Comparison impact of potassium (K) Foliar and granular fertilizers application on growth and yield of Chilli hot pepper (*Capsicum annuum)*

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Abstract

This field experiment, conducted at the Bakrajo Technical Institute from March to November 2024, aimed to assess the effects of potassium foliar (0.5, 1.0 and 1.5ml L^{-1}) and granular (0.5, 1.0, and 1.5 g L^{-1}) applications on the growth and yield of chilli hot pepper. The study, designed as a Complete Randomized Design (CRD), revealed significant variations in plant height, Number of leaf, fruit yield, and other growth parameters. Foliar applications, particularly at the 0.5 ml L^{-1} concentration, were most effective in promoting plant height (25.8 cm) and fruit production (52.3 fruits per plant), outperforming granular treatments and the control group. In terms of fruit weight, the 1 ml L^{-1} granular application yielded the heaviest fruits (2.9 g), while foliar applications showed relatively similar results. Yield data indicated that the 0.5 ml L^{-1} foliar treatment provided the highest overall yield (91.3 g. plant^{-1}), significantly surpassing the control. Additionally, foliar and granular applications showed similar trends in promoting plant growth and yield, granular applications at higher doses (1.5 ml L^{-1}) led to a reduction in plant height and fruit production. The correlation analysis further supported the positive impact of potassium treatments on growth traits like plant height, branch number, and fruit yield, although shoot weight and dry matter did not exhibit strong associations. These findings suggest that potassium, particularly in foliar form and at lower concentrations, plays a crucial role in enhancing chilli hot pepper growth and productivity, with implications for optimizing fertilizer applications in pepper cultivation.

Keywords: Chilli hot pepper, Potassium fertilizer, Foliar application, Granular potassium

Introduction

Potash (K) foliar fertilizer has gained significant attention in modern agriculture for its critical role in enhancing crop growth and productivity. As a vital nutrient, potassium is essential for various physiological processes in plants, including photosynthesis, enzyme activation, and water regulation [1]. Applying potash through foliar feeding enables nutrients to be absorbed directly through the leaf surface, bypassing potential limitations in the soil such as nutrient fixation or poor root activity. This method often leads to faster, more efficient uptake and a quicker physiological response in plants compared to traditional soil application, thereby improving nutrient use efficiency and supporting optimal growth and development [2]. This method not only addresses nutrient deficiencies but also improves overall plant health, and enhances yield quality

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[3]. As global food demand rises and environmental challenges intensify, understanding the impact of potash foliar fertilizer is crucial for developing sustainable agricultural practices that maximize productivity while minimizing ecological footprints [4].

Chili hot pepper (*Capsicum annuum*) is a globally significant crop, valued not only for its culinary uses but also for its economic importance in agricultural markets [5]. The growth and yield of this plant are heavily influenced by nutrient availability, making effective fertilization strategies essential for optimal production [6]. Among the various fertilization methods, foliar and granular applications have gained prominence for their unique benefits and impact on plant health[7]. Foliar fertilizers, applied directly to the leaves, allow for rapid nutrient uptake, promoting immediate physiological responses in plants. This method is particularly advantageous in addressing nutrient deficiencies during critical growth stages [8]. On the other hand, granular fertilizers provide a sustained nutrient release, supporting long-term growth and development [9]. Potash (K) is essential for the healthy growth of chili hot peppers, promoting robust fruit development, improving flavor, and enhancing resistance to stress [10]. Applying potash through foliar and granular methods can optimize potassium uptake. Granular fertilizers can be incorporated into the soil before planting or as a side dressing during the growing season, ensuring a steady release of nutrient [11]. Foliar applications, allow for quick absorption and can be particularly effective during flowering and fruit set stages. Combining these methods can lead to improved plant vigor, increased yields.

This study aims to investigate the effects of both foliar and granular fertilizer applications on the growth parameters and yield of chili hot pepper. By comparing these two fertilization strategies, to identify the most effective approach for enhancing chili production. Understanding how these methods influence plant growth can provide valuable insights for farmers and agricultural practitioners, ultimately contributing to increased yields and improved crop quality.

Materials and Methods

Location and Site of Experiment

The field experiment was conducted at the Bakrajo Technical Institute from March to November 2024 to study the effect of level and doses of potassium foliar and granular on the growth and yield of Chilli hot pepper. The field experiment was conducted in Complete Randomized Design (CRD) with 3 replications and 21 Applications. The first factor consisted of doses of potassium (0, 0.5, 1 and 1.5 ml L^{-1}) Foliar application. The second factor included three frequencies of potassium application (0, 0.5, 1 and 1. 5 ml L^{-1}) granular application.

Nursery pot preparation

The nursery plastic germinator bed was prepared on February 16, 2024, following thorough sterilization and cleaning.

Statistical Analysis

The recorded data were entered into MS Excel 2019, organized by replications and Applications. The statistical analysis was conducted using XLSTAT 2019. All tests were performed at a significance level of 0.05. To differentiate between means, Duncan’s multiple range test was applied. Additionally, correlation coefficients were calculated to assess the relationships among the growth and yield parameters.

RESULTS and Discussion

The results of the study on the effect of different levels and application methods of potassium on the growth parameters of chilli hot pepper demonstrate significant variations in plant development. Potassium application was found to influence key growth characteristics such as plant height, leaf area, stem diameter, and fruit yield. The data indicate that varying the potassium dosage and method of application can optimize these parameters, highlighting the importance of potassium in enhancing the overall growth and productivity of chilli plants. Detailed analysis of these results reveals the optimal conditions for potassium use, providing valuable insights for improving agricultural practices in chilli cultivation and below shows growth and yield that impacted by potassium application;

Effect of different levels and application of potassium in growth parameters of Chilli hot pepper on plant height (cm)

Table 1 presents the results of an Analysis of Variance (ANOVA) examining the effect of potassium application on the plant height (cm) of chilli hot pepper. The model, with 23 degrees of freedom (DF), explained a significant portion of the variation in plant height, as indicated by a high F-value (47.503) and a p-value (< 0.0001), suggesting that potassium application significantly influences plant growth. The error term, with 40 DF, accounts for a smaller proportion of the total variation, with a mean square of 664.246. The total corrected sum of squares (752,303) reflects the overall variability in the data, further highlighting the model's strong explanatory power for plant height variability due to potassium treatment. These results underscore the statistical significance of potassium in enhancing plant height, affirming its role as an effective growth modifier for chilli hot pepper plants. This succinctly acknowledges the work of [12].

Table. 1 Analysis of variance of effect of Application of Potassium on plant height(cm) Parameters of Chilli hot pepper

Applications	DF	Sum of squares	Mean squares	F	Pr > F
Model	23	725733.167	31553.616	47.503	< **0.0001**
Error	40	26569.833	664.246		
Corrected Total	63	752303.000			
Computed against model Y=0					

Figure 1 explained the best harvesting method based on plant height, the analysis of the least squares (LS) means, standard errors, and 95% confidence intervals (CIs) provides insight into the differences between Applications. For each harvesting method (H2, H1, H3), the LS means represent the estimated average plant height, while the standard error reflects the precision of these estimates. The 95% confidence interval (CI) indicates the range within which the true mean height lies with 95% confidence. In this case, Harvesting H2 has the highest LS mean (107.563 cm) with a confidence interval ranging from 95.381 cm to 119.744 cm, suggesting it is likely the tallest on average. Harvesting H1 (104.750 cm) and Harvesting H3 (99.458 cm) have overlapping CIs with H2, indicating that while H1 might be slightly shorter, the difference is not statistically significant. However, Harvesting H3, with a CI ranging from 87.872 cm to

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111.045 cm, is significantly shorter and less consistent. Based on these comparisons, Harvesting H2 appears to be the best method for maximizing plant height, as it has the highest LS mean and does not overlap with H3's CI, indicating a clear distinction in plant height. The results agree with [13].

