

Research Article



Selection of Excellent Cigar Tobacco Varieties in Yunnan Province of China

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ABSTRACT In order to establish a prominent cigar brand in China, Yunnan Province has emerged as a significant region for cigar cultivation due to its ecological conditions that closely resemble those of Cuba. In tobacco farming, the selection of appropriate varieties is critical; thus, identifying new cigar varieties suitable for promotion within the Yunnan region represents an essential step. This study selected 18 cigar varieties for a shade planting experiment, which included Yunxue 36, Yunxue 6, Yunxue 1, Yunxue 2, Yunxue 38, Yunxue 39, Yunxue 40, Cuba 1, Yunxue 34, DeXue 4, Haiyan 103, CX14, CX26, Haiyan 204, Yunxue 41, Cuba 2, Chuan Xue 2 and Connecticut Broadleaf. We collected data on typical agronomic traits (such as leaf area and thickness as well as chlorophyll content) and tobacco yield from these varieties. The data were analyzed and compared to identify outstanding varieties. The results indicate that among the tested varieties, Yunxue 6 exhibited the largest leaf area; this was followed by Yunxue 41 and Yunxue 1 which displayed relatively thin leaves. Furthermore, Yunxue 40 and Yunxue 41 demonstrated the highest chlorophyll content with Cuba 1 and Cuba 2 ranking next in line. Notably, Yunxue 36 achieved the highest yield followed by Cuba 2 and Yunxue 34. These three varieties distinguished themselves prominently among all eighteen tested cigar varieties and are recommended for primary cultivation in the Yunnan region. Future research will be conducted to further support the sustainable development of the cigar-growing industry in Yunnan.

Keywords: Cigar; Variety; Agronomic Traits; Tobacco industry; Aroma; Leaf

To cite this article: Wang, Z., Fang, B., Zhen, A., Ren, L., Duan, X., Tang, X., Shen, J. (2025). Selection of Excellent Cigar Tobacco Varieties in Yunnan Province of China. *Journal of Biological and Agricultural Advancements*, 3(2), 1-6.

Article History: Received: 30 November 2024; **Accepted:** 27 December 2024; **Published Online:** 31 August 2025

INTRODUCTION Cigar is a special tobacco product made of pure tobacco leaf, with mellow aroma, bitter taste and strong satisfaction of quality characteristics, in recent years, its sales in the international and domestic market has maintained a rising momentum (Li et al., 2019). The style and chemical composition of cigar tobacco are jointly affected by genetic factors, ecological environment and cultivation and drying technology, in which light intensity is an important factor determining the style, important chemical composition and aroma substance content of tobacco leaves (Chen, 2015, Zeng et al., 2024, Saeed et al., 2024).

Photosynthesis is an important process of plant growth, which converts light energy into chemical energy and provides necessary nutrients and water for plants, thus promoting the growth and development of plants (Li et al., 2020). Light is one of the most important factors in plant production, and the rational use of light energy plays a very important role in improving the comprehensive quality of plants. This paper briefly summarizes the need of light for plants and the effects of light on plant growth

and development, and provides theoretical basis for future research on the effects of light on plant growth and development. The change of light intensity leads to the change of plant growth (Rashid et al., 2024, Mushtaq et al., 2024).

Wu (Wu et al., 2017) pointed out that the change of light intensity has an impact on plant growth, which is manifested in many aspects such as growth, morphology and yield. Yonglan (Yonglan et al., 2017) pointed out that strong light will affect plant growth, and excessive light will cause light inhibition, resulting in reduced photosynthesis and damage to plant reaction centers. The study of Takagi (Takagi et al., 2019) showed that a certain degree of shading can promote the growth of plants in a special period. Moderate shading has a significant impact on plant growth and morphology. Wang Changna (Wang, 2024) found that when the shading net was covered with strawberries, the single fruit weight and yield of each plant could be increased when the light was reduced to 50%.

