Effects of Different Transplanting Dates on the Growth and Development, Agronomic Traits and Economic Traits of Yunyan 87 in the Zunyi Tobacco-growing Area

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Abstract [**Objectives**] This study was conducted to determine the suitable transplanting period for Yunyan 87 in the Zunyi tobacco-growing area. [**Methods**] Four transplanting date treatments were established in Suiyang County, Zunyi City, Guizhou Province: April 23 (T_1), May 3 (T_2), May 13 (T_3), and May 23 (T_4). The growth process, agronomic traits, economic traits, and single-leaf weight were investigated. [**Results**] With the delay of transplanting date, the field growth period was shortened from 127 to 106 d. T_2 had the highest number of effective leaves at the maturation stage and the highest topping plant height, reaching 22 leaves per plant and 125.13 cm, respectively. The growth advantage of T_4 was weakened at late stages, and its stem girth, leaf number and leaf size were lower than those of other treatments. The economic traits showed a trend of first increasing and then decreasing. T_2 achieved the highest yield, average price, output value, proportion of high-grade tobacco, and proportion of high- and medium-grade tobacco, reaching 2 113.05 kg/hm^2, 23.62 yuan/kg, 49 904.1 yuan/hm^2, 40.72%, and 90.20%, respectively. T_2 had the highest single-leaf weight of middle leaves, while T_1 showed the highest single-leaf weight of upper leaves, although the difference from T_2 was not significant. Therefore, transplanting in early May was beneficial for coordinating the growth process, improving the grade structure, and enhancing economic benefits, whereas excessively late transplanting reduced the overall performance. [**Conclusions**] This study provides a reference for the production of Yunyan 87 in the Zunyi tobacco-growing area.

Key words Yunyan 87; Transplanting date; Growth period; Agronomic trait; Economic trait; Zunyi tobacco-growing area

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Yunyan 87 was bred by crossing Yunyan 2 with K326 and is characterized by broad adaptability and good cultivation and curing performance. It is one of the representative fluecured tobacco varieties in China[1]. The transplanting date is an important cultivation measure for regulating the field growth process of fluecured tobacco. It can affect root system establishment, vegetative growth, dry matter accumulation, and leaf maturation of tobacco plants through changes in the temperature, light, precipitation, and accumulated temperature configurations at different growth stages. If transplanted too early, tobacco seedlings are prone to low temperature, insufficient light, or drought, resulting in slow seedling recovery and premature flowering. If transplanted too late, the plants may grow too rapidly in the early stage and the growth period may be shortened, and the maturation stage may coincide with low temperatures or continuous rainy weather, which further disturbs the normal maturation and substance transformation of tobacco leaves[2-5].

Previous studies have shown that with the delay of transplanting date, the field growth period of fluecured tobacco is generally shortened, and agronomic traits, yield, output value, and the proportion of high-grade tobacco often exhibit a trend of first increasing and then decreasing. However, the optimal transplanting date is markedly influenced by variety, altitude, soil, cropping system, and interannual climate[6-14]. In some regions with early-season drought, moderately delaying transplanting can avoid drought and improve tobacco leaf quality. In regions with abundant rainfall and heat resources or with early temperature drops during the maturation stage, excessively late transplanting will shorten the effective growth period. Therefore, the optimal transplanting date obtained for one tobacco-growing area cannot be directly applied to other ecological regions. That is to say, regional verification should be carried out in combination with local climate resources and the main cultivated varieties[10-16].

The Zunyi tobacco-growing area is located in northern Guizhou, where the rainy and hot seasons coincide. However, low temperatures and continuous rain in spring, periodic drought, and lateseason temperature drops may all affect the growth and maturation of tobacco plants. At present, systematic studies on the suitable transplanting period for Yunyan 87 under the ecological conditions of Suiyang, Zunyi, remain relatively insufficient. Therefore, four transplanting date treatments were established in this study to compare their effects on the growth process, dynamic growth, agronomic traits at the maturation stage, grade structure of cured tobacco leaves, and economic benefits of Yunyan 87, aiming to determine a more suitable transplanting time and provide a reference for the production of Yunyan 87 in the Zunyi tobacco-growing area.