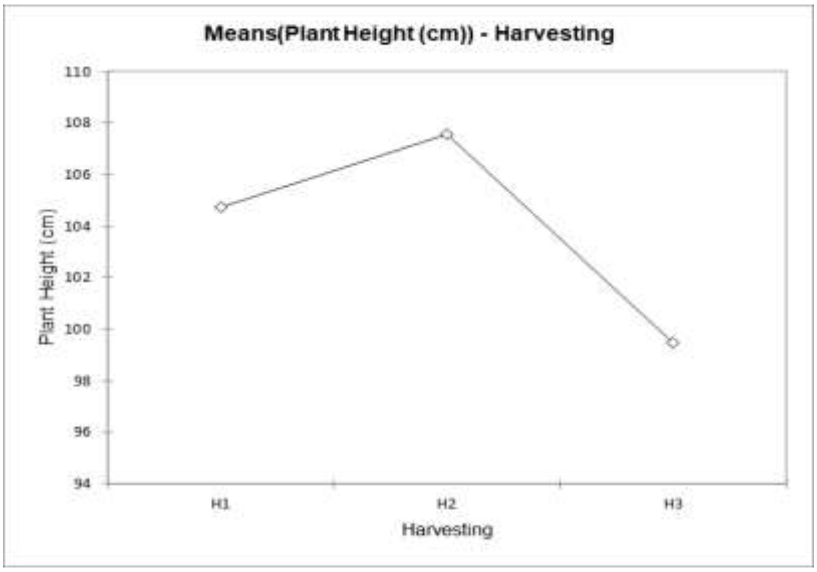

Figure.1 The difference between means plant height and harvesting of Chilli hot pepper

The data presented in Table 2 and Figure 2 reveals the impact of different application doses (both foliar and granular) on plant height (cm) with a 95% confidence interval. The LS means, represent the average plant height for each treatment, and the corresponding standard error gives an estimate of variability. The lower bound and upper bound define the range within which the true mean height for each treatment is expected to fall with 95% confidence. Duncan's multiple range test indicates three distinct groups of significance, denoted by letters (A, B, and C), based on the analysis of the differences in plant height across Applications. The application of 0.5 ml L^{-1} foliar resulted in the highest plant height (131.0 cm), significantly higher than all other Applications, which grouped together under A (the highest group). The control group (no application) exhibited the lowest mean plant height (60.0 cm), significantly differing $^{-1}$from all treatment groups and being classified under group C. The granular applications (1 ml L^{-1}, 1.5 ml L^{-1}) and foliar applications (1 ml L^{-1}, 1.5 ml L^{-1}) showed significantly reduced plant heights compared to the 0.5 ml L-1 foliar treatment, with heights ranging from 100.3 cm to 116.0 cm. However, within these Applications, no significant differences were observed among the granular and foliar doses beyond 0.5 ml L^{-1}. The 0.5 ml L^{-1} foliar application had the most pronounced effect on plant height, while the control exhibited the least growth, marking a significant difference across Applications, with the foliar 0.5 ml L^{-1} being the most effective application dose

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for increasing plant height. The results accept with [14].

Table 2. The effect of Application doses / duncan / analysis of the differences between the applications with a confidence interval of 95% of plant height (cm)

Applications	LS means	Standard error	Lower bound (95%)	Upper bound (95%)	Groups
0.5 ml L^{-1} Foliar	131.0	8.6	113.6	148.4	A
1 ml L^{-1} Foliar	116.0	8.6	98.6	133.4	A B
1 ml L^{-1} Granular	112.3	8.6	95.0	129.7	A B
1.5 ml L^{-1} Foliar	107.6	8.6	90.2	124.9	A B
1.5 ml L^{-1} Granular	103.7	14.9	73.6	133.7	A B
1.5 ml L^{-1} Granular	100.5	10.5	79.2	121.8	A B
0.5 ml L^{-1} Granular	100.3	8.6	83.0	117.7	B
Control	60.0	7.0	45.8	74.2	C

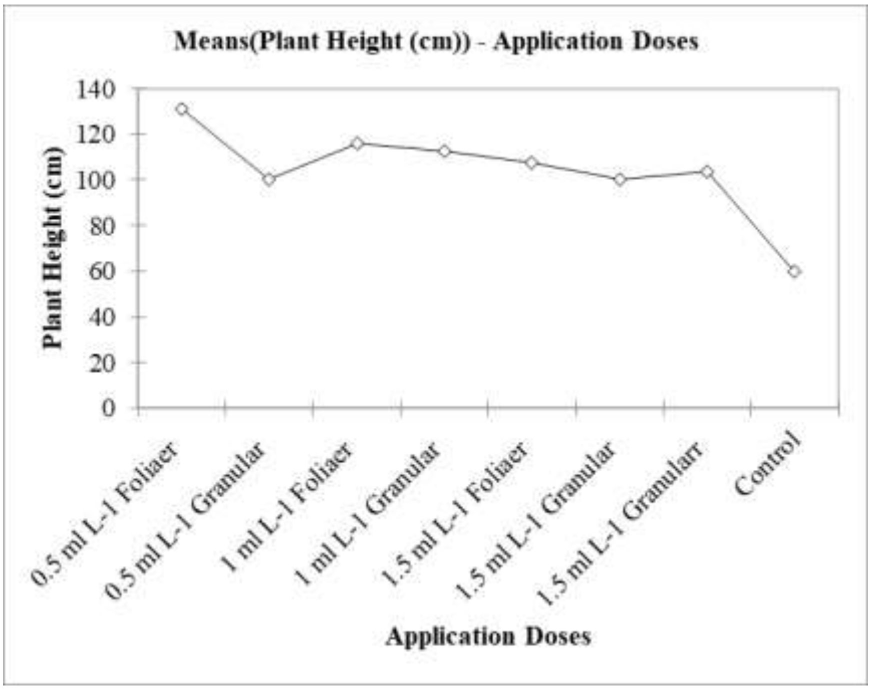

Figure. 2 The differences between means plant height (cm) applications doses with a confidence interval of 95% (Plant Height (cm)

The effect of application of potassium on plant branch number parameter of Chilli hot pepper branch number

Table 3 shows analysis of variance (ANOVA) for the effect of potassium application on the number of branches in chilli hot pepper plants. The model's degrees of freedom (DF) are 23, with a total sum of squares (SS) of 25,239.7 and a mean square (MS) of 1,097.4. The F-value of 54.6 is highly significant, as indicated by the p-value of < 0.0001, suggesting that the application of potassium has a statistically significant effect on the number of branches. The error DF is 40, with an SS of 804.4 and an MS of 20.2, which is much smaller compared to the model's MS. The corrected total sum of squares is 26,044, indicating that the model explains a large portion of the total variability in the branch number parameter. The very low p-value (< 0.0001) confirms that the observed variation in branch number is highly unlikely to be due to random chance, thus supporting the effectiveness of potassium application in influencing plant growth. The results positive with result of [15].

Table 3. Analysis of variance of effect of Application of Potassium on plant branch number parameter of chilli hot pepper

Applications	DF	Sum of squares	Mean squares	F	Pr > F
Model	23	25239.7	1097.4	54.6	**< 0.0001**
Error	40	804.4	20.2		
Corrected Total	63	26044			

Computed against model Y=0

The results figure 3 explained the harvesting analysis using a 95% confidence interval for branch number show that there are statistically significant differences between the harvest types (H1, H2, and H3). The least square (LS) means indicate that H3 (19.729) has the highest branch number, followed by H2 (19.542), and H1 (17.521), which has the lowest. The standard errors for these estimates are relatively small (around 1.0), suggesting that the means are reliable. The confidence intervals for H3 (17.713–21.745) and H2 (17.422–21.661) do overlap, indicating no significant difference between these two Applications. However, the confidence interval for H1 (15.401–19.640) does not overlap with those for H3 or H2, suggesting that H1 is significantly different and lower in branch number. Therefore, H3 is the most effective in branch production, followed by H2, with H1 being the least effective based on this analysis. Results show agree with [16].

