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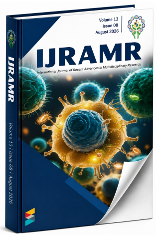

REVIEW ARTICLE

EFFECTS OF PLANTING DENSITY, FERTILIZER DOSAGE, AND APPLICATION FREQUENCY ON YIELD AND QUALITY OF BURLEY CSC TOBACCO VARIETY IN DAK LAK, VIETNAM

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ABSTRACT

This study aimed to determine the optimal plant density, fertiliser rate, number and timing of fertiliser applications for the Burley CSC tobacco cultivar in Dak Lak Province, Vietnam, to ensure high yield and desirable leaf quality. During the 2025–2026 growing season, the plant density and fertiliser rate experiment was arranged in a split-plot design with three plant densities (27,500, 31,000, and 34,500 plants ha^{-1}) and three fertiliser rates (190, 220, and 250 kg N ha^{-1}), with constant rates of 110 kg P_2O_5 and 300 kg K_2O ha^{-1} and three replications. A randomised complete block design was used to evaluate four fertiliser application regimes at 220:110:300 kg $N_2O_{52}O$ ha^{-1}: two applications at 8 and 25 days after transplanting (DAT), and three applications at 8, 25 and 40; 8, 25 and 45; or 8, 25 and 55 DAT. Plant density, fertiliser rate, and application regime significantly affected growth, yield, and quality. The combination of 34,500 plants ha^{-1} and 220:110:300 kg $N_2O_{52}O$ ha^{-1} produced a yield of 3.54 t ha^{-1}, 83.8% grade 1+2 leaves, nicotine content of 4.02%, and a total sensory smoking score of 36.9 points, classified as Good. Increasing N to 250 kg ha^{-1} did not significantly increase yield but increased bacterial wilt incidence and nicotine content, adversely affecting smoking quality. Among application regimes, three applications at 8, 25 and 45 DAT were most suitable, producing 3.61 t ha^{-1}, 84.9% grade 1+2 leaves, and a sensory smoking score of 36.7 points. Based on these findings, a preliminary optimised agronomic practice is proposed for the Burley CSC cultivar in Dak Lak Province: 34,500 plants ha^{-1}, 220:110:300 kg $N_2O_{52}O$ ha^{-1}, and three fertiliser applications at 8, 25 and 45 DAT. Further studies over one to two growing seasons are required to confirm the stability and consistency of this practice.

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INTRODUCTION

Burley tobacco is an important raw material used in the manufacture of American-blend cigarettes. In Vietnam, the annual demand for Burley tobacco is approximately 2.500-2.700 tons, whereas domestic production currently meets only 1.500-1.700 tons of this demand. Dak Lak Province is currently the largest Burley tobacco-producing region in Vietnam, owing to its favourable climatic conditions for tobacco growth, development, harvesting and air-curing. The KY14 cultivar has been exclusively cultivated in Dak Lak, Vietnam, since 2010, because of its relatively vigorous growth, high yield, high proportion of grade 1+2 leaves, and characteristic chemical composition and smoking properties (Bui Quoc Viet et al., 2025). However, the long-term monoculture of a single cultivar has increased pest and disease pressure. Field surveys have shown that the incidence of bacterial wilt ranges from 10% to 30%, with exceptionally high levels exceeding 60% in some fields. In addition, KY14 is relatively susceptible to calcium deficiency in the soil, which causes curling and poor development of the upper leaves. To ensure sustainable tobacco production and minimise losses caused by pests and diseases, the Tobacco Research Institute successfully evaluated and selected the promising Burley tobacco cultivar CSC during 2021-2025. The CSC cultivar has agronomic and technological characteristics comparable to those of KY14, but has greater resistance to major insect pests, including Myzus persicae nicotianae, Spodoptera litura, and Helicoverpa armigera, as well as to tobacco leaf curl virus disease caused by begomoviruses. It is also less affected by calcium deficiency. In particular, CSC has favourable plant morphology characterised by a compact canopy, narrow leaf angles, and good leaf durability, which facilitate efficient photosynthesis and allow the cultivar to be grown at higher plant densities. In Burley tobacco production, in addition to cultivar characteristics, plant density, fertiliser application rate, particularly nitrogen (N), and fertiliser application timing are critical determinants of yield and leaf quality. Different cultivars may require specific agronomic practices to optimise their yield potential. According to Bui Quoc Viet et al., 2025, a plant density of 31.000 plants ha^{-1}, a fertiliser rate of 220 kg N:110 kg P_2O_5:300 kg K_2O ha^{-1}, and retaining 26 leaves per plant at harvest resulted in the highest yield and quality of KY14. For the Burley 21 cultivar, plant densities of 20.000 plants ha^{-1} in Iran and 31.250 plants ha^{-1} in India have been reported to provide satisfactory yield and quality (Alizadeh et al., 2013; Umamaheswara Rao and Subbarao, 1997). Burley tobacco leaf intended for cigarette manufacturing is required to have a minimum nicotine content of 3%. Although increasing nitrogen application can enhance both yield and nicotine content, excessive nitrogen rates or inappropriate application timing may reduce nitrogen-use efficiency and adversely affect tobacco quality (MacKown et al., 1999; Frame et al., 2011; Badr, 1968; Bailey et al., 2025).

Against this background, the study entitled *"Effects of Plant Density, Fertilizer Rate, and Fertilizer Application Frequency on the Growth, Yield, and Quality of Burley Tobacco Cultivar CSC in Dak Lak Province, Vietnam"* was conducted to optimise the agronomic production practices and improve the efficiency and sustainability of Burley tobacco production in the region.

MATERIALS AND METHODS

Experimental site and plant material: The experiments were conducted in Ea Bung Commune, Dak Lak Province, Vietnam, during the 2025-2026 growing season. The experimental field had previously been cultivated with irrigated rice. The study area has climatic and soil conditions favourable for the cultivation and air-curing of Burley tobacco, with an average annual temperature above 24°C, a mean maximum temperature of approximately 34°C, and minimum temperatures ranging from 18 to 20°C. From December of the previous year to May of the following year, the weather is generally dry and hot, with low rainfall (1.6-14.8 mm) and relatively low relative humidity (35-78%).

Soil analysis of the experimental site in Ea Sup District, Dak Lak Province, showed a pH_{KCl} of 5.43. The total nitrogen (N) content was 0.40 mg g^{-1}, while available N was 4.13 mg per 100 g of soil. The total and available P_2O_5 contents were 0.12% and 13.58 mg per 100 g of soil, respectively. The total K_2O content was 0.57%, and available K_2O was 13.13 mg per 100 g of soil. The organic matter content was 0.46%, and the cation exchange capacity (CEC) was 5.29 meq per 100 g of soil. The exchangeable Ca^{2+} and Mg^{2+} contents were 2.78 and 1.25 meq per 100 g of soil, respectively, while the chloride (Cl^-) concentration was 19 mg kg^{-1}. The plant material used in the study was the Burley tobacco cultivar CSC. Lime was applied at a rate of 1.0 t ha^{-1} during the ploughing and harrowing stage.

