

# Tree Endo-Nutrition in Guava: Effects of Injection Depth, Angle, Hole Diameter, and Pressure on Nutrient Absorption

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## Abstract

Tree trunking technology anew method fertilization for trees but it's technology want some tic chon to using afield trial was conducted during the summer growth season of 2022 at a farm in the El Qusiyah district, Assiut governorate, which is situated 325 kilometers south of Cairo, Egypt, at a latitude of (27°29'2.58" N) and a longitude of (30°39'3.23" E). The trial aimed to assess and investigate the appropriate depth and diameter for using the tree trunk injection method of nutrient addition. To determine this, a pre- experiment was carried out, and the findings showed that the ideal diameter was (4 mm) and the proper depth was one-third of the trunk. The findings demonstrated that this depth allowed for an absorption rate of 22 ml per day within the trunk. Various rates of solution fertilizer (19-19-19) were used, and some findings suggested that the tree trunk injection method had a significant effect, as the crop yield was measured in tons per hectare the results indicates the solution tank at 100 cm above soil and injection at a 45° angle with the 4mm hole diameter injection at 10cm above soil surface increases by prostatic pressure and leading to improved solution absorption rate.

**Keywords:** Tree endo nutrition, Nutrient addition, Absorption rate, Drainage rate, Optimal depth and diameter, Balanced fertilizer

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## 1. Introduction

The natural distribution of mineral nutrients is an important factor influencing plant species. This distribution favors the spread of species with adaptations to either nutrient excess or deficiency [1]. Additionally, applying fertilizers to the soil—specifically those vital plant nutrients needed in greater quantities is the traditional approach [2]. Despite being the most common method, soil fertilization has certain drawbacks. There have been recorded varying degrees of nitrate pollution in different fruit-producing regions, which are linked to over-fertilization and specific environmental factors such as sandy soils and heavy rainfall [3]. To ensure efficient fertilizer management, it is necessary to evaluate the best nutrient sources, optimal fertilization rates, suitable timing, and proper fertilizer placement [4]. Trunk injection technology (TJT) is a promising, precise, and environmentally friendly treatment method that has demonstrated valuable effectiveness through the use of various injection apparatus [5]. Trunk injections provide a safer and more environmentally friendly alternative, as it directly delivers therapeutic materials into plant tissue [6]. Research has demonstrated the exceptional success of trunk injection in enhancing citrus tree yield and fruit quality [5].

This method serves as a targeted approach for delivering nutrients or plant protection compounds directly into the stem or trunk of woody plants, offering an alternative to conventional spraying and soil drenching. Moreover, trunk injections have several advantages over traditional methods, including increased nutrient uptake efficiency, reduced environmental risks, minimized harm to non-target organisms, and suitability for application in populated areas where other fertilization methods may not be practical [7,5]. Despite its potential, trunk injection has not yet been fully optimized for commercial crop production. Injection is typically performed at low pressures (<60 psi) using manual squeezing or a spring-loaded syringe system, with most systems requiring pre-drilled holes for application [8]. Furthermore, the pathway and effectiveness of material distribution throughout the tree are influenced by various anatomical characteristics, including the size and arrangement of xylem vessels, tracheid, and vessel parenchyma cells [9]. Recent studies indicate that the cohesion of dipolar water molecules generates the high tensile strength necessary for maintaining a continuous water column from the roots to the leaves. However, wounds smaller than 12 mm in diameter typically heal

