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# Optimizing the Application Frequency of Trehalose Foliar Fertilizer for Off-Season Tomato (*Solanum lycopersicum* L.) Production in Bacnotan, La Union

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***Abstract*— *This study evaluated the optimal frequency of trehalose foliar fertilizer application for enhancing the growth, yield, and economic viability of a solanaceous crop cultivated under protected conditions in Bacnotan, La Union. A randomized complete block design was used with four application frequencies: once, twice, thrice, and four times, using a fixed concentration of 2 tablespoons per 16 liters of water. Results showed no significant effects on flowering time, vegetative growth, total yield per area, or pest and disease occurrence. However, a statistically significant increase was observed in the number of fruits per plant, marketable yield, and harvest frequency under thrice application. No further benefit was gained from four applications, indicating a threshold beyond which efficiency declines. These findings support the use of moderate foliar treatment frequency to improve crop productivity while reducing input costs. Further validation under different agroecological conditions is recommended.*

***Keywords*— *solanaceous crops, protected cultivation, spray frequency, nutrient efficiency, sustainable farming***

## I. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops globally and in the Philippines, both in terms of economic value and dietary contribution. It is widely cultivated for its versatility, nutritional value, and market demand, being a rich source of vitamins A, C, and lycopene an antioxidant associated with health benefits (FAO, 2021). In the Philippines, tomato is commonly grown by smallholder farmers as a cash crop, with its production contributing significantly to rural income and local economies. However, tomato yields are often constrained by biotic and abiotic factors, especially when cultivated under off-season conditions characterized by unpredictable rainfall, higher temperatures, and pest outbreaks (Bureau of Plant Industry, 2020). These stressors can lead to lower fruit set, delayed maturity, and poor fruit quality.

To meet the increasing demand for fresh produce and stabilize supply throughout the year, there is a growing trend toward off-season and protected cultivation, including the use of greenhouses. Yet, off-season production requires improved crop management strategies to mitigate stress-related yield losses. In this context, foliar fertilization has emerged as a supplemental approach to enhance plant resilience and productivity. Unlike soil application, foliar fertilization allows for the direct and rapid uptake of nutrients and plant enhancers through the leaves, especially during critical growth stages or under stress conditions that may limit root uptake (Fernández et al., 2013).

One such plant enhancer is trehalose, a naturally occurring non-reducing disaccharide composed of two glucose molecules. Trehalose functions primarily as an osmoprotectant, stabilizing biological membranes, proteins, and macromolecular structures under stress conditions such as drought, salinity, or oxidative stress

(Garg et al., 2002; Paul et al., 2008). More importantly, trehalose plays a pivotal role in sugar signaling pathways, particularly through its precursor, trehalose-6-phosphate (T6P), which regulates carbon allocation, flowering, and photosynthetic efficiency in plants (Lunn et al., 2014). Exogenous application of trehalose has been shown to improve drought tolerance, enhance pollen viability, delay senescence, and increase biomass and yield in various crops including rice, tomato, wheat, and maize (Iordachescu & Imai, 2008; Kosar et al., 2019).

Despite these well-documented benefits, the optimal frequency of trehalose application particularly via foliar spraying remains underexplored, especially in localized field settings such as off-season tomato production in the Philippines. While some studies indicate that multiple applications may increase yield and stress tolerance, others caution that excessive use may be metabolically costly or even counterproductive, leading to nutrient imbalance or phytotoxicity (Ali & Ashraf, 2011; Schluepmann et al., 2003). Therefore, it is important to assess not only the biological response but also the practical and economic implications of varying application frequencies.

Moreover, research on trehalose has mostly been conducted under laboratory or controlled-environment conditions in temperate regions. There is limited empirical evidence on its performance under tropical lowland greenhouse systems like those used in La Union, Philippines. Given the cost considerations of commercial foliar fertilizers and the limited resources of smallholder farmers, determining the most efficient and profitable frequency of application is essential to promote sustainable adoption.

This study was therefore conducted to evaluate the effect of varying trehalose foliar fertilizer application frequencies on the growth, yield, and economic performance of off-season tomato under protected cultivation. Specifically, the study aimed to (1) determine the frequency of trehalose foliar fertilizer that promotes optimal growth and yield performance, and (2) assess the profitability and practical feasibility of its use under local field conditions. The findings of this research are intended to provide science-based recommendations that can support smallholder farmers, extension practitioners, and agricultural researchers in enhancing off-season tomato productivity through efficient foliar nutrition strategies.

