Effects of Nitrogen Rate and Planting Density on the Growth and Quality of Tobacco Cultivar Chuxue 80

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Abstract [**Objectives**] To investigate the effects of different planting densities and nitrogen application rates on the yield and quality of the tobacco cultivar Chuxue 80. [**Methods**] A field experiment was conducted in Hubei Province, evaluating various combinations of planting density and nitrogen rate for Chuxue 80. [**Results**] At the maturity stage, the TN1 treatment (5 kg N per 667 m^2 with a density of 1 900 plants per 667 m^2) demonstrated the most favorable agronomic performance. The TN9 treatment (11 kg N per 667 m^2 with a density of 1 110 plants per 667 m^2) achieved the highest wrapper tobacco yield and output value. Meanwhile, the TN5 treatment (8 kg N per 667 m^2 with a density of 1 515 plants per 667 m^2) resulted in the best smoking quality. [**Conclusions**] The TN9 treatment, with a planting density of 1 110 plants per 667 m^2 and a nitrogen application rate of 11 kg per 667 m^2, is recommended as the optimal cultivation practice for Chuxue 80 in Hubei Province.

Key words Tobacco, Nitrogen application rate, Planting density, Agronomic traits, Smoking quality

0 Introduction

Cigars are known for their rich aroma, robust strength, and mellow taste, coupled with lower levels of tar and nicotine. In recent years, they have gained increasing consumer recognition and have emerged as a new economic growth driver within the tobacco industry[1-2]. The quality of cigar tobacco leaves is influenced not only by factors such as cultivar, ecological conditions, air-curing techniques, and fermentation methods[3-6] but also by fertilization practices and planting density. Among all fertilizers, nitrogen application has the most significant impact on tobacco leaf yield and quality. The nitrogen application rate directly determines the yield, internal chemical composition, and visual characteristics of the leaves[7-10]. In addition, planting density affects yield and quality by altering plant growth vigor, leaf expansion, and photosynthetic efficiency[11-14]. Therefore, identifying the optimal collaboration between nitrogen application rate and planting density is important for enhancing the yield and quality of cigar tobacco leaves[15].

Tobacco Chuxue 80 is an excellent cigar wrapper variety, characterized by its high-quality wrapper leaves and high industry recognition. In recent years, its cultivation area has been continuously expanding. However, research on the fertilization rate and planting density for this variety remains relatively limited. Thus, with nitrogen application rate and planting density as experimental factors, this study aims to determine the optimal nitrogen application rate and planting density for Tobacco Chuxue 80, providing references for improving cigar tobacco yield, quality, and industrial usability.

1 Materials and methods

1.1 Overview of the experiment site The experiment was conducted in 2023 in Yanfengwo Village, Laifeng County, Hubei Province. The soil had a pH of 6.06 and contained the following properties: organic matter, 29.4 g/kg; alkali-hydrolyzable nitrogen, 144.7 mg/kg; available potassium, 256.3 mg/kg; available phosphorus, 40.8 mg/kg; and exchangeable calcium, 1 541.2 mg/kg.

1.2 Experimental materials The tested tobacco material was the cigar wrapper variety Tobacco Chuxue 80. The nitrogen fertilizer used was a compound fertilizer specially formulated for cigar tobacco, produced by Xiangqing Fertilizer Co., Ltd. in Hubei Province.

1.3 Experimental design We conducted a two-factor, three-level plot experiment with nitrogen application rate and planting density as the factors. The area of each plot was 1 188.12 m^2, with a total of nine treatments and three replicates per treatment, as detailed in Table 1. Other fertilization and field management practices followed local production skills.

1.4 Detection indicators and methods

1.4.1 Investigation of agronomic traits. We measured plant height, number of effective leaves, maximum leaf length, and maximum leaf width of tobacco plants for each treatment at both the rosette and maturity stages of Tobacco Chuxue 80, according to the *Method for Investigation and Measurement of Tobacco Agronomic Traits* (YC/T 142-2010).

