ANALYSIS OF QUALITY TRAIT DIFFERENCES AMONG DIFFERENT CULTIVARS OF *CAMELLIA CHRYSANTHA*

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Abstract. *Camellia chrysantha* is a precious and rare plant with numerous cultivars. To clarify the differences in quality traits among cultivars and provide a basis for future classification and superior germplasm selection, this study evaluated 20 cultivars of *C. chrysantha* using ecological, UV-spectrophotometry, and statistical methods. The results showed significant differences in phenotypic traits among the 20 cultivars, indicating rich genetic diversity. The cultivars with the highest leaf yield were *C. chrysantha* var. conspicua, while the lowest was *C. chrysantha* var. wumingensis. The chemical component content showed significant differences among the cultivars. *C. chrysantha* var. flava had the highest total flavonoid content, *C. chrysantha* var. longzhouensis had the highest total polyphenol content, and *C. chrysantha* var. dongxingensis had the highest polysaccharide content. Principal component and cluster analyses identified high-quality cultivars, including *C. chrysantha* var. *longrui*, *nonggangensis*, *longzhouensis*, *flava*, *tenuifolia*, *pilosa*, *conspicua*, *concava*, and *enchengensis*, mainly distributed in Fangcheng, Ningming, Longzhou, and Daxin areas. These regions have subtropical and South Asian monsoon climates, with ideal environmental conditions for the growth of *C. chrysantha*, including temperature, rainfall, sunlight, and humidity. The study concluded that there are significant differences in quality traits among the 20 cultivars of *C. chrysantha*, providing an important basis for the classification and selection of superior germplasm.
Keywords: *Camellia chrysantha, chemical content, leaf yield, phenotypic, quality traits*

Introduction

Camellia chrysantha is a small tree belonging to the family Theaceae of the genus *Camellia.* Its flowers are waxy and golden yellow, making it the only cultivars in the *Camellia* family with golden petals. It is considered a rare cultivars globally and is known as the “Queen of the Tea Family” and the “Panda of the Plant World” (Li et al., 2019; Hoi et al., 2021). The distribution of *C. chrysantha* is extremely narrow but rich in cultivars diversity. Currently, 42 cultivars and 5 varieties of *C. chrysantha* have been discovered worldwide (Cao et al., 2012; Pang et al., 2022), primarily distributed in southern Guangxi, China, and northern Vietnam (Yang et al., 2009). China has over 30 cultivars and 5 varieties, with 28 cultivars found in Guangxi alone. Vietnam has discovered 22 cultivars, with the main distribution center in northern Vietnam, adjacent

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to Guangxi, the primary production area in China (Hu et al., 2016; Liu et al., 2022;http://www.gxdfz.org.cn/). Additionally, some cultivars of *C. chrysantha* are sporadically distributed or cultivated in Yunnan, Guizhou, and Fujian in China (Zhong et al., 1998; Hong et al., 2016), as well as in Myanmar, Thailand, Malaysia, and Japan (Fu and Jin, 1992). Research on *C. chrysantha* has mainly focused on its active ingredients and pharmacological effects, as it contains bioactive compounds such as polyphenols, polysaccharides, and flavonoids, which exhibit antioxidant, anti-tumor, hypoglycemic, and hypolipidemic properties (Song et al., 2011; Xing et al., 2013; Wei et al., 2015; Dai et al., 2016 and Zhang et al., 2020). However, studies on its quality evaluation are relatively rare. Currently, commonly used methods for evaluating its quality of traditional Chinese medicinal materials can be divided into two broad categories. One is direct observation or simple physical and chemical experiments based on the apparent properties of the medicinal materials to make empirical identifications that meet objective reality. The other is to establish corresponding specific identification and content determination items for traditional Chinese medicinal materials based on their active ingredients or index components using modern analytical instruments (Zhu, 2010).

To further analyze the quality traits of different cultivars of *C. chrysantha*, this study is based on the aforementioned two points. Using ultraviolet spectrophotometry and considering their biological traits, we analyzed the phenotypic traits, leaf yield, and chemical composition differences among 20 cultivars of *C. chrysantha*. We also performed principal component and cluster analyses to provide a basis and guidance for quality evaluation, cultivars classification, and the selection of superior germplasm of *C. chrysantha*.

Materials and methods

Materials

The samples used in this study were collected from the Chongfeng *C. chrysantha* planting base in Dali Village, Jiangping Town, Dongxing City, and Fangchenggang, Guangxi (108° 7′43″E, 21° 38′40″N, and altitude 36.8 m). Due to the rarity and scarcity of leaves of the Tian’e *C. chrysantha* cultivars, only 20 cultivars were collected for this study to protect the rare plants. All *C. chrysantha* plants were mature, healthy, and free of obvious pests and diseases. Detailed information is provided in *Table A1* (*Appendix*). The harvested leaves were sent to the production workshop of Dongxing Tianzhilin Agricultural Technology Co., Ltd., where they were rapidly frozen at -40°C for 2 h, then freeze-dried at 45°C. The dried leaves were crushed, passed through a No. 3 sieve, placed in dry, sealed kraft paper bags, and stored in a refrigerator for later use.

Methods

The preparation of rutin, gallic acid, and glucose reference solutions, as well as the determination methods for total flavonoid, total polyphenol, and polysaccharide content, were all conducted according to the 2015 edition of the Chinese Pharmacopoeia.