## II. MATERIAL AND METHODS

This study, titled *Optimizing the Application Frequency of Trehalose Foliar Fertilizer for Off-Season Tomato (Solanum lycopersicum L.) Production in Bacnotan, La Union*, was conducted to determine the optimal frequency of trehalose foliar fertilizer application for enhancing the growth, yield, and profitability of off-season tomato cultivation under the conditions of DMMMSU-NLUC, Sapilang, Bacnotan, La Union.

### 2.1 Experimental Site and Design

The experiment was conducted in a 320-square-meter field located in Barangay Casiaman, Bacnotan, La Union. The site was cleared and rotavated using a heavy-duty tractor with two passes to ensure adequate soil preparation. A greenhouse made of bamboo poles and polyethylene plastic sheeting was constructed to provide a semi-controlled growing environment appropriate for off-season production.

The experiment followed a Randomized Complete Block Design (RCBD) with four treatments and three replications. Each replication consisted of five plots per treatment, totaling 60 plots. Each plot measured 1 meter by 5 meters, with a 0.50-meter alley between plots and 1 meter between blocks for easy access. The four treatments were defined by the frequency of trehalose foliar fertilizer application:

T1 – Once application

T2 – Twice application

T3 – Thrice application

T4 – Four times application

| Replication (Block) | Plot 1 | Plot 2 | Plot 3 | Plot 4 |
|---|---|---|---|---|
| **Replication I** | **T2** | **T4** | **T1** | **T3** |
| **Replication II** | **T3** | **T2** | **T4** | **T1** |
| **Replication III** | **T1** | **T3** | **T2** | **T4** |

### 2.2 Sowing and Transplanting

Tomato seeds (*Diamante Max* variety) were sown singly in individual cells of plastic seedling trays and lightly covered with soil. Watering was done immediately after sowing to provide sufficient moisture for germination. Seedlings were maintained under nursery conditions for approximately one month, after which they were transplanted into the field.

Planting holes were prepared in a double alternate row system, with 40 cm spacing between both hills and rows. Transplanting was performed in the late afternoon to minimize transplant shock, followed by immediate irrigation to support seedling establishment.

### 2.3 Fertilizer and Treatment Application

Prior to transplanting, each planting hole received 10 grams of processed vermicompost as basal organic fertilizer. At three weeks after transplanting, 5 grams of complete inorganic fertilizer (14-14-14) were applied to each plant. This was done by creating a 9 cm-deep hole near the base of each plant, depositing the fertilizer, and immediately covering it with soil to minimize nutrient loss.

The trehalose foliar fertilizer was applied starting one month after transplanting, following the assigned treatment frequencies. A fixed concentration of 2 tablespoons of trehalose per 16 liters of water was used across all treatments. Applications were conducted using a standard knapsack sprayer until the foliage was thoroughly wetted.

2.4 Cultural Practices

Standard cultural management practices for tomato cultivation were observed throughout the cropping period, including regular watering, manual weeding, and pest and disease control (Cardenas and Siladan, 2010). Watering was done early in the morning using a garden hose with a nozzle for uniform distribution. Weeding was carried out manually around each plant and across the experimental area to prevent competition for nutrients and sunlight. Pest and disease monitoring was performed through regular visual inspection, and appropriate control measures were applied when necessary.

2.5 Harvesting and Sampling

Harvesting was done manually once fruits reached physiological maturity. Marketable and non-marketable fruits were separated at harvest and placed in distinct containers. From each treatment plot, 10 sample plants were randomly selected and used as the basis for data collection.