Materials and Methods

Experimental site and materials

The experiment was conducted at the Puchang Tobacco

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Science and Technology Park in Suiyang County, Zunyi City, Guizhou Province. Suiyang County has a subtropical humid monsoon climate, with coinciding rainy and hot seasons. It has an annual average temperature of approximately 15.2 ℃, an annual average precipitation of approximately 1 158 mm, a frost-free period of approximately 288 d, and an annual average sunshine duration of approximately 1 053.1 h.

The experimental field had flat terrain and good drainage and irrigation conditions. The soil type was yellow soil, with above-average fertility and relatively uniform soil fertility. The previous crop was not flue-cured tobacco or other Solanaceae crops. The flue-cured tobacco variety tested was Yunyan 87.

Experimental design

A randomized complete block design was adopted, with transplanting date as the experimental factor. Four treatments were established, each in three replicates. To ensure that the seedling age and growth vigor of the tobacco seedlings at transplanting were basically consistent among treatments, the sowing dates were adjusted accordingly based on the transplanting dates. The treatments are shown in Table 1.

At transplanting, seedlings with uniform growth, 5 leaves and 1 heart to 6 true leaves, and a stem height of 5 – 8 cm were selected, and the well-cellar transplanting was adopted. The row spacing was 110 cm and the plant spacing was 50 cm. Each plot consisted of 4 rows with 17 plants per row, totaling 68 plants. Each plot had a theoretical area of approximately 37.4 m^2. The total area of the 12 plots was approximately 448.8 m^2, equivalent to approximately 1/15 of 0.67 hm^2.

Table 1 Experimental treatments

Treatment	Sowing date	Transplanting date
T_1	February 10	April 23
T_2	February 20	May 3
T_3	March 2	May 13
T_4	March 12	May 23

Field management measures, including fertilizer type, application rate, irrigation, topping and axillary bud removal, pest and disease control, and mature harvesting, were kept consistent across all treatments. They were carried out in accordance with local high-quality tobacco production techniques.

Investigation of the growth process and dynamic growth indicators

According to YC/T 142—2010 *Investigating and Measuring Methods of Agronomic Charaters of Tobacco*, the rosette stage, budding stage, topping stage, first harvesting and curing stage, and final harvesting stage of each treatment were recorded. The duration of each growth stage and the field growth period were calculated[17].

Starting from 40 d after transplanting, five tobacco plants with uniform growth were selected and tagged in each plot. Investigations were conducted once every 10 d, for a total of three times. The measured indicators included plant height, stem girth, leaf number, and leaf length and leaf width of representative leaves. Each investigation was performed on the same tobacco plants and at the same or corresponding leaf positions to reduce measurement errors caused by different leaf positions.

Investigation of agronomic traits at the maturation stage

Five representative tobacco plants were selected from each plot. The natural plant height was measured from the budding stage to the first green fruit stage. After topping, the topping plant height, number of effective leaves, stem girth, maximum leaf length, and maximum leaf width were measured according to YC/T 142—2010. For each indicator, the plot mean was used as one statistical replicate.

Determination of economic traits of cured tobacco leaves

After the tobacco leaves matured, they were harvested, tagged, and cured on a plot basis, and the actual number of harvested plants in each plot was recorded. The initially cured tobacco leaves were graded according to GB 2635—1992Fluecured Tobacco[18], and the mass of tobacco leaves of each grade was recorded separately. The yield, average price, output value, proportion of high-grade tobacco, and proportion of high- and medium-grade tobacco were calculated according to the flue-cured tobacco purchasing price of Guizhou Province in the experimental year. Yield and output value were uniformly converted to per hectare.

The calculation formulas were as follows:

Average price = Plot output value/Plot tobacco leaf yield;

Proportion of high-grade tobacco = (Mass of high-grade tobacco/Total mass of tobacco leaves) × 100%;

Proportion of high- and medium-grade tobacco = [(Mass of mediumgrade tobacco + Mass of high-grade tobacco)/Total mass of tobacco leaves] × 100%.