within a year, while annual trunk injections using ports smaller than 25 mm in diameter are unlikely to significantly affect tree growth, particularly in large forest trees [10]. The use of pressurized devices allows for the rapid injection of relatively large volumes of product into the tree. Compared to non-pressurized devices, these systems distribute the injected compounds more evenly throughout the tree [6]. The efficiency of tree trunk injection largely depends on the vascular system of the tree, particularly the xylem vessels and parenchyma cells, which facilitate the movement of nutrients and water throughout the plant [9]. The effectiveness of injected compounds is influenced by factors such as tree species, injection depth, and seasonal variations, which affect the rate of absorption and translocation [11]. Recent research indicates that pressurized trunk injection systems improve nutrient distribution by accelerating the uptake and movement of injected substances. Moreover, studies have demonstrated that smaller injection wounds (<12 mm in diameter) heal within a year, reducing the risk of long-term damage to tree health [10]. However, economic viability and labor costs must be carefully evaluated before large-scale implementation in commercial forestry and fruit production systems [12]. To maximize the benefits of tree trunk injection, it is essential to optimize key factors such as injection depth, nutrient formulation, and application frequency. Research suggests that injecting nutrients at one-third of the trunk's depth enhances Absorption Rates Fertilizer (ARF) and minimizes nutrient loss, leading to improved plant health and productivity. Additionally, the choice of fertilizer composition plays a crucial role, as balanced formulations like 19-19-19 NPK have been shown to promote uniform growth and enhance fruit quality [5]. Seasonal variations significantly impact nutrient uptake efficiency, with higher absorption rates observed during periods of active xylem transport, such as spring and early summer [7]. Moreover, studies indicate that pressurized injection systems outperform non-pressurized methods by ensuring faster distribution of nutrients within the vascular system, particularly in species with dense xylem structures [6]. Beyond efficiency, the environmental impact of trunk injection is a critical consideration. Future research should focus on developing species-specific injection protocols, optimizing the delivery of micronutrients, and exploring sustained-release formulations to minimize labor costs and maximize long-term benefits [4]. The aim at this research is to identify the best site in the tree trunk achieves the best sustainability savings coast and efficient alternative to traditional fertilization techniques in both forestry, fruitily and Comerciale agriculture.

## 2. Materials and methods

### 2.1. Experimental Site

A field experiment was carried out in the summer season of (2022-2023) at El Qusiyah district, Assiut governorate located at latitude of 27°29'2.58" N; and longitude 30°39'3.23"E. The region is characterized by a hot arid climate, particularly during summer months. Based on the recorded climate data from April to October (Table 1),

average temperatures ranged from 26.7°C in April to 34.1°C in August. Daily maximum temperatures frequently exceed 35°C, peaking at 38.0°C in August. Minimum temperatures followed a similar trend, rising from 15.5°C in April to 24.6°C in July. Relative humidity remained relatively low, ranging from 22.2% in May to 39.1% in October, with one of the lowest values (24.2%) recorded in June. Wind speed varied between 17.7 and 20.7 km/h, with the highest average occurring in June. These conditions reflect the extreme summer heat, low atmospheric moisture, and moderate wind activity typical of Upper Egypt's climate during the growing season [13].

Soil sample was collected before planting to determine some soil physical and chemical properties according to the methods of [14] and result to are presented in Table (2).

### 2.2. Experimental Design and Treatments

The method of direct injection of fertilizers and nutrients into the tree trunk is necessary to save the costs of agricultural production and determine the appropriate place in the tree trunk and the pressure of the solution absorption rate of the solution is a basic start to determine the injection mechanism and how it has been tried to inject the solution at different heights of the tank (25, 50 and 100 cm) from the soil surface (Figure A) and test different angles of the injection inside the trunk. also, the diameter of the hole inside the tree trunk and experiment with the height of the injection site from the soil surface inside the trunk. Injection Location and Method in the Tree Trunk. A field experiment was conducted to evaluate the effect of different injection locations within the tree trunk on solution absorption efficiency. The injection treatments were applied at three distinct locations. A balanced fertilizer was used (19/19/19) and an aqueous solution was made by adding 5 grams / liter.

1. Outer bark injection (IIR): The solution was injected into the outermost layer of the tree trunk (bark).
2. One-third trunk diameter injection (TIR): The injection was administered at a depth corresponding to one-third of the trunk's diameter.
3. Middle trunk injection (MIR): The solution was injected into the central portion of the tree trunk.

A schematic diagram (Figure B) illustrates the cross-section of the tree trunk, indicating the injection sites relative to the phloem (responsible for nutrient transport) and xylem (responsible for water and mineral transport). The injection depth was standardized at 3 cm, and the trunk diameter measured 9 cm.

This experiment aimed to determine the most effective injection site by analyzing the absorption rate of solution at each location.

### 2.3 Factors affecting the efficiency of solution absorption rate (SAR)

The experiment was conducted to evaluate the impact of solution tank height, injection angle, hole diameter, and

injection site height on solution absorption efficiency. The solution tank was positioned at varying heights above the soil surface to assess its effect on solution pressure and absorption rate. A sharp upward injection angle (45°) was applied to determine its role in minimizing solution loss.

Additionally, different injection hole diameters were tested to analyze their influence on the daily volume of solution absorbed. The injection site height from the soil surface was also varied to examine its effect on absorption efficiency.

