# Balancing Nutrient Use for Flue-Cured Tobacco

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**Field trials determined the optimal fertilizer rates for flue-cured tobacco production in Qujing, Yunnan Province. The study identified strategies for enhanced crop yield, quality, and profitability, as well as improved fertilizer use efficiencies.**

For the 4 million flue-cured tobacco growers in Yunnan, the gap between current and potential yields is understandably of great interest. Balanced nitrogen (N), phosphorus (P), and potassium (K) fertilization is a crucial step towards improved profitability and productivity in this high value crop. The objective of this study was to quantify this relationship and use the responses of flue-cured tobacco to fertilizer as a starting point in providing science-based guidance for nutrient management in Yunnan's production centers.

Treatments were designed to compare a soil-test-based (Agro Services International method) 'optimum' (OPT) fertilizer application against three treatments which omitted N, P, or K, and six other unique NPK combinations (**Table 1**). Flue-cured tobacco was planted at a density of 15,000 plants/ha in a wheat-to-bacco crop rotation. Fertilizers were applied twice during the growing season with 60% applied basally and the remainder using topdressing. Six trials were conducted in Qujing over 6 years (2000 to 2006). This article covers the first 5 years of experimentation.


**Improved** growth of tobacco is clear. Quality was also improved.

The effects of fertilizer treatment on yield and income are summarized in **Table 2**. Relative to the OPT treatment, omission of N, P, or K reduced yields by 6 to 48%. Leaf yield was highest under the OPT and two other treatments that provided combinations of at least 195 kg $P_2O_5$/ha and 240 kg $K_2O$/ha along with 135 kg N/ha. Stem yields were consistently one-third to one-quarter of leaf yields, but followed a trend similar to that observed with leaf yields (data not shown).

Tobacco industry standards and price premiums demand that growers manage for the dual goal of achieving both high yields and a high quality product. In fact, the high value of flue-cured tobacco often depends more on its quality characters than yield. Therefore, tobacco leaf contents of sugar, nicotine, and protein were determined to evaluate the effect of fertilization on product quality (**Table 3**).

**Table 1**. NPK treatments (kg/ha) on tobacco in Qujing, Yunnan.

| Treatment | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|
| OPT-N | 0 | 195 | 240 |
| OPT-P | 135 | 0 | 240 |
| OPT-K | 135 | 195 | 0 |
| $N_{135}P_{195}K_{180}$ | 135 | 195 | 180 |
| $N_{135}P_{195}K_{240}$(OPT) | 135 | 195 | 240 |
| $N_{90}P_{195}K_{240}$ | 90 | 195 | 240 |
| $N_{180}P_{195}K_{240}$ | 180 | 195 | 240 |
| $N_{135}P_{150}K_{240}$ | 135 | 150 | 240 |
| $N_{135}P_{240}K_{240}$ | 135 | 240 | 240 |
| $N_{135}P_{195}K_{300}$ | 135 | 195 | 300 |

**Table 2**. Impact of nutrient management on flue-cured tobacco profit.

| Treatment | Leaf weight, kg/ha | Production value, US$/ha | Cost, US$/ha | Profit, US$/ha | Profit, ±% vs. OPT |
|---|---|---|---|---|---|
| OPT-N | 1,707 d[1] | 1,465 e | 282 | 1,183 | -48.0 |
| OPT-P | 1,785 d | 2,420 bc | 279 | 2,141 | -5.8 |
| OPT-K | 1,792 d | 1,972 d | 233 | 1,738 | -23.5 |
| $N_{135}P_{195}K_{180}$ | 2,389 c | 2,612 abc | 314 | 2,297 | 1.1 |
| $N_{135}P_{195}K_{240}$(OPT) | 2,766 a | 2,614 abc | 341 | 2,273 | - |
| $N_{90}P_{195}K_{240}$ | 2,525 b | 2,260 cd | 321 | 1,939 | -14.7 |
| $N_{180}P_{195}K_{240}$ | 2,427 bc | 2,481 abc | 361 | 2,120 | -6.7 |
| $N_{135}P_{150}K_{240}$ | 2,468 bc | 2,509 abc | 327 | 2,182 | -4.0 |
| $N_{135}P_{240}K_{240}$ | 2,782 a | 2,777 ab | 355 | 2,421 | 6.5 |
| $N_{135}P_{195}K_{300}$ | 2,819 a | 2,797 a | 368 | 2,429 | 6.9 |

[1] Numbers followed by the same letter are not significantly different.