Determination of single-leaf weight

From each plot, 50 leaves were randomly selected from middle leaves of grade C3F and upper leaves of grade B2F, respectively. After weighing, the average single-leaf weight was calculated:

Single-leaf weight = Total mass of 50 tobacco leaves/50

The measured value of each plot was taken as one replicate, and a total of three replicates were obtained.

Data processing

Microsoft Excel 2010 was employed for data organization, and SPSS 25.0 was employed for statistical analysis. Each indicator was expressed as mean ± standard deviation. One-way analysis of variance (ANOVA) was performed with the plot as the statistical unit. When the treatment effect reached a significant level, Duncan's multiple range test was used for multiple comparisons, with the significance level set at $P < 0.05$. For the same indicator, different lowercase letters indicate significant differences among treatments.

Results and Analysis

Effects of transplanting date on the growth and development of Yunyan 87

Effects on the growth process As shown in Table 2, different

transplanting dates markedly changed the field growth process of Yunyan 87. T_1 showed the longest field growth period, at 127 d, and T_2, T_3 and T_4 exhibited field growth periods of 119, 116, and 106 d, respectively. With the transplanting date delayed from April 23 to May 23, the field growth period was shortened by 21 d, indicating that late transplanting significantly compresses the field growth period of tobacco plants.

Table 2 Growth periods of different treatments

Transplanting date	Transplanting to rosette stage//d	Rosette stage to budding stage//d	Budding stage to topping//d	Topping to first harvest and curing//d	First harvest and curing to end of harvest//d	Field growth period//d
T_1	28	32	6	11	50	127
T_2	27	31	6	6	50	119
T_3	29	28	5	6	48	116
T_4	32	26	5	–	48	106

In terms of various growth stages, T_2 took 27 d from transplanting to the rosette stage, the shortest among all treatments, and T_4 took 32 d, which was 5 d longer than T_2. After entering the rosette stage, T_4 required only 26 d from the rosette stage to the budding stage, 6 d shorter than T_1, indicating that the growth process of late-transplanted treatments accelerated markedly after the rosette stage. The period from the first harvest and curing stage to the final harvest lasted 48 – 50 d across all treatments, with only small differences, indicating that the shortening of the field growth period mainly occurred during the stage from transplanting to the first harvest and curing stage.

Effects on the dynamics of plant height As shown in Table 3, at 40 d after transplanting, the plant heights of T_3 and T_4 were 55.37 and 58.81 cm, respectively, significantly higher than those of T_1 and T_2. T_1 had the lowest plant height, at only 30.64 cm. At 50 d after transplanting, T_4 had the highest plant height, at 115.34 cm, which was not significantly different from T_3, but was significantly higher than T_1 and T_2. T_1 remained the lowest, at 70.66 cm.

At 60 d after transplanting, T_3 showed the highest plant height, at 150.42 cm, followed by T_4 at 143.15 cm and T_2 at 138.77 cm, while T_1 was the lowest, at 126.26 cm. Among them, T_3 and T_4 were significantly higher than T_1, while T_2 was at an intermediate level. Overall, moderate late transplanting favored rapid stem elongation of tobacco plants in the early and middle growth stages, but T_4 was already lower than T_3 at 60 d, indicating that the growth advantage in plant height with excessively late transplanting could not be sustained.

Table 3 Changes in plant height, stem girth, and leaf number at different time points after transplanting

Treatment	40 d after transplanting			50 d after transplanting			60 d after transplanting		
	Planting height//cm	Stem girth//cm	Leaf number leaves	Planting height//cm	Stem girth//cm	Leaf number leaves	Planting height//cm	Stem girth//cm	Leaf number leaves
T_1	30.64 ± 2.24 b	6.83 ± 0.41 ab	15	70.66 ± 4.73 c	8.04 ± 0.76 a	20	126.26 ± 10.74 b	9.03 ± 0.52 a	24
T_2	35.43 ± 1.89 b	7.28 ± 0.49 a	14	80.97 ± 7.74 b	8.45 ± 0.49 a	20	138.77 ± 9.65 ab	9.24 ± 0.26 a	25
T_3	55.37 ± 4.83 a	6.37 ± 0.57 b	13	110.12 ± 9.96 a	7.58 ± 0.60 ab	18	150.42 ± 12.67 a	8.48 ± 0.66 b	21
T_4	58.81 ± 5.03 a	5.95 ± 0.26 c	12	115.34 ± 11.19 a	7.01 ± 0.51 b	16	143.15 ± 9.48 a	7.86 ± 0.27 c	19

Different lowercase letters indicate significant differences among treatments at $P < 0.05$. the same applies below.