Zhou Q (Qi et al., 2022) studied birch and found that the growth index was improved under 50% and 75% light. Gao Lingna (Gao et al., 2009) cultivated cucumber seedlings under low light intensity and found that the seedlings grew into strong seedlings. Nosko (Nosko et al., 2022) cultivated red oak trees under low light levels and found that their leaf area and yield increased. These results were consistent with ZhangJ 's study (Jinfeng et al., 2022) on the influence of maple tree morphology under low light intensity. Another study found that with the decrease of light intensity, the plant growth of soybean leaves would decrease (Wang et al., 2020), which is consistent with the results of the study on winter melon seedlings (Shi et al., 2019). The aim of study was the selection of cigar varieties that had large leaf area, with high chlorophyll content and also had high yield to improve the the foundation for the future development of Yunnan's cigar planting industry.

MATERIALS AND METHODS

Test material

The experiment was carried out in Baoshan, Yunnan Province (east longitude 96°17', north latitude 22°51') from February to June 2023. The cigar varieties evaluated in this study included Yunxue 1, Yunxue 2, Yunxue 6, Yunxue 34, Yunxue 36, Yunxue 38, Yunxue 39, Yunxue 40, Yunxue 41, Cuba 1, Cuba 2, Haiyan 103, Haiyan 204, CX14, CX26, Dexue 4, Chuanye 2 and Connecticut Broadleaf. The experimental site was characterized by brown soil with the following basic physical and chemical properties of the plough layer: organic matter content of 11.67 g/kg; available nitrogen at a level of 52.63 mg/kg; total nitrogen recording at approximately 0.89 g/kg; available phosphorus quantified as 27.61 mg/kg; total phosphorus measured at around 0.22 g/kg; available potassium noted to be at a concentration of 192.95 mg/kg; total potassium reaching about 3.34 g/kg; and a pH value of 6.6.

Experiment design

The trial design employed a randomized block design, encompassing 18 varieties with three replicates for each treatment, and a single plot area of 22.5 m². Sixty plants were planted in each cell (repeated), utilizing 300-well seedling plates to cultivate non-toxic and robust seedlings. Cigar plants were transplanted on February 23, 2023, followed by topping at day 49 after transplantation, retaining between 16 to 20 leaves. The experimental area is equipped with drip irrigation systems to ensure a reliable water supply. All other field management practices are implemented in accordance with the local production plan, thereby maintaining consistency in agricultural operations across all plots.

Determination method

Samples were collected 90 days post-transplantation, coinciding with the flat top stage. The effective leaves of each plant were sequentially numbered from bottom to top, ranging from 1 to 20, with the lower, middle, and upper sections comprising 6, 7, and 7 leaves respectively.

Agronomic Traits: In accordance with the tobacco industry standard YC/T 142—2010, measurements for plant height, stem

circumference, as well as the length and width of the upper, middle, and lower leaves were conducted at the flat top stage.

Chlorophyll Content Determination: Four leaf discs (6 mm in diameter) were randomly excised using a puncher and subsequently immersed in 80% acetone. The discs underwent shaking to ensure complete immersion before adjusting the volume to a total of 10 mL. Samples were stored in darkness for a duration of 48 hours until they turned completely white. During this dark treatment period, samples were shaken every eight hours. Optical density (OD) values at wavelengths of 663 nm and 646 nm were measured utilizing a UV-2600 spectrophotometer; chlorophyll content was then calculated based on these measurements.

Leaf Area Index Determination: At the flat top stage, both length and width of leaves were recorded. The leaf area index (LAI) was expressed as follows:

$$LAI = w \times (L \times D) \times N \times n / S$$

where L represents average leaf length; D denotes average leaf width; w is defined as the leaf area conversion coefficient (0.6345 for this experiment); N indicates number of effective leaves; n signifies number of plants per unit land area; and S refers to unit land area.

Economic Traits Determination: Post-harvest tobacco leaves underwent grading according to "Cigars" (GB2635—2018). Yield calculations for each treatment utilized purchase prices established by Yunnan Tobacco Station while statistical analyses encompassed average price evaluations alongside proportions pertaining to high-quality tobacco.