Phenotypic trait measurement

A ruler was used to measure stem circumference, plant height, main stem height, crown diameter, leaf length, leaf width, and petiole length. Crown height was calculated

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based on plant height and main stem height, and crown width was determined from the crown diameter. Leaf count and leaf area (calculated from leaf length and width) were also recorded. Leaf fresh weight and dry weight were measured using an electronic balance. All these data, along with the component contents, were entered into a comprehensive table for statistical analysis.

Standard curve plotting

Total flavonoid standard curve plotting

A 0.2 mg·mL^{-1} Rutin standard solution was prepared in seven gradients: 0, 0.4, 0.8, 1.2, 1.6, 2.0, and 2.4 mL. The color development and measurement process followed the method for total flavonoid content determination. Using 510 nm as the wavelength for absorbance measurement, the absorbance was measured using a UV-visible spectrophotometer (Model 521801007, Shanghai Jinghua Technology Instrument Co., Ltd.). The standard curve was plotted with rutin standard concentration (mg·mL^{-1}) on the x-axis and absorbance (A) on the y-axis, resulting in the regression equation y = 0.266x - 0.003 with an R^2 of 0.9999, indicating a linear range of 0-2.4. The standard curve is shown in *Figure 1*.

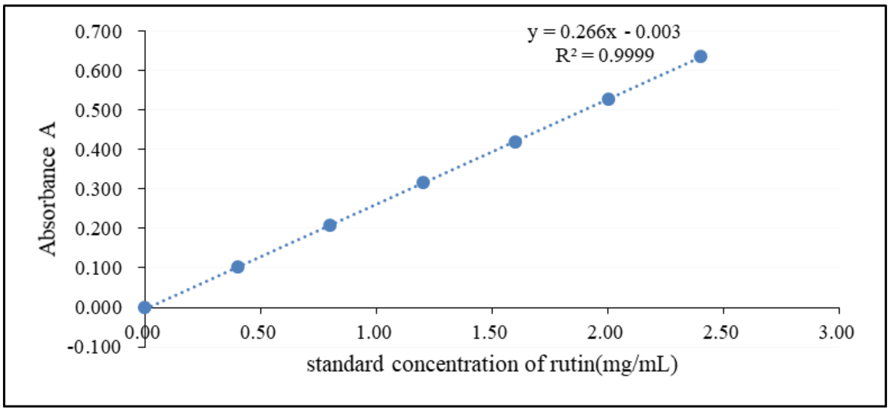

Figure 1. *Standard curve for total flavonoids*

Standard curve for total polyphenols

A 0.01 mg·mL^{-1} Gallic acid standard solution was prepared in seven gradients: 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, and 2.0 mL. The color development and measurement process followed the method for total polyphenol content determination. Using 765 nm as the wavelength for absorbance measurement, the absorbance was measured, and a standard curve was plotted with gallic acid concentration (mg·mL^{-1}) on the x-axis and absorbance (A) on the y-axis, resulting in the regression equation y = 0.0683x + 0.0031 with an R^2 of 0.9925, indicating a linear range of 0 -2.8. The standard curve is shown in *Figure 2*.

Standard curve for polysaccharides

A 0.1 mg·mL^{-1} glucose standard solution was prepared in nine gradients: 0, 50, 100, 150, 200, 250, 300, 350, and 400 μL. The color development and measurement process followed the method for polysaccharide content determination. Using 490 nm as the

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wavelength for absorbance measurement, the absorbance was measured, and a standard curve was plotted with glucose concentration (mg·mL^{-1}) on the x-axis and absorbance (A) on the y-axis, resulting in the regression equation y = 0.06236x + 0.0096 with an R^2 of 0.9995, indicating a linear range of 0.05-0.4. The standard curve is shown in *Figure 3*.

