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Investigation of the allelopathic effect of two medicinal plant in agroforestry system

Cuihui Cao[1,3], Huali Tian[2,3], Daoyong Jiang[1], Yanping Tang[1], Jie Ni[1], Lizhen Zhang[1] & Nanyang Jiang[1]✉

In order to enhance the sustainable development of the agroforestry system, this work explored the allelopathic effects between two medicinal plants. *Siraitia grosvenorii* was selected as the recipient plant and investigated the allelopathic effects of different concentrations of fig tree (*Ficus carica* L.) stem aqueous extracts on seed germination, seedling growth, and physiological indicators of *S. grosvenorii* through simulated rainfall and fogging pathways, exploring whether the two medicinal plants are suitable for integrated planting management. It found that the low concentration of fig tree stem (*Ficus carica* L.) stem aqueous extracts (5.0–10.0 g/L) not only promoted the seed of another medicinal plant *S. grosvenorii*, but also significantly improved its biomass and photosynthetic parameters. However, with the increase of the concentration of fig tree stem aqueous extracts (15.0–25.0 g/L), the activities of superoxide dismutase and peroxidase of *S. grosvenorii* first increased and then decreased, and the content of malondialdehyde increased. The synthetic allelopathy index of *S. grosvenorii* showed a pattern of first increase and then inhibition. It indicated that there is a certain allelopathic relationship between the two medicinal plants, making them suitable for intercropping in the agroforestry system.

Keywords *Siraitia grosvenorii* (Swingle) C. Jeffrey, *Ficus carica* L., Stem aqueous extract, Agroforestry system

As a common management practice in forest ecosystems, the agroforestry system of medicinal plants is considered a sustainable development model. By planting high-quality medicinal plants locally and utilizing the land and water resources in the forest clearing, a single forest land can be transformed into a complex ecosystem with multiple functions and structures[1,2]. The medicinal agroforestry system has a higher capacity to absorb and utilize the light energy, water, and nutrients required for growth compared to single land-use systems, thereby further improving land use yield and land production efficiency[3]. Medicinal plant intercropping systems enhance land-use efficiency and reduce pest transmission, yet their success requires precise allelopathic regulation[4].

Allelopathy refers to the phenomenon where plants release certain allelochemicals that affect the growth and development of neighboring plants[5,6]. Allelopathic plants release these compounds into the surrounding atmosphere and soil through volatilization, leaf leaching, root exudation, and residue decomposition, promoting or inhibiting plant growth through interspecific interactions, and altering crop-weed plant communities[7,8]. Utilizing the stimulatory/inhibitory effects of allelochemicals on plant growth and development, while avoiding autotoxicity in cultivation systems, is crucial for long-term agricultural development[9]. Recent studies have revealed significant concentration-dependent effects of allelochemicals. For instance, phenolic compounds act as signaling molecules to enhance antioxidant defenses in recipient plants at low concentrations (<5 μM), while inducing reactive oxygen species (ROS) burst and membrane lipid peroxidation at high concentrations (>20 μM)[10,11]. Meanwhile, moisture levels significantly influence allelochemical secretion, as water stress can enhance the production of phenolic compounds in Phytoecia species. Similarly, temperature fluctuations during plant developmental stages may modulate the degradation rate of allelopathic substances, affecting their efficacy. Seedling stages exhibit greater tolerance to allelopathy compared to mature plants, likely due to reduced metabolic activity and resource allocation. It suggests that allelopathic effects may extend beyond traditional inhibitory roles. Therefore, in order to establish harmonious relationships between species in the medicinal agroforestry system, it is necessary to conduct in-depth research on allelopathic effects within the medicinal agroforestry system.

[1]Department of Chemistry and Pharmacy, Guilin Normal University, Feihu Road, Guilin 541199, Guangxi, China. [2]Key Laboratory of Ecology of Rare and Endangered Species and Environmental Protection, College of Life Sciences, Ministry of Education, Guangxi Normal University, Yanzhong Road, Guilin 541000, Guangxi, China. [3]Cuihui Cao and Huali Tian have contributed equally to this work. ✉email: nanyangjiang@126.com

Siraitia grosvenorii (Swingle) C. Jeffrey (*S. grosvenorii*) is a perennial vine native to China, belonging to the Cucurbitaceae family of plants[12]. The main active ingredient of *S. grosvenorii* is mogrosides (Mog), which account for approximately 3.8% of its content. Mogrosides are triterpene glycosides and are part of the cucurbitane class of compounds[13,14], including Mog III, Mog IV, Mog V, Mog VI, etc. Among them, Mog V is the main sweet component. Studies have shown that extracts from *S. grosvenorii* have beneficial properties, such as antioxidant[15], antitumor[16], anti-inflammatory[17], antifibrotic effects[18], etc.