Experimental Design: Tobacco seeds were sown in disease-free nursery beds. When the seedlings reached the 4–6-leaf stage, they were transplanted into the experimental fields.

Experiment 1: Effects of plant density and fertiliser rate. The experiment was arranged in a split-plot design with three replications, with each experimental plot covering 50 m². Plant density was assigned to the main plots and comprised three treatments: M1 = 27,500 plants ha^{-1} (90 × 40 cm), M2 = 31,000 plants ha^{-1} (90 × 35 cm), and M3 = 34,500 plants ha^{-1} (90 × 30 cm). Fertiliser rate was assigned to the subplots and comprised three treatments: P1 = 190 kg N, 110 kg P_2O_5, and 300 kg K_2O ha^{-1}; P2 = 220 kg N, 110 kg P_2O_5, and 300 kg K_2O ha^{-1}; and P3 = 250 kg N, 110 kg P_2O_5, and 300 kg K_2O ha^{-1}. Seedlings were transplanted on December 15, 2025.

Experiment 2: Effects of fertiliser rate and application frequency. The experiment was arranged in a randomised complete block design (RCBD) with three replications, with each experimental plot covering 50 m². A plant density of 31,000 plants ha^{-1} and a fertiliser rate of 220 kg N, 110 kg P_2O_5, and 300 kg K_2O ha^{-1} were used throughout the experiment. Four fertiliser application schedules were evaluated. The CT1 treatment received two fertiliser applications at 8 and 25 days after transplanting (DAT). The three fertiliser application treatments were CT2, CT3, and CT4, with time fertiliser applications at 8, 25, and 40 DAT; 8, 25, and 45 DAT; and 8, 25, and 55 DAT, respectively. Phosphorus (P_2O_5) was applied in full at transplanting, whereas N and K_2O were equally divided among the scheduled fertiliser applications. Thus, N and K_2O were applied in two equal portions under CT1 and in three equal portions under CT2, CT3, and CT4. Seedlings were transplanted on December 21, 2025.

Air-curing method. Burley tobacco leaves were air-cured in curing barns measuring 9 × 5 × 2.5 m. The barns were equipped with two tiers for hanging the tobacco leaves and were covered with dark-colored tarpaulin. At harvest maturity, the leaves were tied to bamboo sticks, each 100 cm in length, with approximately 15 cm between adjacent bunches of leaves. The curing process lasted 24–28 days and consisted of three stages: yellowing, browning, and drying.

Observations and Statistical Analysis: The following agronomic and quality parameters were recorded: growth duration, total number of leaves, number of harvested leaves, topping height, stem diameter, leaf length and width, pest and disease incidence, cured-leaf yield, fresh-to-dry weight ratio, proportion of Grade 1 and Grade 2 leaves, stem proportion, and leaf thickness. Samples of grade 2 leaves collected from the middle portion of the plant canopy were analysed for nicotine content according to CORESTA 85:2017, total nitrogen according to TCVN 7252:2003, reducing sugars according to CORESTA 38:2010, and chloride content according to TCVN 7251:2003. Smoking sensory quality was evaluated according to TCVN 13583:2022. Agronomic and yield data were analysed by using STATISTIX 8.2, and treatment means were compared using the LSD test at $p \leq 0.05$. Parameters without applicable LSD values were evaluated descriptively based on observed trends.

Indicators for Observation and Evaluation: Crop management practices throughout the experiments followed the technical guidelines of the Vietnam Tobacco Institute and Hoa Viet Co., Ltd.Growth and yield-related traits, including leaf number, plant height, and yield components, were recorded in accordance with the National Technical Regulation QCVN 01-85:2012/BNN&PTNT for testing the value for cultivation and use of flue-cured tobacco varieties.Cured-leaf grade was evaluated according to the grading standards of Hoa Viet Co., Ltd. Sensory quality of the cured tobacco leaves was evaluated using a scoring method in accordance with the Vietnamese National Standard TCVN 13583:2022.

RESULTS AND DISCUSSION

Effects of plant density and fertiliser rate on the growth, yield, and quality of Burley tobacco cultivar CSC in Dak Lak prvince

Effects of plant pensity and fertiliser rate on the growth and development of cultivar CSC

Time to bud initiation, first leaf maturity and final harvest: The results in Table 1 showed that the time from transplanting to 50% bud initiation ranged from 67.3 to 68.7 days. Increasing plant density from 27.500 to 34.500 plants ha^{-1} tended to shorten bud initiation from 68.3–68.7 to 67.3–68.0 days. In contrast, increasing the N rate from 190 to 250 kg N ha^{-1} slightly delayed bud initiation by 0.4–0.7 days, depending on plant density. The time to first-leaf maturity at M1 remained stable at 73.0 days across N rates, whereas M2 and M3 showed greater variation (71.0–72.3 days). M3P1 recorded the earliest first-leaf maturity (71.0 days), while M1P1, M1P2, and M1P3 were the latest (73.0 days). Final harvest occurred consistently at 119 days after transplanting across all treatments. Overall, plant density and N fertiliser rate appeared to affect bud initiation and first-leaf maturity but had little effect on the total growth duration of cultivar CSC under Dak Lak conditions. The earlier development observed at higher plant densities may be associated with increased competition for light and nutrients, although the differences among treatments were relatively small.

Leaf Number, Plant Height, Stem Diameter, and Leaf Thickness: The results in Table 2 showed that the total number of leaves ranged from 26.4 to 27.2 leaves plant^{-1}, while the number of harvested leaves ranged from 22.9 to 24.0 leaves plant^{-1}. M3P3 recorded the highest number of harvested leaves (24.0 leaves plant^{-1}). However, neither plant density nor fertiliser rate, either individually or in interaction, significantly affected the total or harvested leaf number of cultivar CSC ($p > 0.05$). Plant density and fertiliser rate had different effects on the other agronomic traits. Topping height increased with increasing plant density and fertiliser rate, from 99.3 cm in M1P1 to 116.5 cm in M3P3. Considering plant density alone, topping height was significantly greater at M3 (34,500 plants ha^{-1}), whereas the difference between M1 (27.500 plants ha^{-1}) and M2 (31.000 plants ha^{-1}) was not significant. In contrast, stem diameter tended to decrease with increasing plant density, ranging from 3.12–3.31 cm at M1 to 2.99–3.13 cm at M3, with the largest diameter recorded in M1P3 (3.31 cm). However, differences among treatment combinations were not significant. Plant density had no significant effect on stem diameter, whereas fertiliser rate had a significant effect, with mean stem diameter increasing from 3.07 cm at P1 to 3.21 cm at P3. Leaf thickness tended to decrease with increasing plant density, from 106.1 µm at M1 to 99.6 µm at M3, but increased with increasing fertiliser rate, from 99.5 µm at P1 to 106.2 µm at P3. Overall, higher plant density promoted greater vertical growth but tended to reduce stem diameter and leaf thickness, whereas increased fertiliser supply tended to enhance stem diameter and leaf thickness.

