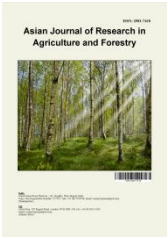

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Study on the Effect of Foliar Fertilizers on the Growth and Yield of V108 Heat-Tolerant Cucumber Variety

Nguyen Tuan Khoi [a++*] and Pham Thi Thom [b#]

[a] Faculty of Agronomy, BacGiang Agriculture and Forestry University - Viet Yen town, Bac Giang Province, Vietnam.
[b] Faculty of Natural Resources and Environment, BacGiang Agriculture and Forestry University - Viet Yen town, Bac Giang Province, Vietnam.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This study evaluates the efficacy of various foliar fertilizers on the growth and yield of the heat-tolerant cucumber variety TV108. The experimental design included six different foliar fertilizers and a control, with applications made weekly at a concentration of 1 mL per liter of water. Results showed that all foliar treatments significantly enhanced plant height compared to the control. Among these, Treatment T4 (ATONIK foliar fertilizer) demonstrated the most pronounced effect, achieving a main stem height of 216.57 cm by the 70th day, which was significantly higher than other treatments and the control. Treatment T4 also excelled in increasing stem diameter, with a final measurement of 1.48 cm, and in promoting both male and female flower formation. The fruit set rate was highest in Treatment T4, reaching 28.67% on day 56 and maintaining at 8.67% by day 70. This

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[++] Ph.D in Biological Sciences;
[#] Ph.D in Construction Engineering and Technology;
**Corresponding author: E-mail: khoint@bafu.edu.vn;*

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treatment also proved most effective in reducing the incidence of key diseases and pests, including powdery mildew, white mold, green worms, and yellow beetles. Regarding yield, Treatment T4 produced the highest individual fruit yield (2.32 kg/plant), actual yield (33.8 tons/ha), and theoretical yield (84.91 tons/ha). Additionally, it enhanced fruit quality, as indicated by the largest fruit length (15.22 cm), diameter (4.13 cm), and the highest Brix value (3.50%). These results substantiate that Treatment T4 is the most effective foliar fertilizer for enhancing both growth and quality of heat-tolerant cucumbers under experimental conditions.

Keywords: Foliar fertilizers; heat-tolerant cucumbers; growth performance; yield improvement; cucumber varieties.

1. INTRODUCTION

Cucumbers (*Cucumis sativus*) hold a prominent place in global agriculture due to their widespread consumption and significant economic value [1,2]. They are a staple in many diets, valued for their hydrating properties, low-calorie content, and essential nutrients such as vitamins A and C, potassium, and fiber [3,4]. Despite their importance, cucumber production faces substantial challenges, particularly from environmental stressors such as heat [5]. High temperatures can severely impact cucumber plants, leading to reduced growth rates, lower yields, and compromised fruit quality [6,7]. These effects are particularly pronounced in regions where temperatures frequently exceed optimal levels for cucumber cultivation [8].

To mitigate these issues, heat-tolerant cucumber varieties, such as TV108, have been developed. These varieties are bred to withstand higher temperatures without significant loss of productivity. However, while the development of such varieties is a significant step forward, optimizing their cultivation practices is equally crucial [9]. Effective management strategies are needed to ensure that these heat-tolerant varieties can reach their full potential under stress conditions [10].

One such strategy is foliar fertilization, an agronomic practice that involves the direct application of nutrients to plant leaves [11]. This method allows for the rapid absorption of essential nutrients, which can enhance plant growth, improve stress tolerance, and boost overall productivity [12,13]. Foliar fertilizers are particularly beneficial in conditions where root absorption is compromised, such as in heat-stressed environments [14,15]. Despite the recognized advantages of foliar fertilization, there is a lack of detailed studies on its specific effects on heat-tolerant cucumber varieties like TV108.

This research aims to address this gap by systematically evaluating the effects of different foliar fertilizers on the growth, yield, and quality of the heat-tolerant cucumber variety TV108. The study focuses on key growth parameters, including plant height and stem diameter, which are critical indicators of overall plant health and vigor. Additionally, the research examines flower formation and fruit set rates, which directly influence yield, as well as the plant's resistance to common diseases and pests. The ultimate goal of this study is to identify the most effective foliar fertilizer treatment, thereby providing practical recommendations for enhancing cucumber production in heat-stressed environments. By improving our understanding of how foliar fertilizers affect heat-tolerant cucumber varieties, this research contributes to the development of more resilient and productive agricultural practices in the face of climate change.