The fig tree (*Ficus carica* L.) is a fig plant of the Moraceae family, a highyielding traditional medicinal plant with antitumor, antioxidant, anti-inflammatory, anti-fatigue, and anticancer properties[19,20]. Studies have shown that after inter-cropping with fig trees, the growth rate and net photosynthetic rate of Taxus cuspidata significantly improved, promoting the growth of both plants[21]. Planting medicinal plants under the forest canopy increases the nutritional content of the soil, enhances the rhizosphere microbial communities of other plants, strengthens the ability of microbes to utilize soil carbon sources, increases the number of dominant microbes, and enriches other species, thus having a positive impact on the soil environment[22]. Therefore, further research on the composite planting of medicinal plants can more effectively utilize land resources and reduce the use of pesticides and fertilizers[23].

The promotive or inhibitory effects of two medicinal plants are key to the medicinal agroforestry system. The medicinal agroforestry system is a multifunctional production system for medicinal plants, which, compared to monoculture practices, is a more beneficial land use practice that helps improve soil quality and soil biodiversity[24,25]. The medicinal agroforestry system not only promotes ecological diversity and sustainability, but also provides social, economic, and environmental benefits.

In this work, *S. grosvenorii* was selected as the recipient plant and investigated the allelopathic effects of different concentrations of fig tree (*Ficus carica* L.) stem aqueous extracts on seed germination, seedling growth, and physiological indicators of *S. grosvenorii* through simulated rainfall and fogging pathways. The allelopathy of fig stem extracts on the medicinal plant Siraitia grosvenorii was systematically evaluated for the first time, focusing on the concentration dependent physiological regulation mechanism, which provided new insights for plant interaction in the agroforestry system.

Results

The impact of fig tree stem water extract on the germination of *S. grosvenorii* seeds

Under various concentrations of fig tree stem aqueous extract, the germination rate (GR) of *S. grosvenorii* varies, with the E10.0 concentration reaching the maximum value for GR. The GR of *S. grosvenorii* decreases with the increasing concentration of the fig tree stem aqueous extract, and high concentrations of the fig tree stem aqueous extract result in significantly lower GR, GP, GI, and SVI values for *S. grosvenorii* compared to the control (Table 1). All values represent the mean ± SD.

The impact of fig tree stem aqueous extract on the growth of *S. grosvenorii* seedlings

The dry weight of *S. grosvenorii* seedlings varies with the concentration of the fig tree stem aqueous extract. The E10.0 treatment with the fig stem aqueous extract showed a better promotional effect on the plant's overground part weight (OPW), underground part weight (UPW), and total part weight (TPW). The OPW, UPW, and TPW reached their peak values at E10.0. The OPW, UPW, and TPW at concentrations higher than E10.0 were significantly lower than the control, and the indicators showed a decreasing trend with the increase in extract concentration (Table 2). All values represent the mean±SD.

The impact of fig tree stem aqueous extract on the photosynthesis of *S. grosvenorii*

With the increase in the concentration of the fig stem aqueous extract, the Pn, Tr, Gs, and Ci of *S. grosvenorii* show a trend of initially increasing and then slowly declining. The E10.0 treatment with the fig stem aqueous extract has a strong promoting effect on the Pn, Tr, Gs, and Ci of *S. grosvenoriii* (Fig. 1). The contents of Chla (chlorophyll a), Chlb (chlorophyll b), and Chl (total chlorophyll) in *S. grosvenorii* increase at E10.0 and reach their peak at E10.0, then slowly decrease as the concentration of the extract increases (Fig. 2). All values represent the mean ± SD.