**Table 3**. Impact of nutrient management on flue-cured tobacco quality.

| Treatment | Sugar content, % | Nicotine content, % | Protein content, % | Sugar/ nicotine |
|---|---|---|---|---|
| OPT-N | 18.95 | 3.52 | 9.92 | 5.38 |
| OPT-P | 24.43 | 4.50 | 11.33 | 5.43 |
| OPT-K | 23.86 | 4.33 | 11.69 | 5.51 |
| $N_{135}P_{195}K_{180}$ | 25.89 | 4.32 | 11.59 | 5.99 |
| $N_{135}P_{195}K_{240}$(OPT) | 27.61 | 3.10 | 11.24 | 8.91 |
| $N_{90}P_{195}K_{240}$ | 27.38 | 3.82 | 11.15 | 7.17 |
| $N_{180}P_{195}K_{240}$ | 26.52 | 4.56 | 12.56 | 5.82 |
| $N_{135}P_{150}K_{240}$ | 26.42 | 4.44 | 11.28 | 5.95 |
| $N_{135}P_{240}K_{240}$ | 27.66 | 3.53 | 11.04 | 7.84 |
| $N_{135}P_{195}K_{300}$ | 27.90 | 3.21 | 11.32 | 8.69 |

**Table 4**. Effect of nutrient management on nutrient allocation in tobacco.

| | N content, % | | P content, % | | K content, % | |
|---|---|---|---|---|---|---|
| Treatment | Leaf | Stem | Leaf | Stem | Leaf | Stem |
| OPT-N | 1.45 | 1.16 | 0.31 | 0.17 | 2.87 | 1.98 |
| OPT-P | 1.88 | 1.49 | 0.10 | 0.05 | 2.82 | 1.89 |
| OPT-K | 1.89 | 1.53 | 0.19 | 0.16 | 0.82 | 0.76 |
| $N_{135}P_{195}K_{180}$ | 1.98 | 1.55 | 0.32 | 0.21 | 2.74 | 1.91 |
| $N_{135}P_{195}K_{240}$(OPT) | 2.52 | 1.66 | 0.36 | 0.22 | 3.14 | 2.42 |
| $N_{90}P_{195}K_{240}$ | 2.04 | 1.36 | 0.26 | 0.17 | 2.76 | 2.38 |
| $N_{180}P_{195}K_{240}$ | 2.50 | 1.65 | 0.26 | 0.19 | 2.95 | 2.35 |
| $N_{135}P_{150}K_{240}$ | 1.95 | 1.58 | 0.32 | 0.23 | 2.75 | 2.29 |
| $N_{135}P_{240}K_{240}$ | 2.48 | 1.63 | 0.36 | 0.22 | 2.99 | 2.44 |
| $N_{135}P_{195}K_{300}$ | 2.49 | 1.66 | 0.35 | 0.21 | 3.13 | 2.41 |

The different nutrients and fertilizer rates had a considerable effect on sugar content in leaves, but did not influence protein. According to industry criteria, the OPT treatment produced better overall quality due to a higher preferred balance between nicotine and sugar contents.

In terms of economic returns to growers, differences in NPK application demonstrated a significant effect on profitability per hectare. Omission of N had the largest impact on net return, followed by K and then P. Although the OPT provided the best overall product quality as perceived by the processing industry, the yield and quality combination achieved by the treatment providing the highest K rate of 300 kg $K_2O$/ha did return the highest overall production value and best economic return to growers.

