51% and S2 treatment increased soil alkaline dissolved nitrogen content by 18.85% compared with CK treatment. Among the three treatment groups, soil available phosphorus content was highest in S1 treatment (82.72 mg kg-1) and lowest in S2 treatment (45.47 mg kg-1).

Table 1 Determination of soil properties in rose gardens with different treatments

Treatments	pH	SWC (%)	OM (g kg^{-1})	AN.(mg kg^{-1})	AP (mg kg^{-1})	AK (mg kg^{-1})
S1	7.68±0.05a	19.67±0.40b	12.25±0.40b	27.47±1.96a	82.72±1.76a	299.43±2.22a
S2	7.52±0.07b	20.73±0.47a	13.99±0.10a	27.55±0.35a	45.47±1.07c	227.13±3.96b
CK	7.77±0.05a	19.73±0.40b	9.82±0.23c	23.18±0.33b	55.29±3.17b	206.53±4.35c

Note: S1, alfalfa treatment; S2, clover treatment; and CK, clean tillage treatment.

SWC, soil water content; OM, organic matter; AN, alkaline nitrogen; AP, available phosphorus; AK, quick-acting potassium

Different lowercase letters in the same column in the table indicate that the differences between different treatment groups reached the level of significance (P<0.05).

Physiological variables

As far as the data of stem diameter of roses are concerned (see Table 2), after 90 days of grassing, the highest value of stem diameter was recorded in the S1 treatment (2.13 cm), while the CK group showed poor growth performance with the lowest value of stem diameter (1.83 cm).At 180 days the data showed that the stem diameter of the S1 group had increased by 0.64 cm compared to that of the three months before, while the S2 group and the CK group showed lesser growth (0.26 cm and 0.57 cm). At 360 days of herbage, the highest level of rose stem diameter of 3.50cm was reached in S1 treatment and the lowest (3.37cm) in CK treatment. The average increase in rose stem diameter from six months ago in all treatment areas ranged from 0.73 to 1.1 cm. the largest increase in rose stem diameter was recorded in S2 treatment and the smallest increase in rose stem diameter was recorded in S1 treatment. As a whole, the effect of the different herbaceous treatments on the amount of stem diameter growth of roses was not significant. From the plant height data, it can be seen that after 90 days of grassing, the S1 group showed a higher growth promotion effect, with the plant height reaching 56.33cm, while the control group, CK, showed a poorer growth performance at 51.50cm. 180 days of grassing in the rose garden, the growth advantage of the rose plant height of the S2 treatment became greater, and the rose plant height of the S2 treatment was statistically significantly better than that of the CK group (P<0.05), with the specific difference being 9.67 cm. data at 360 days of grass growing showed that plant height of S2 treatment was significantly (P<0.05) higher than control group by 11.19%, while there was no significant difference (P>0.05) among the rest of the groups.

Table 2 Mean stem diameter and plant height growth of roses in different treatments

Treatments	90d		180d		360d	
	Stem diameter (cm)	Plant height (cm)	Stem diameter (cm)	Plant height (cm)	Stem diameter (cm)	Plant height (cm)
S1	2.13±0.42a	56.33±4.31a	2.77±1.08a	63.30±1.53ab	3.50±0.50a	69.77±2.54b
S2	2.07±0.49a	54.83±5.35a	2.33±0.64a	66.67±5.13a	3.43±0.51a	76.83±1.76a
CK	1.83±0.15a	51.50±1.32a	2.40±0.10a	57.00±2.34b	3.37±0.80a	69.10±4.42b

Note: S1, alfalfa treatment; S2, clover treatment; CK, clean tillage treatment; the same as below.

Different lowercase letters in the same column in the table indicate that the differences between different treatment groups reached the level of significance, the same below (P<0.05).

Photosynthetic characteristics

The effects of raw herbaceous cultivation on photosynthetic parameters of roses were shown in Figure 1. The photosynthetic rate of CK treatment was 19.97 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (Figure 1A), which was significantly higher than that of S1 and S2 treatments (P<0.05), and was 13.7% and 25.04% higher than that of S1 and S2 treatments, respectively, and the net photosynthetic rate of the rose leaves of S2 treatments was significantly higher than that of the S1 treatments (P<0.05). The effects of different herbaceous treatments on leaf stomatal conductance were also different, with the lowest stomatal conductance (0.31 $mol \cdot m^{-2} \cdot s^{-1}$) in the S1 treatment, which was significantly lower than that in the S2 and CK treatments (Figure 1B) (P<0.05), and the differences between stomatal conductance of the rose leaves in the CK and S2 treatments were not significant. Regarding the data on rose leaf blade intercellular CO_2 concentration, the rose leaf blade intercellular CO_2 concentration in each treatment was CK>S2>S1 in descending order, and the numerical differences in rose leaf blade intercellular CO_2 concentration among the three treatments were not significant (Figure 1C). The transpiration rate of rose leaves in different herbaceous treatments also differed, which was shown as S2>S1>CK (Figure 1D), in which the highest transpiration rate of rose leaves in S2 treatment was 6.23 $\mu mol \cdot m^{-2} \cdot s^{-1}$, which was 11.05% and 18.7% more than that of S1 and CK treatments, respectively, and the transpiration rate of rose leaves in S2 treatment was significantly higher than that in S1 and CK treatments (P< 0.05), while there was no significant difference between the transpiration rate of rose leaves in S1 treatment and CK treatment (P>0.05).