As the concentration of the fig tree stem aqueous extract increases, the activity of SOD (superoxide dismutase) in *S. grosvenorii* continues to rise. When the concentration of the fig tree stem aqueous extract is E10.0, the content of SOD in *S. grosvenorii* is significantly higher than that of the control. SOD activity peaked

Plant species	Concentration (g/L)	GR (%)	GP (%)	GI (%)	SVI (%)
S. grosvenorii	0.0	44.67 ± 0.94	40.00 ± 1.63	7.83 ± 0.3	0.21 ± 0.0096
	E5.0	45.33 ± 0.47	41.33 ± 0.94	7.89 ± 0.16	0.28 ± 0.0018
	E10.0	50.67 ± 1.89	46.00 ± 1.63	8.83 ± 0.49	0.38 ± 0.0207
	E15.0	30.67 ± 0.94	27.33 ± 0.94	5.39 ± 0.49	0.18 ± 0.0098
	E20.0	29.33 ± 1.89	26.67 ± 0.94	5.11 ± 0.51	0.18 ± 0.0159
	E25.0	22.00 ± 1.63	14.67 ± 0.94	4.44 ± 0.28	0.12 ± 0.0073

Table 1. Effect of different concentrations of fig trees tem aqueous extracts t on the seed germination of *S. grosvenorii.* Mean ± SD, n = 3. Different lowercase letters among treatments indicate significant differences ($p < 0.05$).

Plant species	Concentration (g/L)	OPW (g/plant)	UPW (g/plant)	TPW (g/plant)
S. grosvenorii	0.0	0.6891 ± 0.0017	0.2308 ± 0.0023	0.9199 ± 0.0031
	E5.0	0.8844 ± 0.0068	0.1655 ± 0.0076	1.0499 ± 0.0012
	E10.0	0.9501 ± 0.0049	0.2704 ± 0.0048	1.2205 ± 0.0008
	E15.0	0.7616 ± 0.0027	0.1612 ± 0.0053	0.9228 ± 0.0058
	E20.0	0.6047 ± 0.0061	0.1433 ± 0.0085	0.7480 ± 0.0042
	E25.0	0.3947 ± 0.0059	0.1097 ± 0.0021	0.5044 ± 0.0073

Table 2. Effect of different concentrations of fig trees tem aqueous extracts on the seed germination of *S. grosvenorii*. Mean ± SD, n = 3. Different lowercase letters among treatments indicate significant differences ($p < 0.05$).

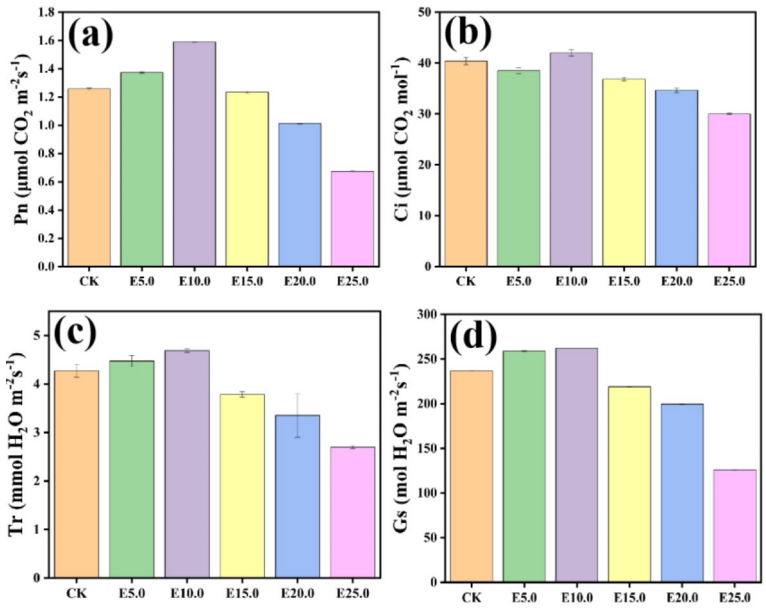

Fig. 1. Effect of fig tree stem aqueous extract on (**a**) Pn, (**b**) Ci, (**c**) Tr and (**d**) Gs of *S. grosvenorii*. Values are reported as mean ± SD, n = 3. CK, 0.0 g/L; E5.0, 5.0 g/L; E10.0, 10.0 g/L; E15.0, 15.0 g/L; E20.0, 20.0 g/L; E25.0, 25.0 g/L. Lowercase letters represent significant differences in each treatment group ($p < 0.05$). Incorporating error bars for standard deviation.