**Table (1):** Weather conditions during the experiment

Month	Avg Temperature (°C)	Max/Min Temperature (°C)	Relative Humidity (%)	Wind Speed (km/h)
April	26.7	31.3 / 15.5	24.7	18.9
May	31.5	35.4 / 20.7	22.2	18.2
June	33.7	37.6 / 23.6	24.2	20.7
July	34	37.9 / 24.6	27.6	18.8
August	34.1	38.0 / 24.5	28.4	19
September	31.4	35.7 / 22.2	34.4	20
October	27.3	32.2 / 18.6	39.1	17.7

**Table (2):** Some physical and chemical properties of the experimental soil before cultivation

Property	Value	Property	Value
pH (1:2.5 suspension)	8.33	Cl (meq/L)	1.21
EC (1:1) (dS m <sup>-1</sup> )	0.45	Sulfates (SO <sub>4</sub> <sup>2-</sup> )	1.5
SP (%)	30	Nitrates (NO <sub>3</sub> <sup>-</sup> )	0.35
Organic matter (g kg <sup>-1</sup> )	2.90	Available Nutrients	
CaCO <sub>3</sub> (%)	4.10	Available N (mg kg <sup>-1</sup> )	36.00
Physical Properties		Available P (mg kg <sup>-1</sup> )	1.60
Sand (%)	90.30	Available K (mg kg <sup>-1</sup> )	130
Silt (%)	6.50	Soluble cations	
Clay (%)	3.20	Ca (meq/L)	0.15
Texture	Sandy	Mg (meq/L)	0.20
Soluble anions		Na (meq/L)	1.01
CO <sub>3</sub> <sup>--</sup> +HCO <sub>3</sub> <sup>-</sup> (meq/L)	1.85	K (meq/L)	0.74

Each value represents the mean of three replications

**Table (3):** Some chemical composition of nutrient solution used

Properties	5 gm/ liter from mineral (19:19:19)
pH (1:5) Solution	7.20
EC (1:5) ex. (dS m <sup>-1</sup> )	1.50
Total N (%)	0.09
Total P (%)	0.04
Total K (%)	0.07
fertilizer color	White

Each value represents the mean of three replications.