Leaf dimensions at the lower, middle, and upper canopy positions: The results showed that plant density and fertiliser rate substantially affected leaf size at different canopy positions. Increasing plant density tended to reduce leaf dimensions, whereas higher fertiliser rates promoted lamina development. Among the treatment combinations, M1P3 (lowest plant density and highest fertiliser rate) consistently produced the largest leaves on all three canopy positions. For the lower axillary leaves, leaf length and width ranged from 58.0 - 64.7 cm and 26.3 - 29.4 cm, respectively. M1P3 produced the largest leaves (64.7 × 29.4 cm), whereas M3P1 and M3P2 recorded the smallest dimensions. Increasing plant density from M1 (27.500 plants ha^{-1}) to M3 (34.500 plants ha^{-1}) significantly reduced leaf length and width by approximately 5.5–6.2%, while increasing the fertiliser rate from P1 (190 kg N ha^{-1}) to P3 (250 kg N ha^{-1}) markedly enhanced leaf development. The middle leaves had the greatest dimensions among the three canopy positions, with leaf length and width ranging from 60.8–67.7 cm and 24.0–27.1 cm, respectively. M1P3 again produced the largest leaves (67.7 × 27.1 cm), which were significantly larger than those under M3P1 (60.8 × 24.0 cm). Across the main factors, increasing plant density from M1 to M3 reduced leaf dimensions by approximately 5.6–5.9%, whereas increasing the fertiliser rate from P1 to P3 increased them by approximately 5.6–5.8%. The upper axillary leaves were the smallest, particularly in width, with leaf length and width ranging from 55.7–62.5 cm and 18.7–21.8 cm, respectively. M1P3 produced the largest leaves (62.5 × 21.8 cm), while the smallest values were observed in M3P1 and M3P2. Notably, upper-leaf width was particularly sensitive to plant density, decreasing by up to 7.1% from M1 to M3, whereas increasing the fertiliser rate from P1 to P3 increased leaf dimensions by approximately 6.1–6.3%. Overall, the results indicate that lower plant density combined with a higher fertiliser rate favoured leaf expansion across all canopy positions, with the response being particularly pronounced in the upper leaves.

Effects of Plant Density and Fertiliser Rate on Yield and Quality of Burley Tobacco Cultivar CSC

Yield and Selected Technological Quality Traits: Fresh leaf weight is an important trait directly related to tobacco yield. As shown in Table 4, fresh leaf weight ranged from 49.0 to 67.7 g plant^{-1}, with the highest value recorded in M1P3 (67.7 g) and the lowest in M3P1 (49.0 g). Overall, fresh leaf weight tended to decrease with increasing plant density but increased with higher fertiliser rates. At M1, increasing the fertiliser rate from P1 (190 kg N ha^{-1}) to P3 (250 kg N ha^{-1}) increased fresh leaf weight from 56.3 to 67.7 g plant^{-1}, equivalent to an increase of approximately 16.8%. At P1, increasing plant density from M1 to M3 reduced fresh leaf weight by approximately 13%. Cured-leaf yield ranged from 31.8 to 35.9 quintals ha^{-1}, with the highest yield obtained from M3P3 (35.9 quintals ha^{-1}), which was comparable to M3P2 (35.4 quintals ha^{-1}) but significantly higher than M1P1, M1P2, M2P1, and M3P1. Increasing plant density and fertiliser input generally increased yield. At P2, yield increased significantly from 32.8 quintals ha^{-1} at M1 to 35.4 quintals ha^{-1} at M3. Across fertiliser rates, mean yield increased from 32.8 quintals ha^{-1} at P1 to 34.1 and 34.8 quintals ha^{-1} at P2 and P3, respectively. P2 and P3 were significantly higher than P1 but did not differ significantly from each other, indicating that increasing N from P1 to P2 improved yield, whereas a further increase to P3 provided no significant additional benefit. The proportion of Grade 1 + 2 leaves, an important indicator of raw material quality and economic value, ranged from 80.3 to 85.5%. M1P3 recorded the highest proportion, whereas M3P1 had the lowest.

Table 1. Effects of plant density and fertiliser rate on the time to bud initiation, first leaf maturity, and final harvest of Burley tobacco cultivar CSC in Dak Lak

Treatment	Time from tranplanting to (DAT)		
	50% bud initiation	First leaf maturity	Final harvest
M1P1	68.3	73.0	119.0
M1P2	68.7	73.0	119.0
M1P3	68.7	73.0	119.0
M2P1	67.7	71.3	119.0
M2P2	68.0	72.0	119.0
M2P3	68.3	72.3	119.0
M3P1	67.3	71.0	119.0
M3P2	67.7	71.7	119.0
M3P3	68.0	72.3	119.0

Table 2. Effects of plant density and fertiliser rate on agronomic traits of Burley tobacco cultivar CSCin Dak Lak

Treatment	Total number of leaves	Number of harvested leaves	**Plant height** (cm)	**Stem diameter** (cm)	**Leaf thickness** (μm)
M1P1	26.7	23.2	99.3 c	3.12 ab	103.7
M1P2	26.6	22.9	103.6 bc	3.20 ab	106.2
M1P3	26.8	23.6	107.6 ab	3.31 a	108.3
M2P1	27.1	23.7	105.1 bc	3.09 ab	98.1
M2P2	27.2	23.6	109.2 ab	3.15 ab	102.1
M2P3	26.8	23.9	110.8 ab	3.20 ab	106.6
M3P1	27.0	23.3	106.3 bc	2.99 b	96.7
M3P2	26.8	23.7	111.3 ab	3.05 ab	98.6
M3P3	26.4	24.0	116.5 a	3.13 ab	103.6
$LSD_{0.05\ (MĐ*PB)}$	*0.98*	*1.06*	*9.34*	*0.27*	-
M1	26.7	23.2	103.5 b	3.21a	106.1
M2	27.0	23.8	108.3 ab	3.14a	102.3
M3	26.8	23.6	111.4 a	3.06a	99.6
$LSD_{0.05\ (MĐ)}$	*0.71*	*0.73*	*7.23*	*0.21*	-
P1	26.9	23.4	103.6 b	3.07 b	99.5
P2	26.9	23.4	108.0 a	3.13 ab	102.3
P3	26.7	23.8	111.6 a	3.21 a	106.2
$LSD_{0.05\ (PB)}$	*0.48*	*0.55*	*4.25*	*0.12*	-
CV (%)	*1.74*	*2.26*	*3.85*	*3.80*	-

Note: Means followed by the same letter are not significantly different at the 5% significance level ($p \leq 0.05$).