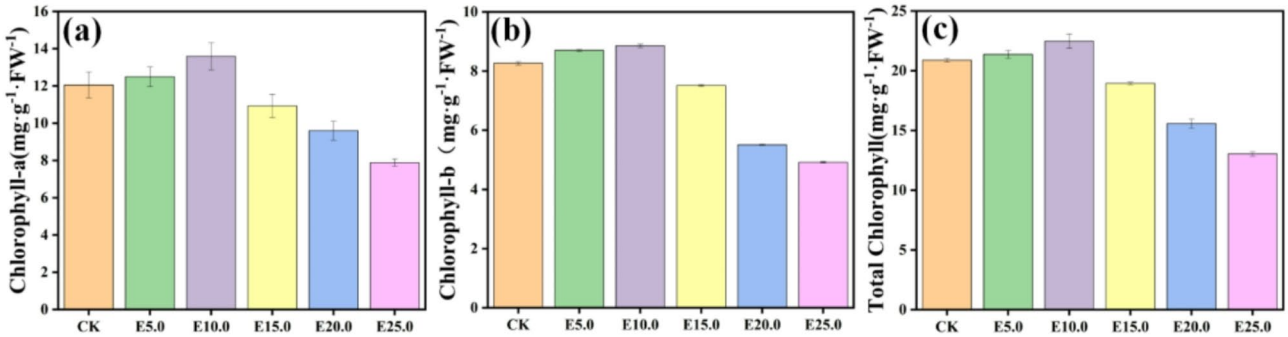

Fig. 2. Effect of fig tree stem aqueous extract on the content of (**a**) chlorophyll a, (**b**) chlorophyll b and (**c**) total chlorophyll of *S. grosvenorii*. Values are reported as mean ± SD, n = 3. CK, 0.0 g/L; E5.0, 5.0 g/L; E10.0, 10.0 g/L; E15.0, 15.0 g/L; E20.0, 20.0 g/L; E25.0, 25.0 g/L. Lowercase letters represent significant differences in each treatment group ($p < 0.05$). Incorporating error bars for standard deviation.

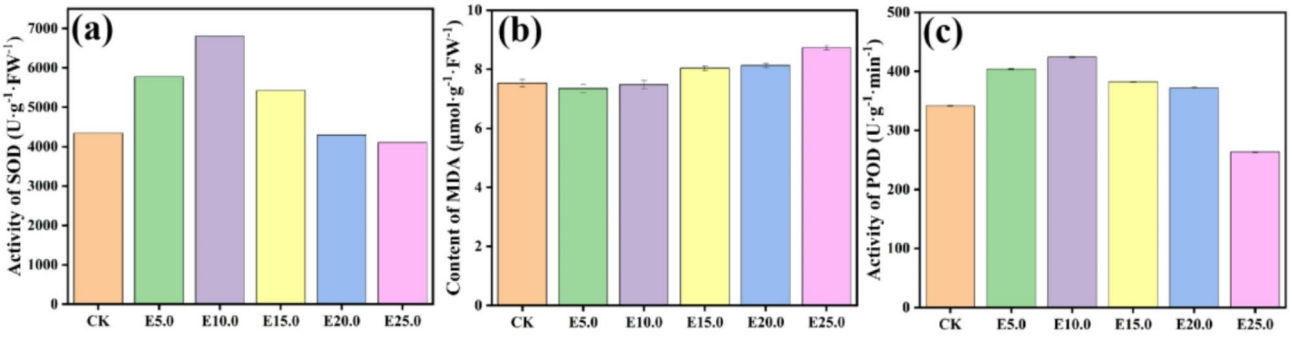

Fig. 3. Effect of fig tree stem aqueous extract on (**a**) SOD, (**b**) MDA and (**c**) POD content of *S. grosvenorii*. Values are reported as mean ± SD, n = 3. CK, 0.0 g/L; E5.0, 5.0 g/L; E10.0, 10.0 g/L; E15.0, 15.0 g/L; E20.0, 20.0 g/L; E25.0, 25.0 g/L. Lowercase letters represent significant differences in each treatment group($p < 0.05$). Incorporating error bars for standard deviation.

