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Response of Growth and Yield of Cucumber (*Cucumis sativus* L.) to NPK Fertilizer Application and Mulch Treatment

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ABSTRACT

Cucumber (*Cucumis sativus* L.) is an important horticultural crop in Indonesia, valued for its high market demand and short growth cycle. However, its productivity is often constrained by suboptimal nutrient management and unfavorable growing conditions. This study aimed to evaluate the interactive effects of NPK fertilizer dosages and mulch types on the growth and yield of cucumber plants. A factorial randomized block design was employed, with three levels of NPK fertilizer (0, 200, and 300 kg/ha) and three types of mulch (no mulch, silver-black plastic mulch, and straw mulch), resulting in nine treatment combinations, each replicated three times. The results showed that NPK application significantly increased fruit number and yield, with 200 kg/ha considered optimal for economic efficiency. Mulching, particularly with straw, significantly improved fruit weight and overall plant performance. However, the interaction between fertilizer and mulch was not statistically significant for most parameters, although the combination of 300 kg/ha NPK and straw mulch tended to produce the best outcomes in plant height, flowering time, and fruit quality. These findings suggest that balanced fertilization combined with appropriate mulching practices can enhance cucumber productivity sustainably. The study contributes to the development of more efficient cultivation strategies for cucumbers in tropical agricultural systems.

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is one of the most important horticultural crops in Indonesia due to its high market demand and relatively short life cycle, making it suitable for intensive cultivation. Despite its significant potential, cucumber productivity remains unstable, largely due to suboptimal nutrient management and growing conditions. Effective fertilization practices, particularly involving nitrogen (N), phosphorus (P), and potassium (K) as found in NPK fertilizers, are crucial for enhancing cucumber growth during both vegetative and generative phases (JENA, 2022; Lee et al., 2024; Kehinde-Fadare et al., 2022). Specifically, nitrogen plays a key role in chlorophyll formation and vegetative tissue development, phosphorus contributes to root development and overall plant vitality, while potassium is essential for osmotic regulation and the transport of nutrients and photosynthetic products (Khalifa, 2022; Ayipio et al., 2021).

The application of optimal NPK fertilizer rates has been proven to significantly increase cucumber yields; several studies indicate that producing one quintal of cucumbers requires approximately 0.44 kg of N, 0.15 kg of P_2O_5, and 0.13 kg of K_2O (Jena, 2022; Lee et al., 2024). Furthermore, improved nutrient uptake efficiency is closely linked to optimized fertilizer dosages, ultimately enhancing fruit yield and biomass production (Kehinde-Fadare et al., 2022; Sallam et al., 2021). In line with this, recent research combining drip irrigation with bio-mineral fertilizers has shown that such approaches enhance nutrient availability, particularly nitrogen, while reducing the reliance on chemical fertilizers, thus supporting sustainable agricultural practices (Khalifa, 2022; Bello et al., 2023).

An essential aspect of cucumber cultivation is the management of the microenvironment, which can be significantly improved through mulching. Mulch helps suppress weed competition, retain soil moisture, reduce erosion, and stabilize soil temperature (Rivers et al., 2024; Yan et al., 2022). The synergistic effects between NPK fertilization and effective mulching strategies have shown promising results in promoting cucumber

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growth and yield. Research indicates that both organic and synthetic mulches can improve soil conditions and enhance nutrient availability for plants (Reddy et al., 2021; Adekiya et al., 2022). In particular, different types of mulch can affect the physiological parameters and fruit yield of cucumber, supporting the notion that mulching is an integral component of successful cultivation practices (Yan et al., 2022; Reddy et al., 2021). Based on these findings, further research is needed to evaluate the specific interactions between varying NPK fertilizer doses and types of mulch used. This study aims to identify balanced fertilization practices and cultivation techniques that can sustainably improve cucumber productivity. The findings are expected to contribute significantly to increasing cucumber yields in Indonesian agricultural lands while supporting environmentally friendly farming practices.

MATERIALS AND METHODS

The study was conducted in Lune Village, Pajo Subdistrict, Dompu Regency, West Nusa Tenggara Province, from April to June 2024. The materials used in this research included cucumber seeds of the Hercules F1 Hybrid variety and NPK Mutiara fertilizer. The tools utilized were a measuring tape, labeling tags, hoe, bucket, plastic rope, bamboo stakes, scissors, camera, analytical balance, mulch, and writing instruments.

The experiment employed a two-factorial Randomized Complete Block Design (RCBD). The first factor was NPK fertilizer dosage, consisting of three levels: 0 kg/ha, 200 kg/ha, and 300 kg/ha. The second factor was mulching treatment, also comprising three levels: (M0) no mulch, (M1) silver-black plastic mulch, and (M2) straw mulch. The combination of these two factors resulted in nine treatment combinations, each replicated three times, yielding a total of 27 plots.