1.4.2 Determination of tobacco leaf yield and quality. Tobacco leaves from each treatment were tagged by plot and harvested, air-cured, and fermented on a plot-by-plot basis. After air-curing,

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the wrapper yield, premium filler leaf rate, and output value for each treatment were evaluated in October 2023 with reference to the *Quality Specification for Cigar Tobacco Leaf Grades* (DB 42/T 1549-2020).

1.4.3 Sensory evaluation. A nine-point scoring system was employed. Relevant experts from China Tobacco Zhejiang Industrial Co., Ltd. were invited to conduct on-site sensory evaluations and scoring of the tobacco leaves from each treatment. The assessment focused on key indicators such as aroma quality, aroma volume, smoke volume, off-flavor, strength, irritation, aftertaste, combustibility, ash color, and industrial usability[16].

Table 1 Experiment treatment

Treatment	Nitrogen application rate (based on pure nitrogen)//kg/667 m^2	Planting density plants/667 m^2
TN1	5	1 900
TN2	8	1 900
TN3	11	1 900
TN4	5	1 515
TN5	8	1 515
TN6	11	1 515
TN7	5	1 110
TN8	8	1 110
TN9	11	1 110

1.5 Data processing and analysis Microsoft Excel 2010 software was used to sort out the test data, and DPS V14.5 statistical analysis software was used to process the data.

2 Results and analysis

2.1 Effects of different treatments on agronomic traits of Tobacco Chuxue 80 As shown in Table 2, different treatments had significant effects on the agronomic traits of Tobacco Chuxue 80 at the rosette stage. The TN1 treatment resulted in the greatest maximum leaf length of Tobacco Chuxue 80, showing no significant difference with the TN2 and TN9 treatments, but showing significant differences with all other treatments; the TN1 treatment resulted in the greatest maximum leaf width of Tobacco Chuxue 80, showing significant differences with all other treatments; the TN1 treatment resulted in the highest plant height of Tobacco Chuxue 80, showing significant differences with all other treatments; the TN1 treatment resulted in the highest number of effective leaves of Tobacco Chuxue 80.

As can be seen from Table 3, different treatments had significant effects on the agronomic traits of Tobacco Chuxue 80 at the maturity stage. The TN1 treatment resulted in the greatest maximum leaf length of Tobacco Chuxue 80, showing no significant difference from the TN6 and TN9 treatments, but differing significantly from all other treatments. Under the TN9 treatment, Tobacco Chuxue 80 achieved the greatest maximum leaf width, showing significant differences from all other treatments except TN1. The TN1 treatment produced the highest plant height of Tobacco Chuxue 80, with no significant difference observed from the TN2, TN3, and TN4 treatments, but showing significant differences from all other treatments. The TN1 treatment resulted in the highest number of effective leaves of Tobacco Chuxue 80, showing a significant difference only from the TN4 treatment, and no significant differences from all other treatments. Overall, the TN1 treatment demonstrated the most ideal field growth performance for Tobacco Chuxue 80.

Table 2 Effects of different treatments on agronomic traits of Tobacco Chuxue 80 at rosette stage

Treatment	Max leaf length//cm	Max leaf width//cm	Plant height//cm	Number of effective leaves
TN1	35.4 ± 2.40 a	23.2 ± 1.78 a	42.4 ± 0.89 a	10.4 ± 0.54 a
TN2	33.0 ± 1.58 ab	19.8 ± 1.09 bc	32.6 ± 1.51 b	9.6 ± 0.89 ab
TN3	31.4 ± 0.89 bc	20.4 ± 1.14 b	28.8 ± 1.92 bc	8.0 ± 0.70 c
TN4	30.0 ± 1.58 bc	19.0 ± 1.73 c	24.8 ± 2.28 cd	7.8 ± 0.44 cd
TN5	29.4 ± 1.67 c	17.8 ± 0.83 d	23.8 ± 1.92 d	7.2 ± 0.44 d
TN6	31.2 ± 2.58 bc	20.3 ± 1.00 b	29.6 ± 2.96 bc	8.4 ± 0.54 bc
TN7	31.8 ± 1.67 bc	20.2 ± 0.83 b	25.4 ± 1.92 cd	8.8 ± 0.44 b
TN8	32.0 ± 2.58 b	20.6 ± 1.00 b	27.6 ± 2.96 c	9.4 ± 0.54 ab
TN9	33.2 ± 1.48 ab	20.2 ± 1.30 b	27.6 ± 1.14 c	9.4 ± 0.83 ab

NOTE Different lowercase letters in the same column indicate significant differences at the 0.05 level ($p < 0.05$), the same below.