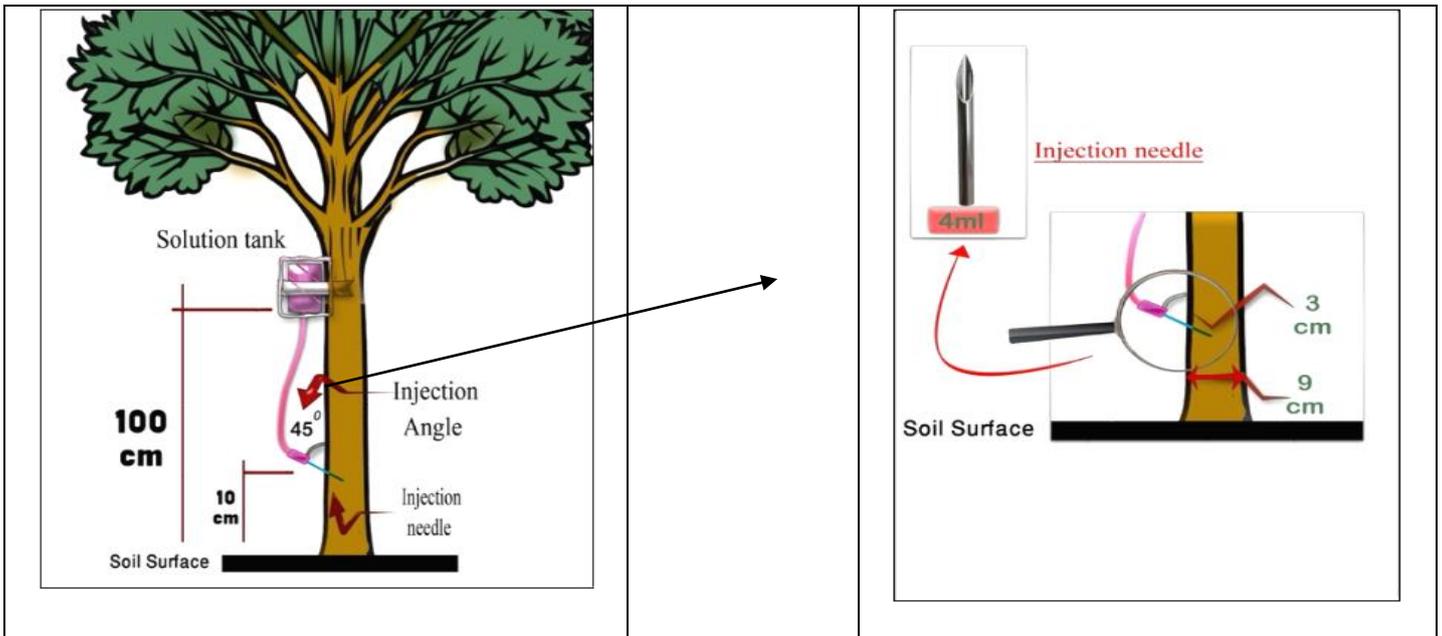


Figure (A): Height of the solution tank from the soil surface

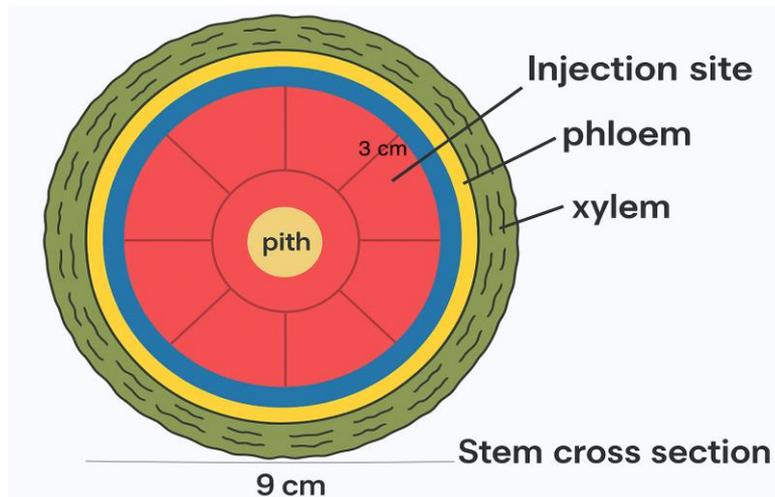


Figure (B): Injection location in the tree trunk

### 3. Results

#### 3.1. Effect of pressure (tank height) on the solution absorption rate(SAR)

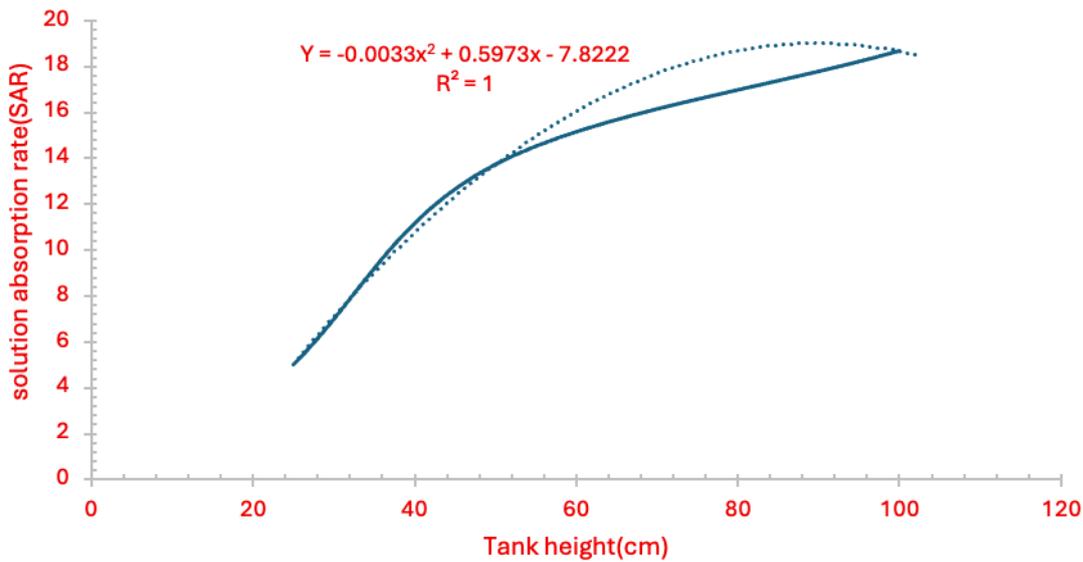
The results of this study clearly demonstrate the effect of pressure, generated by the height of the solution tank, on the absorption rate (SAR) of the solution through the tree trunk. The findings indicate a direct relationship between tank height and solution absorption rate, which aligns with fundamental principles of fluid dynamics. At a height of 25 cm (T1) above the soil surface, the absorption rate was low, corresponding to a relatively low-pressure of 2450 Pascals. As the tank height increased to 50 cm (T2), the absorption rate became moderate, with a pressure of 4900 Pascals. The highest absorption rate was observed at 100 cm (T3) above the soil surface, where the pressure reached 9800 Pascals. This confirms that increasing pressure enhances the efficiency of solution uptake through the tree