RESULTS AND DISCUSSION

1. Plant Height

The observation results on cucumber plant height under the treatment of NPK fertilization and mulching, as presented in the figure below, show that the application of NPK fertilizer, the type of mulch used, and their interaction did not have a significant effect on plant height.

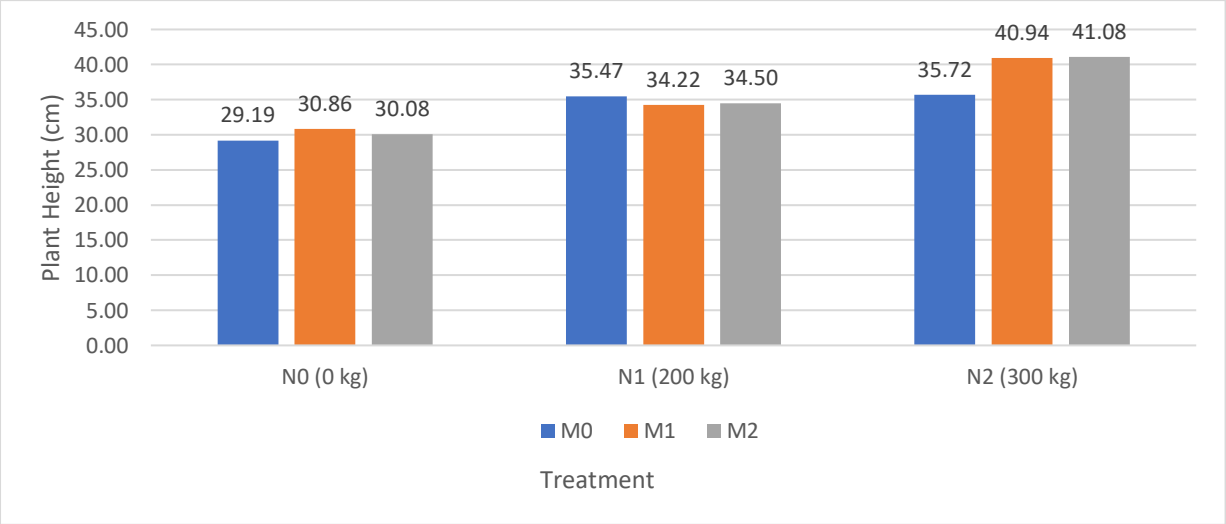

Figure 1. Average plant height of cucumber (cm) under NPK fertilization and mulch application.

Based on Figure 1, the effect of fertilizer dosage (N) and mulch type (M) on plant height showed a strong significance, highlighting the critical role of both factors in optimizing plant growth conditions. Under the treatment without fertilizer (N0), plant height was relatively low across all mulch types, recorded at 29.19 cm (M0), 30.86 cm (M1), and 30.08 cm (M2). These findings indicate that in the absence of adequate nutrient supply, plant growth is naturally limited even with the application of various types of mulch. This conclusion is consistent with previous studies indicating that mulch can improve soil conditions, although its effectiveness may be reduced without appropriate fertilization (Vialle et al., 2024; Molata et al., 2023).

The application of a moderate fertilizer dose (N1 = 200 kg/ha) resulted in increased plant height, namely 35.47 cm (M0), 34.22 cm (M1), and 34.50 cm (M2). This observation supports the notion that

improved nutrient availability promotes healthier vegetative growth, likely due to better nutrient uptake facilitated by enhanced soil structure and moisture retention through mulching (Satria et al., 2022; Yan et al., 2022). The role of mulch in maintaining soil moisture and preventing nitrogen loss through leaching is vital in enhancing fertilizer efficiency (Vialle et al., 2024). These results align with various studies reporting that mulching can enhance plant growth parameters by improving nutrient absorption and reducing soil erosion (Sousa et al., 2023).

Notably, the tallest plants were recorded under the N2 treatment (300 kg/ha), with heights of 35.72 cm (M0), 40.94 cm (M1), and 41.08 cm (M2). This substantial increase may be attributed to the synergistic effect between higher fertilizer dosage and the type of mulch used, particularly M1 and M2. The increase in plant height under these conditions underscores the importance of optimal fertilization strategies and appropriate mulch selection to maximize crop performance. The benefits of mulching in promoting plant growth are associated with its ability to maintain soil moisture and enhance root development, both essential for effective nutrient uptake (Li et al., 2021; Hayat et al., 2023). Additionally, studies have shown that the combination of plastic mulch and effective nutrient management can significantly improve crop yield and plant height by creating a more favorable microclimate, such as reducing direct sunlight exposure and minimizing temperature fluctuations (Panthi et al., 2023; Salah et al., 2024).