Data Examination

Data processing and analysis were performed utilizing Microsoft Excel 2016 and SPSS version 18.0 software. The Least Significant Difference (LSD) method was employed for testing significant differences, with a significance level set at $P < 0.05$.

RESULTS AND DISCUSSION

Agronomic Characteristics of Cigar Varieties

The experimental results showed that the leaf area, leaf thickness and chlorophyll content in this experiment were normally distributed (Figure 1-3). Yunxue 40 and Cuba 1 had leaf area of 1322cm²~1449cm². There were 4 species of 1449cm²~1576cm², including Yunxue 34, CX26, CX14 and Yunxue 36. There were 7 species with 1576cm²~1703cm², including Yunxue 38, Yunxue 1, Yunxue 2, Hai Yan 204, Chuanxue 2, Cuba 2, and Yunxue 39. There were two species of 1703cm²~1830cm², namely HaiYan 103 and Dexue 4. There was one kind of KangZhou broad leaves from 1956cm²~2083cm². There was one specie of 2210cm²~2337cm², Yunxue 41. There was a kind of 2337cm²~2467cm², Yunxue 6. Yunxue 1 had a leaf thickness of 0~36um. There were two kinds of 37um~38um, Yunxue 40 and Yunxue 41. There were 5 species with 38um~39um, namely HaiYan 204, Dexue 4, Cuba 2, Yunxue 6 and Hai Yan 103. There were 5 species in the 39um-40um range: Yunxue 2, Yunxue 34, Chuanxue 2, CX26, and Yunxue 36. There were 4 kinds of 40um~41um. Yunxue 38, Yunxue 39, Cuba 1, CX14. There was one species of KangZhou broad leaves from 43um~44um. One specie, Yunxue 6, had a chlorophyll content of 0-59%. 59%~61%

had 2 species, CX26 and Hai Yan 204. 61%~63% had two species, KangZhou broad leaves and CX14. 63% ~65% have 1 specie, Yunxue 34. 67% ~ 69% of the population had 3 species, namely Hai Yan 103, Yunxue 40, and De xue 4. 69%~71% had 2 species, Yunxue 36 and Yunxue 38. 71% to 73% of the population exhibited three species: Yunxue 2, Yunxue 39, and Chuanxue 2. Meanwhile, 73% to 75% of the species identified were Cuba 1 and Cuba 2. Furthermore, between 75% and 77% of the population displayed two species: Yunxue 1 and Yunxue 41.

Different types of tobacco leaves exhibit distinct genetic characteristics, which correspond to significant differences in adaptability across various ecological environments and cultivation conditions. For instance, certain tobacco varieties are more suited for growth in humid climates, while others thrive in dry or semi-arid regions. This variability in adaptability is not only evident in moisture requirements but also encompasses differing light duration needs. Specifically, adequate lighting can enhance the sugar content of tobacco, thereby improving its overall quality (He et al., 2021). In addition to these adaptive differences, the identification and development of high-quality tobacco varieties are crucial for producing premium tobacco products. To ensure the quality of tobacco, researchers must rigorously evaluate and screen different varieties through scientific methodologies. Only those high-quality varieties that have undergone stringent screening and identification processes can be broadly utilized in the production of tobacco products to satisfy market demand for superior-quality tobacco (Yang et al., 2019).

The development and modification of chloroplasts represent a critical mechanism through which plants respond to varying light intensities, significantly influencing their growth and adaptation to environmental conditions. As the principal site of photosynthesis in plant cells, both the development and functional state of chloroplasts have a direct impact on plants' ability to effectively harness light energy for photosynthetic processes (Lu, 2007). When exposed to different light environments, chloroplasts undergo structural and functional adjustments via a series of intricate physiological and biochemical reactions. For example, under high light conditions, plants may decrease chlorophyll synthesis as a protective measure against photodamage resulting from excessive light absorption; conversely, under low light conditions, they tend to increase chlorophyll content to improve light capture efficiency. Moreover, the thylakoid membrane system within chloroplasts also experiences reconfiguration in response to fluctuations in light intensity. This dynamic adjustment further optimizes the efficiency of both light energy transfer and conversion processes (Zhang et al., 2024, Wang et al., 2024). Liu Jie (Liu et al., 2019) found that the total chlorophyll content of lettuce leaves increased when the light intensity decreased. Fang (Fang et al., 2018) found that the chlorophyll content of plant leaves increased under low light intensity. The selection of variety emerged as the most fundamental factor. This finding aligns with the results obtained from this experiment.