trunk. The polynomial equation fitted to the data suggests a nonlinear relationship between tank height and absorption rate. The high  $R^2$  value of 1 indicates a strong correlation, implying that the model accurately predicts the absorption behavior under different pressure conditions. These results are significant as they highlight the potential of large-volume solution injection technology for tree fertilization. Compared to traditional methods like spraying or soil application fertigation, trunk injection ensures more efficient nutrient absorption, minimizes environmental contamination, and reduces pest-related issues. Additionally, this technique offers economic benefits by reducing fertilizer wastage and optimizing agricultural productivity. Future studies could explore the long-term effects of different pressure levels on tree health and nutrient uptake efficiency. Moreover, investigating the impact on different tree species would provide valuable insights into the broader applicability of this method.

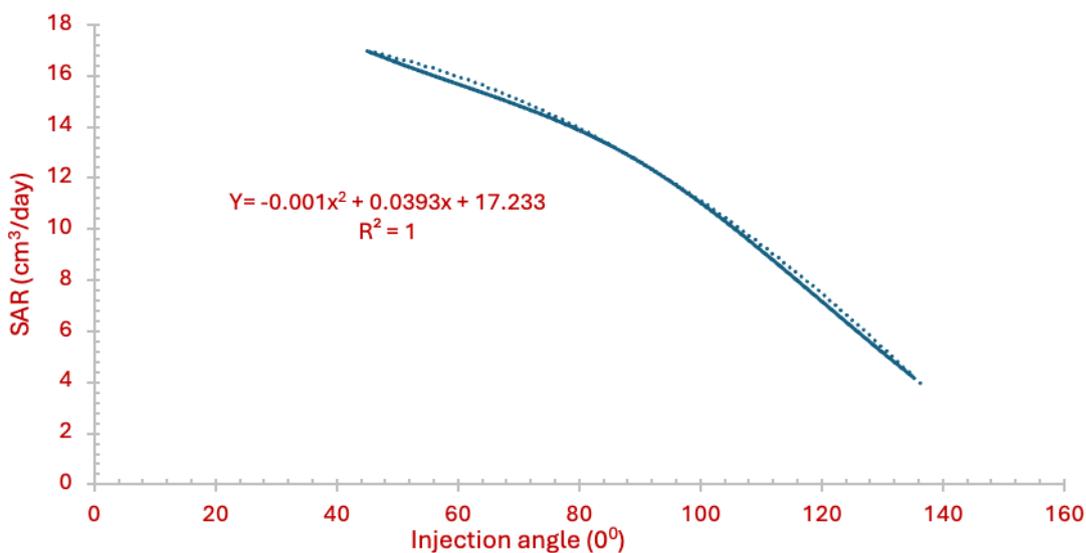
**3.2. Effect of Injection Angle and hole diameter on solution absorption (cm<sup>3</sup>/day) rate of the nutrient**

The graph illustrates the relationship between the injection angle and the daily withdrawal rate of the solution inside the tree trunk. The results indicate that the 45° injection angle achieves the highest withdrawal rate, while the 135° angle leads to a significant decrease, suggesting greater solution loss outside the trunk. This can be attributed to the fact that the 45° angle allows for more efficient absorption into the tree’s vascular tissues, enhancing the withdrawal rate. In contrast, at the 135° angle, the withdrawal rate gradually decreases, as shown by the downward trend in the graph. This decline indicates inefficient absorption, with a large portion of the solution escaping instead of being utilized by the tree. The 90° angle

appears in the middle of the curve, representing a moderate withdrawal rate compared to the other angles. The R<sup>2</sup> = 1 value in the polynomial equation on the graph confirms a strong correlation between the injection angle and the withdrawal rate, reinforcing the importance of selecting the optimal angle to enhance nutrient absorption and minimize wastage. Based on these findings, the 45° injection angle is recommended for maximizing absorption efficiency and reducing solution loss, thereby improving the effectiveness of tree trunk injection fertilization techniques. Future studies could explore the impact of injection angles on different tree species and irrigation systems to further optimize absorption efficiency.