Effects on the dynamics of stem girth As shown in Table 3, T_2 showed the best overall performance in terms of stem girth. At 40, 50, and 60 d after transplanting, the stem girth of T_2 was, respectively, 7.28, 8.45, and 9.24 cm, all of which were the highest values among the treatments, although the differences from T_1 were not significant.

The stem girths of T_3 and T_4 were generally lower than those of T_1 and T_2. At 60 d after transplanting, the stem girths of T_3 and T_4 were, respectively, 8.48 and 7.86 cm, both of which were significantly lower than those of T_1 and T_2, and T_4 was significantly lower than T_3. These results indicated that transplanting in mid-to-late May was unfavorable for the lateral growth of stems, and in particular, transplanting on May 23 exerted a marked inhibitory effect on stem girth formation.

Effects on the dynamics of leaf number As shown in Table 3, at 40 d after transplanting, T_1 showed the highest leaf number, at 15 leaves, and T_2, T_3, and T_4 had 14, 13, and 12 leaves, respectively. At 50 d after transplanting, both T_1 and T_2 had 20 leaves, while T_3 and T_4 had 18 and 16 leaves, respectively. At 60 d after transplanting, T_2 had the most leaves, at 25 leaves, followed by T_1 at 24 leaves, and T_3 and T_4 had 21 and 19 leaves, respectively.

Overall, T_1 produced leaves earlier in the early growth stage, while T_2 showed faster leaf growth in the middle and late stages. T_4 had the fewest leaves at all investigation time points, indicating that excessively late transplanting reduced the number of leaves produced by tobacco plants.

Effects on the dynamics of leaf length and width As shown in Table 4, at 40 d after transplanting, T_2 had the largest leaf length and leaf width, at 56.27 and 22.28 cm, respectively, with no significant differences from T_1. T_3 and T_4 were generally smaller, and T_4 showed a leaf length and leaf width of 46.43 and

17.04 cm, respectively.

At 50 d after transplanting, the leaves of all treatments continued to expand. T_2 still had the largest leaf length and leaf width, reaching 64.70 and 24.33 cm, respectively, while T_4 had the lowest values, at 56.13 and 20.17 cm, respectively. The leaf expansion of T_1 and T_2 was generally superior to that of T_3 and T_4.

At 60 d after transplanting, the leaf lengths of T_1 and T_2 were similar, at 72.13 and 71.97 cm, respectively, while T_4 had the lowest value, at 62.07 cm. T_2 showed the largest leaf width, at 26.73 cm, followed by T_1 at 26.07 cm, and both the two values were significantly higher than those of T_3 and T_4. Based on the results of the three investigations, transplanting from late April to early May favored full leaf expansion, whereas the leaf length and leaf width of tobacco plants transplanted on May 23 remained at relatively low levels.

Table 4 Changes in leaf length and leaf width during the growth process of tobacco plants

Treatment	40 d after transplanting		50 d after transplanting		60 d after transplanting	
	Leaf length//cm	Leaf width//cm	Leaf length//cm	Leaf width//cm	Leaf length//cm	Leaf width//cm
T_1	54.03 ±5.93 a	21.77 ±1.42 a	64.10 ±7.04 a	24.00 ±1.40 ab	72.13 ±4.49 a	26.07 ±1.55 a
T_2	56.27 ±7.11 a	22.28 ±1.59 a	64.70 ±5.26 a	24.33 ±1.25 a	71.97 ±4.16 a	26.73 ±2.31 a
T_3	49.07 ±4.78 b	18.37 ±1.60 b	59.57 ±5.22 bc	21.70 ±1.48 bc	69.40 ±3.19 a	23.53 ±1.34 b
T_4	46.43 ±4.61 b	17.04 ±1.31 b	56.13 ±6.62 c	20.17 ±1.69 c	62.07 ±4.21 b	22.57 ±1.46 b

