Effect of foliar application of Urea and Nano urea levels on quality, physiological and leaf nutrient content attributes of Acid lime (Citrus aurantifolia Swingle) cv. Kagzi.

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ABSTRACT

The study's outcomes shed light on the effects of different Urea and Nano urea applications on various attributes of acid lime cv. Kagzi fruits. Notably, when Urea was applied at a 2.0% rate, it brought about substantial improvements in several key parameters. Firstly, fruit characteristics displayed noteworthy changes, with the fruit weight increasing to 67.90 gm, fruit length measuring 57.92 mm, and fruit breadth reaching 47.96 cm. Secondly, Juice properties saw positive developments, as the juice content rose to 51.19%, and the TSS level reached 10.46°brix, resulting in a higher TSS/Acid ratio of 1.65. Thirdly, nutritional content was enhanced, evident in the elevated levels of ascorbic acid (60.89 mg/100 ml) and a juice pH of 2.40. Additionally, the chlorophyll content also experienced an increase, with chlorophyll a at 1.217 mg/g, chlorophyll b at 0.717 mg/g, and a total chlorophyll content of 1.933 mg/g. Moreover, the relative water content in acid lime leaves was found to be 75.86% It is worth mentioning that the Ta treatment, which included Urea at 2.0%, exhibited minimized acidity levels at 6.47%. In terms of leaf nutrient content, the 2.0% Urea application (T, treatment) resulted in the highest leaf nitrogen content (2.05%) and leaf phosphorous content (0.16%). These findings underscore the significant impact of Urea on the quality, nutritional content, and growth attributes of acid lime cv. Kagzi, with the 2.0% Urea treatment proving most favourable for most measured parameters.

Key words: Citrus, Acid Lime, Kagzi, Quality, Urea, Nano urea, Leaf N, P, K

Introduction

Acid lime, scientifically referred to as Citrus aurantifolia Swingle, is an evergreen fruit tree belonging to the Rutaceae family. It is characterized by its small size and bears fruits known as acid limes. This fruit is well known for its distinctive tangy flavour and is highly valued for its versatile applications in both culinary and medicinal uses. The acid lime tree is native to Southeast Asia, particularly India, and is commonly cultivated in tropical and subtropical regions around the world Globally, India holds first rank in production of acid lime (Citrus aurantifolia Swingle) with production 35.86 lakh metric tons and an area 3.06 lakh hectares as per third advance estimate of Ministry of Agriculture and farmers Welfare data of the year 2021-22 (Anon., 2021-22). Acid lime is gaining popularity among citrus growers due to its versatility in adapting to diverse agro-climatic and soil conditions, cost effective cultivation, year round fruit bearing capability, improved fruit storage properties, and steady demand in the domestic market (Ladaniya *et al* 2020) The increasing interest in foliar fertilizers is driven by the numerous advantages of foliar application methods. These include the rapid and efficient response to plant needs, reduced product quantities required and the independence from soil conditions. The application of supplementary foliar fertilization during crop growth has been acknowledged for its ability to enhance the mineral status of plants and ultimately boost crop yield (Kolota and Osinska 2001) Most plants absorb foliar applied urea rapidly and hydrolyse the urea in the cytosol (Witte *et al*. 2002). Urea and Nano urea can be applied to plants through the foliage, enabling efficient nitrogen management that reduces nitrogen losses to the environment. (Yildrim *et al*. 2007). Acid lime is cultivated in tropical and subtropical regions of India Acid lime (*Citrus aurantifolia* Swingle) is prized for its tangy flavour in culinary delights and beverages, while also providing essential nutrients and antioxidants for health benefits. Its versatility extends to medicinal properties, and its cultivation contributes significantly to agriculture and culinary industries. Acid lime crop is economically important for farmers as it provides year round harvest, ensuring a steady return With the growing concern for sustainable agriculture and environmental protection, there was a need felt to explore alternate nutrient management practice Traditional urea application may lead to nutrient losses through leaching and volatilization. Evaluating the efficacy of Nano urea in comparison can provide insight into its potential to enhance nutrient use efficiency, thereby conserving nutrient resources. By comparing the effect of Urea and Nano urea on acid lime, which foliar treatment results in better productivity and improved fruit quality. Keeping all these facts in mind, the present investigations were conducted to provide valuable information to farmers and the agriculture industry to optimize their nutrient management practices

Materials and Methods

The investigation titled "Comparative assessment of Urea and Nano urea foliar applications on quality, physiological and leaf nutrient content attributes of Acid lime (*Citrus aurantifolia* Swingle) cv. Kagzi, was carried out from June to December 2022 at the well-established Kagzi lime orchard of College of Horticulture and Forestry, Jhalawar, a constituent College of Agriculture University, Kota. The study involved 14-year-old acid lime plants, totalling fifty-four in number, spaced at regular intervals of 6 m x 6 m. The experiment included nine treatments, incorporating different concentrations of Urea (0.5%, 1.0%, 1.5%, and 2.0%) and Nano Urea (500 ppm, 1000 ppm, 1500 ppm, and 2000 ppm). Two rounds of foliar spraying were administered for each treatment, commencing on 7th July 2022, followed by the second spray 30 days later. The soil composition predominantly had a clay loam texture with traces of heavy clay. The primary objective of this study was to assess the influence of Urea and Nano Urea foliar applications on the quality attributes of Kagzi Acid Lime, yielding significant insights for the improvement of agricultural practices

1. "Quality parameters were recorded light of December 2022" fortnight at horticultural maturity of fruits during second

2. "Leaf nutrient analysis and physiological parameters were initially measuredand then again at the completion of the experiment as per standard analytical procedures".