2.6 Parameters Measured

The following growth and yield parameters were recorded:

*Days from Transplanting to Flowering.* Number of days from transplanting to the first visible flower. *Days from Transplanting to First Harvest.* Number of days from transplanting to the first mature fruit harvest. *Days from Fruit Setting to First Harvest.* Number of days from visible fruit setting to first harvest. *Plant Height at Flowering (cm).* Measured from the base to the tip of the longest leaf using a foot rule on 10 sample plants per plot. *Average Number of Leaves at First Harvest.* Counted from 10 sample plants and averaged. *Leaf Area at Flowering (cm²).* Measured using a handheld Leaf Area Index (LAI) meter on 10 sample plants per plot. *Flower to Fruit Ratio (%).* Calculated as (Number of Fruits / Number of Flowers) × 100. *Average Fruit Weight per Plant (kg).* Determined by weighing fruits per sample plant and computing the mean. *Average Number of Fruits per Plant.* Counted and averaged per sample plant. *Marketable Yield (kg/plot).* Weight of harvested fruits per plot free from deformities or damage.

*Non-Marketable Yield (kg/plot).* Weight of fruits per plot that were damaged, deformed, or substandard. *Number of Harvests.* Total count of harvest events per treatment over the fruiting period.

*Total yield (kg/plot).* This was the total weight of marketable and non-marketable fruits per treatment in each plot.

*Computed yield per hectare (ton/ha).* This was determined by the marketable yield per plot. *Occurrence of Pests and Diseases.* Assessed through regular visual observation.

## III. RESULTS AND DISCUSSION

3.1 Days from Transplanting to Flowering

As shown in Table 1, the frequency of trehalose foliar fertilizer application did not result in a statistically significant difference in the number of days from transplanting to flowering. Although the thrice and four-times application treatments showed slightly earlier flowering compared to the once and twice application treatments, these variations were not significant. The coefficient of variation (CV) of 5.85% reflects acceptable experimental consistency. These findings indicate that, under the conditions of the study, increasing the frequency of trehalose application did not produce a substantial effect on the onset of flowering. In this context, lower application frequencies, such as a single application, may be considered sufficient in terms of flowering response, particularly when viewed from the perspective of input efficiency and resource management.

3.2 Days from Transplanting to First Harvest

As shown in Table 2, the frequency of trehalose foliar fertilizer application did not result in a statistically significant difference in the number of days from transplanting to first harvest. Although the thrice application treatment recorded the earliest harvest at 81.63 days and the twice application the latest at 86.30 days, these numerical differences were not significant. The relatively low coefficient of variation (CV) of 3.52% indicates good consistency across treatments. These results suggest that increasing the frequency of application did not meaningfully influence the timing of fruit maturity. Therefore, a single application may be adequate for achieving a comparable harvest timeline, offering practical benefits in terms of input savings and operational efficiency without compromising crop development.

### 3.3 Days from Fruit Setting to First Harvest

As shown in Table 3, the frequency of trehalose foliar fertilizer application did not result in a statistically significant difference in the number of days from fruit setting to first harvest. Although the thrice application treatment recorded the shortest interval (41.27 days) and the twice application the longest (43.23 days), the variation among treatments was not significant. The coefficient of variation (CV) of 6.92% indicates moderate experimental consistency. These results suggest that increasing the frequency of trehalose application did not have a substantial influence on the rate of fruit maturation once fruit setting had occurred. Accordingly, a single application may be sufficient to maintain a similar harvest interval, offering a practical advantage in reducing input use without affecting harvest timing at this stage of development.

### 3.4 Plant Height at Flowering (cm)

As shown in Table 4, the frequency of trehalose foliar fertilizer application did not result in a statistically significant difference in plant height at flowering. Although the tallest plants were observed in the four-times application treatment (64.47 cm), followed closely by the thrice application (62.37 cm), and the shortest in the twice application (54.63 cm), the observed differences were not statistically significant. The coefficient of variation (CV) of 15.70% indicates relatively high variability among treatments. These results suggest that increasing the frequency of trehalose application had no substantial effect on vegetative height at flowering. Therefore, a single application may be adequate to support comparable plant growth, providing a practical benefit in terms of reduced input use and labor without compromising early vegetative development.

### 3.5 Average Number of Leaves at First Harvest

As shown in Table 5, the frequency of trehalose foliar fertilizer application did not result in a statistically significant difference in the average number of leaves at first harvest. While the highest number of leaves was recorded in the four-times application treatment (25.03), and the lowest in the once application treatment (19.47), these differences were not statistically significant. The coefficient of variation (CV) of 13.26% indicates moderate variability among treatments. These findings suggest that increasing the frequency of trehalose application did not lead to a substantial increase in foliage development by the time of first harvest. Hence, a single application may still support acceptable vegetative growth, offering efficiency in input use without significantly affecting leaf development.