2. MATERIALS AND METHODS

2.1 Materials

Cucumber Variety TV108: This is a heat-tolerant F1 cucumber variety from Thailand.

ALASKA Foliar Fertilizer: This product is imported from the United States, with main ingredients including fish meal and fresh seaweed, characteristic of the Alaska region. The nutrient content of N-P-K is 5:1:1, respectively.

GROW MORE Foliar Fertilizer: This product is from a well-known brand imported from California, USA. The nutrient content of N-P-K is 10:10:10, respectively.

ATONIK Foliar Fertilizer: This is a high-quality fertilizer product manufactured by the leading Japanese brand, ASAHI. The nutrient content of N-P-K is 5:5:5, respectively.

Protective Strip

T1 (Control)	T2	T3	T4	T5	T6	T7
T6	T5	T7	T1 (Control)	T3	T2	T4
T3	T4	T2	T6	T1 (Control)	T7	T5

Protective Strip

Protective Strip

Protective Strip

Fig. 1. Experimental design

FISH ALASKA EMULSION Foliar Fertilizer: This product is imported from the United States, with main ingredients including fish meal and seaweed from cold marine regions. The nutrient content of N-P-K is 10:1:1, respectively.

DAU TRAU Foliar Fertilizer: Produced and distributed by Binh Dien Co., Ltd. The nutrient content of N-P-K is 10:1:5, respectively.

SULFUR S16 Foliar Fertilizer: This is a 100% imported foliar fertilizer from South Korea. The nutrient content of N-P-K is 5:1:5, respectively.

2.2 Methods

Experimental formulations were prepared by diluting 1 ml of foliar fertilizer in 1 liter of clean water, and applied by spraying once every 7 days. The treatments were as follows:

T1: No foliar fertilizer (Control)
T2: DAU TRAU foliar fertilizer
T3: ALASKA foliar fertilizer
T4: ATONIK foliar fertilizer
T5: FISH ALASKA EMULSION foliar fertilizer
T6: Grow More foliar fertilizer
T7: SULFUR S16 foliar fertilizer

The cucumber cultivation and care methods were carried out in accordance with the QCVN 01-87:2012/BNNPTNT standard of the Ministry of Agriculture and Rural Development of Vietnam.

The experiment was arranged in a completely randomized block design (CRBD) with 6 treatments, 3 replications, and 1 control treatment.

The data were statistically processed using the IRRISTAR 5.0 and Excel 2011 programs, including the analysis of experimental error (CV%) and the evaluation of the least significant differences (LSD) at the 5% level among the experimental treatments.

3. RESULTS AND DISCUSSION

The detailed analysis of the data in Table 1 reveals that all experimental treatments (T2 to T7) had a favorable impact on plant height growth compared to the control. Among these, treatment T4 exhibited a statistically significant enhancement, reaching a main stem height of 216.57 cm by the 70th day. This height exceeded not only the control but also all other treatments. Despite slight variations in growth rates across treatments, the final heights of T2, T3, T5, T6, and T7 were relatively consistent, falling within a narrow range of 215.54 cm to 216.24 cm. The low coefficient of variation (CV%) of 4.7% further supports the uniformity of growth responses among the treatments. The least significant difference (LSD) at the 5% significance level was calculated to be 3.6 cm, indicating that any differences in main stem height exceeding this value can be considered statistically significant. Therefore, treatment T4 demonstrated the highest effectiveness in promoting main stem height growth, making it the most successful treatment under the given experimental conditions.

The data presented in Table 2 indicate that all treatments (T2 to T7) had an impact on increasing the main stem diameter compared to the control, with varying degrees of effect. Among the experimental treatments, T4 had the most pronounced effect, with a stem diameter of 1.48 cm on the 70th day, surpassing the control and other treatments. Treatment T4 also exhibited robust growth from the 28th day onward, showing significant differences in diameter compared to the other treatments. Meanwhile, the remaining treatments (T2, T3, T5, T6, T7) demonstrated more uniform growth, with final diameters ranging from 1.34 cm to 1.38 cm, closely matching the control (1.34 cm).