Table 3. Effects of plant density and fertiliser rate on leaf dimensions of Burley tobacco cultivar CSC in Dak Lak during the 2025–2026 growing season

Unit: cm

Treatment	Lower axillary leaf		Middle leaf		Upper axillary leaf	
	Length	Width	Length	Width	Length	Width
M1P1	60.3 bc	28.8 ab	63.1 bcd	26.0 ab	58.0 bcd	20.5 abc
M1P2	63.7 ab	29.2 ab	66.3 ab	26.6 ab	61.7 ab	21.2 ab
M1P3	64.7 a	29.4 a	67.7 a	27.1 a	62.5 a	21.8 a
M2P1	59.0 c	27.9 abc	61.6 cd	25.3 bc	56.8 cd	20.1 bcd
M2P2	60.8 abc	28.2 ab	63.6 bcd	25.9 ab	58.9 a-d	20.3 bc
M2P3	62.1 abc	28.7 ab	65.0 abc	26.2 ab	59.9 abc	20.5 abc
M3P1	58.1 c	26.3 c	60.8 d	24.0 c	56.1 cd	18.7 d
M3P2	58.0 c	27.4 bc	60.9 d	25.3 bc	55.7 d	19.6 cd
M3P3	60.8 abc	28.7 ab	63.6 bcd	26.1 ab	59.0 a-d	20.7 abc
$LSD_{0.05\ (MĐ*PB)}$	*4.12*	*1.88*	*4.00*	*1.66*	*4.12*	*1.45*
M1	62.9 a	29.1 a	65.7 a	26.6 a	60.7 a	21.2 a
M2	60.6 b	28.3 b	63.4 b	25.8 b	58.5 b	20.3 b
M3	59.0 b	27.5 b	61.8 b	25.1 b	56.9 b	19.7 c
$LSD_{0.05\ (MĐ)}$	*2.09*	*0.82*	*1.94*	*0.77*	*2.18*	*0.61*
P1	59.1 b	27.7 b	61.8 b	25.1 b	56.9 b	19.8 b
P2	60.9 ab	28.3 ab	63.6 ab	25.9 ab	58.8 ab	20.4 ab
P3	62.5 a	28.9 a	65.4 a	26.5 a	60.5 a	21.0 a
$LSD_{0.05\ (PB)}$	*2.52*	*1.20*	*2.49*	*1.05*	*2.49*	*0.93*
CV (%)	*4.04*	*4.13*	*3.81*	*3.95*	*4.13*	*4.44*

Higher fertiliser rates tended to increase the proportion of grade 1 + 2 leaves, while increasing plant density slightly reduced it. Stem proportion ranged from 36.0 to 38.0% and was lowest in M2P3 and highest in M2P2. Because stem proportion is inversely related to the proportion of lamina recovered after stemming, a lower stem proportion is generally favourable for processing efficiency.

Overall, M3P3 produced the highest cured-leaf yield, whereas M1P3 was superior in fresh leaf weight and grade 1 + 2 proportion. M2P3 provided a more balanced combination of yield, leaf grade, and low stem proportion. Notably, M3P2 produced a yield comparable to M3P3 while requiring a lower N rate, suggesting greater fertiliser-use efficiency.

Table 4. Effects of plant density and fertiliser rate on yield and technological quality traits of Burley tobacco cultivar CSC in Dak Lak (2025–2026)

Treatment	**Fresh leaf weight** (g)	**Cured-leaf yield** (quintals ha⁻¹)	**Grade 1 + 2 leaves** (%)	**Stem proportion** (%)
M1P1	56.3	31.8d	82.4	37.3
M1P2	64.7	32.8 cd	83.3	37.0
M1P3	67.7	33.8 a-d	85.5	36.7
M2P1	52.0	32.7 cd	82.6	37.0
M2P2	53.3	34.0 abc	82.9	38.0
M2P3	55.0	34.7 abc	84.6	36.0
M3P1	49.0	33.7 bcd	80.3	37.3
M3P2	58.0	35.4 ab	83.8	36.7
M3P3	60.3	35.9 a	82.5	37.3
$LSD_{0.05\ (MD*PB)}$	-	*2.15*	-	-
CV (%)	-	*3.42*	-	-

Note: *Means followed by the same letter are not significantly different at the 5% significance level ($p \leq 0.05$). Cured-leaf yield: M1 = 32.8 b; M2 = 33.8 ab; M3 = 35.0 a; $LSD_{0.05}$(plant density) = 1.36 quintals ha⁻¹. P1 = 32.8 b; P2 = 34.1 a; P3 = 34.8 a; $LSD_{0.05}$(fertiliser rate) = 1.19 quintals ha⁻¹.*

Table 5. Chemical composition of Burley tobacco cultivar CSC under different plant densities and fertiliser rates in Dak Lak during the 2025–2026 growing season

Treatment	**Chemical composition** (%)			
	Nicotine	Total nitrogen	Reducing sugars	Chloride
M1P1	3.14	3.35	2.3	0.20
M1P2	3.42	3.73	2.5	0.23
M1P3	4.04	3.99	1.8	0.22
M2P1	3.31	3.79	1.9	0.19
M2P2	3.39	3.87	1.5	0.20
M2P3	4.18	3.54	2.8	0.27
M3P1	3.42	3.53	3.2	0.27
M3P2	4.02	3.64	1.9	0.25
M3P3	4.67	4.01	1.4	0.19

Table 6. Sensory evaluation scores of CSC tobacco materials across planting densities and fertilizer application rates in Dak Lak (2025–2026 crop)

Unit: points

Treatment	**Aroma**[1]	**Taste**[2]	**Strength**[3]	**Burn rate**[4]	**Color**[5]	**Total points**[6]
M1P1	9.1	11.0	6.2	4.0	6.0	36.3
M1P2	9.3	10.8	6.5	4.0	6.0	36.6
M1P3	9.7	10.9	6.3	4.0	6.0	36.9
M2P1	9.4	11.3	6.1	4.0	6.0	36.8
M2P2	9.3	11.2	6.1	4.0	6.0	36.6
M2P3	9.3	11.2	6.1	4.0	6.0	36.6
M3P1	9.5	11.5	6.0	4.0	6.0	37.0
M3P2	9.3	11.3	6.3	4.0	6.0	36.9
M3P3	9.1	11.2	5.8	4.0	6.0	36.1

Note: Sensory criteria classification scale:[1]Aroma grading: Good: 10.0–12.5; Fair: 7.5–10.0; Moderate: 5.0–7.5; Poor: 2.5–a: 1.5–3.0 points;[6]Total point grading: Good: 41.0–51.3; Fair: 30.8–41.0; Moderate: 20.5–30.8; Poor: 10.3–20.5 points.