Effects of transplanting date on agronomic traits at the maturation stage

As shown in Table 5, the transplanting date exerted varying degrees of influence on the agronomic traits of Yunyan 87 at the maturation stage. The number of effective leaves showed a trend of first increasing and then decreasing with the delay of transplanting date. T_2 showed the highest value, at 22 leaves per plant, with no significant difference from T_1. T_4 had only 16 leaves per plant, significantly lower than other treatments.

The natural plant height generally decreased with the delay of transplanting date. T_1 had the highest value, at 173.85 cm, followed by T_2 at 171.02 cm, and there was no significant difference between the two. T_4 showed the lowest value, at 157.67 cm. The topping plant height was highest in T_2, at 125.13 cm, while T_1 and T_3 had values of 122.71 and 121.00 cm, respectively, and there were no significant differences among the three. T_4 was only 108.83 cm, significantly lower than other treatments.

The stem girths of T_1 and T_2 were 11.69 and 11.22 cm, respectively, with no significant difference. T_4 exhibited the lowest stem girth, at 9.53 cm. The maximum leaf length was highest in T_1, at 76.36 cm, while T_2 and T_3 showed values of 72.41 and 71.55 cm, respectively, and there were no significant differences among the three. The maximum leaf length of T_4 was 64.15 cm, significantly lower than other treatments. The maximum leaf width was highest in T_2, at 28.67 cm, with no significant difference from T_1, and T_3 and T_4 had values of 25.85 and 24.37 cm, respectively, significantly lower than those of T_1 and T_2.

Table 5 Agronomic traits of flue-cured tobacco at the maturation stage under different transplanting dates

Treatment	Number of effective leaves//leaves/plant	Natural plant height//cm	Topping plant height//cm	Stem girth//cm	Maximum leaf length//cm	Maximum leaf width//cm
T_1	21 ±1 ab	173.85 ±12.31 a	122.71 ±8.87 a	11.69 ±0.68 a	76.36 ±4.95 a	28.39 ±2.15 a
T_2	22 ±1 a	171.02 ±8.86 a	125.13 ±9.25 a	11.22 ±1.08 a	72.41 ±6.60 a	28.67 ±2.75 a
T_3	20 ±1 b	164.12 ±14.32 ab	121.00 ±11.55 a	10.28 ±0.83 ab	71.55 ±6.22 a	25.85 ±2.19 b
T_4	16 ±2 c	157.67 ±14.84 b	108.83 ±5.94 b	9.53 ±0.55 b	64.15 ±3.38 b	24.37 ±1.55 b

Comprehensive analysis showed that T_1 and T_2 had better agronomic traits at the maturation stage, and there were no significant differences in most indicators between the two. T_4 was at a relatively low level in terms of the number of effective leaves, topping plant height, stem girth, and leaf size.

Effects of transplanting date on the economic traits of cured tobacco leaves

Effects on yield, output value and grade structure As shown in Table 6, tobacco leaf yield, average price, output value, proportion of high-grade tobacco, and proportion of high- and medium-grade tobacco generally increased first and then decreased as the transplanting date was delayed.

T_2 showed the highest yield, at 2 113.05 kg/hm^2, which was not significantly different from T_1 and T_3, but was significantly higher than T_4. T_4 had the lowest yield, at 1 600.8 kg/hm^2. T_2 exhibited the highest average price, at 23.62 yuan/kg, followed by T_1, T_3, and T_4, and there were significant differences among all treatments. T_2 had the highest output value, at 49 904.1 yuan/hm^2, while T_1, T_3 and T_4 had values of 44 587.65, 36 170.55, and 29 061 yuan/hm^2, respectively, and there were significant differences among all treatments.

T_2 had the highest proportion of high-grade tobacco, at 40.72%, followed by T_1, T_3, and T_4, and there were significant differences among all treatments. The proportion of high- and medium-grade tobacco was 90.20% in T_2 and 88.66% in T_1, with no significant difference between the two. T_4 showed the lowest value, at 79.82%, significantly lower than those of T_1 and T_2.