Note: S1= alfalfa treatment, S2= clover treatment, and CK= clean tillage treatment, the same as below. Different lowercase letters in the same column in the table indicate that the differences between different treatment groups reached the level of significance, the same below (P<0.05).

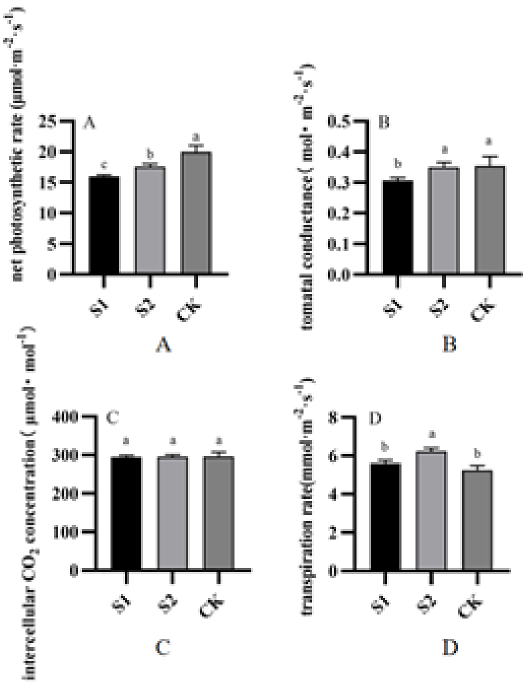

Figure 1 Photosynthetic parameters of *rugosa* under different grassing treatments.

Relationship between soil physicochemical properties and rose-related indicators of different biograss cultivation treatments

The analysis of soil fertility factors with growth and photosynthetic parameters of rose under sod cultivation using Pearson's correlation is shown in Figure 2. Among the selected indicators, rose plant height was significantly positively correlated with soil organic matter and soil water content (P<0.05), highly significantly positively correlated with rose transpiration rate (P<0.01), and significantly negatively correlated with soil pH (P<0.05). Soil alkaline dissolved nitrogen was significantly and positively correlated (P<0.05) with soil organic matter and significantly and negatively correlated (P<0.05) with net photosynthetic rate of rose. Soil available phosphorus was significantly and positively correlated with soil AK (P<0.01), with rose stomatal conductance (P<0.05), soil quick-acting potassium was significantly and negatively correlated with rose net photosynthesis rate and stomatal conductance (P<0.01), soil organic matter was significantly and negatively correlated with soil pH (P<0.01), and soil organic matter was significantly and positively correlated with rose transpiration rate (P<0.01).

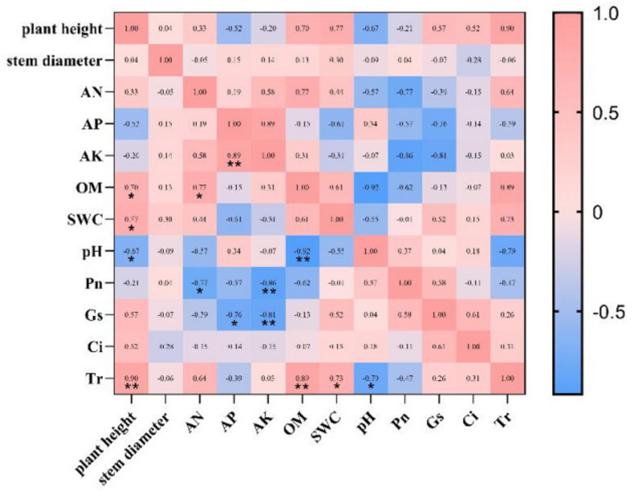

Figure 2 Correlation matrix of indicators.

Note: SWC, soil water content; OM, soil organic matter; AN, alkaline nitrogen; AP, available phosphorus; AK, quick-acting potassium; Pn, the net photosynthetic rate; Ci, intercellular CO_2 concentration; Tr, transpiration rate; Gs, stomatal conductance. *At 0.05 level (two-tailed), the correlation is significant. **Significant correlation at 0.01 level (two-tailed).