Table 1. Effects of various foliar fertilizer products on the main stem height of TV108 cucumber variety

Treatment	Days after planting (cm)									
	7	***14***	***21***	***28***	***35***	***42***	***49***	***56***	***63***	***70***
T1 (Control)	9.27	15.63	20.56	40.42	94.64	130.40	153.39	177.34	191.20	215.54
T2	9.44	15.57	20.48	40.68	94.52	130.57	153.59	177.37	191.20	216.24
T3	9.26	15.70	20.63	40.48	94.66	130.59	153.13	177.52	191.60	215.77
T4	10.09	15.76	21.81	41.91	96.10	132.69	154.18	180.39	193.03	216.57
T5	9.47	16.33	20.50	40.`58	94.73	130.64	153.39	177.22	191.57	215.77
T6	9.27	15.50	20.57	40.54	94.77	130.48	153.53	177.54	191.22	215.87
T7	9.27	15.53	20.48	40.36	110.52	130.52	153.37	177.38	191.56	215.70
CV%										*4.7*
$LSD_{0.05}$										*3.6*

A more detailed analysis of the data reveals that the coefficient of variation (CV%) of 5.2% indicates a moderate degree of variability in the stem diameter measurements across different treatments and time points. This level of variation suggests that while there was some inconsistency in the growth responses, the overall trend remains reliable. The least significant difference (LSD) value at the 5% significance level was calculated to be 3.3 cm. This means that any differences in main stem diameter exceeding 3.3 cm between treatments are statistically significant. Based on these statistical metrics, treatment T4 emerged as the most effective in enhancing main stem diameter growth compared to all other treatments and the control. These findings suggest that T4 provides a measurable and significant advantage in stem development under the experimental conditions.

The results presented in Table 3 show that the number of male flowers varied significantly between treatments and over the experimental period. Treatment T4 demonstrated superior effectiveness, with a notable increase in the number of male flowers from day 42 to day 56, reaching a peak of 29.3 flowers on day 56, which was higher than the control and other treatments. Additionally, T4 maintained a higher number of male flowers at the end of the experiment (6.3 flowers on day 70). In contrast, treatments T2, T3, T5, T6, and T7 showed relatively stable male flower formation, with the number of male flowers peaking on day 56 and gradually decreasing thereafter, similar to the control. This difference indicates that T4 has a stronger and more sustained effect on promoting male flower formation compared to the other treatments, especially during the period from 42 to 56 days after planting.

The results indicate that treatment T4 had the most positive impact, with superior female flower numbers at most experimental time points, reaching 39.33 flowers on day 56 and 18.33 flowers on day 70. This strong growth suggests that T4 not only promotes early female flower formation but also maintains stable development of female flowers throughout the growth period. In contrast, treatments T2, T3, T5, T6, and T7 also enhanced female flower formation compared to the control, but did not achieve the same level of effectiveness as T4. The number of female flowers for these treatments peaked on day 56 and then gradually decreased, similar to the trend observed in the control.

Table 2. Effects of foliar fertilizer products on the main stem diameter of TV108 cucumber variety

Treatment	Days after planting (cm)									
	7	***14***	***21***	***28***	***35***	***42***	***49***	***56***	***63***	***70***
T1 (Control)	0.09	0.13	0.21	0.31	0.44	0.73	0.80	1.12	1.20	1.34
T2	0.09	0.14	0.25	0.31	0.45	0.72	0.81	1.11	1.21	1.37
T3	0.09	0.14	0.23	0.31	0.44	0.72	0.81	1.12	1.20	1.35
T4	0.09	0.16	0.27	0.35	0.50	0.79	0.83	1.19	1.29	1.48
T5	0.09	0.13	0.22	0.31	0.45	0.71	0.81	1.13	1.21	1.38
T6	0.09	0.14	0.23	0.31	0.45	0.72	0.80	1.13	1.20	1.36
T7	0.09	0.14	0.22	0.33	0.45	0.71	0.80	1.12	1.19	1.36
CV%										*5.2*
$LSD_{0.05}$										*3.3*

Table 3. Effects of foliar fertilizer products on male flower formation in TV108 cucumber variety

Treatment	Days after planting (Male flower)						
	28	***35***	***42***	***49***	***56***	***63***	***70***
T1 (Control)	1.00	5.00	14.33	21.00	25.33	15.00	4.67
T2	2.00	4.67	16.00	21.67	26.67	16.67	4.00
T3	0.67	5.0	14.33	21.67	27.00	16.33	4.67
T4	2.67	6.33	19.67	25.33	29.33	21.00	6.33
T5	1.00	4.0	15.33	21.67	25.00	19.67	4.00
T6	0.67	4.33	15.33	22.00	24.67	19.33	4.00
T7	2.33	4.67	15.33	21.33	25.67	19.00	4.00