Table 6 Yield, output value and grade structure of flue-cured tobacco under different transplanting dates

Treatment	Yield kg/hm²	Average price yuan/kg	Output value yuan/hm²	Proportion of high-grade tobacco//%	Proportion of high- and medium-grade tobacco//%
T_1	2 047.35 ±251.40 a	21.77 ±1.35 b	44 587.65 ±4 358.85 b	37.45 ±2.51 b	88.66 ±8.54 a
T_2	2 113.05 ±230.85 a	23.62 ±1.53 a	49 904.10 ±4 599.90 a	40.72 ±2.30 a	90.20 ±8.32 a
T_3	1 827.45 ±220.35 ab	19.78 ±1.47 c	36 170.55 ±2 618.55 c	28.55 ±2.54 c	82.90 ±4.95 ab
T_4	1 600.80 ±181.20 b	18.15 ±1.13 d	29 061.00 ±1 694.40 d	22.21 ±1.89 d	79.82 ±4.80 b

Compared with T_4, the yield, average price and output value of T_2 increased by 32.00%, 30.14%, and 71.72%, respectively, and the proportion of high-grade tobacco and the proportion of high- and medium-grade tobacco increased by 18.51 and 10.38 percentage points, respectively. These results indicated that transplanting on May 3 not only increased tobacco leaf yield, but also markedly improved the grade structure and income per unit mass.

Effects on single-leaf weight As shown in Table 7, the single-leaf weight of middle leaves showed a trend of first increasing and then decreasing with the delay of transplanting date. T_2 had the highest single-leaf weight of middle leaves, at 10.69 g, with no significant difference from T_1. T_3 and T_4 exhibited values of 9.65 and 8.05 g, respectively, both significantly lower than those of T_1 and T_2.

Table 7 Single-leaf weight of cured tobacco leaves under different transplanting dates

Treatment	Single-leaf weight of middle leaves//g	Single-leaf weight of upper leaves//g
T_1	10.48 ±0.42 a	11.51 ±0.73 a
T_2	10.69 ±0.59 a	11.03 ±0.58 a
T_3	9.65 ±0.24 b	10.49 ±0.29 b
T_4	8.05 ±0.56 c	9.43 ±0.35 c

The single-leaf weight of upper leaves generally decreased with the delay of transplanting date. T_1 and T_2 exhibited values of 11.51 and 11.03 g, respectively, and there was no significant difference between the two. The value of T_3 was 10.49 g, and that of T_4 was the lowest, at 9.43 g, which was significantly lower than other treatments. These results indicated that when transplanting was delayed to midtolate May, the filling degree of both middle and upper leaves decreased.

Discussion and Conclusion

Transplanting date affected tobacco plant growth by altering the climatic configuration during the growth period

In this study, when the transplanting date was delayed from April 23 to May 23, the field growth period of Yunyan 87 was shortened by 21 d, which is consistent with the results of studies in most tobacco-growing areas showing that late transplanting accelerates the growth process and compresses the field growth period[2-5,9-11]. The plant heights of T_3 and T_4 were greater at 40 – 50 d after transplanting, possibly because higher temperatures in the early stage after late transplanting accelerated the growth rate of tobacco plants. However, faster plant height growth does not equate to better overall growth quality of tobacco plants. The stem girth, leaf number, and leaf size of T_4 were all lower than those of other treatments, indicating that its growth was characterized more by an accelerated growth process, while dry matter accumulation and full leaf expansion were limited. Previous studies have also shown that changes in transplanting date affect photosynthesis, carbon and nitrogen metabolism, and leaf tissue structure of tobacco plants. A suitable climatic configuration is conducive to leaf development and material accumulation, whereas transplanting too early or too late may cause growth imbalance[13-15].