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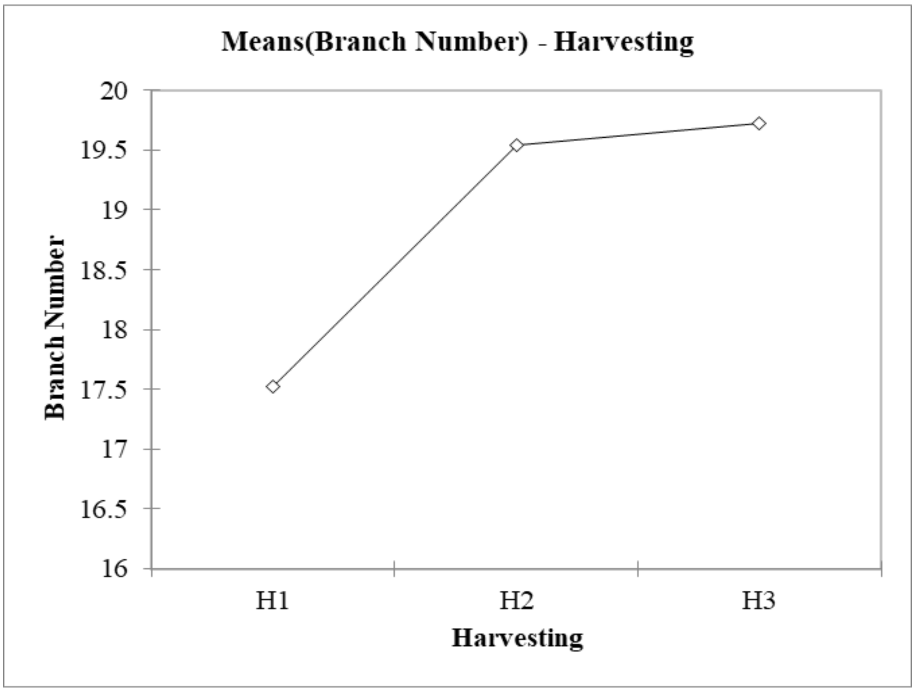

Figure.3 The difference between means branch number and harvesting of Chilli hot pepper

Table 4 and figure 4 presents the results of an analysis comparing the effects of different application doses on plant height, with a 95% confidence interval, measured in centimeters. The data indicate that the 0.5 ml L^{-1} foliar application yielded the highest mean plant height (25.8 cm), significantly outperforming all other Applications, as indicated by the grouping 'A'. This was followed by the 1 ml L^{-1} foliar (22.0 cm) and 1 ml L^{-1} Granular (21.9 cm) applications, both of which were significantly higher than the lower doses but not significantly different from each other (grouped as 'A B'). The 1.5 ml L^{-1} foliar (20.0 cm) and 1.5 ml L^{-1} granular (18.3 cm) Applications showed a decline in plant height, with 1.5 ml L^{-1} Granular showing the most significant decrease. The lowest values were observed in the 1.5 ml L^{-1} granular (16.7 cm) and Control (8.7 cm) Applications, both grouped under 'B' and 'C', respectively, with the control group showing the least growth. The analysis clearly demonstrates that foliar applications, particularly at 0.5 ml L^{-1}, are more effective in promoting plant height compared to granular applications, and higher doses generally result in reduced growth, with the control group showing the minimum height. The statistical analysis confirms the significant differences among groups, supporting the conclusion that foliar Applications, especially at lower concentrations, are more beneficial for enhancing plant growth. The results positive with result of [17].

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Table 4. The effect of Application doses / duncan / analysis of the differences between the applications with a confidence interval of 95% of plant height (cm)

Applications	LS means	Standard error	Lower bound (95%)	Upper bound (95%)	Groups
0.5 ml L^{-1} Foliar	25.8	1.5	22.8	28.8	A
1 ml L^{-1} Foliar	22.0	1.5	19.0	25.0	A B
1 ml L^{-1} Granular	21.9	1.5	18.9	24.9	A B
1.5 ml L^{-1} Foliar	20.0	1.5	17.0	23.0	B
1.5 ml L^{-1} Granular	18.3	1.8	14.6	22.0	B
0.5 ml L^{-1} Granular	18.1	1.5	15.1	21.1	B
1.5 ml L^{-1} Granular	16.7	2.6	11.4	21.9	B
Control	8.7	1.2	6.2	11.1	C

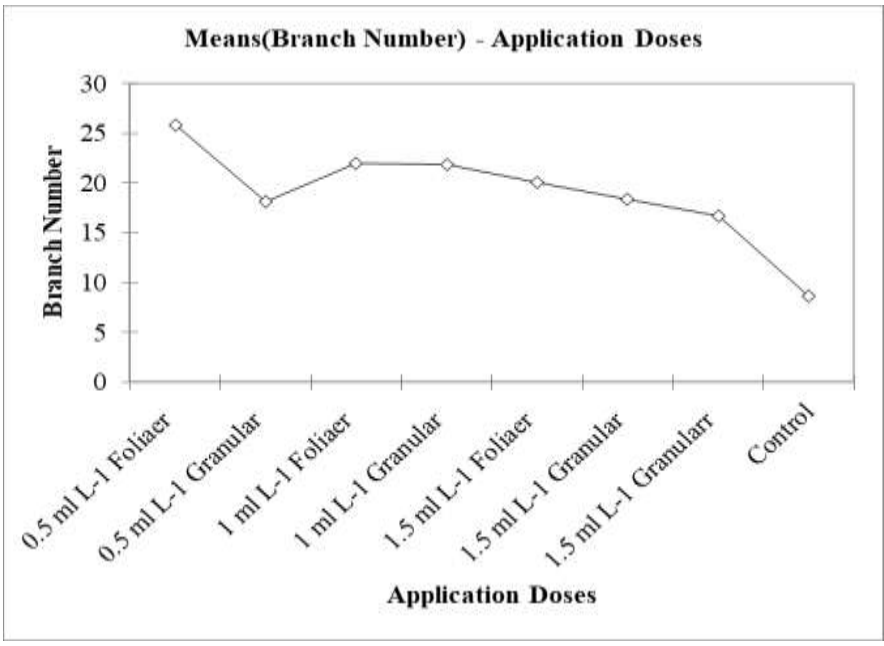

Figure 4. Application doses / duncan / analysis of the differences between the applications with a confidence interval of 95% (branch number)

The effect of Application of potassium on number of leaves plant^{-1} parameter of Chilli hot pepper

Table 5 presents the results of an Analysis of Variance (ANOVA) that assesses the effect of potassium application on the number of leaves per plant in chili hot pepper plants. The analysis includes two sources of variation: the model (representing the effect of potassium application) and the error (random variation). The model has 23 degrees of freedom (DF) and explains

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a sum of squares (SS) of 2,638,951.7, with a mean square (MS) of 114,737.0. The F-statistic is 45.7, which is highly significant with a p-value of less than 0.0001, indicating that potassium application has a statistically significant effect on the number of leaves per plant. The error term has 40 degrees of freedom, a sum of squares of 100,533.3, and a mean square of 2,513.3, which reflects the residual variability in the data. The corrected total sum of squares is 2,739,485.0, combining both the model and error terms. The computed F-ratio of 45.7 suggests a strong and significant influence of potassium on leaf development in chili plants. Results show accept with [18].