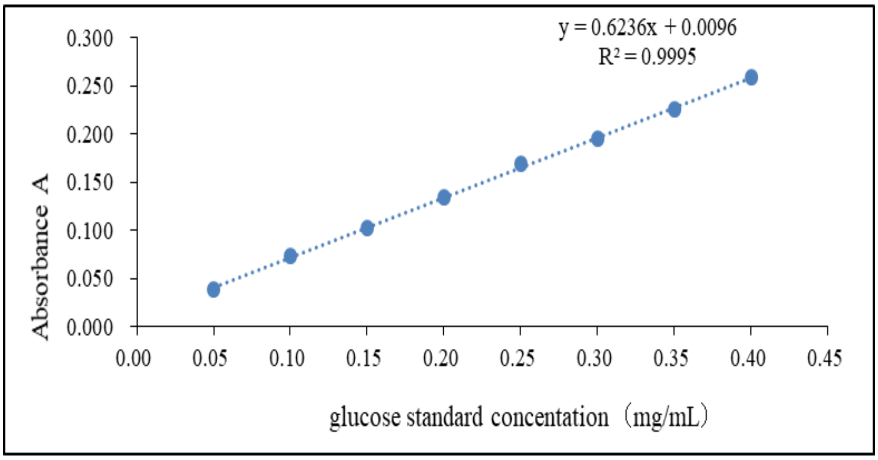

Figure 2. *Standard curve for total polyphenols*

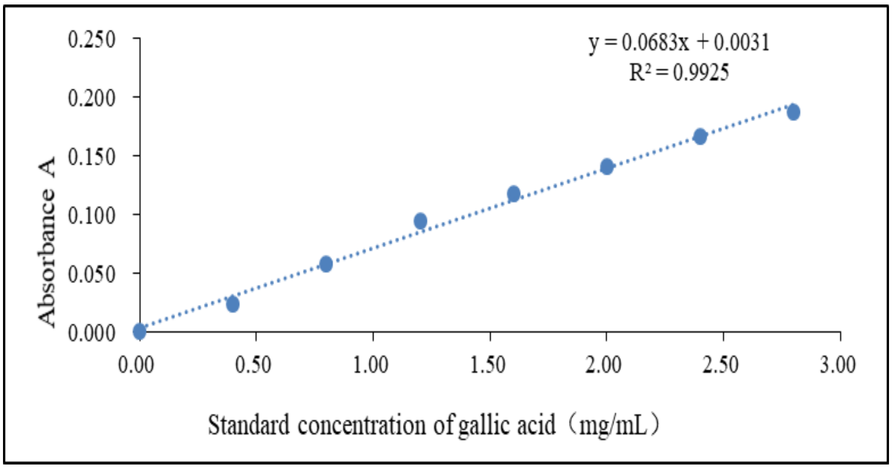

Figure 3. *Standard curve for polysaccharides*

Results and analysis

Variation in phenotypic traits of 20 C. chrysantha cultivars

The coefficients of variation for various phenotypic traits of the 20 *C. chrysantha* varieties are shown in *Table A2*. From the table, it is evident that the variation ranges from 12.77% to 79.74% across different traits, indicating a significant degree of variability among the varieties. The coefficients of variation from highest to lowest are: leaf count (79.74%) > leaf area (61.49%) > leaf fresh weight (57.77%) > leaf dry weight (55.18%) > petiole length (31.85%) > leaf length (31.32%) > stem circumference (31.31%) > leaf width (30.72%) > crown height (27.04%) > crown diameter (25.68%) > leaf length/width ratio (12.77%). The coefficient of variation for leaf count

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(79.74%) is the highest among the 11 phenotypic traits, while the leaf length/width ratio (12.77%) shows the lowest variability. These results indicate a rich genetic diversity among the 20 *C. chrysantha* varieties.

Analysis of yield, total flavonoids, polyphenols, and polysaccharide content among 20 varieties of C. chrysantha

According to *Table A3*, among the 20 varieties of *C. chrysantha*, the ranking of leaf yield from highest to lowest is: GXM > GFC > GDS > GDX > GFP > GLR > GLA > GLZ > GZD > GDLY > GBY > GMB > GEC > GLMH > GAM > GSJ > GLG > GXY > GDH > GWM. The variety with the highest leaf yield is *C. chrysantha*, while the variety with the lowest leaf yield is *C. chrysantha*. Single-factor analysis of variance indicates significant differences ($P < 0.05$) between *C. chrysantha* and *C. chrysantha,* and highly significant differences ($P < 0.01$) between *C. chrysantha* and *C. chrysantha*, *C. chrysantha*, and *C. chrysantha*.

Among 20 varieties of *C. chrysantha*, the total flavonoid content ranks from highest to lowest as GDH > GXY > GLR > GLG > GLZ > GMB > GAM > GFC > GSJ > GZD > GXM > GEC > GBY > GWM > GDLY > GLMH > GDS > GFP > GLA > GDX. The highest content is found in Light Yellow *C. chrysantha* at 22.745%, and the lowest in Dongxing *C. chrysantha* at 1.340%. Single-factor analysis of variance on the total flavonoid content of these 20 *C. chrysantha* varieties shows that there is no significant difference between Light Yellow, Longrui, Nonggang, and Xiye *C. chrysantha*, but they differ significantly from Siji, Zhongdong, Xianmai, Encheng, Boye, Daoluan leaf, Dingsheng pingguo, Fangpu, Long'an, and Dongxing *C. chrysantha* ($P < 0.01$). Longzhou *C. chrysantha* shows no significant difference in total flavonoid content compared to Aomai, Light Yellow, Fusui, Longrui, Maoban, Nonggang, and Xiye *C. chrysantha*, but reaches significant levels compared to Daoluan leaf, Dingsheng pingguo, Dongxing, Fangpu, Long'an, Lemon Yellow, and Wuming *C. chrysantha* ($P < 0.01$). Siji *C. chrysantha* differs significantly from Dongxing and Long'an *C. chrysantha* ($P < 0.01$). Dongxing *C. chrysantha* shows significant differences in content compared to Boye, Encheng, Siji, Xianmai, and Zhongdong *C. chrysantha* ($P < 0.05$), and reaches extremely significant levels compared to Aomai, Light Yellow, Fusui, Longzhou, Longrui, Maoban, Nonggang, and Xiye *C. chrysantha* ($P < 0.01$).

The total polyphenol content ranks from highest to lowest as GLZ > GXY > GLR > GAM > GMB > GZD > GLG > GFS > GEC > GXM > GDH > GLMH > GDS > GSJ > GWM > GBY > GDX > GDLY > GLA > GFP, with Longzhou *C. chrysantha* having the highest content at 0.318% and Fangpu *C. chrysantha* the lowest at 0.127%. Single-factor analysis of variance shows that Longzhou *C. chrysantha* differs significantly in total polyphenol content from all other varieties except Aomai, Longrui, and Xiye *C. chrysantha* ($P < 0.01$). Fangpu *C. chrysantha* and Long'an *C. chrysantha* differ significantly in total polyphenol content ($P < 0.05$) compared to Xianmai *C. chrysantha*, and show extremely significant differences ($P < 0.01$) compared to Encheng, Fusui, Nonggang, Zhongdong, Maoban, Aomai, Longrui, Xiye, and Longzhou *C. chrysantha*, with no significant differences observed among the remaining varieties.