Table 7. Pest and disease incidence in the CSC variety under different experimental treatments in Dak Lak during the 2025–2026 growing season

Công thức	**Tỷ lệ sâu bệnh hại** (%)					
	Tobacco aphid	***Armyworm***	***Tobacco budworm***	***Bacterial wilt***	***Tobacco leaf curl virus (TLCV)***	***Cucumber mosaic virus (CMV)***
M1P1	3.6	3.3	2.0	4.7	1.3	0.3
M1P2	4.0	3.7	2.3	4.0	1.7	0.7
M1P3	3.7	3.3	1.3	3.7	1.7	0.3
M2P1	4.3	5.0	2.0	3.0	1.3	0.3
M2P2	4.7	6.3	1.3	5.0	1.7	0.7
M2P3	4.3	4.0	1.3	4.7	1.7	0.7
M3P1	4.7	5.7	1.3	3.0	1.7	1.0
M3P2	4.3	4.7	1.7	5.0	0.7	0.7
M3P3	5.0	6.0	1.3	6.0	1.3	1.0

Table 8. Effects of fertilizer application frequency and timing on the growth and development of the CSC variety grown in Dak Lak (2025-2026)

Treatment	**Time from tranplant** (số ngày) **to**		
	50% bud initiation	First leaf maturity	Final harvest
CT1	63.7	65.7	114.0
CT2	64.3	67.7	114.0
CT3	64.3	67.7	114.0
CT4	64.0	65.7	114.0

Table 9. Effects of fertilizer application frequency and timing on growth parameters of the CSC variety grown in Dak Lak during the 2025-2026 cropping season

Treatment	Total number of leaves	Number of harvested leaves	Topping height (cm)	Stem diameter (cm)
CT1	25.9	23.1	108.3 bc	3.09
CT2	26.2	23.7	114.8 ab	3.12
CT3	25.8	23.3	117.0 a	3.17
CT4	26.6	23.5	106.5 c	3.06
$LSD_{0.05}$	*0.79*	*1.31*	*7.90*	*0.31*
CV (%)	*1.51*	*2.81*	*3.54*	*4.92*

Table 10. Effects of fertilizer application frequency and timing on leaf dimensions of the CSC variety in Dak Lak during the 2025–2026 cropping season

Unit: cm

Công thức	Lower axillary leaf		Middle leaf		Upper axillary leaf	
	Length	Width	Length	Width	Length	Width
CT1	60.5 ab	27.8 ab	62.5 ab	24.1 bc	57.9 bc	23.0 ab
CT2	62.6 a	28.8 a	65.4 a	25.6 ab	60.0 ab	23.8 a
CT3	64.7 a	29.7 a	65.9 a	26.4 a	61.9 a	24.6 a
CT4	56.7 b	26.0 b	60.3 b	22.9 c	56.1 c	21.5 b
$LSD_{0.05}$	*5.21*	*2.52*	*3.99*	*2.24*	*3.65*	*2.07*
CV (%)	*4.26*	*4.48*	*3.14*	*4.52*	*3.10*	*4.45*

Table 11. Effects of fertilizer application frequency on yield and technical quality parameters of the CSC variety in Dak Lak during the 2026 cropping season

Treatment	**Cured-leaf yield** (quintals ha^{-1})	**Grade 1 + 2 leaves** (%)
CT1	33.8 ab	82.8
CT2	35.3 a	84.6
CT3	36.1 a	84.9
CT4	32.3 b	83.4
$LSD_{0.05}$	*2.63*	–
CV (%)	*3.82*	–

Table 12. Chemical composition of raw materials of the CSC variety under different fertilizer application frequencies

Công thức	Chemical composition (%)			
	Nicotine	Total nitrogen	Reducing sugars	Chloride
CT1	2.88	3.16	1.0	0.44
CT2	2.93	3.57	1.3	0.37
CT3	3.09	3.49	1.6	0.40
CT4	2.84	2.85	2.1	0.61

Table 13. Sensory smoking evaluation scores of raw materials of the CSC tobacco variety in the fertilizer application frequency and timing trial in Dak Lak during the 2025–2026 cropping season

Unit: points

Treatment	Aroma	Taste	Strength	Burn rate	Color	Total points
CT1	9.4	11.2	6.2	4.0	6.0	36.8
CT2	9.2	10.9	6.1	4.0	6.0	36.2
CT3	9.5	11.2	6.0	4.0	6.0	36.7
CT4	9.0	11.0	6.1	3.6	6.0	35.7

Evaluation of raw material quality of Burley tobacco cultivar CSC in Dak Lak

Chemical Composition: In tobacco production, nicotine, reducing sugar, and chloride are important factors that affect tobacco quality and product value. The chemical composition of the experimental treatments is presented in Table 5. Nicotine is one of the most important quality attributes of Burley tobacco. In this study, nicotine content ranged from 3.14 to 4.67%, with the highest recorded value in M3P3 (4.67%) and the lowest in M1P1 (3.14%). At M1, increasing the fertiliser rate from P1 to P3 increased nicotine content from 3.14 to 4.04%. Similarly, at P1, increasing plant density from M1 (27.500 plants ha^{-1}) to M3 (34.500 plants ha^{-1}) resulted in a slight increase in nicotine content, from 3.14 to 3.42%.

This response differs from the conventional view that nicotine accumulation increases under lower plant density but is consistent with several recent studies conducted within specific density ranges. Padır and Ekren, 2024 reported that increasing nicotine content in flue-cured tobacco cultivar K326 as plant density increased from 23.810 to 35.714 plants ha^{-1}. Similarly, Usman et al., 2017 found that mean nicotine content of flue-cured tobacco cultivars increased from 2.17 to 2.46%, when plant density increased from approximately 15.152 to 18.519 plants ha^{-1}. Studies in China have also reported increased nicotine or total alkaloid accumulation with increasing plant density within certain ranges in flue-cured tobacco (Zhang et al., 2018, 2024) and cigar tobacco cultivar Xiangxue-1 (Chen et al., 2026).