Treatment Details

The area of the experimental block was 2160 m^2 accommodating 54 acid lime cv Kagzi plants. Treatment comprises two factors, first four levels of Urea and second, four levels of Nano Urea and control. Thus a total of nine treatments having a unit replication of two plants with a total of 54 plants were tested applying these treatments. The details of treatments evaluated under study are given in table 2.

Table 2 : Details of various treatments including Urea and Nano Urea

T_0 (water spray),

T_1 (Urea @ 0.5%).

T_2 (Urea @ 1.0%),

T_3 (Urea @ 1.5%).

T_4 (Urea 2%),

T_5 (Nano urea @ 500 ppm).

T_6 (Nano urea @1000 ppm),

T_7 (Nano urea @ 1500ppm)

T_8 (Nano urea 2000ppm) as applied foliar treatments

Leaf chlorophyll content was quantified following the method suggested by Sadasivam and Manickam (1997). Leaf N content was determined using alkaline potassium permanganate method (Thakur *et al.* 2012). The leaf P and K content in leaf samples was assessed using the methodology outlined by Thakur *et al.* (2012).

The data collected during the experiment was subjected to statistical analysis using Analysis of variance (ANOVA) technique. The significance of the treatment was tested through F-test at a 5% level of significance. To evaluate the significance of the differences, the critical difference (CD) was calculated among the different treatments.

Result and Discussion

Below are the comprehensive results of the experiment, supported by relevant tables:

Fruit Weight: Significant variations were observed in the fruit weight of Kagzi lime in response to various Urea and Nano urea treatments. Table 1.0 presents the results, revealing that the maximum fruit weight (67.90 g) was recorded in cv. Kagzi lime with the T, treatment (Urea @2%), while the minimum fruit weight (40.89 g) was recorded in the To treatment Although there was an increase in fruit weight of acid lime with Nano urea, the Ts treatment with Nano urea application @ 2000 ppm showed a value of 52.68 g. Despite this, the overall highest fruit weight was recorded with the T_4 treatment.

Fruit length (mm): Various urea and Nano urea treatments led to significant variations in the fruit length of acid lime. The findings presented in table 1 demonstrate that the highest fruit length (52.72 mm) in acid lime cv. Kagzi was observed in the T. treatment (Urea @ 2%). while the lowest fruit length (41.76 mm) was recorded in the To treatment. Similarly, the application of different levels of Nano urea also increased the fruit length in acid lime cv. Kagzi, with the maximum fruit length (45.70 mm) recorded in the Ts treatment using Nano urea @ 2000 ppm. The overall results indicate that the fruit length was highest in the T_4treatment (Urea (@ 2%) compared to the Nano urea treatments.

Fruit breadth (mm): The findings presented in table 1 indicate that the highest fruit breadth in acid lime cv. Kagzi (47.36 mm) was observed in the T_4 treatment (Urea (@) 2%), while the minimum length (40.87 mm) was recorded in the T_0 (Control) treatment. The application of different levels of Nano urea resulted in an increase in fruit length, with the maximum value (46.35 mm) measured in the T'_8 treatment (Nano urea@ 2000ppm) However, the overall maximum enhancement in fruit length (47.36 mm) was recorded in the T_4 treatment (Urea @ 2%) when compared to the Nano urea treatments.

Juice (%): The results presented in table 1 demonstrate that the maximum juice recovery in Kagzi lime (51.19%) was achieved in response to the T_4 treatment (Urea @ 2%), while the minimum (38.34%) was observed in the T_0 (Control) treatment. Additionally, the application of Nano urea treatments resulted in an increase in juice recovery percentage, and the highest Juice recovery (49.21%) was obtained through the T_8 treatment (Nano urea @ 2000 ppm). Overall, upon comparative evaluation of Urea and Nano urea treatments, it was found that the highest juice recovery (51 19%) was estimated in the T_4 treatment, which included Urea @ 2.0%

TSS (brix): The data presented in table 1 illustrates the variations in the total soluble solids (TSS) content of acid lime cv. Kagzi under different Urea and Nano urea treatments. The highest TSS value (10.46 brix) was recorded in the T_4 treatment, where Urea was applied at a rate of 2% The application of Nano urea at different doses resulted in inconsistent variations in TSS levels, with the highest values (10.28°brix) observed in both the T_5treatment (Nano urea 500 ppm) and the T_7 treatment (Nano urea (@ 1500 ppm), which were higher than the control group (9.30°brix). However, upon overall evaluation, the maximum TSS content (10.46 brix) was measured in the T_4 treatment with Urea at 2.0%

Acidity (%): Upon examining the data presented in table l, it becomes evident that the acidity of the lime juice samples displayed significant variations in response to the different foliar treatments. The lowest acidity of 6.47% was recorded in the T_4 treatment (Urea (@) 2%), and this value was notably lower compared to the other treatments. In contrast, the highest acidity content of 7.25% was observed in the T_0 treatment, which served as the control. Moreover, the various doses of Nano urea treatments revealed a reduction in acidity content across all the Nano urea treatments. The minimum acidity content (6.53%) was estimated in the T_8 treatment, where Nano urea was applied at a rate of 2000 ppm during the horticultural maturity of acid lime fruits.