Maximum use efficiency for applied nutrients should fall in stride with those crop production systems which are both high yielding and most profitable. Plant nutrient allocation was determined by measurement of plant tissue nutrient concentrations. Leaf nutrient concentrations were sensitive indicators to nutrient omission and were consistently higher for treatments supporting the greatest yields (**Table 4**). The majority of macronutrients were transferred to the leaves. Leaf K concentrations were highest among the three macronutrients.

Similar to the yield response, N uptake and use efficiency was influenced by both P and K rate. Optimal N utilization by flue-cured tobacco was achieved with 135 kg N/ha, a minimum of 195 kg $P_2O_5$/ha plus 240 kg $K_2O$/ha (**Table 5**). High yielding treatments produced the highest N use efficiencies which ranged between 37 to 38%. Treatments

**Table 5**. Effect of nutrient management on nutrient uptake and use efficiency in tobacco.

| Treatment | N uptake, kg/ha | N use efficiency, % | P uptake, kg/ha | P use efficiency, % | K uptake, kg/ha | K use efficiency, % |
|---|---|---|---|---|---|---|
| OPT-N | 30.8 | - | 6.2 | 2.1 | 59.3 | 16.7 |
| OPT-P | 42.5 | 8.7 | 2.1 | - | 61.7 | 17.7 |
| OPT-K | 43.1 | 9.3 | 4.4 | 1.2 | 19.3 | - |
| $N_{135}P_{195}K_{180}$ | 57.4 | 19.7 | 9.0 | 3.6 | 77.9 | 32.5 |
| $N_{135}P_{195}K_{240}$(OPT) | 82.2 | 38.1 | 11.6 | 4.9 | 105.1 | 35.8 |
| $N_{90}P_{195}K_{240}$ | 60.6 | 33.1 | 7.7 | 2.9 | 85.6 | 27.6 |
| $N_{180}P_{195}K_{240}$ | 71.9 | 22.8 | 7.6 | 2.8 | 87.6 | 28.4 |
| $N_{135}P_{150}K_{240}$ | 58.1 | 20.2 | 9.4 | 4.8 | 82.4 | 26.3 |
| $N_{135}P_{240}K_{240}$ | 80.8 | 37.0 | 11.6 | 4.0 | 100.9 | 34.0 |
| $N_{135}P_{195}K_{300}$ | 82.7 | 38.4 | 11.4 | 4.8 | 106.4 | 29.0 |

Note: Fertilizer use efficiency definition in this study is apparent fertilizer use efficiency (%) = (nutrient uptake by flue-cured tobacco in the nutrient treatment - nutrient uptake by flue-cured tobacco in the CK treatment) / amount of the nutrient applied in the fertilizer × 100%.

omitting P or K returned remarkably low N use efficiencies of 8.7 and 9.1%, respectively.

The treatment effect on P and K use efficiency mirrored N use efficiency trends. The OPT was most favorable to P and K utilization by tobacco with no real advantage observed under higher fertilization rates. Omission plots consistently provided the lowest use efficiencies. Since flue-cured tobacco required much less P, the range of values was much lower than N or K.


**Optimum** rates of NPK increased yields, profits, and nutrient use efficiency.

## Conclusion

Based on these results, the selection of 135-195-240 kg N-$P_2O_5$-$K_2O$/ha as the OPT is an effective but conservative choice for this production system. Widespread adoption of the identified OPT over a fertilizer recommendation capable of achieving better results would likely be based on a need to ration scarce fertilizer K reserves within the region.

Although flue-cured tobacco leaf quality was best under the OPT NPK input level, increased awareness concerning the yield and profit advantages observed in this study under higher K and P input strategies...keeping current N input constant...should be stressed. Nutrient use efficiency, most critically for N, was equally as high under the pre-selected OPT and the study's most profitable combination of N, P, and K. BC

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