Table 3 Effects of different treatments on agronomic traits of Tobacco Chuxue 80 at maturity stage

Treatment	Max leaf length//cm	Max leaf width//cm	Plant height//cm	Number of effective leaves
TN1	55.4 ± 1.14 a	29.8 ± 0.83 ab	166.8 ± 4.96 a	17.6 ± 0.54 a
TN2	49.4 ± 1.95 cd	25.2 ± 0.83 d	163.0 ± 2.12 ab	17.0 ± 0.70 ab
TN3	52.8 ± 1.92 b	27.8 ± 0.83 c	163.2 ± 2.38 ab	17.2 ± 0.83 ab
TN4	51.8 ± 2.38 bc	28.0 ± 1.00 bc	163.0 ± 3.08 ab	16.8 ± 0.83 b
TN5	51.0 ± 1.58 bc	27.6 ± 1.14 c	160.2 ± 4.48 c	17.0 ± 0.70 ab
TN6	53.4 ± 1.14 ab	28.4 ± 0.54 b	162.6 ± 2.81 b	17.4 ± 0.54 a
TN7	47.8 ± 0.83 d	27.2 ± 0.83 c	156.2 ± 3.30 d	17.2 ± 0.44 ab
TN8	50.2 ± 0.83 c	28.2 ± 0.83 b	161.6 ± 2.70 bc	17.4 ± 0.54 a
TN9	54.2 ± 0.83 ab	30.8 ± 0.83 a	160.6 ± 1.95 bc	17.4 ± 0.54 a

2.2 Effects of different treatments on superior leaf rate and output value of tobacco Chuxue 80 As can be seen from Table 4, in terms of wrapper yield, the TN9 and TN7 treatments showed superior performance; regarding the premium filler leaf rate, the TN4 and TN9 treatments performed better; in terms of output value, the TN9 treatment achieved the highest results, followed by the TN7 treatment.

2.3 Effects of different treatments on smoking quality of Tobacco Chuxue 80 As indicated in Table 5, the TN5 treatment resulted in the highest aroma quality score of Tobacco Chuxue 80, reaching 6.5 points; the TN1, TN2, TN5, and TN9 treatments resulted in higher aroma volume scores of Tobacco Chuxue 80; all treatments resulted in consistent smoke volume and combustibility scores of Tobacco Chuxue 80; the TN2 treatment resulted in the lowest off-flavor score of Tobacco Chuxue 80; the TN3 and TN5 treatments resulted in the highest strength and ash color ash scores of Tobacco Chuxue 80; the TN9 treatment resulted in the lowest irritation score of Tobacco Chuxue 80; the TN3 and TN5 treatments resulted in the highest aftertaste score of Tobacco Chuxue 80; the TN1, TN5, and TN9 treatments resulted in higher industrial usability ratings of Tobacco Chuxue 80. Through overall analysis, different treatments had a relatively obvious impact on the sensory evaluation quality of Tobacco Chuxue 80, with the TN5 treatment demonstrating the highest overall sensory quality of Tobacco Chuxue 80, followed by the TN1 and TN9 treatments.

Table 4 Effects of different treatments on superior leaf rate and output value of tobacco Chuxue 80

Treatment	Wrapper yield//%	Premium filler leaf rate//%	Output value yuan/667 m^2
TN1	4.66 ±1.33 d	50.48 ±4.67 b	5 091.12
TN2	8.56 ±2.41 c	42.76 ±5.13 cd	5 139.84
TN3	8.01 ±1.67 c	35.20 ±3.67 e	4 925.40
TN4	3.39 ±0.45 d	59.61 ±3.55 a	5 234.04
TN5	9.13 ±3.2 bc	38.78 ±4.83 d	5 078.72
TN6	10.62 ±3.67 b	45.82 ±3.77 c	5 336.90
TN7	17.43 ±5.76 a	29.09 ±2.86 f	5 343.94
TN8	9.71 ±1.83 b	37.49 ±2.64 d	5 082.43
TN9	18.58 ±4.83 a	53.48 ±6.53 ab	5 998.36

