

## Effects of Fertilizer Dosage and Nutrient Balance on the Growth and Nutrient Uptake of Greenhouse Tomatoes

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**ABSTRACT.** *The standard dosage of Albert's fertilizer (T2) was compared with high dosage of Ca(NO<sub>3</sub>)<sub>2</sub> with KCl amendment (T4) and high dosages of all the other nutrients (other than Ca(NO<sub>3</sub>)<sub>2</sub>) (T3) in Albert's fertilizer, keeping Calcium nitrate with Kristalon (Hydro) as a reference solution (T1) with respect to nutrient uptake, growth and yield of greenhouse tomato under grow-bag culture.*

*A higher inter-node length and plant height were found with the application of high dosage of Albert's fertilizer (T3 and T4). However, thicker stems and shorter inter-nodes in T1 and T2, respectively indicated their vigorous growth. Higher dosages of N together with its favorable balance among N, P and K in Kristalon fertilizer (T1) appeared to be contributive for high rate of N uptake. Higher K dosage (with higher K:N ratio) in T4 and lower N:P ratio in T3 (2:1) appeared to be favorable for plant K and P uptake, respectively. The total and marketable yields of Kristalon fertilizer and the high dosage of Albert's fertilizer were higher than T2. The highest fruit formation was found in T1 but higher incidence of blossom end rot and lower fruit size caused it to be low yielding.*

### INTRODUCTION

Precision in plant nutrient supply in hydroponics culture is the most challenging management problem for growers. Precise control of plant nutrients in the hydroponics fertilizer is yet to achieve by the greenhouse vegetable growers in Sri Lanka. Albert's fertilizer (marketed by CIC<sup>2</sup> and Unipower<sup>3</sup>), the most widely used source of plant nutrients in greenhouse vegetable cultivation in Sri Lanka, comes as two separate packs of Ca(NO<sub>3</sub>)<sub>2</sub> and all the other nutrients (1 kg each). Under standard dosage, these two packs are mixed at 1:1 ratio and applied at the rate of 0.2-1.0 g/plant/day, based on the growth stage of the crop. As a result, deficiency and toxicity symptoms followed by yield losses and degradation of fruit quality are usually found with the use of Albert's fertilizer.

As an initial step towards the improvement of use of Albert's fertilizer, the balance between macro nutrients and the dosage of Albert's fertilizer was altered and compared with the standard dosage of Albert's fertilizer and another popular fertilizer for greenhouse tomato cultivation.

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## MATERIALS AND METHODS

The experiment was conducted under greenhouse conditions at Peradeniya (mid-country Wet zone) during *Yala* season in 2004. The experiment was conducted as a RCBD with four treatments and three replicates. A renowned hydroponics fertilizer, Kristalon with calcium nitrate (Hydro-Agri<sup>4</sup>) was used in Treatment 1 (T1) as a reference fertilizer and applied according to the recommended dosage of Hydro-Agri, Netherlands. The Treatment 2 (T2) was the standard dosage of Albert's fertilizer (CIC) (1:1 ratio). The recommended rate of growth stage-wise variation in fertilizer dosages was followed for T2 where 0.2, 0.3, 0.4, 0.3, 0.2 g/plant of Ca(NO<sub>3</sub>)<sub>2</sub> were applied with equal amounts from the pack of other nutrients at 0-4, 4-6, 6-8, 8-12, 12-24 weeks after transplanting, respectively. Dosage of Albert's fertilizer was increased by doubling the dosage of other plant nutrients (1:2 ratio) in T3 and doubling Ca(NO<sub>3</sub>)<sub>2</sub> and adding KCl in T4 (2:1:2 ratio). As a result, the nutrient balances (K:N, N:P and K:Ca ratios) of the standard dosage of Albert's fertilizer were improved from 1.2, 3.4 and 1.4 to 1.9, 2.0 and 2.8, respectively in T3. The improved levels were comparable to that of Kristalon fertilizer (T1) (1.5, 3.4 and 2.9, respectively), except for N:P. Meanwhile, all these nutrient balances were much higher (5-6) in T4 due to high dosages of N and K.

In addition, water supply was done, beginning from 100-600 l and increasing up to 1200 l/plant across the treatments. The resultant concentrations in the hydroponics solutions of the treatments varied within the Electrical Conductivity (EC) range of 1.0-1.4 dS/m. The pH was maintained at 5.5-6.5. Indeterminate type tomato hybrid, Alambra F<sub>1</sub> was cultivated using manually irrigated, coir dust and sand (at 1:1) filled grow-bag culture. The basic crop management practices were done according to the procedures described by Weerakkody (2003).