Total nitrogen content ranged from 3.35 to 4.01%, with the highest and lowest values observed in M3P3 and M1P1, respectively. Nitrogen content varied relatively little with plant density but increased from 3.56% at P1 to 3.85% at P3, indicating a stronger response to fertiliser rate. This result is consistent with the findings of Zhu et al., 2024). Reducing sugar content ranged from 1.4 to 3.2%, with the highest value in M3P1 and the lowest in M3P3. Across fertiliser rates, reducing sugar content tended to decline from 2.47% at P1 to approximately 2.0% at P2 and P3. At M3, increasing the fertiliser rate from P1 to P3 reduced reducing sugar content from 3.2 to 1.4%. This response may reflect a shift in carbon-nitrogen metabolism under higher N supply, favouring nitrogen and alkaloid accumulation while limiting carbohydrate accumulation in the leaves, as reported by Chen et al., 2020; Ren et al., 2025. Chloride content is another important quality attribute because excessive chloride can impair tobacco combustibility and reduce raw-material quality. In the present study, chloride content remained low across all treatments, ranging from 0.19 to 0.27%, well below the 1% level generally considered problematic for tobacco combustibility. Thus, none of the treatments appeared to pose a chloride-related risk to leaf quality.

Sensory assessment of raw tobacco leaves: The sensory evaluation results of raw material quality for the CSC variety under different planting densities and fertilizer treatments are shown in Table 6. The sensory evaluation results presented in Table 6 show that the total smoking scores of the CSC variety grown in Dak Lak ranged from 36.1 to 37.0 points, corresponding to the "Fair" grade (30.8–41.0 points). The CSC tobacco raw material exhibited sensory characteristics typical of Burley tobacco, including a distinct aroma (9.1–9.7 points) and a relatively strong and rich smoking impact, consistent with its nicotine content (6.0–6.5 points). The smoking taste was relatively smooth, with little tongue irritation, which was associated with the relatively low reducing sugar content (10.8–11.5 points). Both combustibility and colour received scores of 4.0 and 6.0, respectively, corresponding to the maximum scores within their respective rating scales. These results suggest that the cultivation, harvesting, and air-curing practices were appropriate for producing raw material with desirable physical and sensory characteristics.

Overall, the sensory evaluation indicated that the CSC variety cultivated in Dak Lak produced Burley tobacco raw material of acceptable quality, with an overall rating comparable to that of KY14, a widely recognised high-quality Burley variety in Vietnam. Both varieties were classified as "Fair" based on the total sensory score. These findings suggest that CSC has potential for commercial production of Burley tobacco raw material in Dak Lak and may provide a promising alternative for domestic raw material development and, potentially, export-oriented production. Pests and diseases are major factors directly affecting tobacco yield and quality. Monitoring and evaluating pest and disease incidence during the 2025-2026 growing season provided a scientific basis for recommending the CSC variety and developing integrated pest management strategies for large-scale production. The results are presented in Table 7. Overall, pest and disease incidence in the CSCvariety during the 2025-2026 growing season remained at negligible to low levels and did not substantially affect plant growth and development. Specifically, three major insect pests were recorded: tobacco budworm, tobacco aphid, and beet armyworm, with incidence ranging from 1.3% to 6.3%. Among these pests, beet armyworm was the most prevalent, with an incidence of 3.3–6.3%, followed by tobacco aphid (3.6-5.0%) and tobacco budworm (1.3-2.3%). Although tobacco aphids occurred relatively frequently, their population density remained low (less than 20 aphids per upper leaf), resulting in negligible damage to the crop.

Two viral diseases were recorded in the field, namely tobacco leaf curl virus (TLCV) and cucumber mosaic virus (CMV). TLCV occurred at a higher incidence (0.7-1.7%) than CMV (0.3-1.0%). Bacterial wilt has been one of the major diseases affecting tobacco production in Dak Lak in recent years. In the present study, bacterial wilt incidence among the experimental treatments ranged from 3.0% to 6.0%. The disease generally became more prevalent toward the end of the growing season, when most leaves had already been harvested; therefore, its effect on final tobacco yield and quality was limited. Regarding the effects of agronomic practices, increasing plant density from 27.500 to 34.500 plants ha^{-1} and increasing nitrogen application tended to increase the incidence of most major pests and diseases, particularly tobacco aphid, beet armyworm, bacterial wilt, TLCV, and CMV. In contrast, tobacco budworm did not show a consistent response to changes in plant density or nitrogen application. For bacterial wilt, increasing the nitrogen rate resulted in a clear increase in mean disease incidence, from 3.56% under P1 to 4.67% under P2 and 4.78% under P3. The observed increase in pest and disease pressure with increasing plant density and nitrogen application in CSC was consistent with previous observations for the KY14 and CSC varieties in 2023 and 2024. Overall, plant density and fertiliser rate had noticeable effects on the growth, yield, and quality of CSC tobacco. Among the treatments evaluated, M3P2, comprising a planting density of 34.500 plants ha^{-1} and fertiliser application at $220N:110P_2O_5:300K_2O$ kg ha^{-1}, produced favourable yield, grade, and quality while using nitrogen more efficiently than M3P3, which received $250N:110P_2O_5:300K_2O$ kg ha^{-1}. Increasing the nitrogen rate to 250 kg N ha^{-1} increased yield, but the difference was not significant compared with the 220 kg N ha^{-1} rate. Moreover, the higher nitrogen rate increased bacterial wilt incidence and resulted in excessive nicotine accumulation, which may adversely affect tobacco quality. Therefore, the M3P2 treatment appears to provide a more appropriate balance between productivity, raw material quality, and fertiliser efficiency for CSC tobacco production under the conditions of Dak Lak.

Effects of Fertilizer Application Frequency on the Growth and Development of the CSC Tobacco Variety Cultivated in Dak Lak

Effects of Fertilizer Application Frequency on Growth and Development Parameters of the CSC Variety

Growth period of the CSC variety: The results presented in Table 8 indicate that the frequency and timing of fertilizer application induced only minor variations in the days to 50% flowering and first leaf maturity, while exerting no influence on the final harvest date of the CSC variety in Dak Lak during the 2025-2026 growing season. Specifically, applying fertilizer in two split doses during early growth stages (8 and 25 days after transplanting- DAT) under Treatment 1 (CT1) resulted in the earliest onset of 50% flowering (63.7 DAT) and first leaf maturity (65.7 DAT). Splitting fertilization into three applications slightly delayed 50% flowering and first leaf maturity by 0.3-0.6 days. Among these 3-split regimes, CT2 (8, 25, and 40 DAT) and CT3 (8, 25, and 45 DAT) exhibited the longest durations to 50% flowering and first leaf maturity, with no statistically significant differences between them. Conversely, delaying the third application to 50 DAT in CT4 (8, 25, and 50 DAT) slightly advanced both stages to 64.0 and 65.7 DAT, respectively. Regarding the final harvest, all treatments consistently required 114.0 DAT to complete harvesting, demonstrating that this developmental benchmark is highly stable and largely independent of fertilizer timing. Overall, adjusting fertilizer application frequency and schedule primarily caused minor shifts in the timing of 50% flowering and initial leaf ripening, without altering the overall crop duration of the CSC variety.