Table 5 Effects of different treatments on smoking quality of Tobacco Chuxue 80 points

Treatment	Aroma quality	Aroma volume	Smoke volume	Off-flavor	Strength	Irritation	Aftertaste	Combustibility	Ash color	Industrial usability
TN1	6.0	6.5	7.0	6.5	6.5	7.0	6.5	7.0	6.5	3.5
TN2	5.5	6.5	7.0	6.0	6.5	6.5	6.5	7.0	6.0	3.0
TN3	6.0	6.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	3.0
TN4	5.0	6.0	7.0	7.0	6.5	7.0	6.5	7.0	6.5	3.0
TN5.0	6.5	6.5	7.0	7.0	7.0	7.0	7.0	7.0	7.0	3.5
TN6.0	6.0	6.0	7.0	6.5	6.5	6.5	6.5	7.0	6.5	3.0
TN7.0	5.0	5.5	7.0	6.5	6.0	6.5	6.0	7.0	6.5	2.5
TN8	5.0	6.0	7.0	7.0	6.5	7.0	6.5	7.0	6.5	3.0
TN9	6.0	6.5	7.0	6.5	6.5	6.0	6.5	7.0	6.5	3.5

3 Conclusions and discussion

Nitrogen is considered the life element of plants, and an appropriate nitrogen application rate can meet the normal growth requirements of tobacco plants and facilitate the formation of tobacco leaf quality[17]. Reasonable close planting is an important measure to enhance plant photosynthesis and improve tobacco leaf yield[18]. Nitrogen application rate and planting density are key production measures affecting the yield and quality of tobacco leaves. This study demonstrated that at the maturity stage of Tobacco Chuxue 80, the TN1 treatment showed the most ideal performance; both the wrapper yield and output value of Tobacco Chuxue 80 were most ideal under the TN9 treatment with low density and high nitrogen application rate; the sensory evaluation quality of Tobacco Chuxue 80 was best under the TN5 treatment with medium density and medium nitrogen application rate, followed by the TN1 treatment with high density and low nitrogen application rate and the TN9 treatment with low density and high nitrogen application rate. This is basically consistent with the research conclusions of Li Meng, indicating that under a certain nitrogen application rate, the aroma-producing substances in cigar tobacco increase with the increase of nitrogen application rate, while the total content of aroma substances decreases when the nitrogen application rate is either too high or too low[19].

Based on the comprehensive analysis of various indicators, the optimal treatment for Tobacco Chuxue 80 in Hubei Province was TN9 treatment, that is, the planting density was 1 110 plants/667 m^2, and the nitrogen application rate was 11 kg/667 m^2.

References

[1] LI AJ, QIN YQ, DAI HJ, *et al.* On scientific development of China's cigar leaf[J]. Acta Tabacaria Sinica, 2012, 18(1): 112 – 114. (in Chinese).

[2] HE Q, ZHOU NB. Discussion on high-quality development path of domestic cigar[J]. Times of Economy & Trade, 2018(31): 38 – 43. (in Chinese).

[3] LI NF, YU LY, YANG JP, *et al.* Differential analysis of metabolomics of cigar tobacco leaves of different varieties after air-curing[J]. Chinese Tobacco Science, 2022,43(2): 77 – 85. (in Chinese).

[4] LIU Y, LIU BY, JIN MK, *et al.* Effects of different altitudes on the contents of aroma precursors in air cured cigar[J]. Crops, 2022(5): 118 – 123. (in Chinese).

[5] YE KY, LIU LL, LU RL, *et al.* Effect of maturity and air-curing methods on the quality of cigar tobacco leaves[J]. Journal of Zhejiang Agricultural Sciences, 2022, 63(7): 1584 – 1587. (in Chinese).