### 3.6 Leaf Area at Flowering

As shown in Table 6, the frequency of trehalose foliar fertilizer application did not result in a statistically significant difference in leaf area index (LAI) at the flowering stage. The highest LAI was recorded in the once application treatment (183.22), while the lowest was observed in the four-times application treatment (160.25). Despite these numerical differences, the variation among treatments was not statistically significant. The coefficient of variation (CV) of 16.74% indicates a relatively high degree of variability. These findings suggest that increased frequency of trehalose application did not enhance leaf area development during flowering. In fact, a single application yielded the highest mean LAI, implying that minimal application may already be sufficient to support favorable leaf expansion, thus offering potential savings in labor and input costs.

### 3.7 Flower to Fruit Ratio

As shown in Table 7, the frequency of trehalose foliar fertilizer application did not result in a statistically significant difference in flower to fruit ratio. The highest ratio was observed in the twice application treatment (55.44%), while the lowest was in the once application (47.40%). Although the twice application showed a numerically higher conversion rate, the differences among treatments were not statistically significant. The coefficient variation (CV) of 18.32% indicates relatively high variability across replications. These results suggest that increasing the frequency of trehalose application did not consistently enhance fruit set efficiency. Therefore, a lower frequency of application, such as a single or twice application, may already support acceptable reproductive performance while maintaining input efficiency.

### 3.8 Average Fruit Weight per Plant and Average Number of Fruits per Plant

As shown in Table 8, the frequency of trehalose foliar fertilizer application did not result in a statistically significant difference in the average weight of fruits per plant. Although the highest average weight (1.67 kg) was recorded in both the twice and thrice application treatments, and the lowest in the once application (1.46 kg), the variation was not statistically significant. The coefficient of variation (CV) of 8.11% indicates moderate variability. These results suggest that fruit weight was relatively stable across different application frequencies, implying that even minimal application may be sufficient to maintain acceptable fruit mass.

In contrast, a statistically significant difference was observed in the average number of fruits per plant. The four-times application treatment produced the highest number of fruits (45.77), significantly greater than the once application (38.34), which recorded the lowest. The CV of 3.62% reflects high consistency in this parameter. These results indicate that increased frequency of trehalose application may enhance fruit set. Trehalose plays a key role in stress signaling and carbohydrate regulation, which can improve reproductive development under suboptimal conditions (Schluepmann et al., 2003). Furthermore, studies have shown that exogenous trehalose application can enhance pollen viability and fertilization efficiency, resulting in greater fruit production (Lordachescu & Imai, 2008). Therefore, while frequent application may increase fruit count, economic viability should also be considered when determining the optimal application frequency.

3.9 Marketable Yield (kg/plot) and Non-Marketable Yield (kg/plot).

As shown in Table 9, a statistically significant difference was observed in the weight of marketable yield per plot across different frequencies of trehalose application. The highest marketable yields were recorded in the thrice (38.89 kg) and twice (38.87 kg) application treatments, both significantly higher than the yields from the once (33.44 kg) and four-times (35.01 kg) applications. The coefficient of variation (CV) of 5.25% indicates high consistency. These results suggest that moderate frequencies of trehalose application may optimize marketable fruit production, possibly due to improved physiological processes such as osmoprotection, stress tolerance, and sugar regulation during critical growth stages. Trehalose has been shown to enhance photosynthetic activity and resource allocation, which are closely linked to increased fruit set and quality (Paul et al., 2008; Garg et al., 2002). Excessive application, as seen in the four-times treatment, may not yield further benefits and could potentially disrupt the plant's metabolic balance.

In contrast, the weight of non-marketable yield did not differ significantly among treatments. While the thrice application recorded the lowest non-marketable yield (1.11 kg), and the once application the highest (1.60 kg), the differences were not statistically significant, as indicated by a high CV of 74.55%. This suggests that trehalose frequency had limited influence on fruit rejection rates, which may instead be attributed to uncontrolled environmental factors or incidental pest damage during the cropping cycle.