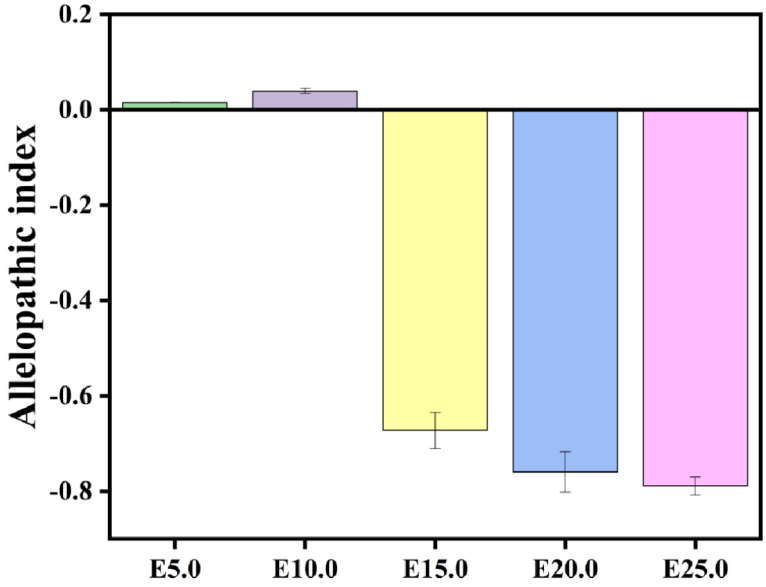

Fig. 4. Allelopathic effects of fig tree stem aqueous extracts at different concentrations on *S. grosvenorii*. SE was calculated as the average allelopathic index (RI) of all indicators with each treatment of *S. grosvenorii*. Values are reported as mean ± SD, n = 3. CK, 0.0 g/L; E5.0, 5.0 g/L; E10.0, 10.0 g/L; E15.0, 15.0 g/L; E20.0, 20.0 g/L; E25.0, 25.0 g/L. Lowercase letters represent significant differences in each treatment group ($p < 0.05$). Incorporating error bars for standard deviation.

in the 10.0 g/L treatment group, indicating ROS scavenging activation under mild stress[26]. With the increase in the concentration of the fig tree stem aqueous extract, the activity of POD (peroxidase) in *S. grosvenorii* shows a trend of increasing first and then decreasing, reaching its maximum value at E10.0. As the concentration of the fig tree stem aqueous extract increases, the content of malondialdehyde (MDA) in *S. grosvenorii* shows an upward trend. At E25.0, the content of MDA in *S. grosvenorii* reaches its maximum value (Fig. 3). All values represent the mean ± SD.

The allelopathic effect of fig tree stem aqueous extract on *S. grosvenorii*

Using the five indicators of GR (Germination Rate), GP (Germination Percentage), GI (Germination Index), SVI (Seedling Vigor Index), and TPW (Total Part Weight) to examine the comprehensive allelopathic effect (SE) value, we can infer the overall allelopathic effect intensity of different concentrations of fig tree stem aqueous extracts on *S. grosvenorii* (Fig. 4). All values represent the mean±SD. When the concentration of the fig tree stem aqueous extract is E5.0 and E10.0, it promotes the growth of *S. grosvenorii*, with the maximum value of SE being 0.034 at E10.0. Except for the concentrations E5.0 and E10.0, all other concentrations showed negative SE values, demonstrating an inhibitory effect on *S. grosvenorii*.

Discussion

Medicinal plants are widely used in the pharmaceutical and food industries due to their medicinal value, making their high-yield cultivation extremely important[27]. The fig tree is a well-known plant that is both medicinal and edible. This work seeks to find suitable medicinal plants to intercrop with fig trees to promote seed germination and seedling growth. Allelopathy is a ubiquitous ecological mechanism in nature and is an important factor affecting seed germination and seedling growth. The aqueous extract of fig tree stems has varying degrees of promotion or inhibition on the germination of *S. grosvenorii* seeds. The higher the concentration of the extract, the stronger its inhibitory effect on the germination of recipient plant seeds, which is consistent with previously reported trends[28]. It has been reported that allelochemicals at low concentrations have a promoting effect on plant growth and at high concentrations have a strong inhibitory effect on plant growth[29–31]. The aqueous extract of the stems of fig trees in low concentrations has a good promoting effect on the germination of the *S. grosvenorii* seeds, which can be attributed to increased osmotic pressure in the recipient plant cells and stimulation of respiratory enzyme activity in the cells, thus increasing the cell's water absorption capacity and improving the plant's ability to produce nutrients[32].