Cigar variety Yield

The yield of 18 cigar varieties followed the normal distribution (Figure 4), and there was one CX14 with a yield of 0~1.48kg/m². There were two kinds of 1.48kg/m²- 1.66 kg/m², namely De xue 4 and Yunxue 6. There were three kinds of 1.66kg/m²~1.83kg/m², which were Cuba 1, Hai Yan 204 and Hai Yan 103. There were 5 kinds of 1.83kg/m²-2.01kg/m²: Yunxue 2, Yunxue 40, Yunxue 39, CX26, and Yunxue 41. There were four species with a biomass ranging from 2.01 kg/m² to 2.19 kg/m², specifically Chuanxue 2, Yunxue 1, Kangzhou Broad Leaves, and Yunxue 38. There were two kinds of 2.19kg/m²-2.37kg/m², Cuba 2 and Yunxue 34. There was one specie of 2.72kg/m²~2.90kg/m², Yunxue 36. The findings of this experiment indicate that sunlight cultivation conditions significantly influence the height of tobacco plants and the size of their leaves. Under optimal sunlight conditions, tobacco plants are able to perform photosynthesis more efficiently, thereby enhancing their overall growth and development. This is manifested not only in an increase in plant height but also in an expansion of leaf area, which is a result of Zhou Yibo and his team (Zhou et al., 2014).

During the cultivation of tobacco, adequate sunlight is essential for enhancing both the yield and economic value of the crop. Sufficient exposure to sunlight promotes photosynthesis, enabling tobacco plants to synthesize organic compounds more effectively, thereby bolstering their growth vigor. Generally, when tobacco leaves receive an optimal amount of sunlight, chlorophyll can efficiently convert carbon dioxide and water into energy-rich substances such as glucose. These energy compounds not only support the growth and development of the plants but also establish a foundation for the accumulation of subsequent chemical constituents (Fang et al., 2018). Experimental studies have demonstrated that tobacco fields receiving 6-8 hours of direct sunlight daily produce leaves with significantly superior quality compared to those exposed to insufficient or excessive sunlight. Furthermore, favorable lighting conditions enhance both the color and luster of tobacco leaves, rendering them more appealing in market contexts (Zhang et al., 2021, Yan et al., 2024b).

This experiment demonstrated that sunlight cultivation positively influenced both the yield and the economic value of cigars. The study of He Mingchang (He et al., 2021) was in confirmation of this experiment, research indicates that inadequate light intensity can adversely affect the population of tobacco plants. Under suboptimal lighting conditions, both the germination rate and survival rate of seedlings decline, ultimately leading to a reduction in the number of plants capable of normal growth. Furthermore, insufficient light may impair the tillering ability of these plants, resulting in fewer branches per plant and subsequently diminishing overall plant density. Moreover, the impact of inadequate light on tobacco leaf yield is particularly pronounced. The decrease in photosynthetic efficiency prevents leaves from fully synthesizing essential organic compounds, which not only hampers leaf growth rates but also results in thinner leaves with reduced surface area.