**Fig. (1):** Influence of tank height on solution absorption rate(SAR)in tree trunk



**Fig. (2):** Influence of Injection angle on SAR (cm<sup>3</sup>/day) in tree trunk

### 3.3. Evaluation of the height of the injection site above the soil surface

The graph illustrates the relationship between the injection height above the soil surface and the withdrawal rate of the solution. The results indicate that injecting the solution at a height of 10 cm above the soil surface achieves the highest absorption rate. This is evident from the peak in the graph, where the withdrawal rate reaches its maximum, suggesting that this height optimizes nutrient uptake while minimizing solution loss and site pollution. Conversely, injection at heights of 5 cm and 15 cm above the soil surface results in lower absorption rates. As seen in the graph, these points correspond to a decline in the withdrawal rate, indicating reduced efficiency in nutrient uptake. This

reduction may be due to improper distribution of the solution within the tree's vascular system or increased solution loss at these heights.

The  $R^2 = 1$  value in the polynomial equation confirms a strong correlation between injection height and withdrawal rate, reinforcing the importance of selecting an optimal injection height. Based on these findings, a height of 10 cm above the soil surface is recommended for maximizing absorption efficiency and minimizing pollution risk. Future studies could explore the effects of different soil types, tree species, and environmental conditions to further refine the optimal injection height for various agricultural and forestry applications.

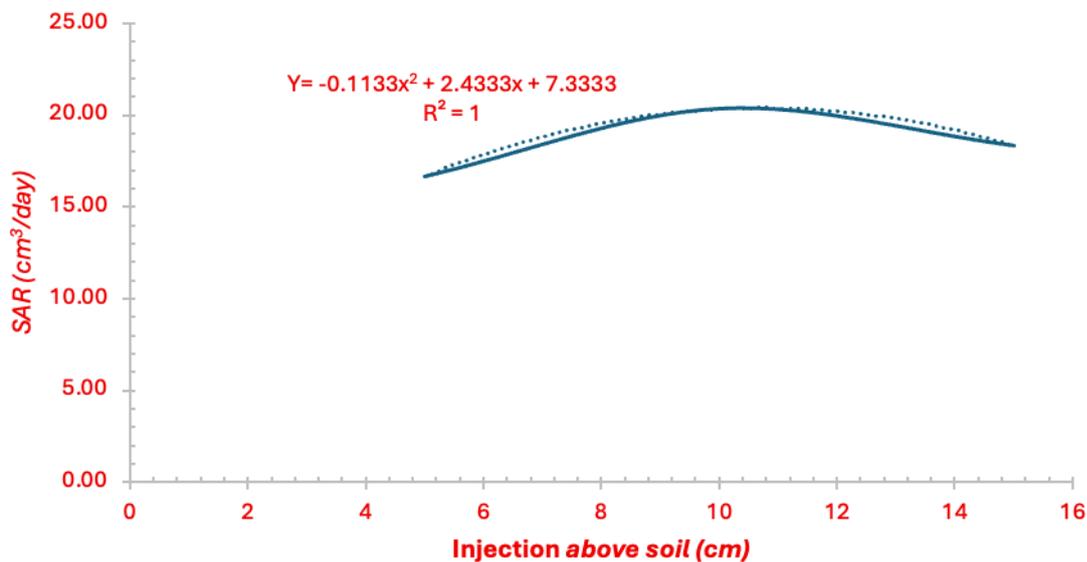


Fig. (3): Influence of Injection above soil on solution absorption in tree trunk

### 3.4. Evaluation of solution absorption rate by depth of injection into the stem

The graph illustrates the relationship between injection depth and daily withdrawal rate of the solution within a tree trunk with a 15 cm diameter. The injection was tested at three different locations within the trunk: the outer bark (I1R1), the first third of the diameter (T1R), and the middle (M1R). The numerical values presented serve as examples for these injection sites. The results indicate that injection at the first third of the trunk (T1R) showed the highest absorption rate, reaching 22.00 ml/day, as depicted by the peak point on the graph. This can be explained by the fact that this depth provides a balance between access to vascular tissues and reduced exposure to air or clogging. In contrast, the absorption rate was lower when injected in the

middle (M1R), with a rate of 15.00 ml/day. This could be due to the lower density of vascular tissues in this region or increased internal resistance to solution transport. For injection in the outer bark (I1R1), the absorption rate was 18.50 ml/day, which is lower than the first third but higher than the middle. This could be attributed to a higher concentration of vascular tissues in the bark, but with a greater risk of solution loss due to leakage or evaporation before full absorption. Analysis of the Graph and Mathematical Equation The graph shows a bell-shaped curve, indicating that there is an optimal injection depth, which is located around the first third of the diameter, where absorption is at its highest. The mathematical equation ( $R^2 = 1$ ) reflects a strong correlation between depth and withdrawal rate, reinforcing the reliability of the results.