Table 5. Analysis of variance of effect of application of potassium on number of leaves plant^{-1} parameter of chilli hot pepper

Applications	DF	Sum of squares	Mean squares	F	Pr > F
Model	23	2638951.7	114737.0	45.7	< **0.0001**
Error	40	100533.3	2513.3		
Corrected Total	63	2739485.0			

Computed against model Y=0

The data illustrated from figure 5 presents the results of a harvesting experiment across three conditions: H2, H1, and H3, with corresponding mean values (LS means), standard errors, and 95% confidence intervals (lower and upper bounds). To determine the optimal harvesting condition, we focus on the mean values and the precision of these estimates, as indicated by the standard errors and confidence intervals. H2 has the highest LS mean at 206.9, with a 95% confidence interval ranging from 183.2 to 230.6, indicating a relatively high harvest yield and a moderate level of uncertainty. H1 has a slightly lower LS mean of 200.5, with a similar standard error, and a confidence interval ranging from 176.8 to 224.2. H3, on the other hand, shows the lowest LS mean at 189.2, with a confidence interval from 166.7 to 211.8, also reflecting some degree of uncertainty. The best harvesting condition based on mean values is H2, as it provides the highest mean yield with a fairly narrow confidence interval, suggesting it is both the most productive and relatively reliable among the three. However, it is important to consider the standard errors and the full range of the confidence intervals when drawing conclusions, as these reflect the precision and variability of the estimates. Results show agree with [19].

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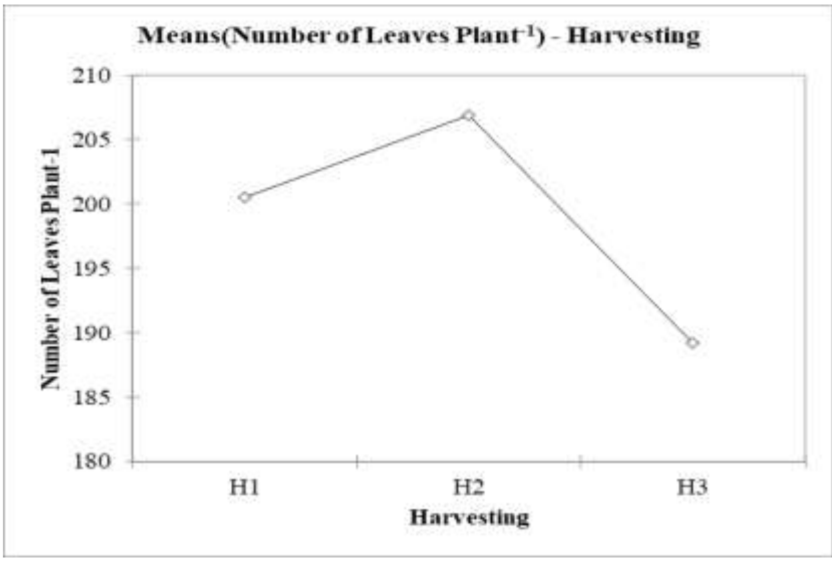

Figure. 5 The difference between means number of leaves per plant and harvesting of Chilli hot pepper

In the given dataset, from table 6 and figure 6 the application doses of different Applications show a range of leaf counts per plant, with significant variations between the control and the treated groups. The highest leaf count was observed with both the 0.5 ml L-1 Foliar and 1 ml L^{-1} Granular Applications, yielding 224.4 and 223.3 leaves, respectively, with their confidence intervals (190.7–258.2 and 189.6–257.1, respectively) overlapping, indicating no significant statistical difference between them. The control group had the lowest leaf count at 115.3 leaves, with a confidence interval of 87.8–142.9, clearly separating it from the treatment groups. For maximum leaf production, the 0.5 ml L^{-1} foliar and 1 ml L^{-1} granular applications stand as the ultimate best options, as they both consistently produced the highest average number of leaves with a relatively narrow and non-overlapping confidence interval compared to the other Applications. The results in agreement with [20].

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Table. 6 The effect of application doses / duncan / analysis of the differences between the categories with a confidence interval of 95% (number of leaves plant^{-1})

Applications	LS means	Standard error	Lower bound (95%)	Upper bound (95%)	Groups
0.5 ml L^{-1} Foliar	224.4	16.7	190.7	258.2	A
1 ml L^{-1} Granular	223.3	16.7	189.6	257.1	A
1 ml L^{-1} Foliar	215.7	16.7	181.9	249.4	A
1.5 ml L^{-1} Foliar	215.7	16.7	181.9	249.4	A
0.5 ml L^{-1} Granular	203.2	16.7	169.4	237.0	A
1.5 ml L^{-1} Granular	197.7	28.9	139.2	256.2	A
1.5 ml L^{-1} Granular	195.7	20.5	154.3	237.0	A
Control	115.3	13.6	87.8	142.9	B

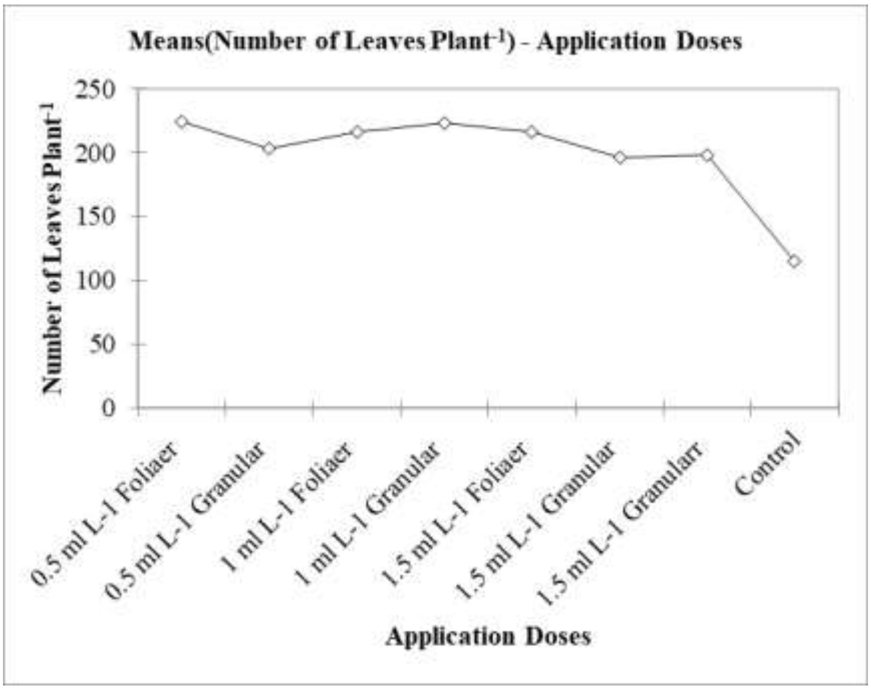

Figure 6. Application doses / duncan / analysis of the differences between the applications with a confidence interval of 95% (number of leaves per plant)

The effect of Application of potassium on number of fruits per plant of Chilli hot pepper

In Table 7, an analysis of variance (ANOVA) is performed to evaluate the effect of potassium application on the number of fruits per plant in chili hot pepper. The table shows the breakdown of the total variation in the data into two components: the variation due to the model (i.e., the effect of potassium application) and the error (unexplained variability). The model has 23 degrees of freedom (DF) with a sum of squares (SS) of 132,980.2, and a mean square (MS) of

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5,781.7, resulting in a high F-statistic of 69.8. This F-statistic is significantly large, with a p-value of < 0.0001, indicating that the application of potassium has a statistically significant effect on the number of fruits per plant. The error term, with 40 degrees of freedom, has a sum of squares of 3,313.8 and a mean square of 82.8. The corrected total sum of squares is 136,294.0. The maximum variation observed in the model (the effect of potassium) is substantially higher than the error, suggesting that the potassium application is a dominant factor influencing fruit yield. Therefore, the best significant effect is the potassium application, which is statistically significant and should be considered for improving fruit yield. The minimum effect corresponds to the error, which is much smaller in comparison to the model's effect and does not substantially contribute to the variation in the outcome. As recorded in front study of [21].