Concurrently, insufficient light negatively influences the accumulation of key components within tobacco leaves—such as

nicotine content—which consequently affects both the quality and market value of tobacco products; Zhao (Zhao et al., 2017) noted that when light intensity exceeds a certain threshold, the photosynthetic efficiency of tobacco plants declines, adversely affecting their growth and development as well as final yield. Specifically, during the growth phase of tobacco, excessive light can lead to an increase in leaf temperature and accelerate water evaporation, ultimately enhancing plant transpiration. This phenomenon not only results in a rapid depletion of soil moisture but may also induce leaf scorching, further compromising plant health. Moreover, intense light inhibits chlorophyll synthesis in tobacco leaves, disrupting the normal process of photosynthesis and ultimately leading to reduced yields.; Li Suyun has discovered through extensive research and practical experience that reducing light intensity significantly enhances both the yield and quality of tobacco leaves.

During the actual planting process, Li Suyun observed by comparing tobacco fields under varying light conditions that plants grown in lower light environments exhibited more uniform growth and greener foliage. This phenomenon can be attributed to the fact that, in weak light conditions, the respiration rate of tobacco plants is relatively diminished, leading to reduced energy consumption; consequently, a greater proportion of nutrients can be allocated for leaf growth and development. Furthermore, weaker light levels may also decrease the incidence of pests and diseases. Many pests favor bright lighting conditions; thus, their activity range and reproductive capacity are constrained in low-light environments. It is important to note that reducing light intensity does not equate to completely obstructing sunlight; rather, it is accomplished through scientifically informed shading net configurations or adjustments in planting density. This approach not only avoids significant increases in production costs but also effectively improves both the quality and yield of tobacco leaves. As a result, this practice provides enhanced economic benefits for tobacco farmers (Li et al., 2013).

Correlation Analysis of Eighteen Cigar Varieties

The results of the correlation analysis (Table 1) demonstrated that a remarkable and positive correlation existed between the leaf area and the chlorophyll content. Specifically, as the leaf area increased, the chlorophyll content tended to rise accordingly. On the contrary, a negative correlation was observed between the leaf area and the yield. This implies that an increase in the leaf area was accompanied by a decrease in the yield (Yan et al., 2024a). Additionally, it was found that the chlorophyll content was negatively correlated with both the leaf area and the yield. In other words, higher chlorophyll content was associated with smaller leaf areas and lower yields. Moreover, the negative correlation between the leaf area and the yield persisted throughout the analysis, suggesting a consistent and inverse relationship between these two variables. Tobacco yield was closely related to tobacco varieties, cultivation measures and cultivation environment, and improving agronomic traits was the preferred measure to increase yield (E. et al., 2017).