2. Flowering Time

The observation results on the flowering time of cucumber under NPK fertilization and mulch application, along with the analysis of variance, are presented in the figure below. The results indicate that NPK fertilizer application, mulch type, and their interaction did not have a significant effect on the flowering time of the plants.

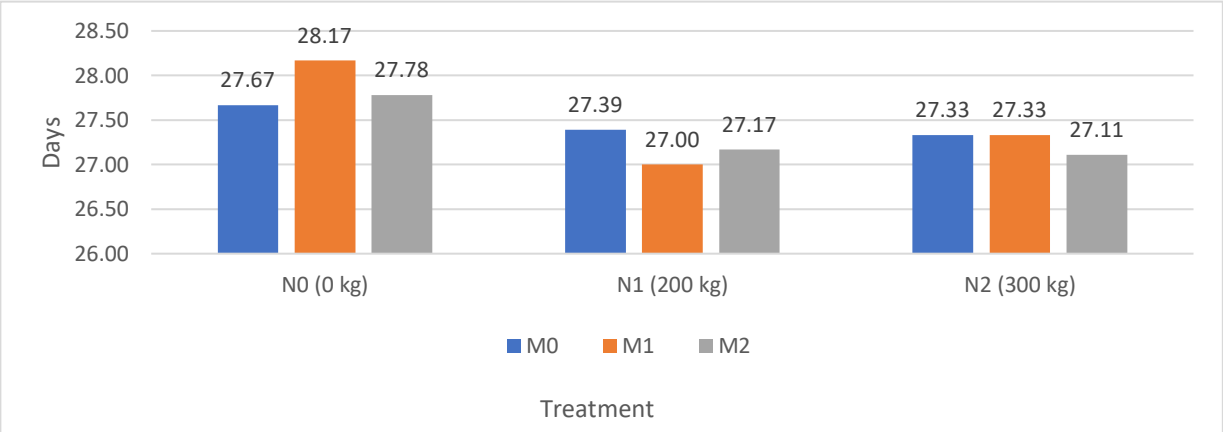

Figure 2. Average flowering time of cucumber under NPK fertilization and mulch application

Based on Figure 2, the interaction between fertilizer dosage (N) and mulch type (M) significantly affects the flowering time of plants, as indicated by the data presented. The study results show that increasing fertilizer application generally accelerates flowering time, although the degree of influence varies across treatments. In the N0 treatment (without fertilizer), flowering occurred between 27.67 days (M0) and 28.17 days (M1), indicating that the absence of nutrients may delay flowering, especially when the type of mulch applied is not effective (Verma et al., 2023). This is consistent with findings that adequate nutrient availability is essential to ensure timely progression through the flowering phase in various plant species, as highlighted in studies emphasizing the role of nutrients in floral induction (Verma et al., 2023; Satria et al., 2022).

When a moderate fertilizer dosage (N1 = 200 kg/ha) was applied, earlier flowering was observed, ranging from 27.00 days (M1) to 27.39 days (M0). The N1M1 combination resulted in the earliest flowering time, indicating a positive plant response to balanced fertilization. This finding aligns with reports by Zhai et al. (2022), who noted that optimal nitrogen fertilization plays a key role in promoting earlier flowering. Furthermore, timely fertilization can enhance the development of vegetative structures that support reproductive growth, in line with research highlighting the importance of timing and dosage in maximizing flowering and fruit set (Liu et al., 2023; Gaat et al., 2023).

In treatments with the highest fertilizer dosage (N2 = 300 kg/ha), flowering time remained relatively stable, recorded at 27.33 days (M0 and M1) and 27.11 days (M2). Interestingly, the combination with M2

mulch yielded the earliest flowering time under high fertilization conditions, suggesting that an optimal growing environment created by specific mulching practices can mitigate the potential negative effects of over-fertilization (Rafiuddin et al., 2023). This supports the idea that mulch not only helps conserve soil moisture but also plays a vital role in improving the microenvironment for plant growth, thereby positively influencing flowering time (Xu et al., 2023; Kartina et al., 2024). The interaction between mulch treatment and high fertilizer levels can create conditions that promote rapid plant growth and earlier flowering, as demonstrated in various studies highlighting the synergistic effects of nutrient application and mulching on flower production (Winarso, 2025).

3. Fruit Length

The observation results on cucumber fruit length under NPK fertilizer application and mulch treatment, along with the analysis of variance, are presented in the figure below. The results indicate that NPK fertilizer application, type of mulch, and their interaction did not have a significant effect on fruit length.