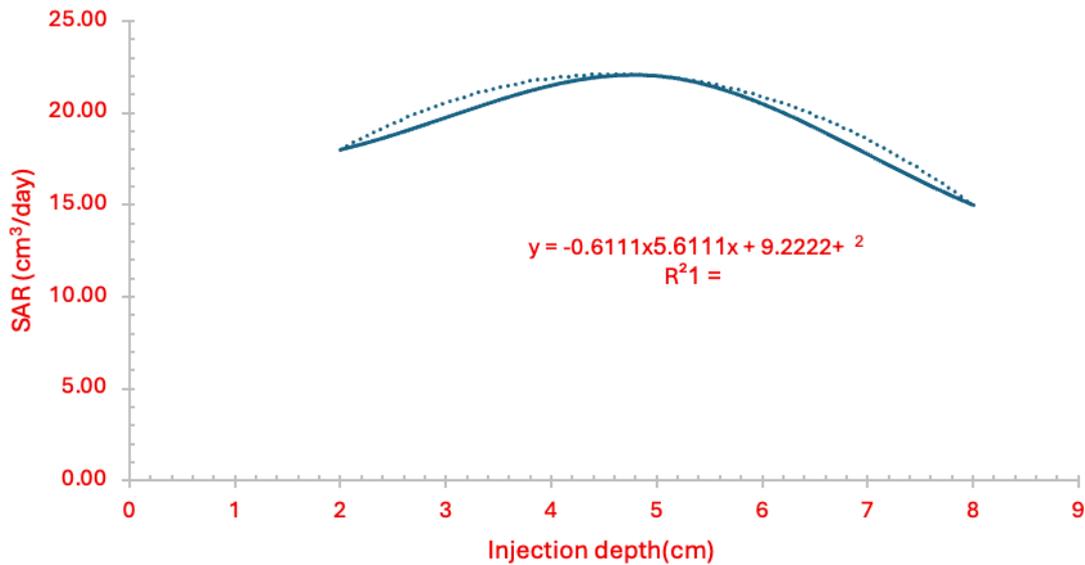


Fig. (4): Influence of Injection depth(cm) on solution absorption in tree trunk

3.5. Evaluation of the of solution absorption of the rate by the hole diameter

The graph illustrates the relationship between hole diameter and withdrawal rate per day, showing a positive correlation between the two variables. As the hole diameter increases, the absorption rate also increases, reaching its highest value at the largest tested diameter. This trend can be attributed to the larger surface area provided by a bigger hole, which allows for greater exposure to vascular tissues

responsible for absorbing the solution. Additionally, a larger hole may reduce resistance to solution uptake, facilitating higher absorption efficiency. The mathematical equation on the graph indicates a quadratic relationship, suggesting that the rate of increase in absorption may slow down at larger diameters. This means that after a certain threshold, further increasing the hole diameter may not significantly enhance absorption or could lead to negative effects such as excessive damage to the tree or increased solution loss.