Discussion

Raw grass cultivation is in an efficient soil management method, planting raw grasses can improve soil structure and effectively accumulate soil nutrients.[13-14] Planting grasses such as ***Trifolium repens*** **L**, *Lolium perenne* L, *Vigna sinensis* SariVar, ***Medicago sativa*** and *Vicia sativa* in *pomelo* (*Honey pomelo)*,[6] *kiwifruit (Actinidia chinensis)*,[7] and pear (*Pyrus spp*) orchards,[15] all promoted soil nutrient accumulation. In this study, it was found that planting alfalfa and clover had significantly better effects on soil organic matter and quick-acting nutrient accumulation than the clean tillage treatment, in which clover significantly increased soil organic matter, alkaline dissolved nitrogen, available phosphorus, quick-acting potassium, and soil water content after two years of planting, and planting clover had a better effect of improving the soil, probably due to the fact that there were a large number of rhizobacteria in the roots of clover with a strong nitrogen-fixing capacity. Rose garden rows planted clover, clover continued to grow, can effectively enhance soil fertility. The decay of clover stems and leaves covered in the lower layer can also increase soil fertility to a certain extent, which is consistent with the research results that indicate that planting clover in corn gardens[16] tea gardens,[17] and yam Gardens[18] can increase soil nutrients and fertilize the ground. Soil organic matter content is an important index for soil fertility evaluation, which is related to plant growth and development, abundant and excellent yield.[19] In this experiment, for the accumulation effect of soil organic matter showed that alfalfa > clover > clean tillage treatment, alfalfa treatment significantly increased the soil organic matter content, which was consistent with the research results of Zhao Lu et al.[20] in the experiment of planting alfalfa green manure in rice fields. In addition, the study of grassing in *Citrus reticulata* Blanco[21] and kiwifruit,[22-23] found that planting grasses in orchards could reduce the pH of alkaline soils, which was also consistent with the findings of this experiment.

Plant height and stem diameter are intuitive morphological indicators reflecting plant growth. Yang Yanyan et al.[24] found that after planting white clover, perennial ryegrass and ryegrass respectively in jujube orchards, the plant height, stem diameter, length of jujube hangers and leaf chlorophyll content of jujube trees increased, with white clover cultivation treatments of grass cultivation having the most significant promotion effect. In this study, plant height and stem diameter of roses were increased by planting clover and alfalfa compared with the control, and the plant height of roses in the clover treatment was significantly higher than that of roses in the alfalfa treatment and the clean tillage treatment (P<0.05). It may be that raw grass cultivation improved soil fertility and better met the need of soil nutrients for rose growth and development.

In this study, it was found that grass cultivation had a certain effect on the photosynthetic characteristics of rose leaves. The intercellular CO_2 concentration, transpiration rate and stomatal conductance of S2 treatment remained high, and transpiration rate of S2 group was significantly higher than that of CK group (P<0.05), and grass cultivation could effectively increase the photosynthetic rate of plant leaves, which was consistent with the results of the study on grass cultivation in apple orchards.[25] Correlation analysis of soil physicochemical properties and photosynthesis-related indexes of rose found that the transpiration rate of rose was significantly positively correlated with soil water content (P<0.05), significantly negatively correlated with soil pH (P<0.05), and highly significantly positively correlated with soil organic matter. Rose stomatal conductance was highly significantly negatively correlated with soil fast potassium content, and significantly negatively correlated with soil effective phosphorus, while rose net photosynthetic rate was highly significantly negatively correlated with soil fast potassium content, and significantly negatively correlated with soil alkaline dissolved nitrogen. This indicates that soil fertility factors have a very close relationship with plant photosynthetic characteristics. This is consistent with the results of Ni Le,[26] who analyzed the correlation between net photosynthetic rate and soil nutrients of *Thunder Vine* (*Tripterygium wilfordii)* Hook. f. under different sets of planting patterns. Yang Ye,[27] studied the relationship between soil nutrients and leaf photosynthesis of red birch at different altitudes, and found that soil total phosphorus and soil total potassium content had significant correlation with the intercellular carbon dioxide concentration and transpiration rate of red birch leaves, respectively. Soil phosphorus and potassium also have a very close relationship with plant photosynthesis. This is consistent with the results of this experiment. This study focused on the analysis of soil fertility, plant growth and leaf photosynthetic properties in rose gardens, and the effect of grassing on the ecological environment of rose garden is more complicated, for this reason, it is necessary to design a series of experiments to extend the observation time and appropriately increase the number of observation indexes, so as to comprehensively elucidate the specific effects of grassing cultivation.

Conclusion

In conclusion, planting alfalfa and clover can improve soil nutrients and pH, promote the growth of roses, and improve the photosynthetic performance of leaves, indicating that planting alfalfa and clover has the potential to fertilize the ground and promote the sustainable production of roses, which is of some significance as a guide for the scientific cultivation and maintenance management of roses.

Acknowledgments

None.

Conflicts of interest

The authors declare that there is no conflicts of interest.

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