TSS/Acidity ratio: The TSS/Acidity ratio is a crucial parameter used to assess fruit quality in acid lime and other citrus fruits, indicating the balance between sweetness and acidity, which are essential aspects of fruit taste. The T_4. treatment, with Urea applied at 2%, resulted in the highest TSS/Acidity ratio (1.65), indicating a better balance between sweetness and acidity in the fruit and favourable fruit quality. In contrast, the T_o treatment (Control) exhibited the lowest TSS/Acidity ratio (1.27), suggesting an imbalanced combination of sweetness and acidity in the fruit. Nano urea treatments showed varying trends in the TSS/Acidity ratio at different doses, implying inconsistent effects on fruit quality. Among the Nano urea treatments, the T_8 treatment with Nano urea applied at 2000 ppm recorded the highest TSS/Acidity ratio (1.56), indicating a relatively better balance of sweetness and acidity compared to other Nano urea treatments. Overall, the comparative evaluation of urea and Nano urea treatments revealed that the best TSS/Acidity ratio (1.65) was obtained in the T_4 treatment, where Urea was applied at 2.0%. This suggests that the Urea treatment at this concentration was more effective in achieving the desired fruit quality with the right balance of sweetness and acidity.

Ascorbic acid (mg/100 ml of juice): The level of ascorbic acid in acid lime fruits displayed significant variation when exposed to different treatments involving Urea and Nano urea. Among these treatments, the highest concentration of ascorbic acid, measuring 61.89 mg/100ml, was observed in T_4 treatment, which involved the application of Urea at a concentration of 2%. On the other hand, the control group (T_0 treatment) exhibited the lowest ascorbic acid content, measuring 44.56 mg/100ml. The ascorbic acid content increased with varying doses of Nano urea, and the maximum ascorbic acid content (57.75 mg/100ml) was achieved in T_8treatment (Nano urea (@ 2000ppm). However, the overall comparative assessment revealed that the highest ascorbic acid content (61.89 mg/100ml) was recorded in T_4 treatment, where Urea was applied at a concentration of 2.0%

Juice pH: The current research on foliar applications of Urea and Nano urea treatments in acid lime cv. Kagzi fruits revealed variations in juice pH The highest juice pH value (2.40) was observed in T_4. treatment, which showed similar performance to T_3 and T_2 treatments with pH values of 2.38 and 2.35, respectively. On the other hand, the lowest juice pH (2.22) was recorded in the control group, T_0. Moreover, the application of Nano urea treatments at different levels resulted in lower juice pH values (ranging from 2.22 to 2.28) compared to various Urea levels.

Physiological Attributes

Chlorophyll content (mg g')

The application of foliar treatments comprising Urea and Nano urea on acid lime cv. Kagzi led to a noticeable increase in total chlorophyll content across various treatments. The changes in chlorophyll accumulation of Kagzi lime leaves in response to foliar application of Urea and Nano Urea treatments are depicted in Fig. 1 The T_4 treatment, which involved Urea at a 2% concentration, exhibited the highest chlorophyll a, chlorophyll b, and total chlorophyll content with values of

1.217 mg g^3. 8. 0717 mg g^1, and 1933 mg g, respectively. Conversely, the lowest accumulation of chlorophyll a (1.140 mg g^1), chlorophyll b (0.463 mg g and total chlorophyll (1.603 mg g^1) was observed in the T_0 (control) treatment, which did not receive any foliar treatment.

Relative water content (%)

The graphical representation of data in fig 2 illustrates the changes in RWC (Relative water content) of acid lime cv. Kagzi leaves. The overall maximum relative water content (75.86%) in Kagzi lime leaves was estimated in T_4 treatment (Urea @ 2.0%) during December 2022 and minimum relative water content (68.05%) was measured in T_0 (Control) treatment.

Leaf nutrient analysis

Effect of N (%) of acid lime cv. Kagzi leaves

The experiment conducted on acid lime cv. Kagzi trees involved the application of different treatments, including Urea and Nano urea, through foliar application. The researchers measured the effect of these treatments on the final leaf nitrogen status of the acid lime trees after harvesting the fruits in December 2022.

The results, as depicted in Figure 4, showed that the treatment T_4, which involved the application of Urea at a concentration of 2%, resulted in the highest leaf nitrogen content, with a value of 2.05%. Following closely behind was the T_3, treatment, which used Urea at a concentration of 1.5%, and it exhibited a leaf nitrogen status of 2.01%. The third most effective treatment was T_8, which utilized Nano urea at a concentration of 2000 ppm, and it yielded a leaf nitrogen content of 2.01%.

From these findings, it can be inferred that the application of Urea, particularly at a higher concentration of 2%, had a more significant impact on increasing the leaf nitrogen status of the acid lime cv. Kagzi trees compared to the application of Nano urea at the given concentration. This suggests that Urea, when applied via foliar application, might be a more efficient nitrogen source for enhancing the nitrogen content in the leaves of the acid lime trees.