Plant growth was determined in terms of internode length, plant height, stem girth (at the third node) leaf number and Leaf Area Index (LAI) at three stages. Reproductive development was determined based on the earliness of flowering and fruit set and number of flowers and fruits. Finally, the yield and the quality of fruits were also determined. The leaf nutrient compositions determined at Early Flowering (EF) and Late Fruit Growth (LFG) stages were considered as estimates of the uptake rate of plant nutrients. The medium nutrient contents were considered as a measure of the availability of nutrients. Data analysis and statistical analysis were done through ANOVA procedure.

## RESULTS AND DISCUSSION

### Vegetative growth

As shown in Table 1, plant height of treatments with high dosages of Albert's fertilizer (T3 and T4) were significantly higher than the standard dosage (T2) and Kristalon with Ca(NO<sub>3</sub>)<sub>2</sub> fertilizer (T1) throughout the crop life. This could be a result of shorter internodes in the lower part of the stem of T2 and lesser number of nodes in T1 (11 in T1 while 13 in T3 and T4 at early flowering). However, the stem girth which reflects the vigor of the plant (Wilbure, 1983) was significantly higher in T1 throughout the crop life. Rapid

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<sup>4</sup> Hydro-Agri, Rotterdam, B.V. P.O. Box 58, 3130 AB, Vlaardingen, The Netherlands.

rate of stem elongation shown by T3 and T4 (tall plants) appears to be a sole effect of high concentration (high EC) of the supply solution, which exerts a nutrient pressure on the root system (Adams and Ho, 1995<sup>a</sup>).

**Table 1. Vegetative growth of tomato under different hydroponic fertilizers**

Fertilizer treatment	Plant height (cm) <sup>*1</sup>	Inter-node length (cm)	Stem girth (cm) <sup>*2</sup>	LAI - at EF	LAI - at LFG
T1	300 <sup>b</sup>	9.92 <sup>a</sup>	5.94 <sup>a</sup>	5.69 <sup>a</sup>	10.28 <sup>bc</sup>
T2	306 <sup>b</sup>	9.45 <sup>b</sup>	5.34 <sup>b</sup>	4.32 <sup>b</sup>	16.75 <sup>a</sup>
T3	333 <sup>a</sup>	9.56 <sup>ab</sup>	5.12 <sup>bc</sup>	5.68 <sup>a</sup>	12.65 <sup>b</sup>
T4	327 <sup>a</sup>	9.98 <sup>a</sup>	4.85 <sup>c</sup>	6.18 <sup>a</sup>	10.06 <sup>c</sup>

**Note:** <sup>\*1</sup> at 20 wks; <sup>\*2</sup> at the 3<sup>rd</sup> node (the values having the same letters in the same column are not significantly different at p=0.05).

Leaf number which was closely associated with the number of internodes did not show a significant treatment difference. The LAI was lower in T2 until the EF while higher during the LFG stage (Table 1). Hence, the standard dosage of Albert's fertilizer appeared to be promoting leaf growth during fruit growth and development.

### Reproductive development and yield

Tomato plants gave arise to 20 inflorescences per plant, each containing 6 flowers and converting only 4-5 to fruits during their 6 month lifespan. The fruit number per cluster was marginally higher in Kristalon fertilizer treatment (5-6). Even though the vegetative growth was rapid in T3 and T4, it did not continue in terms of earliness of flowering.

The lowest total yield and marketable yield were found in the standard dosage of Albert's fertilizer (T2) (1.5 and 1.4 kg/plant, respectively) while the same were 2.4-2.6 kg and 2.0-2.3 kg/plant, respectively in the other three treatments. Rapid vegetative growth could be one of the reasons for better yields in treatments with high dosages of Albert's fertilizer. Even though Kristalon fertilizer (T1) lead to form a relatively high number of fruits per cluster, smaller fruit weight and higher percentage of unmarketable yield (11.6% of the harvested fruits due to blossom end rot (BER), its marketable yield was not significantly higher than the treatments with high dosage of Albert's fertilizer (T3 and T4). Smaller fruits in T1 could be an influence of low EC (Dorais *et al.*, 2002). According to earlier reports (Adams and Ho, 1995<sup>b</sup>), very high percentage of BER in Kristalon treatment (T1) could not be an influenced of EC because mean solution EC of T1 was not too high (1.3 dS/m). When compared with mean K:Ca ratio of T1 (2.9), increased K:Ca ratio (to 4.2) at fruit development, which hinders Ca absorption of tomato (Nukaya *et al.*, 1995) could be the main reason for high incidence of BER.