The polysaccharide content ranks from highest to lowest as GDX > GLR > GWM > GZD > GLG > GDS > GLA > GLMH > GLZ > GDH > GFP > GSJ > GXY > GDLY > GMB > GAM > GXM > GBY > GEC > GFC, with Dongxing *C. chrysantha* having the highest content at 2.516% and Fusui C. chrysantha the lowest at 1.345%. Dongxing *C.*

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chrysantha and Longrui *C. chrysantha* differ significantly in polysaccharide content ($P < 0.05$) compared to Maoban *C. chrysantha* and Daoluanye *C. chrysantha*, and show extremely significant differences ($P < 0.01$) compared to Aomai, Xianmai, Boye, Encheng, Fusui *C. chrysantha*, with no significant differences observed among the remaining varieties. Fusui *C. chrysantha* shows no significant differences in polysaccharide content compared to Encheng, Boye, Xianmai, Aomai *C. chrysantha*, but differs significantly ($P < 0.05$) from Maoban, Daoluanye, and Fangpu *C. chrysantha*, and shows extremely significant differences ($P < 0.01$) compared to Siji, Fangpu, Light Yellow, Longzhou, Lemon Yellow, Long'an, Nonggang, Zhongdong, Wuming, Longrui, and Dongxing *C. chrysantha*.

Principal component analysis of 20 cultivars of C. chrysantha based on phenotypic traits and content differences

Using R language, factor analysis was conducted on the phenotypic characteristics and contents of 20 varieties of *C. chrysantha*. Three factors with variances greater than 1 were identified as principal components for analysis, as shown in *Table 1,* which presents the total eigenvalues and variance contributions of these three factors. According to *Table 1,* the eigenvalue of the first principal component is 9.595, accounting for 59.970% of the total variance. The cumulative variance of the three principal components accounts for 82.363% of the total variance. Based on the factor scores of the three principal components, calculated by multiplying each sample's scores by the square root of the corresponding variance, the comprehensive scores of each sample were determined. These scores were calculated by multiplying each sample's scores for each principal component by its contribution ratio (variance divided by the total variance of the three factors). As shown in *Figure 4,* samples labeled GMB, GXM, GLZ, GAM, GLR, GLG, GEC, and GXY rank in the top 8 for comprehensive scores of principal components, indicating they are of high quality.

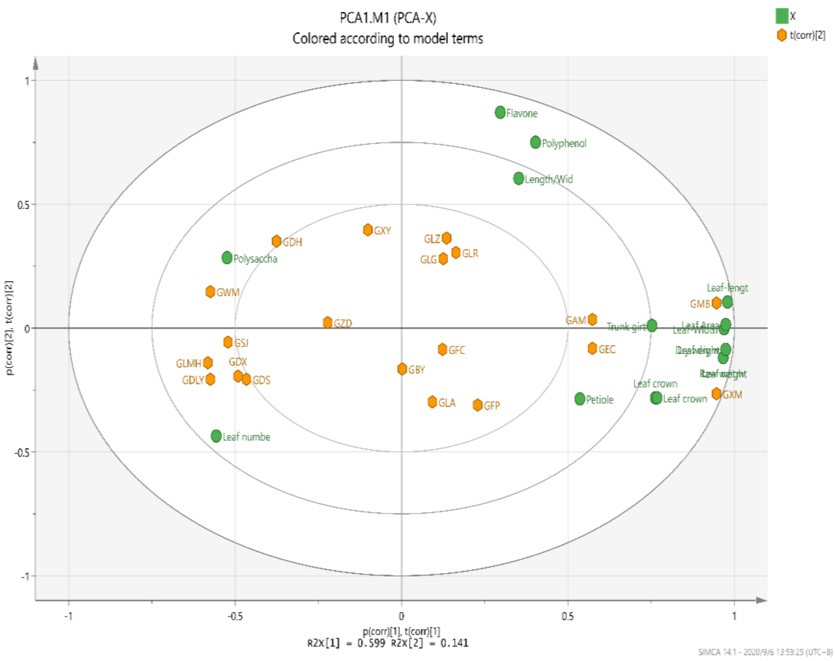

Figure 4. *Comprehensive scores of 20 varieties of C. chrysantha based on phenotypic traits and content differences*

***Table 1.** Eigenvalues and variance contribution rates of principal component analysis*

Main ingredient	Sum of squares of extracted loadings		
	Total eigen value	**Variance contribution rate (%)**	**Cumulative contribution rate (%)**
1	9.595	59.970	59.970
2	2.252	14.076	74.045
3	1.331	8.317	82.363