Effect on P (%) of acid lime cv. Kagzi leaves

The paragraph discusses the effects of foliar application of Urea and Nano urea treatments on acid lime cv. Kagzi trees, specifically focusing on their impact on leaf phosphorous (P) content. According to the results presented in Figure 5, it was observed that both Urea and Nano urea treatments led to an increase in leaf phosphorous content in the acid lime cv. Kagzi trees. The highest leaf phosphorous content (0.153%) was recorded in the T_4, treatment group, which involved the application of Urea at a concentration of 2.0% Interestingly, the T_8 treatment group, using Nano urea at a concentration of 2000 ppm, showed an equivalent leaf phosphorous content of 0.153% to that of the T_4 treatment

The data displayed in Figure 5 provides evidence that both Urea and Nano urea treatments are effective in augmenting the leaf phosphorous content in the acid lime cv. Kagzi trees. It suggests that the foliar application of these treatments can be beneficial in enhancing the phosphorous uptake and assimilation in the leaves, which can potentially contribute to improved plant growth, health, and fruit production.

Effect on K (%) of acid lime cv. Kagzi leaves

The results presented in Figure 6 indicate that the application of foliar spray treatments containing both Urea and Nano urea on Kagzi lime trees led to a consistent decrease in leaf potassium content across all the treatments. This reduction in leaf potassium content was observed when comparing the values after the application of the treatments to the initial values before the treatments were administered. The significant reduction in leaf potassium content in both the Urea and Nano urea treatments implies that these foliar spray treatments had an impact on the uptake, translocation, or utilization of potassium within the Kagzi lime trees. The decrease in leaf potassium levels suggests that either the applied nutrients (Urea and Nano urea) directly influenced the potassium levels or induced physiological responses in the trees that affected potassium uptake and distribution. The finding of a consistent decrease in leaf potassium content across all treatments suggests that both Urea and Nano urea treatments might have similar effects on the potassium status of the Kagzi lime trees.

Effect of Urea and Nano urea treatments on physico-chemical characteristics of acid lime cv. Kagzi fruits

The increase in fruit weight observed with the T_4 treatment (Urea @ 2%) can be attributed to the enhanced nitrogen availability provided by urea, which is a vital nutrient required for protein, enzyme, and chlorophyll synthesis involved in various biochemical processes within the plant. The foliar application of urea through the T_4. treatment likely stimulated the photosynthetic rate, leading to higher carbohydrate production and ultimately resulting in increased fruit weight. The role of nitrogen in enhancing cell wall strength and flexibility might have influenced fruit shape and breadth. Additionally, nitrogen closely associates with the absorption and assimilation of other essential nutrients like potassium (K) and calcium (Ca), crucial for cell expansion and fruit development. The increase in fruit length can be attributed to enhanced water uptake and turgor pressure within the fruit, facilitating the expansion and elongation of fruit tissues. the results of this study are in agreement with previous findings reported by various researchers in different fruit crops. Debajeet al. (2011) observed similar trends in acid lime, while Jat and Laxmidas (2014) reported comparable results in guava. Likewise, Prasad *et al.* (2015) and Al-Obeedet al. (2017) found analogous outcomes in Kinnow mandarin. These findings are further supported by Rathore and Chandra (2003), Prasad et al. (2015), and Sawale *et al*. (2021) in Sai Sharbati. Moreover, El-Tanany *et al.* (2009), Debaje et al. (2011), Prasad *et al.* (2015), Al-Obeeder *et al*. (2017), and Yadav *et al.* (2020) also reported consistent results in their studies on acid lime and Kinnow mandarin. The convergence of these outcomes strengthens the validity of the current study's findings and reinforces the understanding of the impact of the treatments on fruit growth and development. The higher juice recovery obtained in the T_4 treatment can be attributed to several factors. Firstly, the application of T_4. might have stimulated increased carbohydrate production, leading to an enhancement in cell number and size in various fruit tissues. Including the juice sac in acid lime. Additionally, urea, present in the T_4. treatment, plays a role as a source of nitrogen. It increases the osmotic pressure within the fruit cells, causing water to move from the surrounding tissue into the fruit cells, thereby increasing the juice percentage. The present findings are consistent with the results reported by Lakshmipathi *et al.* (2015), Prasad *et al* (2015), Rokaya *et al*. (2019) in Kinnow mandarin. Yadav *et al* (2020) in acid lime, and Senjam and Singh (2021) in Assam lemon. The convergence of these results reinforces the understanding of the impact of the T_4. treatment on juice recovery and supports the effectiveness of urea as a nutrient in enhancing juice yield in acid lime The increase in TSS observed under various treatments can be attributed to the influence of Urea and Nano urea on metabolic pathways, resulting in the accumulation of sugar in the fruit juice and an increase in enzymatic activity, contributing to higher TSS levels. These findings align with the results reported by Prasad et al (2015), Chouhan et al (2018) in acid lime, Yadav *etal* (2020) in acid lime, and Senjam and Singh (2021) in Assam lemon. Acidity in acid lime fruits is influenced by various physiological factors, including organic acid synthesis, respiration rates, sugar content, and nitrogen availability, which can potentially affect acidity levels. This is supported by the research conducted by Chouhan *et al*. (2018) and Yadav *et al*. (2020) in acid lime, Abdallah (2020) in Minneola Tangelo, and Senjam and Singh (2021) in Assam lemon, which corroborate the present findings and further emphasize the factors influencing TSS and acidity in acid lime fruits. The high TSS: acid ratio recorded in the T_4 treatment can be attributed to enhanced sugar accumulation in the acid lime fruits. With an increased supply of nitrogen, the acid lime plant might produce and accumulate more sugars, leading to higher TSS levels in the fruit juice. These findings are in line with the results reported by Saleem et al. (2008) in sweet orange. The research also indicates that the availability of nitrogen contributes to a rise in N_2 content within the acid lime cv. Kagzi fruits. This increase can be attributed to higher availability of ammonia, which enhances the presence of glutathione. Glutathione indirectly leads to an increase in the levels of ascorbic acid and has the ability to regenerate ascorbic acid from its oxidized form (dehydroascorbic acid), thereby maintaining an active pool of ascorbic acid within the fruit tissue. These results are further supported by previous research by Carpenter *et al*. (2018), Chouhan *et al*. (2018) conducted on acid lime under Malwa plateau region, as well as the findings of Rokaya *et al.* (2019). The consistency of these supporting studies strengthens the validity and relevance of the present investigations. The higher juice pH could be attributed to the fact that urea application might influence the uptake and utilization of other essential nutrients such as potassium (K) and calcium (Ca) which play a role in maintaining the pH balance in plant cells. The results of present findings are in accordance with those reported by Lasa *et al*. (2012).