The changes in the dry weight of *S. grosvenorii* seedlings are related to their stimulation of growth. When the concentration of fig tree stem aqueous extracts is the highest (E25.0), the reduction in OPW, UPW, and TPW are the greatest. The differences in weight can be attributed to varying allelopathic forces, which are caused by the structural variability of allelochemical compounds[33]. In this work, we speculate that the high concentration of allelochemicals in fig tree stem aqueous extracts reduced the photosynthetic activity of *S. grosvenorii* seedlings, leading to a decline in OPW, UPW, and TPW. At lower concentrations E5.0 and E10.0, there is a promoting effect on seven parameters (Pn, Tr, Gs, Ci, Chla, Chlb, and Chl), which can be attributed to the relatively mild allelopathic inhibition at lower concentrations[7]. As the concentration of fig tree stem aqueous extracts increases, so does the content of allelochemicals, enhancing the inhibitory effect. This indicates that the allelochemicals in fig tree stem aqueous extracts have a significant inhibitory effect on photosynthesis in plant cells, suppressing the formation of Chl (chlorophyll), thereby reducing the photosynthetic rate and oxygen uptake capacity of the recipient plants, such as Pn, Tr, Gs, and Ci[34,35].

Developmental stages critically influence allelopathic sensitivity. While 3-leaf-stage seedlings were used here, preliminary data show 40% lower phenolic tolerance thresholds during *S. grosvenorii* flowering. This parallels findings in Salvia miltiorrhiza[36], necessitating growth stage-specific management strategies. The increase in POD under 10.0 g/L treatments aligns with the ecological agriculture principle of 'moderate stress enhancing secondary metabolites'[22]. As the concentration of fig tree stem aqueous extracts increases, the activities of SOD and POD in *S. grosvenorii* seedlings first increase and then decrease, while the content of MDA gradually increases. This indicates that the plants have experienced allelopathic stress from the extracts, leading to an overproduction of reactive oxygen species (ROS), thereby increasing the activity of antioxidant enzymes to maintain basic physiological metabolism[37]. However, the regulatory capacity of the antioxidant enzyme system is only temporary and limited. When high concentrations of allelochemicals cause the accumulation of oxidative products to exceed their threshold, enzyme activity will be impaired, POD activity will decrease, and the content of MDA will increase[38]. Analogous to juglone's allelo-pathic effects on Medicago truncatula[39], the sharp MDA increased in >15.0 g/L treatments suggests membrane system damage as a key growth inhibition mechanism. The synthesized allelopathy index can fully express the intensity of allelopathy measured in *S. grosvenorii*. Studies have shown that many plants, such as walnut and alfalfa, produce allelochemicals like phenolic compounds or autotoxic phenomena, which have a highly inhibitory effect on the germination and seedling growth of various cultivated or wild-growing plants[39,40]. In this work, fig tree stem aqueous extracts at low concentrations (E5.0–E10.0) can promote the growth of *S. grosvenorii*. This is mainly attributed to the allelochemicals in the fig tree stem aqueous extracts, which may be released into the soil environment through rain and fog, promoting the formation of mycorrhizae, and directly or indirectly promoting the growth of *S. grosvenorii*. From an ecological perspective, fig stem extracts may indirectly influence nutrient cycling by modulating soil microbial communities. For example, low-concentration phenolics can stimulate phosphate-solubilizing bacteria activity[41], aligning with biomass increases observed in 10.0 g/L treatments. However, controlled conditions cannot replicate field-level biotic interactions, necessitating future metagenomic investigations of rhizosphere microbial mediation. Notably, environmental factors like temperature and moisture were not considered. Recent work demonstrates drought stress significantly increases flavonoid glycoside content in fig leaves[42], highlighting the need for climate-data-integrated field monitoring. While experiments were conducted under subtropical monsoon climate (mean annual temperature: 18.5 °C), *S. grosvenorii* cultivation spans central subtropical to northern tropical zones. Follow-up multi-site trials in Guangxi (24°N) and Yunnan (25°N) are recommended.

Materials and methods

Plant materials

The stems of the fig tree and the seeds of *S. grosvenorii* were collected from the experimental fields in Ziyuan County, Guilin City, Guangxi Zhuang Autonomous Region, China (25°48' N; 110°13' E). The region belongs to the subtropical monsoon climate zone, with an average annual temperature of around 16.7 °C; the average annual sunshine duration is 1275 h, and the average annual rainfall is 1736 mm. The control group received the same volume of distilled water as treatment groups to ensure comparable soil moisture conditions. All soils were sterilized at 121 °C for 30 min to eliminate indigenous microbial interference.

