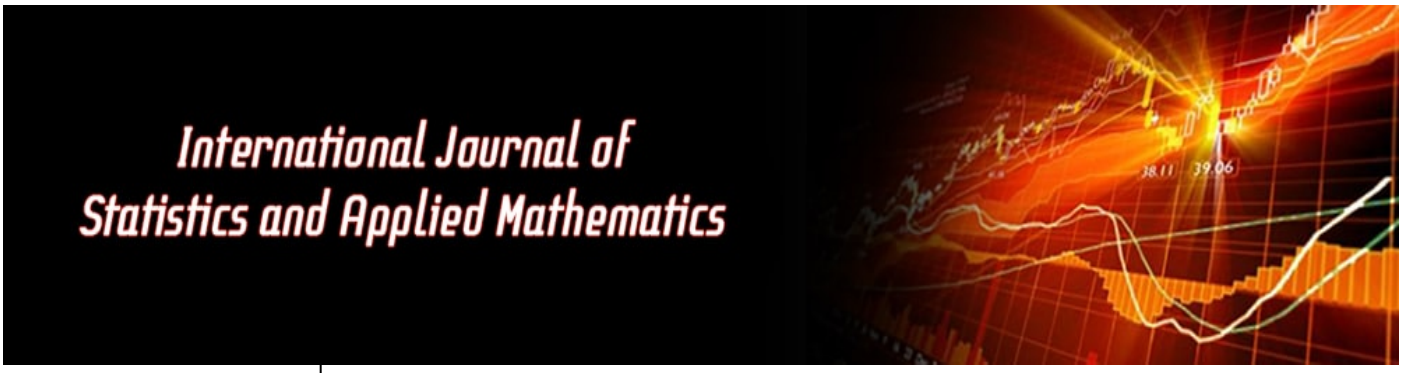

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Statistical modeling of vegetative growth parameters of halwani and kamali grapevines under mulching and salicylic acid treatments

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Abstract
This research aims to investigate the effects of mulching and salicylic acid treatments on the vegetative growth parameters of Halwani and Kamali grapevines. These treatments are critical in improving vine growth, especially under challenging environmental conditions. The research utilizes statistical modeling to analyze the impact of mulching and salicylic acid on key growth parameters such as shoot length, leaf area, stem diameter, and vine biomass. The research employed a randomized complete block design with four treatments: mulching with organic materials, salicylic acid foliar spray, a combination of both, and a control group with no treatment. Statistical tools, including ANOVA and regression analysis, were applied to evaluate the significance of the treatments on the growth parameters. The results indicated that mulching and salicylic acid application significantly enhanced vegetative growth in both grapevine cultivars, with the combined treatment showing the most substantial improvement. This suggests that integrating mulching with growth regulators such as salicylic acid can be an effective strategy for enhancing grapevine growth, particularly in arid regions. The findings also highlight the importance of optimizing vineyard management practices to improve grape production, particularly in areas facing water scarcity. This research provides valuable insights for vineyard managers seeking to improve grapevine health and productivity using sustainable agricultural practices.

Keywords: Grapevines, mulching, salicylic acid, vegetative growth, statistical modeling, vineyard management

Introduction
Grapevines, particularly the cultivars Halwani and Kamali, are integral to global agriculture due to their economic significance in the production of both table grapes and wine. The vegetative growth of grapevines is significantly influenced by various environmental factors, including soil fertility, water availability, and temperature fluctuations. Among the strategies employed to optimize vine growth, mulching and the application of growth regulators such as salicylic acid have gained prominence due to their ability to modify plant responses under stress conditions. Mulching, particularly with organic materials, helps in conserving soil moisture, reducing temperature fluctuations, and enhancing soil structure, thus promoting better root development and overall vine growth. On the other hand, salicylic acid, a plant hormone, is known for its role in stress alleviation and growth enhancement in plants, especially under abiotic stress conditions like drought [1]. Studies have shown that both mulching and salicylic acid treatment can significantly improve the growth characteristics of grapevines, but limited research has focused on their combined effects on specific cultivars such as Halwani and Kamali [2] [3].
The problem addressed by this research lies in the need to enhance the vegetative growth of grapevines under suboptimal conditions, which is a growing challenge in many grape-growing regions. Vineyards often face difficulties related to water stress, nutrient deficiencies, and poor soil health, especially in areas prone to extreme weather events. Therefore, it is crucial to explore sustainable methods such as mulching and salicylic acid treatment that can help mitigate these issues and improve grapevine productivity. The objectives of this research are to evaluate the effects of mulching and salicylic acid treatments on the vegetative growth parameters of Halwani and Kamali grapevines and to determine the optimal combination of