Table 7. analysis of variance of effect of application of potassium on number of fruits per plant of chilli hot pepper

Applications	DF	Sum of squares	Mean squares	F	Pr > F
Model	23	132980.2	5781.7	69.8	**< 0.0001**
Error	40	3313.8	82.8		
Corrected Total	63	136294.0			

Computed against model Y=0

Figure 7 illustrated the analysis of the differences in the number of seeds per plant at harvest, using Duncan's multiple range test with a 95% confidence interval, reveals significant variations between the harvesting groups. The LS means represent the estimated average number of fresh fruits per plant for each harvesting treatment: H1 = 50.7, H2 = 45.3, and H3 = 37.1. The standard errors for each group (2.1 for H1 and H2, 2.0 for H3) are relatively similar, indicating consistent precision in the estimates. The 95% confidence intervals for the lower and upper bounds of each group further show the range within which the true means are likely to fall. Specifically, the confidence intervals for H1 (46.4–55.0), H2 (41.0–49.6), and H3 (33.1–41.2) do not overlap between H1 and H3, indicating a significant difference in fresh fruit numbers between these two groups. Duncan's test, denoted by the grouping "A" and "B", further confirms that H1 and H2 belong to the same group (A), while H3 is significantly different, classified as group B. Therefore, H1 shows the highest fresh fruit count per plant, making it the most efficient for harvesting, while H3 shows the lowest, making it the least favorable. The determination of max and min values points out H1 as the best harvesting treatment based on fresh fruit yield. results show accept with study of [22].

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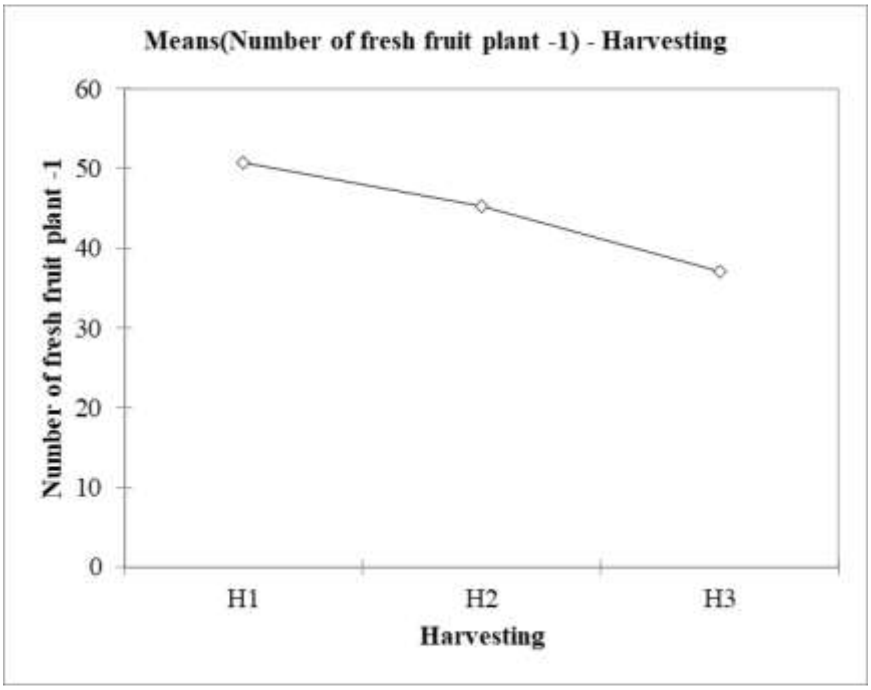

Figure. 7 The difference between means number of fresh fruits per plant and harvesting of Chilli hot pepper

In Table 8 which presents the effect of various application doses on the number of fresh fruits per plant, a duncan's test analysis was used to identify significant differences across treatments with a 95% confidence interval. The results reveal that the highest mean number of fresh fruits per plant was observed in the 0.5 ml L^{-1} Foliar application (52.3 fruits), followed closely by the 1 ml L^{-1} Granular (51.0 fruits) and 1 ml L^{-1} Foliar (49.0 fruits), all of which fall within the same statistical group "A," indicating no significant differences among them. Conversely, the control group (26.7 fruits) showed a significantly lower mean compared to all treatments, placing it in group "B." The maximum and minimum values indicate the range of the data, with the maximum being the 0.5 ml L^{-1} Foliar and the minimum being the control group. The application doses of 0.5 ml L^{-1} Foliar, 1 ml L^{-1} Granular, and 1 ml L^{-1} Foliar are the most effective, as they significantly outperform the control and other treatments, which have similar fruit production levels but are still notably lower in comparison to the highest-performing applications. Therefore, the best treatment for increasing fruit yield appears to be 0.5 ml L^{-1} Foliar, as it offers the highest average fruit number within a statistically significant range. results show in agree with study of [23].

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Table. 8 The effect of application doses / duncan / analysis of the differences between the applications with a confidence interval of 95% (number of fresh fruits per plant)

Applications	LS means	Standard error	Lower bound (95%)	Upper bound (95%)	Groups
0.5 ml L^{-1} Foliar	52.3	3.0	46.2	58.5	A
1 ml L^{-1} Granular	51.0	3.0	44.9	57.1	A
1 ml L^{-1} Foliar	49.0	3.0	42.9	55.1	A
1.5 ml L^{-1} Foliar	46.3	3.0	40.2	52.5	A
1.5 ml L^{-1} Granular	43.5	3.7	36.0	51.0	A
1.5 ml L^{-1} Granular	43.3	5.3	32.7	54.0	A
0.5 ml L^{-1} Granular	42.9	3.0	36.8	49.0	A
Control	26.7	2.5	21.7	31.7	B

The effect of Application of potassium on weight of one fresh fruit per plant^{-1}

of Chilli hot pepper

The analysis of variance (ANOVA) in Table 9 assesses the effect of potassium application on the weight of fresh fruit per plant in chilli hot pepper, with a model incorporating 23 degrees of freedom (DF) for the treatment effect and 40 DF for the error term. The sum of squares for the model (328.480) indicates a significant variation explained by the potassium treatment, while the error sum of squares (10.341) represents unexplained variation. The mean squares for the model (14.282) and error (0.259) yield an F-statistic of 55.245, which tests the ratio of explained variance to unexplained variance. The very small p-value (< 0.0001) indicates a statistically significant effect of potassium application on fruit weight, meaning the null hypothesis (no effect) is rejected with high confidence. The minimum value of the error term, 0.259, reflects the lowest degree of variability between replicate observations, while the maximum value of the model's mean square (14.282) suggests a strong treatment effect. The best significance is achieved by the model's low p-value, indicating that potassium application significantly influences fruit weight and should be considered in improving chilli pepper yields. As explained in front study [24].