Effect of Urea and Nano urea treatments on physiological variables of acid lime cv. Kagzi fruits

The significant increase in chlorophyll a, chlorophyll b, and total chlorophyll

content in the T_4 treatment can be attributed to the positive response of acid lime plants to the foliar application of Urea at a concentration of 2.0%. This response likely led to enhanced chlorophyll synthesis and improved photosynthetic efficiency in the plants. Additionally, the increased activities of Rubisco (Ribulose-1,5-biphosphate carboxylase/oxygenase), a keyenzyme involved in carbon fixation during photosynthesis, may have contributed to the heightened chlorophyll content. These findings align with the work of Dhaliwal and Rohela (2016) in rough lemon and Abdallah (2020) in their studies, further validating the positive impacts of foliar Urea treatments on chlorophyll content in citrus plants. The present results highlight the potential of Urea foliar application as an effective method to enhance photosynthetic activity and overall health in acid lime cv. Kagzi.

The relatively better Relative Water Content (RWC) measured in the T_4 treatment could be attributed to multiple factors. Firstly, there might be an increase in osmotic adjustment, leading to a higher osmotic potential in the leaf cells. This allows the cells to retain more water and maintain higher RWC (%) Secondly, Urea might influence stomatal behaviour, leading to better stomatal regulation and improved water retention in the leaves. Additionally, nitrogen stimulates cell expansion, allowing the leaf cells to accommodate more water and maintain higher RWC (%) These results are consistent with the findings reported by Mohammadi and Khejri (2018) in date palm, providing further support for the positive impact of Urea treatment on the relative water content in acid lime plants.

Effect of Urea and Nano urea treatments on leaf N, P and K content of acid lime cv. Kagzi

The increase in leaf nitrogen content of acid lime cv. Kagzi can be attributed to several factors. Firstly, the rapid uptake of nitrogen from the applied foliar Urea and Nano urea treatments contributed to higher nitrogen levels in the leaves. Secondly, the improved mobility of nutrients in the plants facilitated the efficient movement of nitrogen within the leaf tissues. Thirdly, enhanced urea hydrolysis and nitrogen release further enriched the nitrogen content in the leaves. Lastly, better nitrogen assimilation processes in the plants led to the synthesis of nitrogen-rich organic compounds. These findings are in line with previous studies by Bondada et al. (2001), El-Otmani et al. (2004) in clementine mandarin, Abdallah (2020), and Deparpanah (2017) in pomegranate, which support the positive impact of foliar Urea and Nano urea treatments on leaf nitrogen content in citrus plants

The increase in leaf phosphorus (P) content of acid lime cv. Kagzi can be attributed to indirect biochemical and physiological processes in the plants. The application of foliar Urea and Nano urea likely stimulated root growth and activity due to increased nitrogen availability. Healthy and active roots play a crucial role in nutrient uptake, including phosphorus. Additionally, the metabolism of urea in plants and the subsequent production of ammonia (NH_3) may raise the pH in the vicinity of the urea-treated leaves, creating a slightly alkaline environment. This alkaline environment stimulates the activity of certain phosphatase enzymes responsible for breaking down organic phosphorus in the soil, making inorganic phosphorus more available for uptake by the roots and subsequent transportation to the leaves. These results are consistent with the findings reported by Abdallah (2020). The reduction in leaf potassium (K) status of acid lime cv. Kagzi may be a result of nutrient allocation changes after fruit harvest. The trees may reallocate nutrients that were previously allocated to fruit development and growth towards other parts of the trees, including leaves. This redirection of nutrients leads to a decrease in overall nutrient content in the leaves, including potassium. Additionally, the increased nitrogen levels from the foliar Urea and Nano urea treatments may interfere with the uptake of potassium, contributing to the relative reduction in leaf potassium content. These findings are supported by the research conducted by Kumar et al. (1994) and Nava et al. (2010).