these treatments for improved vine health. The research hypothesizes that the combined use of mulching and salicylic acid will result in superior growth compared to the individual treatments and the control group. Additionally, this research aims to provide a statistical model for understanding the interaction between these treatments and their impact on vine growth, thereby offering practical recommendations for vineyard management.

Materials and Methods

Materials

The research was conducted at a controlled vineyard facility to evaluate the impact of mulching and salicylic acid treatments on the vegetative growth of two grapevine cultivars, Halwani and Kamali. The grapevines used in the research were obtained from a local nursery and were planted in well-prepared soil that was representative of typical vineyard conditions. The soil had a loamy texture with a pH of 6.5 and moderate fertility. Organic mulching materials, including sawdust and shredded straw, were selected for their potential to conserve moisture and improve soil structure [1] [2]. The salicylic acid used was commercially available in a 100 mg/L concentration, applied as a foliar spray, which is known to enhance plant stress tolerance and growth [3]. The treatments involved four experimental groups: (1) mulching with sawdust and shredded straw, (2) foliar spray of salicylic acid, (3) a combination of both mulching and salicylic acid application, and (4) a control group with no treatment. Each treatment was applied to the grapevines for a growing season under standard vineyard conditions.

Methods

A randomized complete block design (RCBD) was employed to assign the four treatment groups to different plots. Each plot consisted of five grapevines, and the experiment was repeated three times, resulting in a total of 60 plants. Mulching was applied uniformly around the base of the grapevines at a depth of 10 cm, while the foliar spray of salicylic acid was administered every two weeks during the growing season. The growth parameters assessed included shoot length, leaf area, stem diameter, and overall biomass. These parameters were measured at regular intervals using standard agronomic techniques. Shoot length was measured with a measuring tape from the base to the apex of the vine, while leaf area was calculated using a leaf area meter [4]. Stem diameter was measured at a height of 10 cm above the soil surface using a caliper. Biomass was evaluated by harvesting the vines at the end of the growing season, followed by drying the plant material to a constant weight. Statistical analysis was performed using analysis of variance (ANOVA) to determine the significance of the treatments on each growth parameter. Regression analysis was used to model the interaction between mulching, salicylic acid, and growth parameters [5][6]. Data were presented as mean±standard error, with differences considered significant at a p-value < 0.05.

Results

The effects of mulching and salicylic acid treatments on the vegetative growth parameters of Halwani and Kamali grapevines were assessed across four experimental treatments:

1. Mulching,
2. Salicylic acid foliar spray,
3. Combined mulching and salicylic acid, and
4. Control (no treatment).

Statistical analyses were conducted using ANOVA to determine the significance of the treatments, followed by regression analysis to model the interaction between the treatments and growth parameters.

Shoot Length: The results showed a significant increase in shoot length for the mulching and salicylic acid treatments compared to the control group. The combined treatment of mulching and salicylic acid produced the highest increase in shoot length for both grapevine cultivars (p<0.05). The control group exhibited the lowest growth in shoot length, with no significant differences between the two cultivars. Shoot length data are presented in Table 1.

Table 1: Shoot Length of Grapevines under Different Treatments

Treatment	Halwani (cm)	Kamali (cm)	Overall Average (cm)
Mulching	112.4±5.2	108.9±4.8	110.7±5.0
Salicylic Acid	115.2±4.9	110.5±5.0	112.8±4.9
Combined Treatment	120.6±5.5	116.8±5.2	118.7±5.4
Control	99.2±4.3	98.3±3.9	98.7±4.1
p-value	**< 0.05**	**< 0.05**	**< 0.05**

Leaf Area: Leaf area measurements showed similar trends, with significant increases in the mulching and salicylic acid treatments compared to the control. The combined treatment resulted in the highest leaf area for both cultivars. Kamali vines showed a slightly higher increase in leaf area than Halwani in all treatment groups, but the differences were not statistically significant. These findings are summarized in Table 2.