Preparation of fig tree stem aqueous extract

The fig tree stems were air-dried at room temperature for 48 h, then fermented in a blender and passed through an 80-mesh sieve to create a fine powder. The fig stem powder samples (5 g) were mixed with 200 mL of distilled

water and continuously agitated at 25°C for 24 h. After mixing with the residue, the mixture was filtered twice to obtain an aqueous extract with a concentration of 25 g/L. Extracts with concentrations of 0.0, 5.0, 10.0, 15.0, 20.0, and 25.0 g/L were prepared using this method and stored at 4°C before use. Total phenolic content was qualitatively determined using the Folin–Ciocalteu method[43], while terpenoids were preliminarily identified via thin-layer chromatography (TLC) (mobile phase: chloroform-methanol = 9:1). Results showed phenolic compounds constituted 68.2 ± 3.5% of extracts, consistent with prior studies on *Ficus carica* secondary metabolites[44]. The concentration gradient (5.0–25.0 g/L) was determined based on preliminary experiments: seed germination rates dropped below 15% of controls at > 25.0 g/L, while no significant allelopathic effects were observed at < 5.0 g/L.

Seed germination experiment

The *S. grosvenorii* seeds were soaked in a 5% sodium hypochlorite solution for 3 minutes for disinfection and sterilization, then rinsed with distilled water at least 3 times and air-dried at room temperature. Two layers of filter paper were placed in sterile petri dishes (90 mm), and three replicates were prepared for each treatment, with 50 seeds per replicate. To each clearly labeled petri dish, 10 mL of fig stem aqueous extract of different concentrations was added. The control group was given 10 mL of deionized water. *S. grosvenorii* seeds were treated with 0.0 g/L, 5.0 g/L, 10.0 g/L, 15.0 g/L, 20.0 g/L, and 25.0 g/L, respectively. All experiments were repeated three times. All clearly labeled petri dishes were placed in an incubator set at a constant temperature of 25 ± 1 ℃, 70% humidity, and a photoperiod of 12 h. Recording the number of germinated *S. grosvenorii* seeds daily and added the corresponding treatment liquid every 24 h to keep the petri dishes moist.

After the seeds germinated, if there was no further germination for three consecutive days, the germination test was considered complete. To detect the impact of the fig stem aqueous extract on the seed germination process, the following indices were tested: Germination Rate (GR), Germination Potential (GP), Germination Index (GI), and Seedling Vigor Index (SVI). The indices were calculated using the following formulas[45]:

$$Germination\ rate\ \ (GR) = \frac{Germination\ number\ of test\ seeds\ on\ the\ last\ day}{Total\ number\ of\ seeds\ tested} \times 100 \quad (1)$$

$$Germination\ potential\ \ (GP) = \frac{Germination\ number\ of\ test\ seeds\ on\ the\ third\ day}{Total\ number\ of\ seeds\ tested} \times 100 \quad (2)$$

$$Germination\ index\ \ (GI) = \sum \frac{Gt}{Dt}. \quad (3)$$

Gt: the number of germinated seeds per day corresponding to Dt. Dt: the number of germination days.

Seedling vigor index (SVI) = Germination rate Seedling weight.