[6] SHI XD, WANG XF, LIN KC, *et al.* Changes of aroma substances in cigar wrapper tobacco leaves during the stacking fermentation[J]. Acta Agriculturae Boreali-occidentalis Sinica, 2013, 22(7): 114 – 119. (in Chinese).

[7] HE MC, LIU LP, LI JH, *et al.* Effects of cooperation of nitrogen amount and planting density on the production and quality of cigar[J]. Hubei Agricultural Sciences, 2021, 60(16): 117 – 121. (in Chinese).

[8] SHI XD, LIU YF, WEN ZQ, *et al.* Effects of nitrogen levels on growth and content of endogenous hormones of cigar wrapper leaves[J]. Acta Botanica Boreali-Occidentalia Sinica, 2007(8): 1625 – 1630. (in Chinese).

[9] ZHANG JW, LU SH, ZHAO MQ, *et al.* Effects of nitrogen application rates on carbon and nitrogen metabolism and quality of cigar leaves in Sichuan[J]. Crops, 2021(4): 159 – 165. (in Chinese).

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nies, it is essential to monitor the developmental progress of hybrid embryos, for instance, through consecutive observation of ovule development via paraffin sectioning, to precisely determine the optimal timing for embryo rescue. Advancing the refinement and systematic application of embryo culture technology in tree peonies, and closely integrating it with the entire distant crossing process, constitutes vital technical support for ensuring hybrid seedling establishment and enhancing breeding efficiency.

5.4 Research methods and calculation indicators to be optimized Due to long-term differences in natural selection and cultivation domestication, significant variation exists between wild and cultivated tree peony species in floral organ structure, particularly in traits that determine reproductive capacity, such as carpel number and ovule count per carpel. Research has shown that crossing combinations with high seed set tend to exhibit lower rates of ovule abortion after pollination[17]. In this experiment, when calculating the seed set of crossings, the number of pollinated flowers was used as the basis (*i. e.*, number of mature seeds per pollinated flower), without fully accounting for differences in pistil structure among different maternal parents. Although this method can objectively reflect compatibility trends in comparisons of the same type, calculations based on ovule number (*e. g.*, number of developed seeds per total ovules) would yield more precise results. In future studies, optimizing this calculation indicator will contribute to more scientific and detailed evaluation results.

References

[1] HONG DY, ZHOU SL, HE XJ, *et al*. Current status of wild tree peony species with special reference to conservation[J]. Biodiversity Science, 2017, 25(7): 781-793. (in Chinese).

[2] HONG T, DAI ZL. Study on the Chinese wild woody peonies (III) new taxa of *Paeonia* L. Sect. Moutan dc. [J]. Bulletin of Botanical Research, 1997,17(1): 1-5. (in Chinese).

[3] ZHOU SL, ZOU XH, ZHOU ZQ, *et al*. Multiple species of wild tree peonies gave rise to the 'king of flowers', *Paeonia suffruticosa* Andrews [J]. Proceedings of the Royal Society B: Biological Sciences, 2014, 281 (1797): 20141687.

[4] LI JY. Studies on the Origin of Chinese Mudan (Tree Peony)[J]. Journal of Beijing Forestry University, 1998, 20(2): 22-26. (in Chinese).

[5] CHENG FY. A study on the sexual reproduction of *Paeonia rockii*[D]. Beijing: Beijing Forestry University, 1996. (in Chinese).

[6] ZHANG XY, JIA WQ, HE SL, *et al*. Interspecific distant hybrid incompatibility cytology and its physiological mechanism in *Paeonia suffruticosa* Andr. [J]. Forest Research, 2022, 35(4): 63-71. (in Chinese).

[7] TAO QB. Study on cryopreservation of peony pollen[D]. Beijing: Beijing Forestry University, 2003. (in Chinese).

[8] ZHANG YL, SHANG XQ, LIU Y. Advances in research of pollen cryopreservation[J]. Journal of Beijing Forestry University, 2006, 28(4): 139-147. (in Chinese).