Conclusions

Based on the rigorous and comprehensive investigation conducted on the comparative foliar application of Urea and Nano urea in acid lime cv. Kagzi trees in Vertisols of Jhalawar district, the study leads to an emphatic conclusion. The T_4 treatment, which involved the application of Urea at a concentration of 2.0%, emerges as the superior choice for enhancing various aspects of the acid lime cv. Kagzi. Firstly, the T_4 treatment demonstrated remarkable advancements in quality attributes, with a particular emphasis on increasing the ascorbic acid content of the fruit. Ascorbic acid, or vitamin C, is a vital component that enhances the nutritional value of the acid lime, making it more appealing to consumers seeking healthier food choices

Secondly, the T_4 treatment exerted a profound and positive impact on the physiological aspects of the acid lime cv. Kagzi. The plants treated with Urea at a 2.0% concentration exhibited unparalleled growth, vigour, and overall health compared to the other treatments This indicates that the T_4 treatment significantly contributed to the overall well-being and vitality of the acid lime plants, potentially leading to improved resistance to environmental stresses and diseases

The evidence presented in the study strongly supports Urea foliar application at a 2.0% concentration as the definitive approach for optimizing the growth, quality, and agricultural potential of acid lime cv Kagzi in the Vertisols of Jhalawar district. By reaffirming the significance of this treatment, the research underscores its importance for sustainable and productive citrus cultivation in the region

In summary, the study's findings highlight the superiority of the T_4 treatment featuring Urea at a 2.0% concentration, which positively impacts the fruit's nutritional value and physiological characteristics. This conclusion has practical implications for citrus growers in Jhalawar district, providing them with valuable insights to maximize the productivity and quality of acid lime cv Kagzi cultivation, ultimately contributing to the region's agricultural success and economic growth

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Table 1.0: Physico-chemicalcharacteristics of acid lime cv. Kagzi fruits in response to foliar application of Urea and Nano urea treatments

Treatments	Fruit wt.(g.)	Fruit lenght(mm)	Fruit breadth (mm)	Juice (%)	TSS(^{0}brix)	Acidity (%)	TSS/ Acidity ratio	Ascorbic Acid (mg/100ml)	Juice pH
T_0	40.89	41.76	40.87	38.34	9.30	7.25	1.27	44.56	2.22
T_1	44.73	43.53	42.09	47.55	9.93	6.98	1.45	53.21	2.32
T_2	48.09	43.63	43.06	46.25	10.26	7.05	1.41	54.38	2.35
T_3	51.46	44.48	44.68	49.66	10.28	6.88	1.46	60.31	2.38
T_4	67.90	52.72	47.36	51.19	10.46	6.47	1.65	61.89	2.40
T_5	40.56	41.24	40.53	46.05	10.28	6.56	1.47	48.54	2.22
T_6	45.85	43.29	42.43	47.36	10.07	6.66	1.46	51.36	2.22
T_7	48.42	43.52	43.13	46.90	10.28	6.68	1.55	55.65	2.24
T_8	52.68	45.70	46.35	49.21	10.15	6.53	1.56	57.75	2.28
SEm(±)	1.41	0.97	0.78	0.68	0.15	0.05	0.02	0.45	0.02
CD 5%	4.25	2.92	2.36	2.06	0.47	0.17	0.06	1.35	0.06

