Optimizing the Nitrogen/Potassium Balance for High Quality Spinach

By Lin Xianyong and Zhang Yongsong

Researchers determined how nitrogen (N) and potassium (K) supply can be managed to maximize vitamin C in spinach while minimizing both nitrate (NO_3^-) and oxalate accumulation.

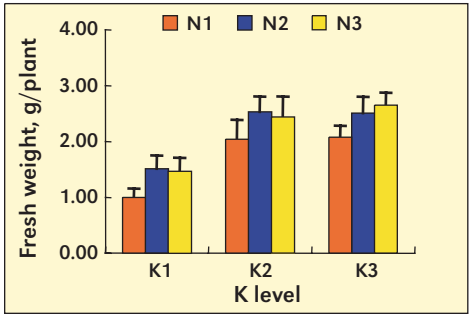
Ascorbate (vitamin C), NO_3^-, and oxalate are three major quality-related compounds present in high quantities in spinach, a frequently consumed vegetable in China. Research indicates that vitamin C in its reduced form functions as an important antioxidant, whereas NO_3^- and oxalate have adverse effects on human health when present in high concentrations.

In the human body, NO_3^- is enzymatically reduced to nitrite (NO_2^-) which, in combination with amine compounds from other foods, can form nitrosamine, a carcinogen. Excess intake of oxalate can increase the risk of developing kidney stones and can also contribute to calcium (Ca) deficiency in humans. Little is known about how N and K supply can influence the plant concentrations of these three compounds. However, it may be possible that proper management of plant nutrients is key to producing spinach with low NO_3^- and oxalate contents while maintaining high vitamin C content.

Figure 1. Effects of N and K level on fresh weight of spinach seedling.

Spinach was greenhouse grown at Zhejiang University using three N levels…N_1 (4.0 mmol/L), N_2 (8.0 mmol/L), and N_3 (12.0 mmol/L), and three K levels…K_1 (0.5 mmol/L), K_2 (4.0 mmol/L), K_3 (8.0 mmol/L). Hoagland nutrient solution was used to prepare the nutrient solutions. Nitrogen was supplied as $Ca(NO_3)_2$ and $NaNO_3$, and K as K_2SO_4. Spinach seeds were germinated and planted in sand and, after growing to about 5 mm in length, the seedlings were transferred to the above hydroponic culture solution. Nitrate, oxalate, and vitamin C contents of the leaf tissue were determined as plant tissue matured.

Both N and K influenced the fresh weight of spinach seedlings (**Figure 1**). At the same K level, biomass increased with N rate up to 8 mmol/L. At the same N level, the lowest K rate produced the smallest amount of fresh weight and this increased with K rate up to 4 mmol/L.



The effect of N on NO_3^- content was similar for both the leaves and petioles (**Figure 2**). Concentrations increased up to the N_2 level with the highest N input level having little additional effect with the exception of a large increase in petiole NO_3^- concentration in plants, also grown under the K_1 level. Potassium showed a similar influence on NO_3^- accumulation although a large

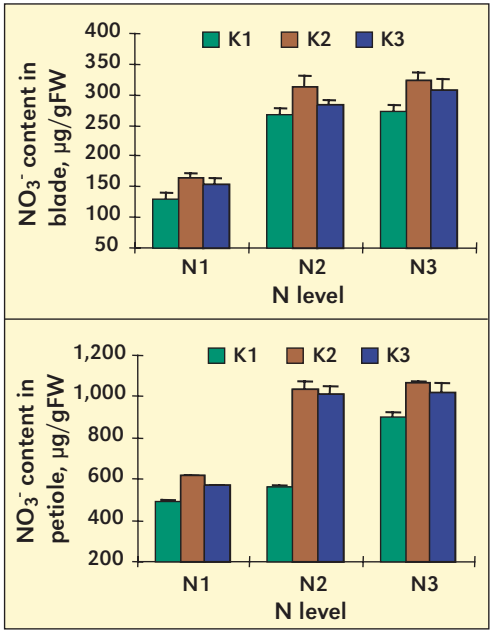


Figure 2. Effects of N and K level on NO_3^- content in blade and petiole of spinach seedling.