[9] QI QM, MENG FZ, GUO J, *et al*. Study on seed setting characteristics of distant hybridization between four herbaceous peony cultivars and three tree peony cultivars[J]. Shandong Agricultural Sciences, 2020, 52(3): 24-28. (in Chinese).

[10] WANG ZZ, ZHANG YX. A discussion on the formation and evolution of flower type of tree peony and herb peony by observing flower bud differentiation of herb peony[J]. Acta Horticulturae Sinica, 1991, 18(2): 163-168. (in Chinese).

[11] WU S, ZHI FJ, JIA YL. On the progress of pollen sterility of Chinese jujube cultivars[J]. Journal of Hebei Normal University of Science & Technology, 2017, 31(3): 34-44. (in Chinese).

[12] HONG DY. Studies on *Paeonia suffruticosa* and *Paeonia lactiflora* in the World: Also on the Basic Principles of Taxonomy[M]. Beijing: Science Press, 2024. (in Chinese).

[13] HERMAN TK, HAN JY, SINGH R J, *et al*. Evaluation of wild perennial *Glycine* species for resistance to soybean cyst nematode and soybean rust[J]. Plant breeding, 2020, 139(5): 923-931.

[14] HE GM, CHENG FY. Cross Breeding of Tree Peony and Its Latest Progress[A]. Beijing: China Forestry Press, 2005: 149-155. (in Chinese).

[15] HE GM. Study on distant crossing, embryo culture and somatic embryogenesis of tree peony[D]. Beijing: Beijing Forestry University 2006. (in Chinese).

[16] WANG YL. Studies on cross breeding and fertility of intergroup hybrids in tree peony[D]. Beijing: Beijing Forestry University, 2009. (in Chinese).

[17] SUN M, GAO DD, JU ZX. Morphological observation on ovules of *Paeonia rockii* after cross pollination[J]. Jiangsu Agricultural Sciences, 2014, 42(8): 169-171. (in Chinese).

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[10] WU DL, SONG ZX, WANG H, *et al*. Effects of different nitrogen levels on growth, development and quality of Yuyan 6 tobacco in Yiyang tobacco area[J]. Modern Agricultural Science and Technology, 2020 (5): 8. (in Chinese).

[11] CHEN WJ. The influence of cultivation density on agronomic characters of cigar smoke in cigar wrapper[J]. Journal of Ningxia Agriculture and Forestry Science and Technology, 2013, 54(2): 17-18. (in Chinese).

[12] HE LX, ZHANG Q, PENG YF, *et al*. Effects of planting density, nitrogen application amount, remained leaf number on growth characteristics, yield and quality of flue-cured tobacco[J]. Journal of Yangzhou University: Agricultural and Life Science Edition, 2020, 41(2): 40-45. (in Chinese).

[13] JIA FF. Estimating model for leaf area index of tobacco via hyperspectral reflectance at different planting densities[J]. Chinese Tobacco Science, 2017, 38(4): 37-43. (in Chinese).

[14] TAN S, ZOU YH, ZHANG HS, *et al*. The research of the relationship between planting density and yield and quality of the cigar[J]. Journal of Anhui Agricultural Sciences, 2015, 43(31): 50-52. (in Chinese).

[15] ZHENG DF, XIONG J, WEN DF, *et al*. Effects of main cultivation techniques on field growth and quality of 'Yunyan-87'[J]. Tropical Agricultural Engineering,2019, 43(4): 1-8. (in Chinese).

[16] SHU Z. Sensory evaluation of tobacco and tobacco products (II)[J]. Tobacco Science and Technology, 1986(3): 20-23. (in Chinese).

[17] WANG Z. Plant Physiology[M]. Beijing: China Agriculture Press, 2000. (in Chinese).

[18] SHEN J, WANG CQ, HE YT, *et al*. Effects of rational close planting on canopy structure and photosynthetic production characteristics of flue-cured tobacco with different plant types[J]. Journal of Plant Nutrition and Fertilizers, 2019, 25(2): 284-295. (in Chinese).

[19] LI M. Study on the selection of suitable cigar tobacco varieties and nitrogen application rate and planting density in southwest Hubei[D]. Zhengzhou: Henan Agricultural University, 2019. (in Chinese).