Cluster analysis of 20 varieties of C. chrysantha

Based on leaf phenotypic traits and three chemical components, hierarchical clustering using Euclidean distance and squared deviations was performed on 20 varieties of *C. chrysantha*. The results are shown in *Figure 5,* with the frequency of phenotypic traits and average values of total flavonoids, total polyphenols, and polysaccharide contents for each cluster presented in *Table A4*. According to *Figure 5* and *Table A4,* the 20 varieties of *C. chrysantha* can be grouped into 4 main clusters: Cluster 1 includes Xianmai, Maoban, Aomai, and Encheng Camellia chrysantha, primarily distributed in Fangcheng, Vietnam, Long'an, Daxin, and Longzhou. This group has the thickest dry circumference, the tallest crown height, the widest crown width, the largest leaf area, the second longest leaf stalk, the heaviest leaf weight, the fewest leaf numbers, and the second highest total flavonoid and total polyphenol contents, but the lowest polysaccharide content. It belongs to large plants with fewer leaves, large leaves with long stems and high leaf yield, moderate total flavonoid and total polyphenol content group. Cluster 2 includes Desheng, Wuming, Dongxing, Lemon Yellow, Zhongdong, Daoluan Leaf, and Siji, primarily distributed in Tiandeng, Wuming, Fangcheng, Longzhou, Ningming, Fusui, and Chongzuo. This group has the thinnest dry circumference, lowest crown height, smallest crown width, smallest leaf area, shortest leaf stalk, lightest leaf weight, most leaf numbers, moderate leaf yield, highest polysaccharide content, and lowest total flavonoid and total polyphenol contents. It belongs to small plants with dense leaves, small leaves with short stalks, moderate leaf yield, and a high polysaccharide content group. Cluster 3 includes Longrui, Nonggang, Longzhou, Light Yellow, and Xiye 5 *C. chrysantha*, primarily distributed in Ningming, Longzhou, and Wuming. This group of *C. chrysantha* plants are medium-sized and low, leaf area, leaf weight, and leaf number are medium to low, leaf yield is the lowest, total flavonoids and total polyphenols are highest, and polysaccharides are second. It belongs to the medium-sized plants, medium-sized leaves, high chemical content, but low leaf yield group. Cluster 4 includes Fangpu, Fusui, Long'an, and Xiye 4 *C. chrysantha*, primarily distributed in Fangcheng, Long'an, Longzhou, and Fusui. This group of C. chrysantha plants are medium-sized and high, leaf area, leaf weight, and leaf number are medium to high, leaf yield is highest, and polyphenol content is lowest. It belongs to the medium-sized plants, medium-sized leaves, high leaf yield but low chemical content group. Overall, if you need a variety with high polysaccharide content, you can choose from the 7 varieties of *C. chrysantha*, such as Desheng, Wuming, Dongxing, Lemon Yellow, Zhongdong, Daoluanye, and Siji, or the 5 varieties of *C. chrysantha*, such as Longrui, Nonggang, Longzhou, Light Yellow, and Xiye. If you need a variety with high total flavonoid and total polyphenol content, you can choose from the 5 varieties of Camellia chrysantha, such as Longrui,

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Nonggang, Longzhou, Light Yellow, and Xiye, or the 4 varieties of Camellia chrysantha, such as Desheng, Wuming, Dongxing, Lemon Yellow, Zhongdong, Daoluanye, and Siji. However, although the 5 varieties of *C. chrysantha*, such as Longrui, Nonggang, Longzhou, Light Yellow, and Xiye, have high chemical content, the leaf yield is the lowest, and planting and cultivation need to be increased according to environmental factors to meet demand.

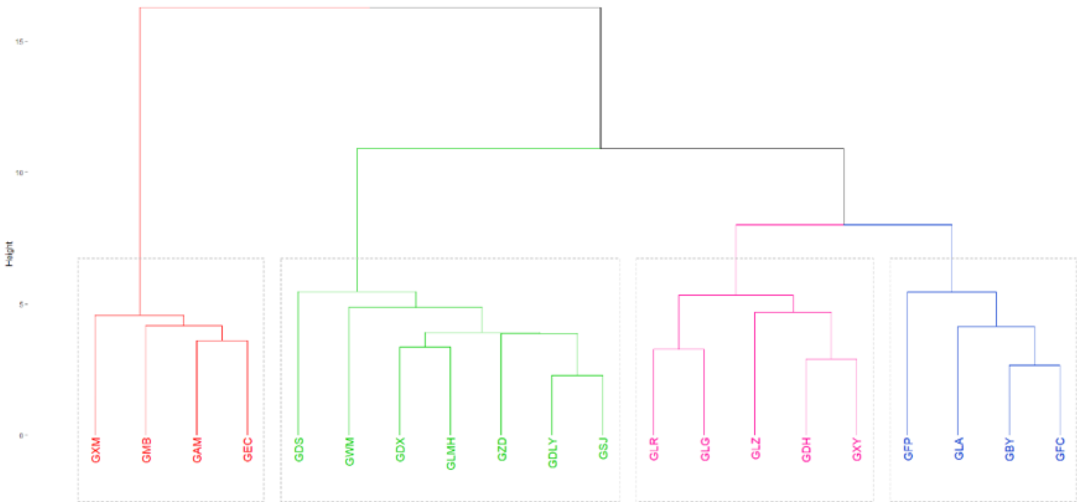

Figure 5. *Cluster analysis of 20 cultivars of C. chrysantha*

Discussion

C. chrysantha, rare and precious with various active ingredients, has been the focus of research in recent years, particularly regarding its effective components and pharmacological effects. However, research on the quality among different varieties of *C. chrysantha* is scarce. In this study, we analyzed the quality traits and their differences among 20 varieties of *C. chrysantha* using commonly used methods for evaluating the quality of Chinese medicinal materials. The results of phenotypic trait analysis showed that the variation range of each phenotypic trait among the 20 varieties of *C. chrysantha* was between 12.77% and 79.74%, indicating a significant degree of variation among these traits. This suggests that the genetic diversity of *C. chrysantha* germplasm materials is rich, with substantial quantitative trait variation. Leaf yield is fundamental for human utilization of biological resources. Insufficient leaf yield cannot meet human needs. Leaf yield can originate from two aspects: the number of individuals of a cultivar and the weight of an individual. Increasing the number of individuals will occupy more land, and simply expanding the number of plantings is insufficient to meet human needs. Therefore, increasing the yield per plant has become an effective way to address this issue, making it an important indicator for evaluating excellent plant traits (Lian, 2006; Mukhopadhyay et al., 2016). From the results of leaf yield differences among the 20 varieties of *C. chrysantha*, it is observed that the variety with the highest leaf yield is *C. chrysantha* ‘Xianmai’, and the variety with the lowest leaf yield is *C. chrysantha* ‘Wuming’, with significant differences in leaf yield observed among the various varieties. This outcome provides a basis for the selection of superior germplasm of *C. chrysantha.*