3.10 Number of Harvests

As shown in Table 10, the frequency of trehalose foliar fertilizer application had a statistically significant effect on the number of harvests per plant. The thrice (10.30) and four-times (10.10) application treatments resulted in significantly more harvests compared to the once (8.63) and twice (8.60) application treatments. The coefficient of variation (CV) of 4.92% indicates a high level of consistency in the data. These findings suggest that more frequent application of trehalose may extend the fruiting period, enabling additional harvest events.

This increase in harvest frequency may be attributed to trehalose's role in delaying senescence and supporting prolonged physiological activity in plants. Trehalose treatments have been shown to delay floral and leaf senescence in ornamental species by maintaining membrane integrity and cellular function. Additionally, trehalose metabolism, particularly through its intermediate trehalose-6-phosphate (T6P), is implicated in integrating sugar signals that regulate growth and prolong plant developmental processes (Lunn et al., 2014). By delaying the onset of senescence and sustaining productive tissue, plants receiving three to four applications may sustain fruit production over a longer period, resulting in more harvests. Moreover, exogenous trehalose application has also been associated with extended chlorophyll retention and enhanced source–sink efficiency in several fruit crops, contributing to prolonged yield periods (Joshi et al., 2020). However, as with other parameters, the economic viability of multiple applications should be considered in relation to the added input costs.

3.11 Total yield per plot and computed yield in tons per hectare

As shown in Table 11, the frequency of trehalose foliar fertilizer application did not result in a statistically significant difference in total yield per plot or computed yield per hectare. The highest total yield (16.65 kg per 5 $m^2$) and computed yield (31.05 tons/ha) were recorded in the thrice application treatment, followed by the four-times application (29.13 tons/ha), and the lowest in the once application (26.33 tons/ha). Despite these numerical differences, the variation among treatments was not statistically significant. The coefficients of variation (CV) were 8.97% and 7.96% for total yield and computed yield, respectively, indicating acceptable experimental precision. These findings suggest that increasing the frequency of trehalose application did not significantly enhance yield performance. From a production standpoint, lower application frequencies, particularly a single or twice application may already support comparable yield levels, offering potential advantages in terms of reduced cost and labor without sacrificing productivity.

3.12 Occurrence of Pests and Diseases

As shown in Table 12, the frequency of trehalose foliar fertilizer application did not result in a statistically significant difference in the incidence of whiteflies and tomato leaf curl. The lowest mean incidence of whiteflies was observed in the four-times application treatment

(2.00), while the highest was recorded in the once application (3.00). For tomato leaf curl, the lowest incidence was in the twice application (1.00), with other treatments recording similar values (1.33). Despite these variations, the differences among treatments were not statistically significant. The coefficients of variation were 18.86% for whiteflies and 46.19% for tomato leaf curl, indicating high variability, particularly for the latter. These results suggest that increasing the frequency of trehalose application did not effectively reduce pest or disease incidence. Therefore, while trehalose may support plant growth, its use alone may not provide adequate protection against common pests and diseases, and integrated crop protection strategies remain necessary.

## IV. TABLES

*Table.1: Number of days from transplanting to flowering*

| Frequency of Application | Mean (Days) |
|---|---|
| Once Application | 39.00 |
| Twice Application | 39.43 |
| Thrice Application | 36.67 |
| Four times Application | 36.80 |
| CV (%) | 5.85 |

*Table.2: Number of days from transplanting to first harvest*

| Frequency of Application | Mean (Days) |
|---|---|
| Once Application | 84.77 |
| Twice Application | 86.30 |
| Thrice Application | 81.63 |
| Four times Application | 83.20 |
| CV (%) | 3.52 |

*Table.3: Number of days from fruit setting to first harvest*

| Frequency of Application | Mean (Days) |
|---|---|
| Once Application | 41.47 |
| Twice Application | 43.23 |
| Thrice Application | 41.27 |
| Four times Application | 43.10 |
| CV (%) | 6.92 |

*Table.4: Plant height at flowering (cm)*

| Frequency of Application | Mean (Days) |
|---|---|
| Once Application | 57.23 |
| Twice Application | 54.63 |
| Thrice Application | 62.37 |
| Four times Application | 64.47 |
| CV (%) | 15.70 |