T_1 showed the longest field growth period, but its plant height growth was relatively slow at 40 – 50 d after transplanting, which may be related to the relatively low temperatures in early spring. A longer growth period is conducive to leaf production and stem thickening. Therefore, T_1 had greater natural plant height, stem girth, and maximum leaf length ultimately. In contrast, T_2 combined a more suitable early growth rate with more sufficient material accumulation in the middle and late stages, and its number of effective leaves, topping plant height, and maximum leaf width all reached relatively high levels. It indicates that when determining the transplanting date in the Zunyi tobacco-growing area, short-term plant height after transplanting should not be used as the sole evaluation criterion, and stem girth, number of effective leaves, leaf size, growth period length and maturation process should also be comprehensively considered.

Transplanting in early May was beneficial for improving the grade structure and economic benefits of tobacco leaves

In this study, the yield of T_2 increased by only 3.21% compared with T_1, but its average price and output value increased by 8.50% and 11.92%, respectively, and the proportion of high-grade tobacco increased by 3.27 percentage points. It indicated that the economic advantage of T_2 mainly stemmed from improvements in the grade structure of tobacco leaves and income per unit mass, rather than from yield increase alone. T_2 had the highest single-leaf weight of middle leaves, and its single-leaf weight of upper leaves was not significantly different from that of T_1, indicating that transplanting on May 3 could improve the grade quality of tobacco leaves while maintaining leaf filling degree.

When the transplanting date was delayed to May 13 and May 23, the yield, average price, output value, and proportion of high-grade tobacco all decreased markedly. In particular, the output value of T_4 was only 2 9061 yuan/hm². The reasons may include a reduced number of effective leaves, smaller stem girth, insufficient leaf expansion, and a shortened maturation period. Studies in different tobacco-growing areas generally agree that a suitable transplanting date can make the temperature, precipitation, and light configurations during the rapid growth and maturation stages more reasonable, thereby improving the maturity, chemical

composition coordination, and grade structure of tobacco leaves. However, the specific date is markedly region-specific[6-14]. Therefore, the suitable transplanting time around May 3 determined in this study is mainly applicable to the ecological and cultivation conditions of Suiyang similar to those of this experiment.

Limitations of the study

This study still has the following limitations. First, the experiment was conducted at only one location in a single year, lacking multiyear and multisite verification, so it was not possible to fully distinguish the transplanting date effect from the interannual climate effect. In different years, the timing of spring low temperatures, drought, and temperature drops during the maturation stage varies, and the suitable transplanting period may undergo a certain offset[15-16]. Second, the sowing dates were adjusted along with the transplanting dates for each treatment. Although the seedling age and leaf age at transplanting were basically consistent, the temperature and light environments during seedling raising at different sowing dates might still produce residual seedling-stage effects. Therefore, strictly speaking, this study evaluated the combined effects of sowing and transplanting dates under the condition of maintaining similar seedling age. Third, this study mainly investigated grade structure and economic traits, and did not measure the conventional chemical composition, physical properties, aroma components, or sensory quality of tobacco leaves. Thus, the evaluation of intrinsic quality remains insufficient.

Summary of conclusions

(1) The transplanting date significantly affected the growth process of Yunyan 87. When the transplanting date was delayed from April 23 to May 23, the field growth period was shortened from 127 to 106 d. Late-transplanted tobacco plants showed faster plant height growth in the early stage, but excessively late transplanting was unfavorable for the formation of stem girth, leaf number, and leaf size.

(2) The April 23 and May 3 transplanting treatments generally showed better agronomic traits at the maturation stage. The May 23 transplanting treatment was at relatively low levels in terms of number of effective leaves, topping plant height, stem girth, and maximum leaf size.

(3) The May 3 transplanting treatment had the highest tobacco leaf yield, average price, output value, proportion of high-grade tobacco, and proportion of high- and medium-grade tobacco, showing the best overall economic performance. Its output value was 11.92% higher than that of the April 23 transplanting treatment and 71.72% higher than that of the May 23 transplanting treatment.

(4) Under the conditions of this experimental year, medium or higher fertility of yellow soil in Suiyang, and well-cellar transplanting, it is recommended that the transplanting period for Yunyan 87 be scheduled from late April to early May, and delaying to mid-to-late May should be avoided, and especially not as late as May 23. This conclusion still needs to be further verified by multiyear and multi-ecological-site experiments.

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