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The efficacy is an important indicator for evaluating the quality of medicinal materials, but the medicinal chemical components form the basis of the medicinal efficacy. The efficacy of medicinal materials is related to the types and concentrations of chemical components they contain. A superior medicinal material must contain a higher amount of effective components and fewer toxic components. *C. chrysantha* contains rich natural active compounds beneficial to human health. Through relevant literature review and synthesis, it is known that the chemical components of *C. chrysantha* mainly include flavonoids, tea polyphenols, tea polysaccharides, etc., exhibiting various pharmacological activities such as anti-tumor, antioxidant, and blood glucose-lowering effects (Yoshikawa et al., 2008; Matsuda et al., 2012; Thitimuta et al., 2017; Tang et al., 2023). The differences in total flavonoids, total polyphenols, and polysaccharide contents among the 20 varieties of *C. chrysantha* indicate significant variations in component levels among different cultivars. Specifically, the variety with the highest total flavonoid content is *C. chrysantha* 'Dunhuang', while the lowest is *C. chrysantha* 'Dongxing'; the variety with the highest total polyphenol content is *C. chrysantha* 'Longzhou', and the lowest is *C. chrysantha* 'Fangpu'; the variety with the highest polysaccharide content is *C. chrysantha* 'Dongxing', and the lowest is *C. chrysantha* 'Fusui'. Based on these findings, the content of active components in *C. chrysantha* can be used as criteria for evaluating its quality and the superiority of germplasm, serving as a primary basis for selecting excellent germplasm (Saxena et al., 2016; Xu et al., 2020; Gao et al., 2024).

In principal component analysis, the cumulative contribution rate of the three principal components reaches 82.363%, indicating that they encompass the majority of information from all tested indicators and can reflect the differences exhibited by different varieties of *C. chrysantha* (She et al., 2012; Truong et al., 2024). Simultaneously, after calculating and ranking the scores of each sample, the results show that varieties including Maoban, Xianmai, Longzhou, Aomai, Longrui, Nonggang, Encheng, and Xiye of *C. chrysantha* exhibit higher comprehensive scores, indicating their superior quality.

The clustering analysis results indicate that the 20 varieties of *C. chrysantha* clearly cluster into different groups, with varieties containing higher component concentrations predominantly clustering in the third group. This group includes varieties such as Longrui, Nonggang, Longzhou, Danyellow, and Xiye. This finding is consistent with the results from the content analysis and principal component analysis. In summary, for those seeking varieties with high polysaccharide content, one can choose from either varieties such as Dingsheng, Wuming, Dongxing, Lemon Yellow, Middle East, Inverted Ovate, and Four Seasons, or varieties like Longrui, Nonggang, Longzhou, Danyellow, and Xiye. For those preferring varieties with high total flavonoid and total polyphenol content, Longrui, Nonggang, Longzhou, Danyellow, and Xiye are suitable choices, or varieties such as Xianmai, Maoban, Aomai, and Encheng. However, despite the high chemical content of Longrui, Nonggang, Longzhou, Danyellow, and Xiye varieties, their yield is the lowest, necessitating increased cultivation and planting based on environmental factors to meet demand.

Authentic medicinal herbs refer to those that are genuinely superior in quality due to their specific environmental conditions, representing a unique comprehensive standard for controlling the quality of medicinal materials in traditional Chinese medicine (Hu, 1989; Alamgir, 2017). The phenomenon of "authenticity" of Chinese medicinal herbs indicates an inherent connection between the environment and medicinal efficacy, with the environment directly influencing the growth and development of medicinal plants (Qi et al., 2019; DB/OL-http://rep.iplant.cn/). *C. chrysantha* was first discovered by Chinese

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botanist Zuo Jinglie on July 29, 1933, in Dali Township, Fangcheng County, Guangxi, China, and is referred to abroad as the magical oriental tea. Research has shown that *C. chrysantha* thrives in environments with strong solar radiation, ample sunlight, average temperatures between 21.0-22.5°C, abundant rainfall exceeding 1100 mm annually, humidity over 77%, calm wind conditions, and substantial shading of up to 80% (Li, 1987; Mukherjee, 2019). According to the principal component analysis and clustering analysis in this study, higher-quality varieties of *C. chrysantha* are predominantly distributed in Fangcheng, Ningming, Longzhou, and Daxin. These regions typically experience long, hot summers with average temperatures ranging from 21.0 to 22.5°C, ample rainfall averaging at least 1148 mm annually, with some areas receiving up to 2100 mm, humidity levels between 77% and 83%, short and warm winters with a long frost-free period, and a noticeable monsoon season characterized by distinct dry and wet periods, which are highly conducive to the growth of *C. chrysantha*. The research findings align with Xie Zongwan's report (Xie, 1995) on authentic medicinal herbs, indicating that these herbs from the aforementioned regions exhibit superior quality and therapeutic efficacy compared to those grown in other areas.