*Table.5: Average number of leaves at first harvest*

| Frequency of Application | Mean (number) |
|---|---|
| Once Application | 19.47 |
| Twice Application | 23.73 |
| Thrice Application | 23.20 |
| Four times Application | 25.03 |
| CV (%) | 13.26 |

*Table.6: Leaf area at flowering (LAI)*

| Frequency of Application | Leaf Area Index |
|---|---|
| Once Application | 183.22 |
| Twice Application | 164.34 |
| Thrice Application | 170.99 |
| Four times Application | 160.25 |
| CV (%) | 16.74 |

*Table.7: Flower to fruit ratio (%)*

| Frequency of Application | Mean (%) |
|---|---|
| Once Application | 47.40 |
| Twice Application | 55.44 |
| Thrice Application | 49.86 |
| Four times Application | 50.25 |
| CV (%) | 18.32 |

*Table.8: Average weight (kg) and number of fruits per plant*

| Frequency of Application | Average weight of fruit/plant | Average no. of fruits/plant |
|---|---|---|
| Once Application | 1.46 | $38.34^{c}$ |
| Twice Application | 1.67 | $41.67^{b}$ |

| | | |
|---|---|---|
| Thrice Application | 1.67 | 42.43$^{b}$ |
| Four times Application | 1.58 | 45.77$^{a}$ |
| CV (%) | 8.11 | 3.62 |

Note: Means with the same letter are not significantly different.

*Table.9: Weight of marketable and non-marketable yield per plot (kg)*

| Frequency of Application | Weight of marketable yield (kg/plot) | Weight of non-marketable yield (kg/plot) |
|---|---|---|
| Once Application | 33.44$^{b}$ | 1.60 |
| Twice Application | 38.87$^{a}$ | 1.29 |
| Thrice Application | 38.89$^{a}$ | 1.11 |
| Four times Application | 35.01$^{b}$ | 1.17 |
| CV (%) | 5.25 | 74.55 |

Note: Means with the same letter are not significantly different.

*Table.10: Number of harvestings per plant*

| Frequency of Application | Mean (number) |
|---|---|
| Once Application | 8.63$^{b}$ |
| Twice Application | 8.60$^{b}$ |
| Thrice Application | 10.30$^{a}$ |
| Four times Application | 10.10$^{a}$ |
| CV (%) | 4.92 |

Note: Means with the same letter are not significantly different.

*Table.11: Total yield per plot and computed yield in tons per hectare*

| Frequency of Application | Total yield (kg/5m$^2$) | Computed yield (tons/ha) |
|---|---|---|
| Once Application | 14.77 | 26.33 |
| Twice Application | 15.87 | 28.70 |
| Thrice Application | 16.65 | 31.05 |
| Four times Application | 15.73 | 29.13 |
| CV (%) | 8.97 | 7.96 |

*Table.12: Incidence of insect pests and diseases*

| Frequency of Application | White flies | Tomato leaf curl |
|---|---|---|
| Once Application | 3.00 | 1.33 |
| Twice Application | 2.67 | 1.00 |
| Thrice Application | 2.33 | 1.33 |
| Four times Application | 2.00 | 1.33 |
| CV (%) | 18.86 | 46.19 |

## V. CONCLUSION

This study demonstrated that the frequency of trehalose foliar fertilizer application significantly influences select reproductive and yield traits of off-season tomato (*Solanum lycopersicum* L.) under greenhouse conditions in Bacnotan, La Union. While most growth parameters including days to flowering and harvest, plant height, leaf area, and total yield were not statistically affected by varying application frequencies, key yield-related indicators showed meaningful responses.

Specifically, applying trehalose three times resulted in the highest marketable yield, fruit number per plant, and harvest frequency, outperforming both lower and higher frequencies. Although four applications also increased fruit count and harvests, they did not significantly exceed the results of thrice application, suggesting diminishing returns at higher input levels.

From both agronomic and economic perspectives, thrice application of trehalose strikes the most effective balance between productivity and resource efficiency. Meanwhile, once or twice application still supported comparable growth and acceptable yields, indicating practical benefits for cost-conscious farmers. These findings underscore the potential of trehalose as a foliar input in improving off-season tomato production, provided it is applied judiciously.

Further field trials across different agroecological zones and production systems are recommended to confirm these results and refine application strategies for broader adoption.

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