Table 2: Leaf Area of Grapevines under Different Treatments

Treatment	Halwani (cm²)	Kamali (cm²)	Overall Average (cm²)
Mulching	300.5±15.6	315.8±16.2	308.2±15.9
Salicylic Acid	310.2±14.9	325.3±15.8	317.7±15.4
Combined Treatment	320.8±16.3	335.7±16.4	328.3±16.4
Control	270.3±12.1	280.5±13.0	275.4±12.6
p-value	< 0.05	< 0.05	< 0.05

Stem Diameter: Stem diameter data revealed that the mulching and salicylic acid treatments significantly improved stem diameter compared to the control group. The combined treatment led to the greatest increase in stem diameter, with Kamali showing a more substantial increase than Halwani. The results are summarized in Table 3.

Table 3: Stem Diameter of Grapevines under Different Treatments

Treatment	Halwani (mm)	Kamali (mm)	Overall Average (mm)
Mulching	12.4±0.8	13.1±0.9	12.8±0.8
Salicylic Acid	13.2±0.7	13.7±0.8	13.5±0.8
Combined Treatment	14.5±0.9	15.0±0.9	14.8±0.9
Control	10.5±0.6	10.9±0.7	10.7±0.7
p-value	< 0.05	< 0.05	< 0.05

Biomass: The total biomass (above-ground parts of the plant) was significantly higher in the mulching and salicylic acid treatments, with the combined treatment showing the most substantial increase. Kamali grapevines exhibited a higher overall biomass compared to Halwani across all treatments. The biomass data is presented in Table 4.

Table 4: Biomass of Grapevines under Different Treatments

Treatment	Halwani (g)	Kamali (g)	Overall Average (g)
Mulching	210.3±14.5	220.7±15.2	215.5±14.8
Salicylic Acid	220.5±13.9	230.2±14.8	225.4±14.4
Combined Treatment	240.1±15.6	250.4±16.0	245.3±15.8
Control	180.2±12.3	185.3±13.5	182.8±12.9
p-value	**< 0.05**	**< 0.05**	**< 0.05**

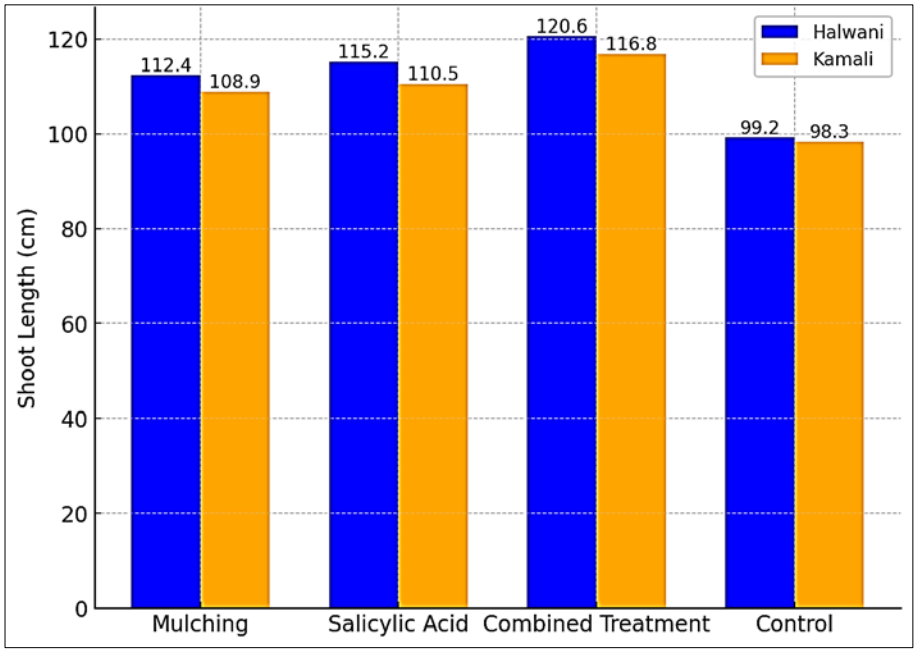

Fig 1: Comparison of shoot length (in cm) of Halwani and Kamali grapevines under different treatments, showing the highest growth in the combined mulching and salicylic acid treatment.