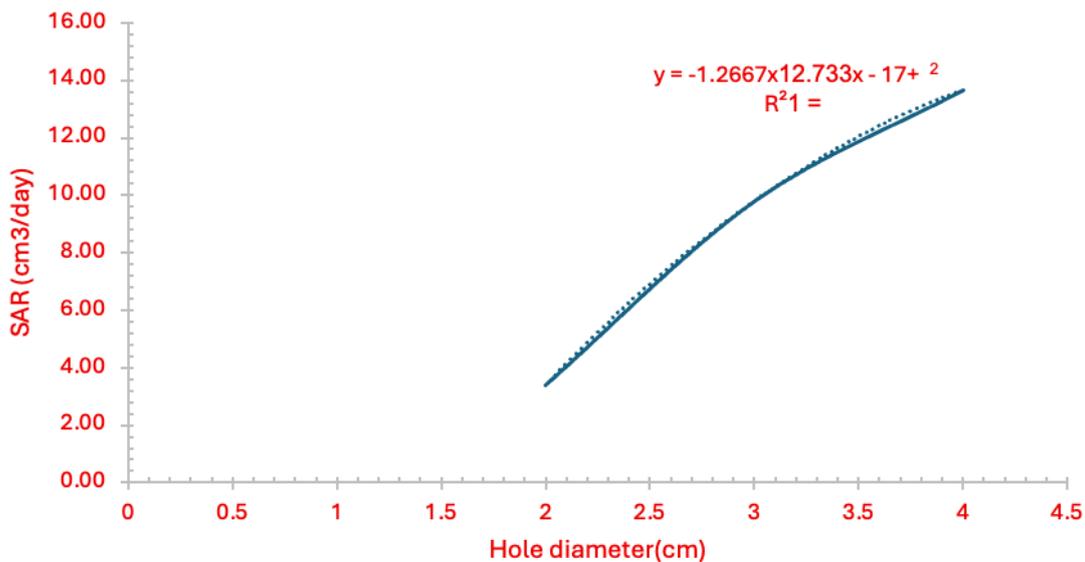


Fig. (4): Influence of Hole diameter(cm) on solution absorption in tree trunk

#### 4. Discussion

The results of this study highlight the significant role of trunk injection techniques in improving nutrient uptake efficiency and increasing tree productivity compared to traditional methods such as soil fertilization or foliar spraying. The findings demonstrate the superiority of trunk injection due to its direct targeting of tree tissues, which minimizes losses from leaching or evaporation and reduces negative environmental impacts.

##### 4.1. Effect of Pressure and Tank Height on solution absorption rate

The study revealed that the height of the solution tank above the soil surface is a critical factor in increasing the absorption rate. The highest values were achieved at a height of 100 cm compared to 25 cm. This can be attributed to the increased hydrostatic pressure created by the higher tank, which facilitates the solution's flow into the tree tissues. These results align with previous studies that showed that increased pressure enhances the distribution of nutrients within plant tissues [6,10].

##### 4.2. Effect of injection angle and hole diameter on solution absorption rate

The findings also indicate that the injection angle significantly impacts the infusion rate. The sharp downward angle of 45° proved to be the most effective compared to the upward 45° and vertical 90° angles. This is likely due to reduced solution loss and better penetration at this angle. Similarly, the diameter of the injection hole played a vital role, with a 4 mm diameter resulting in the highest absorption rates and minimal blockage issues. These findings support previous research that emphasized the importance of optimizing injection techniques for efficient nutrient delivery [12,7].

##### 4.3. Effect of Injection depth and location on (SAR)

The study demonstrated that injecting the solution into one-third of the tree trunk diameter resulted in the highest absorption rates compared to injection into the bark or the trunk's center. This suggests that the anatomical structure of the trunk at this depth facilitates better distribution and uptake of nutrients. Additionally, injecting at a height of 10 cm above the soil surface yielded the best results compared to 5 cm or 15 cm, as it minimized contamination and enhanced absorption.

##### 4.4. Effect of practical implications on (SAR)

The trunk injection method offers several advantages, including precise nutrient application, reduced environmental risks, and increased nutrient use efficiency. However, the adoption of this technique on a commercial scale requires careful consideration of labor costs, equipment maintenance, and the long-term effects on tree health. Future research should focus on optimizing injection parameters for various tree species and evaluating the economic feasibility of this method in large-scale agricultural practices.

#### 5. Conclusions

This study demonstrates the effectiveness of tree trunk injection as an innovative and environmentally friendly fertilization technique that enhances nutrient uptake efficiency and tree productivity compared to conventional methods like soil fertilization or foliar spraying. The findings confirm that several key factors significantly influence solution absorption, including solution tank height, injection angle, hole diameter, injection site height, and injection depth. The results indicate that positioning the solution tank at 100 cm above the soil surface increases hydrostatic pressure, leading to improved absorption rates. Additionally, injecting at a 45° angle achieved the highest withdrawal efficiency by minimizing solution loss and enhancing penetration into the vascular system. The optimal hole diameter of 4 mm facilitated better absorption while preventing blockage issues. Furthermore, injecting at 10 cm above the soil surface and targeting the first third of the trunk's diameter provided the best balance between accessibility to conductive tissues and minimizing solution loss. These findings highlight the potential of trunk injection as a precise, targeted, and highly efficient fertilization method. Compared to traditional approaches, it offers higher nutrient use efficiency, reduced environmental contamination, and better control over nutrient application. However, successful implementation on a commercial scale.

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