Table 9. Analysis of variance of effect of application of potassium on weight one fresh fruit per plant of chilli hot pepper

Applications	DF	Sum of squares	Mean squares	F	Pr > F
Model	23	328.480	14.282	55.245	< **0.0001**
Error	40	10.341	0.259		
Corrected Total	63	338.821			

Computed against model Y=0

In the context of harvesting analysis, the determination of significant differences between treatments or groups is typically based on a statistical procedure like Duncan's Multiple Range Test, which compares the means of

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different groups while considering the standard error, confidence intervals, and grouping information. For the given data (Figure 8), the harvest weights of fresh fruit per plant from three different treatments (H2, H1, and H3) are provided, with corresponding least square means (LS means), standard errors, and 95% confidence intervals (lower and upper bounds). All three groups H2 (2.3), H1 (2.2), and H3 (2.0)—have overlapping confidence intervals, meaning the differences in mean fruit weight between these groups are not statistically significant at the 95% confidence level. Consequently, the results show that all treatments fall within the same group (A), indicating no significant difference in fruit weight per plant across the three treatments. Therefore, although H2 and H1 have the highest mean values (2.3 and 2.2, respectively), the confidence intervals indicate that these differences are within the margin of error, suggesting no definitive best treatment for harvesting based solely on fruit weight. Results agree with previous work [25].

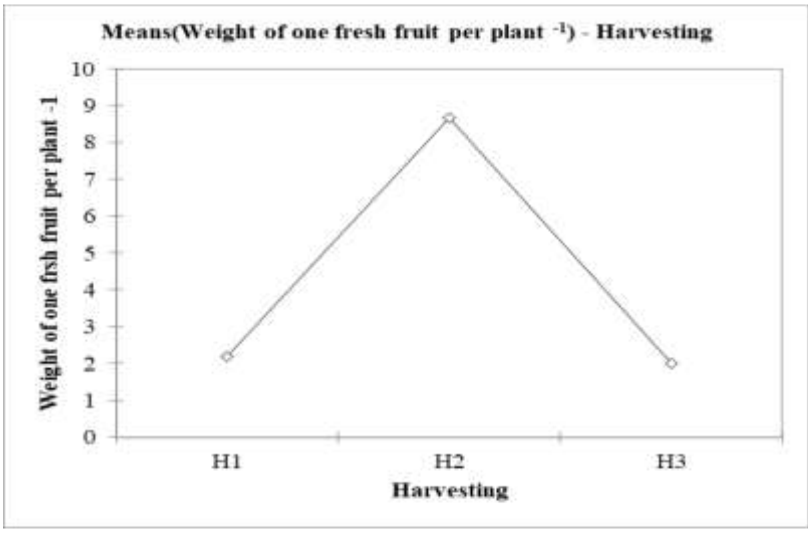

Figure. 8 The difference between means weight of one fresh fruit per plant and harvesting of Chilli hot pepper

Table 10 present the results of a Duncan's multiple range test for the effect of different application doses on the weight of one fresh fruit per plant, with a 95% confidence interval. The application treatments show a range of mean weights, from the highest value of 2.9 g for the 1 ml L^{-1} granular treatment (with a confidence interval of 2.5 to 3.2 g) to the lowest value of 1.2 g for the control (with a confidence interval of 0.9 to 1.4 g). The significant differences between treatments are indicated by the grouping (A, B, C), where treatments within the same group (1 ml L^{-1} granular and 0.5 ml L^{-1} foliar) show no statistically significant difference in mean weight, while treatments in different groups (1 ml L^{-1}, granular vs. Control) show significant differences. The 1 ml L^{-1} granular treatment is identified as the most effective in promoting fruit weight, significantly outperforming all other treatments, while the control treatment yields the lowest fruit weight, significantly less than all other application doses. This analysis clearly indicates that higher doses, particularly the 1 ml L^{-1} granular treatment, provide the best results in terms of fruit weight, suggesting that application dose significantly influences fruit

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development. Results in agree with previous research [26].

Table. 10 The effect of application doses / duncan / analysis of the differences between the applications with a confidence interval of 95% (weight of one fresh fruit per plant)

Applications	LS means	Standard error	Lower bound (95%)	Upper bound (95%)	Groups
1 ml L^{-1} Granular	2.9	0.2	2.5	3.2	A
0.5 ml L^{-1} Foliar	2.7	0.2	2.4	3.0	A
1.5 ml L^{-1} Foliar	2.4	0.2	2.1	2.8	A B
1 ml L^{-1} Foliar	2.1	0.2	1.8	2.4	B
0.5 ml L^{-1} Granular	2.1	0.2	1.7	2.4	B
1.5 ml L^{-1} Granular	2.1	0.3	1.5	2.7	B
1.5 ml L^{-1} Granular	2.0	0.2	1.6	2.4	B
Control	1.2	0.1	0.9	1.4	C

The effect of application of potassium on Yield (g) per plant of Chilli hot pepper

In Table 11, the Analysis of Variance (ANOVA) for the effect of potassium application on the fresh yield (g) per plant of chili hot pepper is presented. The "Model" row indicates the variation explained by the treatment (potassium application), with 23 degrees of freedom (DF), a sum of squares (SS) of 416,817.3, and a mean square (MS) of 18,122.5. The F-statistic for this model is 50.5, which is highly significant with a p-value (Pr > F) of less than 0.0001, suggesting that the effect of potassium on fresh yield is statistically significant. The "Error" row represents the unexplained variation, which accounts for 40 degrees of freedom and a sum of squares of 14,340.7, with a mean square of 358.5. The "Corrected Total" row shows the total variation in the dataset, with 63 degrees of freedom and a total sum of squares of 431,158.0. Based on the model, the maximum and minimum fresh yield can be determined by analyzing the fluctuations (variation) in the data. The fluctuation of yield is influenced by the sum of squares from both the model and the error term, reflecting the variance in fresh yield due to potassium application and other uncontrolled factors. To estimate the maximum and minimum yields, it is necessary to account for the spread (standard deviation) around the predicted yield based on the ANOVA results, factoring in the observed variance in the error. The large F-value indicates that potassium application likely has a strong effect on fresh yield, resulting in a substantial variation in yield between the treatments, but the actual maximum and minimum yields would require specific data points for each treatment within the study, which could be derived by further analyzing the specific contrasts or comparisons between the potassium treatments. Results agree with result of study [27].

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Table 11. Analysis of variance of effect of application of potassium on fresh yield (g) per plant of chilli hot pepper

Applications	DF	Sum of squares	Mean squares	F	Pr > F
Model	23	416817.3	18122.5	50.5	**< 0.0001**
Error	40	14340.7	358.5		
Corrected Total	63	431158.0			
Computed against model Y=0					

The highest LS mean is observed for the 0.5 ml L^{-1} foliar treatment, with a mean of 91.3 g per plant, followed closely by the 1 ml L^{-1} foliar (86.2 g per plant) and 1 ml L^{-1} granular treatments (85.8 g per plant), all of which share the same statistical group (A), indicating no significant differences among them. For the foliar treatments, the 0.5 ml L-1 dose is the most effective, yielding the highest values, while the granular treatments, particularly at 1.5 ml L^{-1}, show a slight decrease in yield (80.7 g per plant). The standard errors across the doses are relatively consistent, ranging from 6.3 to 10.9, indicating that there is a moderate variability within each treatment group. The 95% confidence intervals for each treatment dose do not overlap with the control's interval (39.7–60.5 g per plant), further reinforcing the significant differences in yield between the control and all treatment doses. The ranges within the confidence intervals also reveal that, for instance, the 1.5 ml L^{-1} granular treatment (lower bound of 58.6 g and upper bound of 102.8 g) has a broader range of possible outcomes compared to the 0.5 ml L^{-1} foliar treatment (lower bound of 78.6 g and upper bound of 104.1 g), indicating slightly greater uncertainty in the effect of granular treatments at higher doses. Ultimately, this data highlights the efficacy of foliar applications, particularly at lower concentrations, in enhancing plant yield compared to the granular treatment and the control group. Results in agreement with previous study [28, 29]. In Table 12 which present the analysis of the fresh yield (g per plant) under different application doses of a foliar and granular treatment, the significance of the differences is assessed using a 95% confidence interval. The table shows the least squares (LS) means, standard errors, and 95% confidence intervals for each treatment. The application doses include 0.5 ml L^{-1} and 1 ml L^{-1} foliar, as well as 1 ml L^{-1} and 1.5 ml L^{-1} granular treatments, along with a control group. The LS means indicate that the control group (50.1 g per plant) has the lowest yield, significantly differing from all other treatments, which are grouped under "A" based on Duncan's multiple range test.