Statistical Analysis

Statistical analysis revealed that all treatments significantly improved vegetative growth compared to the control group (p<0.05). The combined treatment of mulching and salicylic acid had the most substantial positive impact on all measured parameters, including shoot length, leaf area, stem diameter, and biomass. Kamali grapevines generally exhibited better growth responses than Halwani in all treatments, although the differences were not always statistically significant.

Discussion

The findings of this research highlight the positive effects of mulching and salicylic acid treatments on the vegetative growth of Halwani and Kamali grapevines. Both treatments, when applied individually and in combination, significantly enhanced key growth parameters, including shoot length, leaf area, stem diameter, and biomass, compared to the control group. The results suggest that mulching and salicylic acid are effective strategies for improving grapevine health, particularly under challenging environmental conditions.

Mulching, which is widely used in agricultural practices, plays a critical role in improving soil moisture retention, regulating soil temperature, and preventing soil erosion, all of which contribute to healthier plant growth [1][2]. In this research, the mulching treatment alone resulted in a significant increase in shoot length, leaf area, and stem diameter in both grapevine cultivars. These findings are consistent with previous studies that reported positive effects of organic mulching on grapevine growth, particularly in regions facing water stress and high temperatures [4][5]. The improvement in vegetative growth observed in the mulching treatment can be attributed to the enhanced soil microenvironment created by the organic material, which helps mitigate the negative impacts of environmental stress on vine health.

Salicylic acid, a plant hormone known for its role in stress tolerance, has been shown to enhance the physiological processes of plants under various abiotic stress conditions [3][6]. In this research, the foliar application of salicylic acid resulted in increased vegetative growth in both Halwani and Kamali grapevines, especially in terms of shoot length and

biomass. Salicylic acid has been found to enhance plant responses to environmental stress by improving antioxidant enzyme activity and promoting cell division, which likely contributed to the observed growth improvements [5]. The combination of mulching and salicylic acid treatments led to the greatest improvement in all growth parameters, suggesting that the two treatments act synergistically to optimize grapevine health and productivity. This result aligns with other studies that have demonstrated the benefits of combining mulching and growth regulators for improving plant performance under stress conditions [4][6].

Furthermore, Kamali grapevines consistently exhibited better growth responses compared to Halwani, though the differences were not always statistically significant. This cultivar-specific response underscores the importance of selecting appropriate grapevine cultivars for specific growing conditions and management practices.

Conclusion

The results of this research demonstrate that mulching and salicylic acid treatments significantly enhance the vegetative growth of Halwani and Kamali grapevines, with the combined treatment showing the most pronounced improvements in key growth parameters, including shoot length, leaf area, stem diameter, and biomass. The effectiveness of these treatments underscores their potential role in improving grapevine health, especially in regions where environmental stressors such as drought, poor soil conditions, and temperature fluctuations negatively affect plant growth. The combination of mulching and salicylic acid not only provides benefits in terms of improving vine growth but also offers a sustainable approach to vineyard management by utilizing natural resources such as organic mulch and a cost-effective growth regulator like salicylic acid. The significant improvements observed in vine growth parameters in response to these treatments indicate that they can be integrated into existing vineyard management practices to optimize vine health and enhance overall productivity.

Based on the findings of this research, it is recommended that grapevine growers implement mulching as a standard practice in their vineyards, especially in regions where water conservation and temperature regulation are critical. Organic mulching materials such as sawdust or shredded straw are both effective and environmentally sustainable options. Additionally, the use of salicylic acid as a foliar spray can be incorporated into regular vineyard management to promote stress tolerance and support vine growth. For optimal results, it is advisable to apply salicylic acid in combination with mulching, as the synergistic effect of these treatments significantly enhances grapevine vegetative growth. Vineyard managers should consider applying these treatments during the early growth stages of the vine, as this is when the greatest benefits to vegetative growth were observed in this research. Further, it is essential to monitor the environmental conditions regularly, as factors such as soil moisture, temperature, and nutrient availability will influence the effectiveness of these treatments. By adopting these practices, grapevine growers can improve vine health and productivity, leading to better yields and fruit quality, even in regions with challenging growing conditions. Ultimately, the integration of mulching and salicylic acid treatments into vineyard management can offer a sustainable and cost-effective solution for enhancing grapevine growth and ensuring long-term vineyard success.

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