The research results presented in Table 5 show that treatment T4 had a significant impact on improving the fruit set rate, with the highest fruit set rate reaching 28.67% on day 56 and maintaining at 8.67% on day 70. Compared to the control, treatment T4 was superior at most time points, demonstrating its ability to maintain high effectiveness throughout the experimental period. Other treatments, including T2, T3, T5, T6, and T7, also contributed to improving the fruit set rate compared to the control, but did not achieve the same high and stable results as T4. Notably, the fruit set rates for these treatments peaked on day 56 and then gradually decreased, similar to the control trend.

The results show that treatment T4 was the most effective in reducing the incidence of diseases and pests. Specifically, the incidence of powdery mildew for treatment T4 was 69.33%, which is significantly lower than the control (98.67%) and other treatments. Similarly, treatment T4 also recorded the lowest incidence of white mold at 44.67%, surpassing the control (75.33%) and other treatments. In controlling green worms, treatment T4 had the lowest count at 3.67 larvae per plant, compared to 5.33 larvae per plant in the control. For the yellow beetle, treatment T4 also showed a significant reduction, with 6.33 beetles per plant, lower than the control (10.67 beetles per plant). Treatments T2 and T3 also demonstrated good control, with lower incidence rates and pest numbers compared to the control, but did not achieve the same high level of effectiveness as T4.

With a coefficient of variation (CV) of 13.3% and an $LSD_{0,05}$ of 6.1 fruits, the number of fruits per plant in treatment T4 (25.67 fruits) was significantly higher than the control (19 fruits) and other treatments, with a statistically significant difference exceeding the $LSD_{0,05}$ threshold. For fruit weight, the CV was 4.4% and the $LSD_{0,05}$was 3.7 grams, indicating low variability among treatments. The difference in fruit weight for treatment T4 (64.05 grams) compared to the control (60.01 grams) was also statistically significant. Although there was no information on CV and LSD for individual yield, actual yield, and theoretical yield, the clear differences in these parameters indicate that treatment T4 achieved the highest individual yield (2.32 kg/plant), the highest actual yield (33.8 tons/ha), and the highest theoretical yield (84.91 tons/ha).

These results confirm that treatment T4 is the most effective foliar fertilizer for enhancing cucumber yield components, with parameters surpassing the $LSD_{0,05}$ threshold, demonstrating that the improvements are statistically significant and substantial compared to other treatments.

Table 4. Effects of foliar fertilizer products on female flower formation in TV108 cucumber variety

Treatment	Days after planting (Female flower)						
	28	***35***	***42***	***49***	***56***	***63***	***70***
T1 (Control)	0.00	11.00	25.33	29.67	34.67	26.67	12.33
T2	0.00	11.67	26.00	31.33	35.00	24.00	13.67
T3	0.00	11.67	25.00	31.00	35.33	24.00	14.00
T4	0.00	16.33	28.33	35.00	39.33	28.00	18.33
T5	0.00	13.00	24.00	30.67	35.00	24.33	14.00
T6	0.00	13.00	23.67	31.33	34.00	25.67	13.33
T7	0.00	13.00	23.67	31.33	34.00	25.67	13.33

Table 5. Effects of foliar fertilizer products on fruit set rate in TV108 cucumber variety

Treatment	Days after planting (%)						
	28	***35***	***42***	***49***	***56***	***63***	***70***
T1 (Control)	0	6.00	14.00	19.33	25.33	13.33	4.67
T2	0	7.00	14.00	19.00	25.00	14.00	4.00
T3	0	6.67	14.67	20.00	25.00	14.67	5.00
T4	0	8.00	17.67	24.67	28.67	17.67	8.67
T5	0	7.00	13.67	21.00	25.33	15.33	4.00
T6	0	7.33	14.67	18.67	25.33	14.00	4.67
T7	0	7.33	14.00	21.00	25.00	15.33	4.67

Table 6. Effects of foliar fertilizer products on the incidence of some diseases in TV108 cucumber variety