Potted plant experiment

To further verify the results of the indoor experiments, a potted plant growth experiment was conducted using fig tree stem aqueous extracts on *S. grosvenorii* seedlings. The potted plant experiment was carried out in the greenhouse of Guilin Normal College on April 25, 2023. Each pot was filled with 6 kilograms of soil, with an upper mouth diameter of 20 cm, a lower mouth diameter of 18 cm, and a height of 25 cm. The stems of the fig tree and the seeds of *S. grosvenori*i were collected from the experimental fields in Ziyuan County. The soil was collected from the experimental fields in Ziyuan County. *S. grosvenorii* seeds were sown in the flowerpots, with 30 seeds per pot. After 12 days of growth, each pot was thinned to 3 seedlings of similar height. The potted plant experiment was conducted from May 4, 2023, to June 12, 2024, lasting for 40 days, with a total of 72 pots of *S. grosvenorii* medicinal plants. During the seedling growth process, they were randomly divided into 6 treatment groups. Each treatment group was given different concentrations of fig tree stem aqueous extracts (0.0 g/L, 5.0 g/L, 10.0 g/L, 15.0 g/L, 20.0 g/L, 25.0 g/L). There were 12 replicates for each experimental group. The changes in aboveground and belowground biomass at different periods (10, 20, 30, and 40 days) were measured. After 40 days, photosynthetic indices and antioxidant enzyme activities and other physiological indicators of each treatment group were measured. Every three days, 100 mL of fig tree stem aqueous extract was irrigated into each pot, with additional water supplied as needed based on soil moisture conditions. When measuring plant biomass, three pots of *S. grosvenorii* medicinal plants were randomly selected from each treatment group, carefully washed with water to remove debris, and the aboveground and underground parts were separated accordingly. The dry weights of the overground parts weight (OPW) and underground parts weight (UPW) of the seedlings were measured using a precision balance after drying at 80 °C until a constant weight was achieved. A portable photosynthesis meter HD-GH10 was used to measure the net photosynthetic rate (Pn), transpiration rate (Tr), stomatal conductance (Gs), and intercellular CO_2 concentration (Ci) of *S. grosvenorii* under clear weather conditions between 09:00 and 11:00. Measurements were repeated until a stable reading was obtained.

The physiological and biochemical characteristics of *S. grosvenorii* seedlings were studied. The contents of chlorophyll a (Chla), chlorophyll b (Chlb), and total chlorophyll (Chl) in the plant leaves were determined using a spectrophotometric method[46]. The activity of superoxide dismutase (SOD) was detected by measuring the ability of the solution to inhibit the photochemical reduction of nitroblue tetrazolium (NBT)[47], while the activity of peroxidase (POD) was detected using the guaiacol method[48]. The content of malondialdehyde (MDA) was assayed using the 2-thiobarbituric acid (TBA) colorimetric method[49].

Comprehensive allelopathic effect index

The comprehensive allelopathic effect is detected by calculating the arithmetic mean of the reaction indices of the allelopathic effect (RI) values for the same several receptor measurement test items[31].

$$RI = 1 - \frac{C}{T}. \tag{4}$$

$$RI = \frac{C}{T} - 1 \tag{5}$$

T: treatment, C: control.

When RI > 0, it means there is a promotion effect; when RI<0, it means there is an inhibitory effect.

Statistical analysis

All experiments were conducted using a completely randomized design, with each experiment repeated three times to obtain the corresponding data. Data were analyzed using one-way ANOVA in SPSS 26.0, with Duncan's multiple range test ($\alpha = 0.05$) for post-hoc comparisons. All values represent mean ± SD. Graphs were created using Origin Pro 2021.

Conclusions

This work, conducted under controlled indoor experimental conditions, examined the effects of various concentrations of fig tree stem aqueous extracts on the germination, morphology, and physiological and biochemical indicators of *S. grosvenorii* seedlings. The differences observed reflected the varying intensities of allelopathic effects of the fig tree on *S. grosvenorii* and provided insights into the impact of intercropping fig tree stem aqueous extracts with *S. grosvenorii* on the growth of both plants. The results indicated that the aqueous extracts of fig tree stems at low concentrations had the most promising effect on the growth promotion of *S. grosvenorii*. Based on concentration-dependent effects, we recommend applying fig stem extracts at less 10.0 g/L (dry weight basis) in *S. grosvenorii-F. carica* intercropping systems, avoiding more 15.0 g/L treatments during seedling stages. Against the backdrop of forest medicine, *S. grosvenorii* is suitable for intercropping with fig trees as a medicinal plant. This work offers a solid theoretical foundation for the development of future medicinal agroforestry systems and provides a new perspective for the construction of the medicinal agricultural and forestry industry system.

Data availability

Data is provided within the manuscript.

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Author contributions

Conceptualization, C.C. and N.J.; Methodology, H.T.; Software, D.J; Validation, Y.T.; Formal analysis, C.C.; Investigation, C.C.; Resources, L.Z.; Data curation, C.C.; Writing—original draft preparation, C.C.; Writing—review and editing, C.C.; Visualization, D.J.; Supervision, J.N.; Project administration, C.C.; Funding acquisition, C.C. and D.J.

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Declarations

Competing interests
The authors declare no competing interests.

Additional information
Correspondence and requests for materials should be addressed to N.J.

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