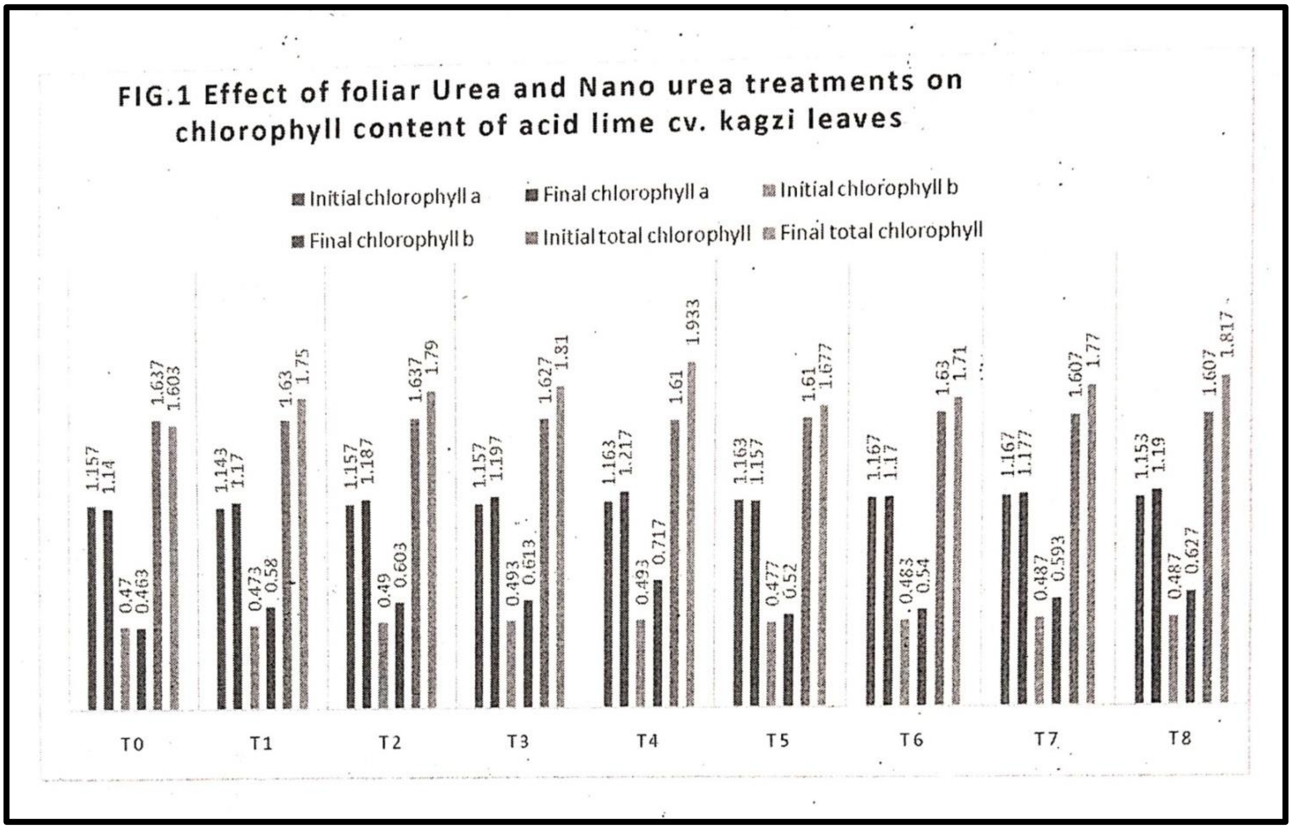


FIG.1 Effect of foliar Urea and Nano urea treatments on chlorophyll content of acid lime cv. kagzi leaves
Initial chlorophyll a
Final chlorophyll a
Initial chlorophyll b
Final chlorophyll b
Initial total chlorophyll
Final total chlorophyll
1.157 1.14 0.47 0.463 1.637 1.603
1.143 1.17 0.473 0.58 1.63 1.75
1.157 1.187 0.49 0.603 1.637 1.79
1.157 1.197 0.493 0.613 1.627 1.81
1.163 1.217 0.493 0.717 1.61 1.933
1.163 1.157 0.477 0.52 1.61 1.677
1.167 1.17 0.483 0.54 1.63 1.71
1.167 1.177 0.487 0.593 1.607 1.77
1.153 1.19 0.487 0.627 1.607 1.817
T0
T1
T2
T3
T4
T5
T6
T7
T8

Fig.4 Effect of Foliar urea and Nano urea on leaf nitrogen content of acid lime cv.Kagzi

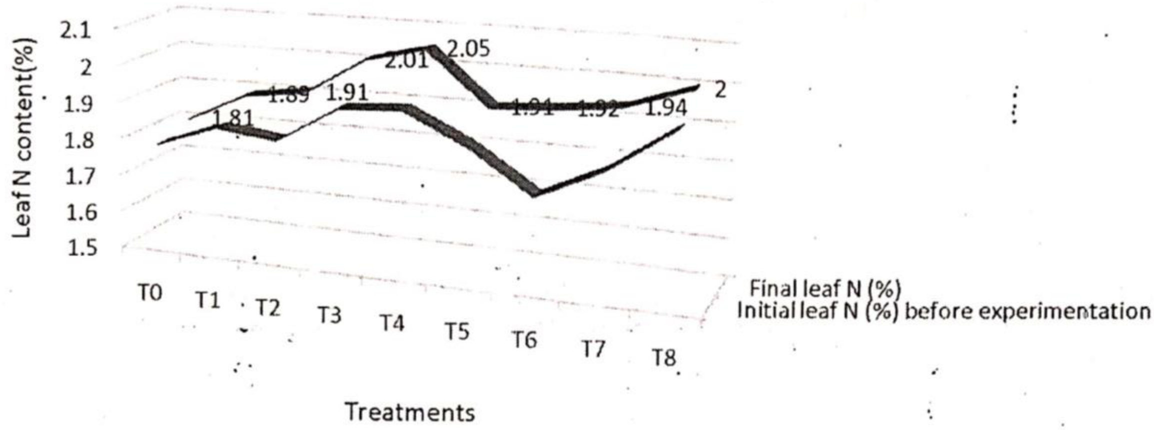
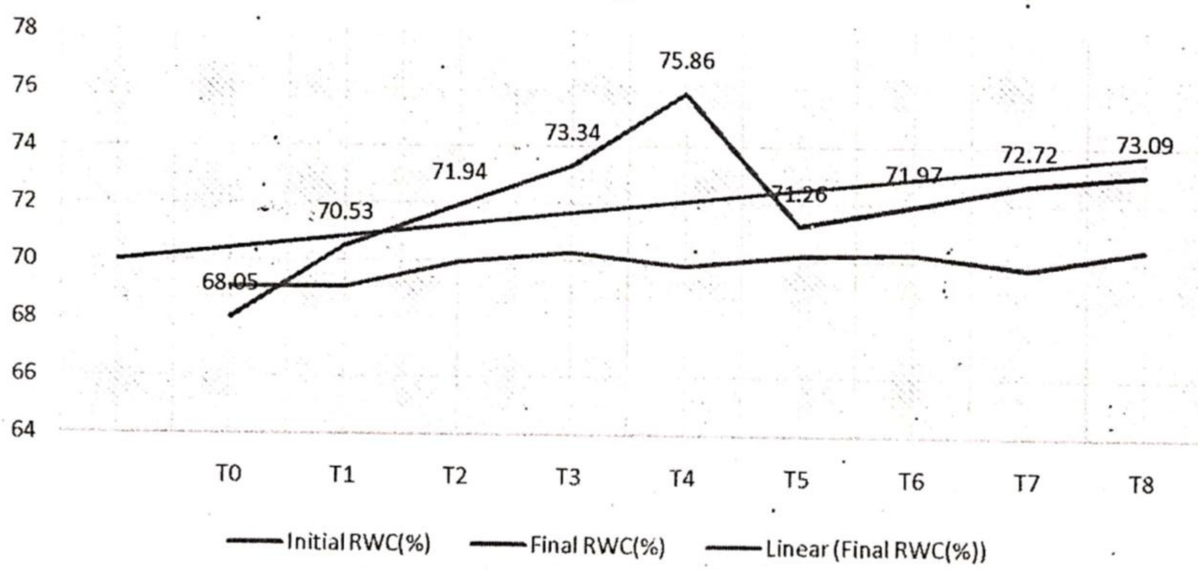