Growth parameters of the CSC variety: The results in Table 9 indicated that fertiliser application frequency and timing had significant effects on topping plant height and stem diameter; conversely, no significant impact was observed on the number of leaves per plant.

The total number of leaves per plant in the CSC variety ranged from 25.8 to 26.6, while the number of harvestable leaves ranged from 23.1 to 23.7 leaves, with no significant differences among treatments. Plant height at topping was strongly affected by the fertilisation regime. In CT1, in which fertiliser was applied twice at early growth stages (8 and 25 days after transplanting [DAT]), plant height at topping reached 108.3 cm. Increasing the application frequency to three splits, with the third application at 40 DAT (CT2) or 45 DAT (CT3), significantly increased plant height by 6.5–8.7 cm compared with CT1. No significant difference was observed between CT2 and CT3, although CT3 recorded the highest value (117.0 cm). In contrast, delaying the third application to 50 DAT (CT4) reduced plant height at topping to 106.5 cm, which was lower than that recorded in CT1. Stem diameter showed a similar response to plant height, with the highest values recorded in CT2 and CT3 (3.12–3.17 cm), followed by CT1 (3.09 cm), while CT4 had the lowest value of 3.06 cm.

Overall, increasing fertiliser application frequency and the timing of fertiliser application significantly affected plant height at topping and stem diameter, but had little effect on the number of leaves per plant. A three-split fertilisation regime, with the third application at approximately 40–45 DAT, appeared to provide the most favourable growth response. Delaying the third application until 50 DAT reduced plant height and stem diameter, suggesting lower fertiliser-use efficiency when nutrients were supplied at a relatively late growth stage. This response may be related to the reduced capacity for nutrient uptake and assimilation as plants approached physiological maturity and senescence. These findings are consistent with those of Badr (1968), who reported that the growth rate and nitrogen uptake of Burley tobacco increase markedly during the pre-topping period, with a substantial proportion of nitrogen accumulated in the stems and leaves before topping and peak nitrogen uptake occurring during the month preceding topping.

Leaf dimensions at lower, middle, and upper stalk positions: The results presented in Table 10 indicate that fertiliser application frequency and timing significantly affected leaf dimensions at all three stalk positions (lower, middle, and upper leaves). In Treatment 1 (CT1), in which fertiliser was applied twice at early growth stages (8 and 25 days after transplanting [DAT]), the length × width of the lower, middle, and upper leaves was 60.5×27.8 cm, 62.5×24.1 cm, and 57.9×23.0 cm, respectively. Increasing the number of fertiliser applications to three splits, with the third application at 40 DAT (CT2) or 45 DAT (CT3), markedly increased leaf dimensions at all three stalk positions. Among the treatments, CT3 recorded the highest values, reaching 64.7×29.7 cm for the lower leaves, 65.9×26.4 cm for the middle leaves, and 61.9×24.6 cm for the upper leaves. No significant differences were observed between CT2 and CT3; however, both treatments produced significantly larger leaves than CT4. In contrast, delaying the third fertiliser application to 50 DAT (CT4) resulted in a significant reduction in leaf dimensions across all three stalk positions. CT4 recorded the lowest values, at 56.7×26.0 cm for the lower leaves, 60.3×22.9 cm for the middle leaves, and 56.1×21.5 cm for the upper leaves. Overall, the results indicate that a three-split fertilisation regime, with the third application at approximately 40-45 DAT, was more favourable for leaf expansion and development of the CSC variety than the other fertilisation schedules evaluated. Delaying the third application until 50 DAT reduced leaf expansion, suggesting that timely nutrient availability during the active leaf-development stage is important for maximising leaf size in CSC tobacco.

Cured Leaf Yield and Quality Grading: The actual cured leaf yield and grade distribution of the CSC tobacco variety were significantly affected by fertiliser application frequency and timing (Table 11). Under Treatment 1 (CT1), in which fertiliser was applied twice at early growth stages (8 and 25 days after transplanting [DAT]), the actual cured leaf yield was 33.8 quintals ha^{-1}. Increasing the application frequency to three splits, with the third application at 40 DAT (CT2) or 45 DAT (CT3), progressively increased cured leaf yield, with the highest yield recorded in CT3 (36.1 quintals ha^{-1}). In contrast, delaying the third application until 50 DAT (CT4) resulted in a marked reduction in yield to 32.3 quintals ha^{-1}. Statistically, CT2 and CT3 produced significantly higher yields than CT4, whereas CT1 showed an intermediate yield and did not differ significantly from the other treatments.

The proportion of Grade I + II cured leaves was highest in CT2 and CT3, ranging from 84.6% to 84.9%, followed by CT4 (83.4%), and was lowest in CT1 (82.8%). These results indicate that increasing fertiliser application frequency, when combined with appropriate application timing, can improve both cured leaf yield and grade distribution. In contrast, delaying the third fertiliser application until 50 DAT, when plants were approaching topping and the later stages of vegetative development, did not provide a yield advantage and may have reduced the efficiency of late-season nutrient application. The observed response is consistent with previous findings reported by Badr (1968) and MacKown et al. (1999), who emphasised the importance of synchronising nitrogen availability with the periods of active growth and nutrient accumulation in tobacco. Overall, the results suggest that three fertiliser applications, with the third application at approximately 40–45 DAT, provide a more favourable fertilisation schedule for achieving high cured leaf yield and a greater proportion of higher-grade leaves in CSC tobacco under the conditions of Dak Lak.

Effects of fertilizer application frequency on raw material quality

Chemical composition: The analytical results of major chemical constituents in the raw material are presented in

Table 12. Chemical composition is a critical quality indicator determining the grade of Burley tobacco, which typically requires high nicotine and low reducing sugar content. The results presented in Table 12 show that increasing the application frequency from two splits in CT1 (8 and 25 DAT) to three splits in CT2 (8, 25, and 40 DAT) and CT3 (8, 25, and 45 DAT) tended to elevate leaf nicotine concentration (increasing from 2.88% to 3.09%), with CT3 recording the highest nicotine level (3.09%). Conversely, delaying the third application to 50 DAT (CT4) resulted in a lower nicotine content of 2.84%, which was below that of CT1. Total nitrogen content ranged from 2.85% to 3.57%, peaking in CT2 (3.57%), followed by CT3 (3.49%) and CT1 (3.16%), and reaching its lowest level in CT4 (2.85%). This indicates that timely nitrogen supplementation enhances nitrogen accumulation in plants. However, applying fertiliser excessively late-nearing the topping and harvesting stages in CT4—did not increase total nitrogen; instead, it caused a sharp decline due to plant senescence, which impaired nitrogen absorption and assimilation capacity. This finding aligns with the research by MacKown et al. (1999), who noted that late nitrogen applications increase leaf nitrate concentrations in Burley tobacco, even though yield may be improved.