Conclusion

This study reveals significant variations in the quality characteristics among the 20 varieties of *C. chrysantha*. According to the results of principal component analysis and cluster analysis, it is evident that *C. chrysantha* varieties such as Longrui, Nonggang, Longzhou, Danhuang, Xiye, Maoban, Xianmai, Oumai, and Encheng are of superior quality. These varieties are predominantly found in regions like Fangcheng, Ningming, Longzhou, and Daxin, characterized by subtropical and southern subtropical monsoon climates that are highly suitable for the growth of *C. chrysantha* due to their optimal temperatures, rainfall, sunshine duration, and humidity. In the cluster analysis, *C. chrysantha* varieties including Longrui, Nonggang, Longzhou, Danhuang, and Xiye form a distinct cluster characterized by medium-sized plants with moderate leaf sizes. These varieties exhibit high levels of various chemical components but lower leaf yields. In practical production, understanding the phenotypic traits and types of *C. chrysantha* can predict their types and levels of active ingredients, facilitating targeted breeding efforts. These findings provide crucial insights for the classification and selection of superior *C. chrysantha* germplasm.

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Conflict of interests. All the authors declared that there is no conflict of interest in this research work.

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APPENDIX

Table A1. *Information of the 20 tested cultivars of C. chrysantha*

Num.	Cultivar name	Latin name	Origin
GAM	Aomai Camellia chrysantha	*Camellia impressinervis* Chang et S.Y. Liang	Longzhou County and Daxin County, Guangxi
GBY	Boye Camellia chrysantha	*Camellia chrysanthoides* Chang	Longzhou County, Guangxi
GDH	Light Yellow Camellia chrysantha	*Camellia flavida* Chang	Longzhou County and Wuming County, Guangxi
GDLY	Daoluanye Camellia chrysantha	*Camellia limonia f. obovata* S.L. Mo et Y.C. Zhong	Fusui County, Guangxi
GDS	Dingsheng Pingguo Camellia chrysantha	*Camellia pingguoensis* D. Fang var. *terminalis* (Liang et Su) S.Y. Liang	Tiandeng County, Guangxi
GDX	Dongxing Camellia chrysantha	*Camellia tunghinensis* Chang	Fangcheng County, Guangxi
GEC	Encheng Camellia chrysantha	*Camellia enchengensis*	Daxin County, Guangxi
GFP	Fangpu Camellia chrysantha	*Camellia niridissima* Chi	Fangcheng County, Guangxi
GFC	Fusui Camellia chrysantha	*Camellia fusuiens* S.Y. Liang et X.J. Deng	Fusui County, Guangxi
GLZ	Longzhou Camellia chrysantha	*Camellia Long zhouensis* J.Y. Luo	Longzhou County, Guangxi
GLA	Long’an Camellia chrysantha	*Camellia longanensis*	Long’an County, Guangxi
GLR	Longrui Camellia chrysantha	*Camellia longruiensis* S.Y. Liang et X.J. Deng	Ningming County, Guangxi
GMB	Maoban Camellia chrysantha	*Camellia Pubipetala* Y. Wan et S.Z. Huang	Long’an County and Daxin County, Guangxi
GLMH	Lemon Yellow Camellia chrysantha	*Camellia limonia* C.F. Liang et S.L. Mo	Longzhou County and Ningming County, Guangxi
GLG	Nonggang Camellia chrysantha	*Camellia longgangensis* C.F. Liang et S.L. Mo	Longzhou County, Guangxi
GSJ	Siji Camellia chrysantha	*Camellia ptilosperma* S.Y. Liang et Q.D. Chen	Chongzuo City, Guangxi
GWM	Wuming Camellia chrysantha	*Camellia Wumingensis* S.Y. Liang et C.R. Fu	Wuming County, Guangxi
GXY	Xiye Camellia chrysantha	*Camellia parvifolia* S.Y. Liang et F.F Li	Longzhou County, Guangxi
GXM	Ximai Camellia chrysantha	*Camellia euphlebia* Meer. et Seealy	Fangcheng County, Guangxi, and northeastern Vietnam
GZD	Fusui zhongdong Camellia chrysantha	*Camellia fusuien* S.Y. Liang et X.J. Dong	Zhongdong Township, Fusui County, Guangxi

Table A2. *Coefficients of variation for phenotypic traits of C. chrysantha leaves*

Num.	Dry week (cm)	Crown height (m)	Crown width (m)	Leaf length (cm)	Leaf width (cm)	Leaf length/width (cm)	Petiole length (cm)	Leaf area (cm²)	Leaf wet weight (g)	Dry leaf weight (g)	Number of blades
GAM	19.29	2.10	1.93	14.99	6.78	2.24	0.87	101.81	1.36	0.66	2 250
GBY	12.33	1.54	1.64	10.26	4.64	2.25	0.71	49.04	1.05	0.51	3 715
GDH	10.60	1.32	1.29	8.80	3.60	2.55	0.47	31.81	0.51	0.23	3 439
GDLY	12.33	1.42	1.39	6.11	2.84	2.16	0.70	17.71	0.40	0.18	10 491
GDS	14.67	1.88	1.95	7.45	3.09	2.40	0.46	23.38	0.41	0.19	17 377
GDX	15.43	1.73	1.43	6.80	2.96	2.33	0.73	20.57	0.57	0.19	10 517
GEC	15.60	1.81	1.73	14.23	5.99	2.39	0.59	86.15	1.95	0.82	1 993
GFP	18.13	2.30	1.83	12.08	5.15	2.37	1.15	62.87	1.14	0.47	4 335