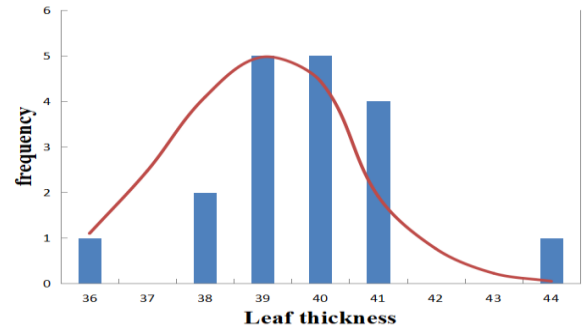


Figure 1: Normal distribution of leaf thickness

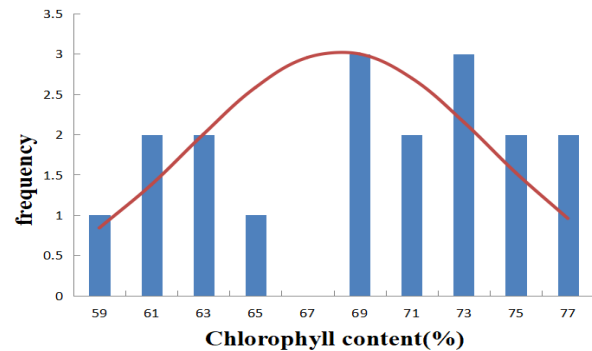


Figure 2: Normal distribution of chlorophyll content

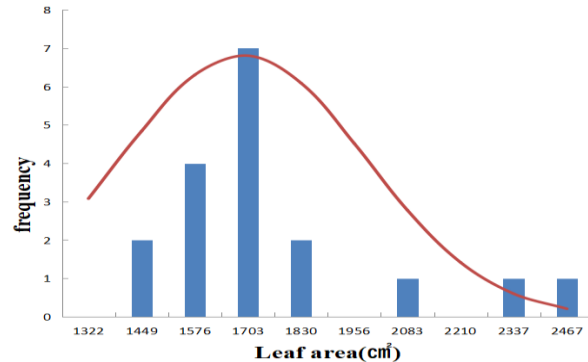


Figure 3: Normal distribution of Leaf area

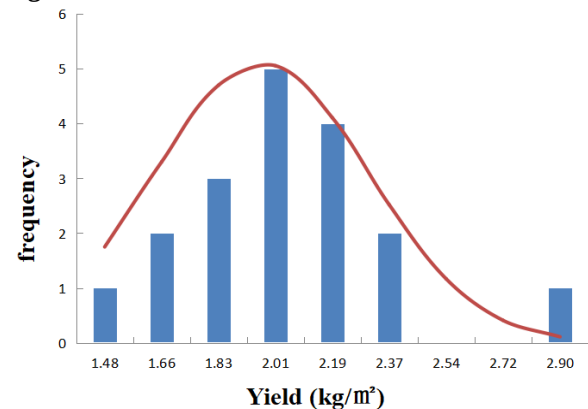


Figure 4: Normal distribution of Yield

Table 1: Correlation analysis for studied traits

Traits	Leaf thickness	Chlorophyll content	Leaf area	Yield
Leaf thickness	1	0.883*	-0.664	-0.267
Chlorophyll content	0.883*	1	-0.239	-0.618
Leaf area	-0.664	-0.239	1	-0.533
yield	-0.267	-0.618	-0.533	1

Note: A single asterisk (*) denotes a statistically significant correlation at the $P < 0.05$ level, while a double asterisk (**) signifies a highly significant correlation at the $P < 0.01$ level.

Studies have shown that total tobacco production decreases when light intensity decreases (Yun et al., 2014). In addition, with the weakening of light intensity, tobacco yield will further decrease: the yields of Yunyan 87 and Hongda tobacco varieties decrease under 80% and 60% natural light conditions, but the yield decline was greater under 60% natural light conditions, and the yield difference between tobacco leaves and natural light conditions reached an extremely significant level (Li et al., 2016).

In the study of Dan BingyanJinxiang (Dan, 2015), because the mesh of the sunshade net was too dense, the light was seriously insufficient. Even though the yield of the top three leaves of flue-cured tobacco increased, the average yield under long-term shade condition was 1660.5kg/hm2, 564kg/hm2 lower than that under natural light condition (Shen et al., 2025)..

CONCLUSION

The results indicated that among the 18 cigar varieties, Yunxue 6 emerged as having the largest leaf area. Subsequently, Yunxue 41 came next, while Yunxue 1 had the thinnest leaves. Regarding chlorophyll content, Yunxue 40 and Yunxue 41 boasted the highest levels, followed closely by Cuba 1 and Cuba 2. In terms of yield, Yunxue 36 achieved the highest mark, with Cuba 2 and Yunxue 34 following in succession. These varieties displayed outstanding agronomic and economic characteristics. They manifested a considerable ability to adapt to the local environment and prevailing conditions, leading to enhanced yields and superior-quality products. Evidently, when compared to other varieties, they manifested pronounced advantages. It has been proposed that these varieties be utilized as alternative planting options for the Yunnan cigar-producing regions. Furthermore, experiments and demonstrations should be conducted in the area to closely observe their stability and adaptability regarding yield. Additional research is necessary on the supportive cultivation and modulation techniques related to these varieties. The ultimate objective is to promote the application of superior varieties along with effective cultivation methods.

Funding: Major Science and Technology Special Project of the Yunnan Provincial Tobacco Company (Project 2022530000241005); Yunnan Provincial Company Project of the China National Tobacco Corporation (Project 2021530000242027)

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