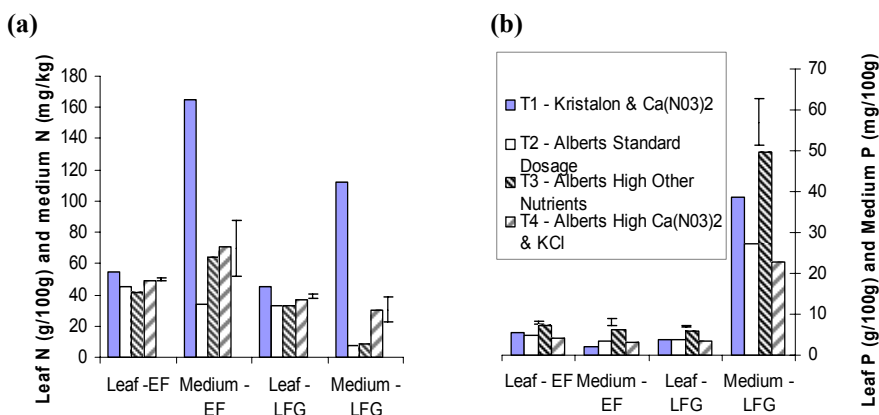
Fruit weight reduced along with the advancing cluster number (starting at 147 and ending at 76 g/fruit), despite fruit thinning. A significantly lower fruit weight could be

found in fruits in the Kristalon treatment (T1). Regarding internal fruit qualities, the juice pH ( $4.9 \pm 0.4$ ) and TSS (Brix value;  $4.0 \pm 0.2$ ) were not significantly different among treatments.

### Plant nutrient uptake

As shown in Figure 1a, significantly higher leaf and medium N was found in plants grown in T1, compared to other treatments at both sampling stages, indicating a higher rate of N uptake. However, the leaf N content was still below the standard value for tomatoes (53 g/100 g) (Agri-food Ontario, 2002). Therefore, the potential for further improvements in N nutrition, especially in Albert's fertilizer can be highlighted. Meanwhile, low nitrate contents in the media of T2 and T3 at the LFG stage indicate N depletion (Fig. 1a), highlighting the importance of supplying additional N dosage such as T4.

Based on the leaf P contents, significantly higher rate of P uptake could be presumed in T3 (Fig. 1b), exceeding the standard value (0.4 g/100 g) (Agri-food Ontario, 2002). Hence, low N:P ratio maintained in T3 (2) appears to be better than the standard Albert's formula for all growth stages. Even though P contents remained in the growth media evidence its abundance in all the treatments, excessive levels at the last sampling stage indicates the wastage of P at the latter part of the reproductive development of tomato.



**Fig. 1. Leaf and medium N and P compositions (EF: at early flowering; LFG: at late fruit growth)**

**Note:** The vertical error bars indicate at  $p=0.05$  LSD.

The highest mean leaf K content was found in T4 ( $50.8 \pm 9.7$  mg/g) and was followed by T2 ( $27.0 \pm 5.0$  mg/g) throughout the crop life. Meanwhile, higher dosage of Ca ( $\text{N0}_3$ )<sub>2</sub> in T4 has increased the leaf Ca content to a higher value ( $38.1 \pm 36.6$  mg/g). Significantly higher K and Ca compositions in the medium of T4 evidence relatively high K and Ca availability in T4. High K and Ca dosages as well as high K:N and K:Ca ratios could be the reason for better K and Ca nutrition in T4. This is well supported by the findings of Kosla and Papadopoulos (2001) where K:N ratio of 2-4 was the best for

greenhouse tomatoes. However, both leaf K and Ca levels in T4 were still below the standard leaf K levels reported for tomato (Agri-food Ontario, 2002).

## CONCLUSIONS

The higher dosages of Albert's fertilizer either by increasing  $\text{Ca}(\text{NO}_3)_2$  and KCl or by increasing the dosage of remaining plant nutrients (together with slight increase in K:N and K:Ca ratios and reduction in N:P ratio increased the growth rate, total yield and the marketable yields than the standard dosage and became equivalent to the reference fertilizer, Kristalon with  $\text{CaNO}_3)_2$ . It was well supported by the uptake rates of P, K and Ca by plants and their availabilities in the medium. However, further improvements in nutrient balance and dosage would be necessary when compared with the higher fruit weight in standard Albert's fertilizer and higher fruit number in Kristalon fertilizer. Meanwhile, reduction of P and Ca and increase in N dosages at the fruit development stage can be suggested for further improvements in fertilizer use efficiency.

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