Treatment	Downy Mildew (%)	Powdery Mildew (%)	Green Worm (larvae/plant)	Yellow Beetle (insects/plant)
T1 (Control)	98.67	75.33	5.33	10.67
T2	85.00	48.33	4.67	9.00
T3	82.00	53.67	4.67	8.67
T4	69.33	44.67	3.67	6.33
T5	80.00	50.33	6.33	9.00
T6	82.00	50.67	5.33	7.67
T7	81.00	55.00	5.67	7.33

Table 7. Effects of foliar fertilizer products on yield components in TV108 cucumber variety

Treatment	Number of fruits per plant (fruits/plant)	Weight per fruit (grams/fruit)	Individual yield (kg/plant)	Harvested yield (tons/ha)	Theoretical yield (tons/ha)
T1 (Control)	19.00	60.01	1.24	20.67	45.38
T2	20.00	63.35	1.16	21.73	42.45
T3	22.00	62.05	1.31	21.37	57.95
T4	25.67	64.05	2.32	33.8	84.91
T5	19.67	60.12	1.49	21.57	54.41
T6	20.33	61.56	1.37	22.67	50.14
T7	20.00	62.63	0.99	19.8	36.33
CV%	*13.3*	*4.4*		*13.1*	
$LSD_{0.05}$	*6.1*	*3.7*		*5.4*	

Table 8. Effects of foliar fertilizer products on quality components of TV108 cucumber variety

Treatment	Fruit length (cm)	Fruit diameter (cm)	Brix (%)
T1 (Control)	12.91	3.21	2.33
T2	14.22	3.97	2.67
T3	15.02	3.23	3.00
T4	15.22	4.13	3.50
T5	14..82	4.05	3.00
T6	15.04	3.79	3.07
T7	14.87	4.01	3.00
CV%	*7.3*	*5.4*	
$LSD_{0.05}$	*2.8*	*4.1*	

The results from Table 8 show that treatment T4 achieved the most outstanding performance in improving fruit quality parameters. Specifically, treatment T4 recorded the largest fruit length (15.22 cm) and the largest fruit diameter (4.13 cm), surpassing the control (12.91 cm and 3.21 cm) and other treatments. The Brix value of cucumbers in treatment T4 also reached the

highest level (3.50%), indicating the sweetest fruit quality compared to the other treatments and the control.

Further analysis of variability (CV) and minimum significant difference (LSD) reveals significant differences in quality parameters. The CV for fruit length was 7.3% and the $LSD_{0,05}$ was 2.8 cm, indicating that the differences between treatments are statistically significant. Treatment T4 showed superior improvement in fruit length compared to other treatments, with the difference exceeding the $LSD_{0,05}$ threshold. For fruit diameter, with a CV of 5.4% and an $LSD_{0,05}$ of 4.1 cm, the difference between treatment T4 and other treatments is statistically significant, demonstrating a significant impact of T4 on fruit size. Although data on CV and LSD for Brix value were not provided, the differences in Brix value among treatments clearly indicate that treatment T4 produced fruit of significantly higher quality.

These results confirm that treatment T4 is the most effective foliar fertilizer for enhancing cucumber quality components, with improvements that are statistically significant and surpass the $LSD_{0,05}$ threshold compared to other treatments.

4. CONCLUSION

The study demonstrates that foliar fertilization significantly impacts the growth, yield, and quality of the heat-tolerant cucumber variety TV108. Among the various treatments applied, Treatment T4 consistently showed superior results across all evaluated parameters. It significantly increased plant height, achieving 216.57 cm by day 70, and stem diameter, reaching 1.48 cm, both of which were higher than those observed in other treatments and the control. Treatment T4 also excelled in promoting flower formation, with the highest number of male and female flowers recorded, and achieved the highest fruit set rate. Furthermore, it proved most effective in controlling diseases and pests, including powdery mildew, white mold, green worms, and yellow beetles, leading to a healthier crop. In terms of yield, Treatment T4 resulted in the highest individual fruit yield (2.32 kg/plant), actual yield (33.8 tons/ha), and theoretical yield (84.91 tons/ha). The quality of the cucumbers was also markedly improved, as evidenced by the largest fruit length (15.22 cm), diameter (4.13 cm), and the highest Brix value (3.50%). These findings confirm that Treatment T4 is the most effective foliar fertilizer for enhancing the performance of heat-tolerant cucumbers, offering significant improvements in both yield and quality. The application of Treatment T4 is recommended for optimizing cucumber cultivation, particularly in heat-stressed conditions, to achieve higher productivity and superior fruit quality.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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