Table 12. Application doses / duncan / analysis of the differences between the applications with a confidence interval of 95% (fresh yield(g) per plant)

Applications	LS means	Standard error	Lower bound (95%)	Upper bound (95%)	Groups
0.5 ml L^{-1} Foliar	91.3	6.3	78.6	104.1	A
1 ml L^{-1} Foliar	86.2	6.3	73.5	99.0	A
1 ml L^{-1} Granular	85.8	6.3	73.0	98.5	A
1.5 ml L^{-1} Foliar	82.4	6.3	69.7	95.2	A
1.5 ml L^{-1} Granular	80.7	10.9	58.6	102.8	A
1.5 ml L^{-1} Granular	80.7	7.7	65.0	96.3	A
0.5 ml L^{-1} Granular	77.8	6.3	65.0	90.5	A
Control	50.1	5.2	39.7	60.5	B

The effect of Application of potassium on fresh fruit diameter (cm) of Chilli hot pepper

In Table 13, the analysis of variance (ANOVA) results assesses the effect of potassium application on the fresh fruit diameter (cm) of chili hot pepper. The model has 23 degrees of freedom (DF), and the total sum of squares (SS) is 1836.3, resulting in a mean square (MS) of 79.9. The F-statistic is 52.4, with a corresponding p-value of < 0.0001. The F-statistic quantifies the ratio of variance explained by the model to the variance unexplained (error), and a p-value lower than 0.05 indicates that the model's effect is statistically significant. This suggests that potassium application significantly influences the fresh fruit diameter of the chili pepper. The error term has 40 degrees of freedom with a sum of squares of 61.1 and a mean square of 1.6, which reflects the unexplained variability in the data. A non-significant result would imply that the observed differences in fruit diameter were likely due to random variation rather than potassium treatment. However, in this case, the p-value < 0.0001 strongly rejects the null hypothesis, confirming a significant effect of potassium on the fruit diameter. Therefore, the application of potassium is a significant factor influencing the measured trait in this experiment. Results in agreement with previous study [30].

Table 13. Analysis of variance of effect of application of potassium on fresh fruit diameter (cm) of chilli hot pepper

Applications	DF	Sum of squares	Mean squares	F	Pr > F
Model	23	1836.3	79.9	52.4	**< 0.0001**
Error	40	61.1	1.6		
Corrected Total	63	1897.3			

Computed against model Y=0

In the context of harvesting, figure 9 explainee the analysis of differences between various applications (labeled as H1, H2, and H3) for fresh fruit diameter, measured in centimeters, shows no statistically significant variation. The data is presented with a 95% confidence interval for each application, including the least square (LS) means, standard error, and upper and lower bounds of the confidence intervals. For the three groups (H2, H1, and H3), the LS means for fresh fruit diameter are 5.4 cm, 5.1 cm, and 5.0 cm, respectively, and their 95% confidence intervals (4.8–6.0, 4.5–5.7, and 4.5–5.6) all overlap. This indicates that there is no clear separation in the fruit diameters between the different harvesting treatments, meaning that the differences observed are not statistically significant. The non-significant result suggests that, within the margin of error, the harvesting methods H1, H2, and H3 yield comparable outcomes in terms of fruit diameter, which could be attributed to the standard error and the lack of a substantial effect from the different harvesting applications on fruit size. Consequently, there is insufficient evidence to reject the null hypothesis, indicating no significant effect of the treatment on fruit diameter at a 95% confidence level. Results agree with previous work of [31].

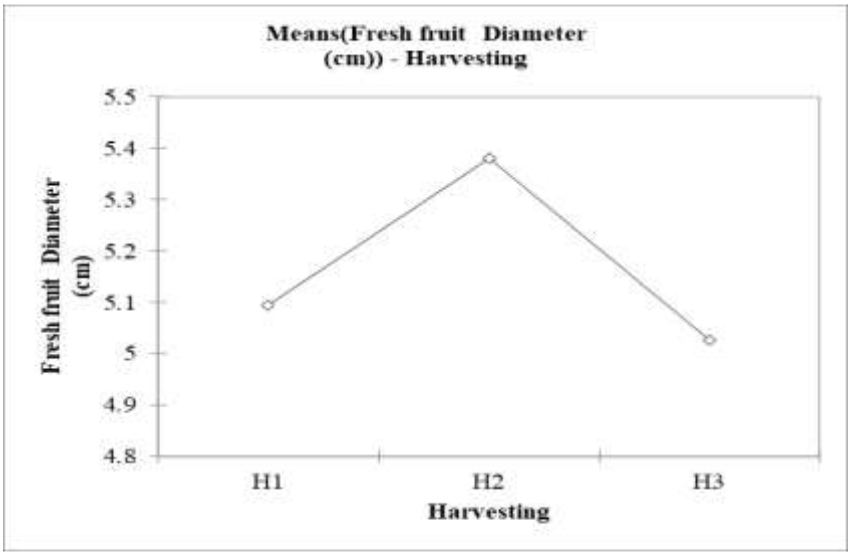

Figure. 9The difference between means fresh fruit diameter and harvesting of Chilli hot pepper

The data in Table 14 present the results of a comparison between different application doses (Foliar and Granular) and their effects on fresh fruit diameter (cm), with a 95% confidence interval. The "LS means" represent the average fruit diameter for each treatment group, and the standard error measures the variability of the estimates. The groups column indicates statistical clustering based on Duncan's multiple range test, which identifies significant differences in means. A significant difference is defined by the non-overlapping confidence intervals between groups. For example, the 0.5 ml L^{-1} Foliar application (6.9 cm) is significantly different from the other treatments, forming its own group (A), while the control group (2.6 cm) is distinctly smaller and forms group C. The 1 ml L^{-1} Foliar and 1.5 ml L^{-1} Foliar treatments (6.0 cm and 5.6 cm, respectively) are grouped together (A/B), indicating a marginal difference between them but significantly different from the control. Treatments with granular applications, regardless of concentration (5.0–5.1 cm), are also grouped together (B), showing no significant difference from one another but significantly different from both the foliar and control groups(marif, 2024). The non-significant differences between granular treatments suggest that, within this experimental setup, increasing the granular dose does not significantly impact the fruit diameter, possibly due to similar absorption or efficacy rates across the doses. This could be attributed to a saturation effect, where the plants reached an optimal threshold for granular application or to the nature of granular applications being less bioavailable than foliar ones, leading to reduced variation in the outcomes. Results in agreement with previous study [32].