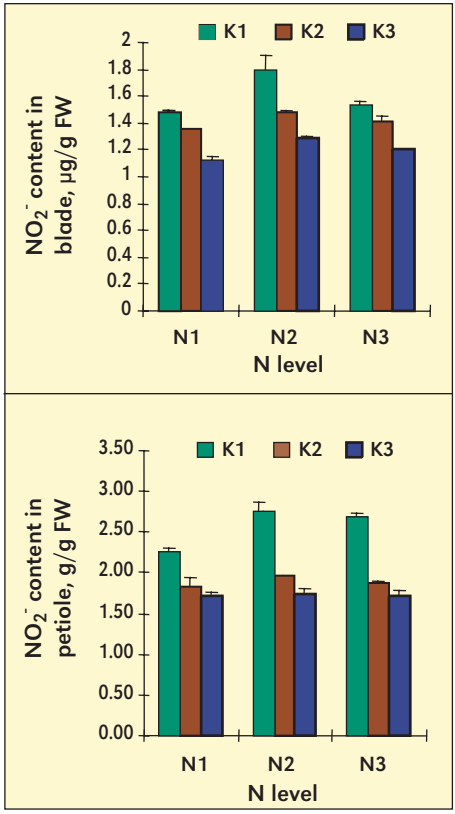


Figure 3. Effects of N and K level on NO_2^- content of spinach seedling.

increase in nitrate was observed as K supply increased from 0.5mmol/L to 4mmol/L. A further increase in K supply to 8mmol/L caused incidences of reduced NO_3^- content in the leaf (N_2K_3) and petiole (N_1K_3) indicating that higher K supplies favored plant NO_3^- assimilation.

Nitrite contents of the leaf and petiole were also affected by N and K supply (**Figure 3**). At the same N level, NO_2^- contents of both plant parts decreased greatly as K supply increased. Comparisons across the same K level show that NO_2^- contents in both plant parts increased greatly at the N_2 level, but further N input showed no further increase in NO_2^- contents and actually showed cases of decreased NO_2^- content. Note that elevated K supply lowered the potential for NO_2^- accumulation in both plant parts, especially under the highest N input levels.

Oxalate Content

The effect of selected N and K input combinations on plant oxalate concentration was blurred by variability between replicates (**Figure 4**). However, comparing means across the same K input level, leaf blade oxalate concentration was suppressed in the N_2K_1, N_2K_2, and N_2K_3 treatments. Thus, a threshold balance between N and K is suggested to exist and an optimal combination will lower oxalate concentrations in spinach plant tissue.

Variation in vitamin C content was large and limited the ability to identify strong trends (**Figure 5**). Although differences were found across each level of K input, results were mixed. Com-

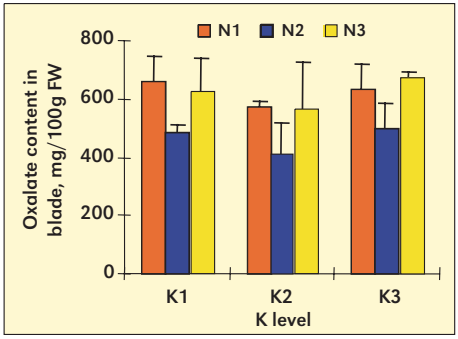


Figure 4. Effects of N and K level on oxalate content of spinach seedling.

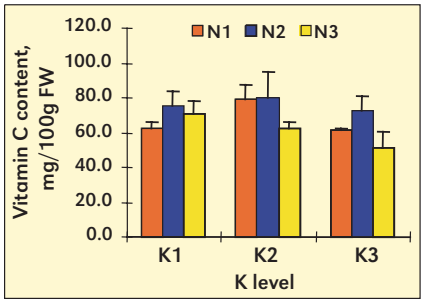


Figure 5. Effects of N and K level on vitamin C content of spinach seedlings.

parisons across means with the same N input level also produced three distinct responses. Nonetheless, vitamin C concentration of spinach tissue does seem to depend on N and K supply, and conditions of excess nutrient supply may result in a dilution effect.

Conclusions

This research affirms that a balanced supply of N and K strongly influences both yield and the nutritional quality of spinach. An optimal N and K level and ratio, in this case 8 mmol N/L and 4 mmol K/L, were essential for spinach to achieve good biomass yields while minimizing tissue NO_3^- and NO_2^-. It is apparent that plant oxalate and vitamin C can be positively affected through optimized N and K nutrition…and in this case, lower leaf blade oxalate concentration was associated with higher vitamin C concentration. Thus, the goal of producing high quality spinach can be consistent with a high yield strategy. BC

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Oil Palm: Nutrient Disorders and Nutrient Management—Pocket Guide

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The price for the publication is US$9.00 (Singapore$15.00). For more information, contact: PPI/PPIC-IPI Southeast Asia Program, 126 Watten Estate Road, Singapore 287599; fax +65 6467 0416 (Attn: Doris Tan). Additional details and an order form are also available at the website: >**www.ppi-ppic-ipi.org**<. BC