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GFS	14.44	2.00	1.95	10.27	4.72	2.23	0.62	49.78	1.11	0.57	6 807
GLZ	20.20	1.89	1.53	10.69	4.03	2.66	0.78	43.75	0.94	0.47	4 287
GLA	12.83	1.38	1.97	11.68	5.27	2.22	0.87	61.98	1.28	0.56	3 522
GLR	13.88	1.54	1.99	12.01	5.05	2.39	0.71	61.06	1.26	0.56	3 768
GMB	23.33	2.45	2.05	18.06	7.04	2.61	0.77	129.17	1.97	0.85	2 227
GLMH	11.60	1.32	1.40	6.40	3.10	2.07	0.52	19.97	0.43	0.18	8 407
GNG	15.78	1.66	1.79	13.34	5.43	2.48	0.63	72.93	0.97	0.41	2 592
GSJ	10.44	1.41	1.23	6.93	3.34	2.08	0.61	23.55	0.44	0.19	5 812
GWM	9.78	1.17	0.86	7.15	2.87	2.53	0.72	20.78	0.41	0.21	2 634
GXY	12.14	1.20	1.54	10.86	4.45	2.48	0.74	48.46	0.74	0.32	2 659
GXM	17.00	2.38	2.61	16.50	6.89	2.41	1.00	114.69	2.16	0.94	3 949
GZD	14.00	1.63	1.84	9.27	4.14	2.25	0.54	38.98	0.66	0.32	6 565
Average	14.58	1.68	1.66	10.62	4.53	2.37	0.71	52.43	0.95	0.43	4 819
SD	4.56	0.46	0.43	3.33	1.39	0.30	0.23	32.24	0.55	0.24	3 842
Coefficient of variation (%)	31.31	27.04	25.68	31.32	30.72	12.77	31.85	61.49	57.77	55.18	79.74

Table A3. *Analysis of differences in yield, total flavonoids, total polyphenols, and polysaccharide content among 20 varieties of C. chrysantha*

Num.	Yield	Total flavonoids	Total polyphenols	Polysaccharides
GAM	3 105.11edcbDCBA	16.255cbaCBA	0.279baCBA	1.657edcDCB
GBY	3 990.48edcbaDCBA	9.536edcFEDCB	0.152gfGFE	1.376eDC
GDH	1 779.42edDC	22.745aA	0.19gfedcGFED	2.089cbaBA
GDLY	4 026.86edcbaDCBA	6.469fedFED	0.147gfGF	1.898dcbDCBA
GDS	6 595.39cbaCBA	4.415fedFE	0.176gfedGFED	2.178cbaBA
GDX	5 742.75dcbaDCBA	1.34fF	0.147gfGF	2.516aA
GEC	3 871.57edcbaDCBA	10.289dcFEDCB	0.207fedcFED	1.372eDC
GFP	4 732.54edcbaDCBA	4.304fedFE	0.127gG	2.057cbaBA
GFC	7 592.91baBA	15.181cbaDCBA	0.218edcFEDC	1.345eD
GLZ	4 177.94edcbaDCBA	18.589baBA	0.318aA	2.123cbaBA
GLA	4 333.13edcbaDCBA	1.899feF	0.128gG	2.142cbaBA
GLR	4 526.78edcbaDCBA	22.6aA	0.288baBA	2.514aA
GMB	3 907.58edcbaDCBA	16.607cbaCBA	0.248cbDCB	1.872dcbDCBA
GLMH	3 800.26edcbaDCBA	5.554fedFE	0.181gfedGFED	2.138cbaBA
GLG	2 555.54edcDCB	21.882aA	0.226dcEDCB	2.189cbaBA
GSJ	2 584.45edcDCB	12.122dcbEDCB	0.167gfedGFE	2.014dcbaCBA
GWM	1 032.65eD	7.356fedFEDC	0.158gfeGFE	2.414baA
GXY	1 950.63edDC	22.744aA	0.291baBA	1.959dcbaDCBA
GXM	8 064.28aA	10.738dcFEDCB	0.198fedcGFED	1.515edDCB
GZD	4 128.37edcbaDCBA	10.954dcFEDCB	0.226dcEDCB	2.196cbaBA

Capital letters in the same column represent statistical significance at the level of $P < 0.01$, while lowercase letters represent statistical significance at the level of $P < 0.05$

Table A4. *Phenotypic characteristics of 20 varieties of Camellia chrysantha in each cluster*

Project	Group			
	1	2	3	4
Number of individuals	4	7	5	4
Variety name	Xianmai, Maoban, Aomai, Encheng	Dingsheng, Wuming, Dongxing, Lemon Yellow, Zhongdong, Daoluanye, Siji	Longrui, Nonggang, Longzhou, Light Yellow, Xiye	Fangpu, Longan, Boye, Fusui
Origin	Fangcheng, Vietnamese,	Tiandeng, Wuming, Fangcheng,	Ningming, ongzhou,	Fangcheng, Long'an,

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	Long'an, Daxin, Longzhou	Longzhou, Ningming, Fusui, Chongzuo	ZWuming	Longzhou, Fusui
Dry week (m)	0.19	0.12	0.15	0.14
Crown height (m)	2.18	1.48	1.54	1.83
Crown width (m)	2.04	1.39	1.61	1.83
Leaf length (cm)	15.93	7.34	11.07	10.98
Leaf width (cm)	6.69	3.27	4.47	4.91
Leaf length/width (cm)	2.41	2.27	2.52	2.27
Petiole length (cm)	0.80	0.62	0.66	0.83
Leaf area (cm^2)	108.50	24.82	50.90	55.13
Leaf wet weight (g)	1.80	0.49	0.87	1.13
Dry leaf weight (g)	0.80	0.22	0.40	0.52
Number of blades	2 493.00	7 430.00	3 394.00	4 703.31
Yield ($g \cdot plant^{-1}$)	4 399.83	3 572.81	3 010.05	5 253.43
Total flavonoids (%)	13.992	7.637	21.597	8.383
Total polyphenols (%)	0.239	0.175	0.260	0.160
Polysaccharide (%)	1.625	2.225	2.174	1.681

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