Table 14. Application doses / duncan / analysis of the differences between the applications with a confidence interval of 95% (fresh fruit diameter (cm))

Applications	LS means	Standard error	Lower bound (95%)	Upper bound (95%)	Groups
0.5 ml L^{-1} Foliar	6.9	0.4	6.1	7.8	A
1 ml L^{-1} Foliar	6.0	0.4	5.2	6.9	A B
1.5 ml L^{-1} Foliar	5.6	0.4	4.8	6.4	B
0.5 ml L^{-1} Granular	5.1	0.4	4.3	5.9	B
1 ml L^{-1} Granular	5.1	0.4	4.2	5.9	B
1.5 ml L^{-1} Granular	5.0	0.7	3.6	6.4	B
1.5 ml L^{-1} Granular	5.0	0.5	4.0	6.0	B
Control	2.6	0.3	2.0	3.3	C

The effect of Application of potassium on shoots weight (g) of Chilli hot pepper

In the analysis of variance (ANOVA) for the effect of potassium application on the fresh fruit diameter of chilli hot pepper (Table 15), the results indicate that the model is highly significant with a very low p-value (< 0.0001). The F-statistic of 29.7, derived from the ratio of the mean square of the model (440,541.7) to the mean square of error (14,813.7), shows strong evidence that potassium application has a statistically significant effect on the fruit diameter. The p-value of less than 0.0001 suggests that the probability of observing such an F-statistic by random chance is extremely low, thus rejecting the null hypothesis and supporting the claim that potassium application influences the fresh fruit diameter. However, the "error" term, representing unexplained variation, is still notable and reflects natural or experimental variability not accounted for by the model. The non-significant result for the error term means that the unexplained variability, although present, does not significantly affect the model's validity or conclusions, reinforcing the strength of the treatment effect in this specific case. As explained in previous work by [33].

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Table 15. Analysis of variance of effect of application of potassium on fresh fruit diameter (cm) of chilli hot pepper

Applications	DF	Sum of squares	Mean squares	F	Pr > F
Model	23	10132460.0	440541.7	29.7	**< 0.0001**
Error	40	592549.4	14813.7		
Corrected Total	63	10725009.4			

Computed against model Y=0

Table 16 presents the results of an analysis of shoot weight (g) under different application doses, with a 95% confidence interval for each group. The data show that all application treatments, whether foliar or granular, yield statistically similar means, with the lower and upper bounds of their confidence intervals overlapping significantly. For instance, the shoot weight of plants receiving 1 ml L^{-1} foliar (431.8 g) is very close to that of 1 ml L^{-1} Granular (419.1 g), and this pattern holds across other doses as well. This indicates that no application method (foliar or granular) or dose (0.5 ml L^{-1}, 1 ml L^{-1}, 1.5 ml L^{-1}) produces a statistically significant difference in shoot weight compared to any other application. The treatments all belong to the same statistical group "A," suggesting they are not significantly different from one another at the 95% confidence level. The only exception is the control group, which has a markedly lower shoot weight (247.2 g) and falls into group "B," showing a significant difference from the other treatments. The lack of significance among the treatments may be due to the fact that the differences in dosages or methods do not exert a large enough effect on the shoot weight within the variability of the data (as indicated by the overlapping confidence intervals). Additionally, the standard errors for most treatments are relatively large, indicating a high degree of variability in the measurements, which could further contribute to the lack of statistical significance. As showed in front study was done by [34].

Table 16. Application Doses / Duncan / Analysis of the differences between the applications with a confidence interval of 95% shoots weight (g)

Applications	LS means	Standard error	Lower bound (95%)	Upper bound (95%)	Groups
1 ml L^{-1} Foliar	431.8	40.6	349.8	513.8	A
1 ml L^{-1} Granular	419.1	40.6	337.1	501.1	A
1.5 ml L^{-1} Foliar	417.1	40.6	335.1	499.1	A
0.5 ml L^{-1} Granular	411.8	40.6	329.8	493.8	A
0.5 ml L^{-1} Foliar	402.8	40.6	320.8	484.8	A
1.5 ml L^{-1} Granular	399.5	49.7	299.1	499.9	A
1.5 ml L^{-1} Granular	395.3	70.3	253.3	537.4	A B
Control	247.2	33.1	180.3	314.2	B

The effect of Application of potassium on dry matter (g) of Chilli hot pepper

In Table 17, the analysis of variance (ANOVA) examines the effect of potassium application on the fresh fruit

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diameter (cm) of chili hot peppers. The model has a significant F-value of 29.8 with a very low p-value (< 0.0001), indicating that the model is highly significant and suggests that the application of potassium has a statistically meaningful effect on fruit diameter. The error term, with a sum of squares of 119991.3 and a mean square of 2999.8, represents the variation within the residuals or unexplained variance after accounting for the effect of potassium. The F-statistic of 29.8, which is calculated by dividing the mean square of the model by the mean square of the error, is large, supporting the rejection of the null hypothesis (that potassium has no effect). The Pr > F value (< 0.0001) further confirms that the model's results are highly unlikely due to chance. The non-significant aspects could stem from various sources such as experimental error, inappropriate factor levels, or inadequate experimental design, although the p-value for the model strongly indicates overall significance. The results show a substantial difference in fresh fruit diameter due to potassium application, justifying its use in agricultural practices for improving chili pepper yield. Previous work by [35] showed agree with it.

Table 17. Analysis of variance of effect of application of potassium on fresh fruit diameter (cm) of chilli hot pepper

Applications	DF	Sum of squares	Mean squares	F	Pr > F
Model	23	2051823.2	89209.7	29.8	**< 0.0001**
Error	40	119991.3	2999.8		
Corrected Total	63	2171814.4			

Computed against model Y=0

In Table 18, the application doses of different treatments (foliar and granular) and their effects on dry matter (g) were analyzed with a 95% confidence interval (CI) to determine significant differences between them. The LS means for all treatments fall within the same group (denoted by "A"), indicating that there is no statistically significant difference between the treatment groups at the 95% confidence level. This means that the dry matter yields from the different dosages and application types (1 ml/L foliar, 1 ml/L granular, 1.5 ml/L foliar.) do not significantly differ from each other, suggesting that variations in dosage or application method do not substantially affect the dry matter production. The only exception is the "Control" treatment, which has a significantly lower mean (111.25 g) and is grouped separately as "B". The reason for the lack of significance between the other treatments could be due to the relatively small differences in dry matter yields, the large standard errors (ranging from 18.26 to 31.62), or the inherent variability in biological systems, all contributing to the overlapping confidence intervals that prevent a clear distinction in effect. Hence, while the treatments show a trend of higher dry matter than the control, the differences between the treatments themselves are not statistically significant within the chosen confidence level. The results agree with previous study by [35].

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Table 18. Application doses / duncan / analysis of the differences between the applications with a confidence interval of 95% (dry matter (g))

Applications	LS means	Standard error	Lower bound (95%)	Upper bound (95%)	Groups	
1 ml L^{-1} Foliar	194.30	18.26	157.40	231.20	A	
1 ml L^{-1} Granular	188.60	18.26	151.70	225.50	A	
1.5 ml L^{-1} Foliar	187.70	18.26	150.80	224.60	A	
0.5 ml L^{-1} Granular	185.30	18.26	148.40	222.20	A	
0.5 ml L^{-1} Foliar	181.27	18.26	144.37	218.17	A	
1.5 ml L^{-1} Granular	179.78	22.36	134.58	224.97	A	
1.5 ml L^{-1} Granular	177.90	31.62	113.99	241.81	A	B
Control	111.25	14.91	81.12	141.38		B

Conclusion

The analysis of plant height in response to different application doses of foliar and granular treatments indicates that the 0.5 ml L^{-1} foliar application had the most significant positive effect on growth, significantly higher than all other treatments.

Furthermore, the statistical analysis, including 95% confidence intervals, clearly demonstrates the impact of application doses on plant height, with the 0.5 ml L^{-1} foliar treatment standing out as the most effective. The variability in plant height was moderate, as indicated by the standard errors and confidence intervals, which did not overlap between the control and the higher treatment groups. These findings support the conclusion that foliar applications, particularly at lower concentrations, are more beneficial for enhancing plant height compared to granular applications, with higher doses of either type generally resulting in reduced growth.

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