Fig.2 Effect of foliar Urea and Nano Urea treatments on Relative water content(%) of acid lime cv.Kagzi leaves



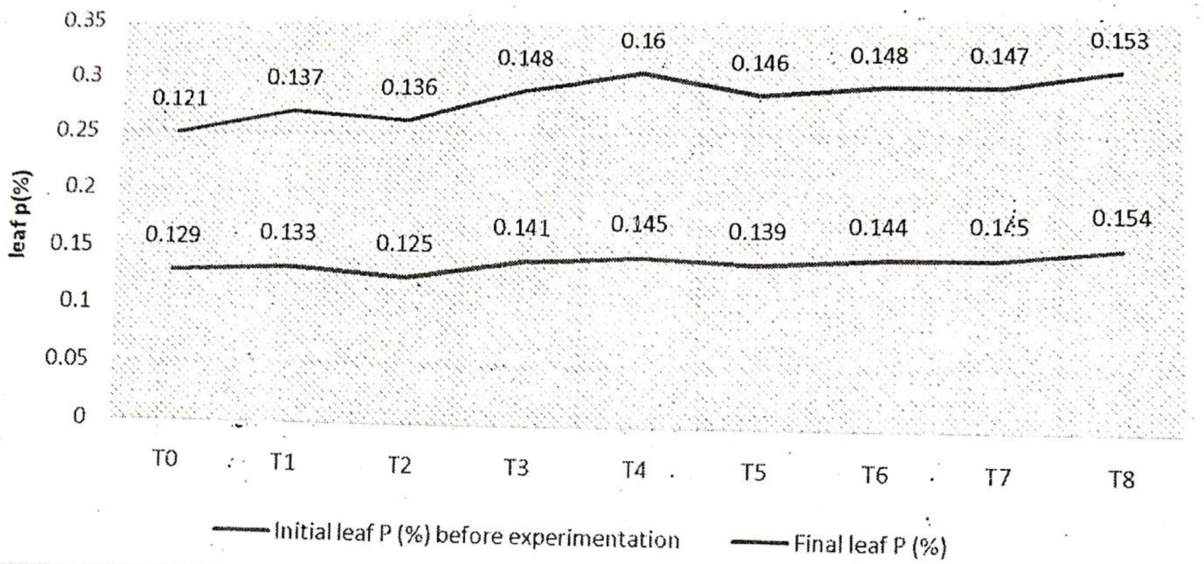


Fig.5 Effect of foliar urea and Nano Urea treatments on leaf phosphorous content of acid lime cv.kagzi

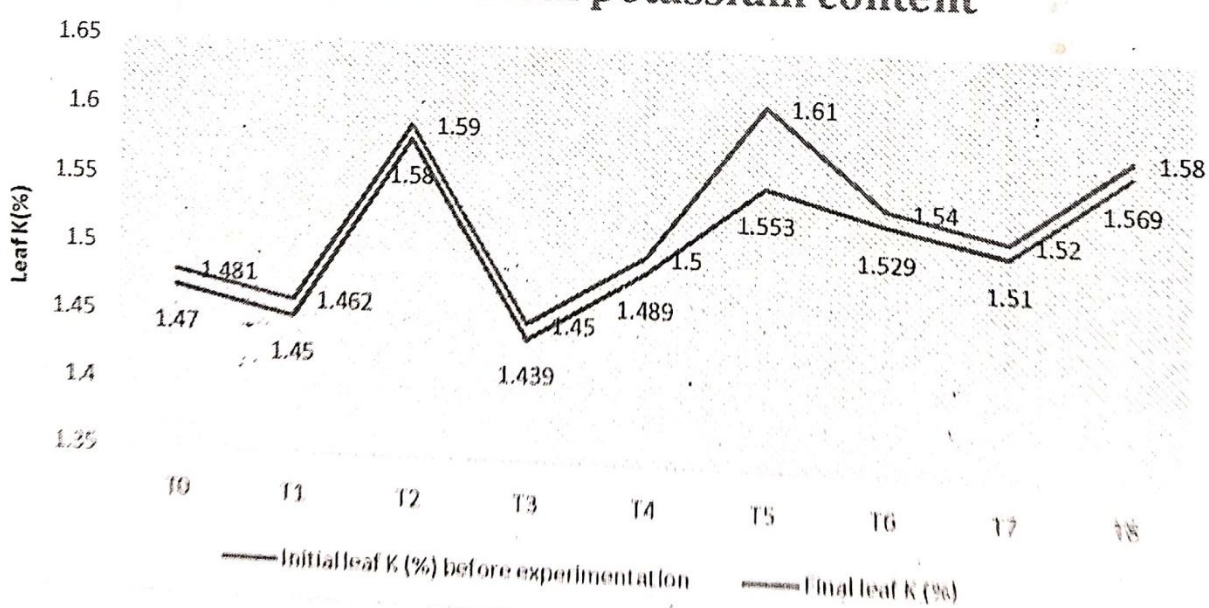


Fig.6 Effect of foliar urea and nano urea treatments on leaf potassium content