Reducing sugar content across all experimental treatments of the CSC variety remained at a low threshold, ranging from 1.0% to 2.1%, which fully satisfies the standard quality specifications for Burley raw materials. Reducing sugar levels showed a gradual upward trend with increased fertilisation frequency and delayed timing: lowest in CT1 (1.0%), rising to 1.3% in CT2, 1.6% in CT3, and reaching a maximum in CT4 (2.1%). This demonstrates that late fertiliser application, particularly nitrogen, tends to increase reducing sugar accumulation in Burley tobacco raw material. Low chloride content is generally considered favourable for the quality and smoking characteristics of tobacco leaves. In the present study, chloride content across the experimental treatments ranged from 0.37% to 0.61%. The CT1, CT2, and CT3 treatments maintained relatively low chloride concentrations, all below 0.44%, whereas CT4 recorded a notably higher value of 0.61%. Excessive chloride accumulation in tobacco leaves may adversely affect smoking characteristics, particularly by reducing combustibility and burn rate. Therefore, the lower chloride concentrations observed under CT1–CT3 suggest more favourable chemical characteristics for cured tobacco quality than those observed under the late fertiliser application regime in CT4.

Sensory smoking properties: The evaluation results of the smoking quality of the CSC tobacco variety across experimental treatments are summarized in Table 13. The sensory evaluation results presented in Table 13 show that the total smoking scores across the experimental treatments ranged from 35.7 to 36.8 points. CT1, CT2, and CT3 recorded total scores ranging from 36.2 to 36.8 points and were all classified as "Fair" according to the sensory evaluation scale. In contrast, CT4 recorded the lowest total score (35.7 points) and was classified as "Moderate." For aroma, CT3 achieved the highest score (9.5 points), followed by CT1 (9.4 points), CT2 (9.2 points), and CT4 (9.0 points). Regarding taste, CT1 and CT3 had the highest scores (11.2 points), followed by CT4 (11.0 points), while CT2 recorded the lowest value. The differences among treatments in terms of smoking strength and colour were relatively small, with all treatments maintaining scores within the "Fair" range.

For combustibility, CT1, CT2, and CT3 all received the maximum score of 4.0 points, whereas CT4 recorded the lowest score (3.6 points). This lower combustibility may be related to the higher chloride content of CT4 (0.61%), as shown in Table 12. These results suggest that delaying fertiliser application until 50 DAT, close to the harvesting stage, may adversely affect the smoking characteristics of cured tobacco, while also increasing chloride accumulation in the leaves, leading to reduced combustibility and the overall sensory score. Tobacco yield is determined by both individual leaf biomass and plant population per unit area. Increasing plant density generally reduces individual leaf size and weight but can increase yield per unit area because of the greater number of plants per hectare (Collins et al., 1993; Tso, 1990). Increasing plant density in combination with an adequate nitrogen supply has also been reported to increase plant height, nicotine, and total nitrogen contents, as well as the incidence of certain major pests and diseases (Shen et al., 2019). In the present study, increasing the nitrogen rate from 190 to 220 kg N ha^{-1} resulted in a clear improvement in cured leaf yield. However, a further increase to 250 kg N ha^{-1} produced only a marginal yield increase, while reducing leaf grade and overall tobacco quality. This finding is consistent with previous studies on Burley tobacco reported by MacKown et al., 1999, Frame et al., 2011, and Bailey et al., 2025. The frequency and timing of fertiliser application also played an important role in determining tobacco yield and quality. Increasing the number of applications from two splits at 8 and 25 DAT to three splits, with the third application at either 40 or 45 DAT, substantially improved cured leaf yield and quality. However, delaying the third application until 50 DAT resulted in reductions in both yield and quality. The results indicate that synchronising fertiliser availability with the active growth and nutrient accumulation stages of CSC tobacco is important for achieving favourable production outcomes. Based on the combined results of growth, yield, grade distribution, chemical composition, pest and disease incidence, and sensory characteristics, an appropriate agronomic package for Burley CSC tobacco under the conditions of Dak Lak was identified. This package comprised a planting density of 34.500 plants ha^{-1}, a fertiliser rate of 220 N:110 P_2O_5:300 K_2O kg ha^{-1}, and three fertiliser applications at 8, 25, and 45 DAT. This treatment combination provided a favourable balance among cured leaf yield, the proportion of higher-grade leaves, chemical composition, and smoking characteristics, and therefore represents a promising production practice for CSC Burley tobacco.

CONCLUSION

Planting density and fertiliser rate had pronounced effects on the growth, yield, and quality of Burley CSC tobacco. A planting density of 34.500 plants ha^{-1} combined with a fertiliser rate of 220N:110P_2O_5:300K_2O kg ha^{-1} showed the most favourable overall performance, producing a cured leaf yield of 35.4 quintals ha^{-1}, a grade I + II leaf proportion of 83.8%, a nicotine content of 4.02%, and a total smoking score of 36.9 points, corresponding to the "Fair" grade. Increasing the nitrogen rate to 250 kg N ha^{-1} did not significantly increase yield compared with 220 kg N ha^{-1}, but increased bacterial wilt incidence and resulted in excessive nicotine accumulation, which adversely affected smoking quality. A three-split fertiliser application at 8, 25, and 45 days after transplanting (DAT) was the most favourable fertilisation schedule for CSC tobacco under the conditions of Dak Lak. This schedule resulted in a cured leaf yield of 36.1 quintals ha^{-1}, a grade I + II leaf proportion of 84.9%, and a total smoking score of 36.7 points. Based on the combined results, a preliminary agronomic package for CSC Burley tobacco is proposed, comprising a planting density of 34,500 plants ha^{-1}, a fertiliser rate of 220 N:110 P_2O_5:300 K_2O kg ha^{-1}, and three fertiliser applications at 8, 25, and 45 DAT. This production practice showed a favourable balance among yield, leaf grade, chemical composition, and smoking quality. Further multi-season validation over at least one to two additional growing seasons in Dak Lak is recommended to confirm the stability and consistency of these agronomic practices under varying environmental conditions.

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