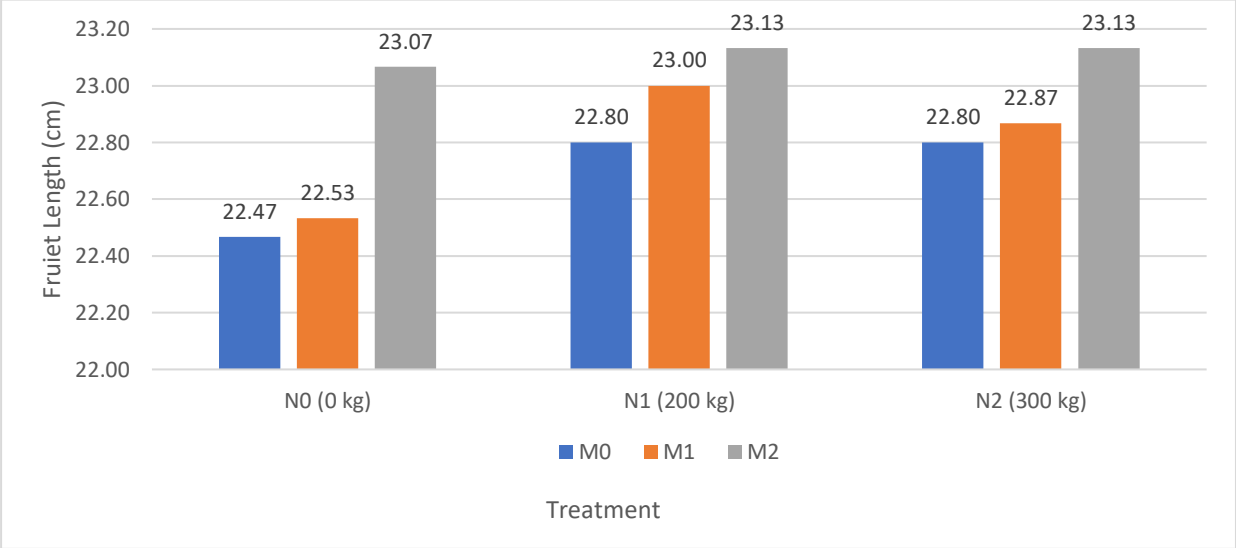

Figure 3. Average fruit length of cucumber (cm) under NPK fertilization and mulch application.

The results of the study on the interaction between NPK fertilizer dosage (N) and mulch type (M) demonstrate that both fertilizer application and mulch usage play important roles in enhancing fruit length in plants. In the control treatment without fertilizer (N0), fruit length ranged from 22.47 cm (N0M0) to 23.07 cm (N0M2). This indicates that although the absence of fertilization may limit fruit development, the use of mulch—particularly M2—can positively influence fruit length even under nutrient-poor soil conditions. These findings are consistent with the study by Guo et al. (2024), which emphasizes the role of mulching in improving soil characteristics and enhancing fruit quality, thereby supporting plant growth.

At a moderate fertilizer dosage (N1 = 200 kg/ha), fruit length increased to between 22.80 cm (M0) and 23.13 cm (M2), with the N1M2 combination yielding the longest fruit. This suggests a synergistic effect between moderate fertilization and the supportive function of mulch in enhancing fruit development. Previous research has shown that effective mulching practices, when combined with balanced fertilization, can maximize nutrient use efficiency and improve fruit quality (Dong et al., 2021). The ability of mulch to retain soil moisture and regulate soil temperature also promotes optimal root growth and better nutrient uptake, ultimately improving fruit development (Beelagi et al., 2023).

In the highest fertilizer dosage treatment (N2 = 300 kg/ha), fruit length remained stable and did not show significant improvement compared to the moderate dosage (N1). This indicates a plateau effect, where increasing the fertilizer dosage from 200 to 300 kg/ha no longer results in additional gains in fruit length, especially when optimal growth conditions have already been achieved through mulching. Similar trends have been observed in other studies, which state that excessive nutrient application can lead to diminishing returns in yield attributes, possibly due to nutrient saturation and ecological impact (Mukta et al., 2024; Liu et al., 2023).

Overall, the consistent performance of M2 mulch at all fertilizer levels highlights its importance in optimizing fruit length, particularly when combined with N1 (200 kg/ha) and N2 (300 kg/ha). This combination effectively creates a favorable growing environment that supports fruit development. Treatments N1M2 and N2M2, both resulting in a fruit length of 23.13 cm, illustrate that selecting the appropriate mulch type can complement fertilizer application to achieve optimal fruit growth and quality (Bogevska et al., 2022).

4. Fruit Diameter

The observation results on the fruit diameter of cucumber under NPK fertilizer application and mulch treatment, along with the analysis of variance, are presented in the figure below. The results indicate that NPK fertilizer application, type of mulch, and their interaction did not have a significant effect on fruit diameter.

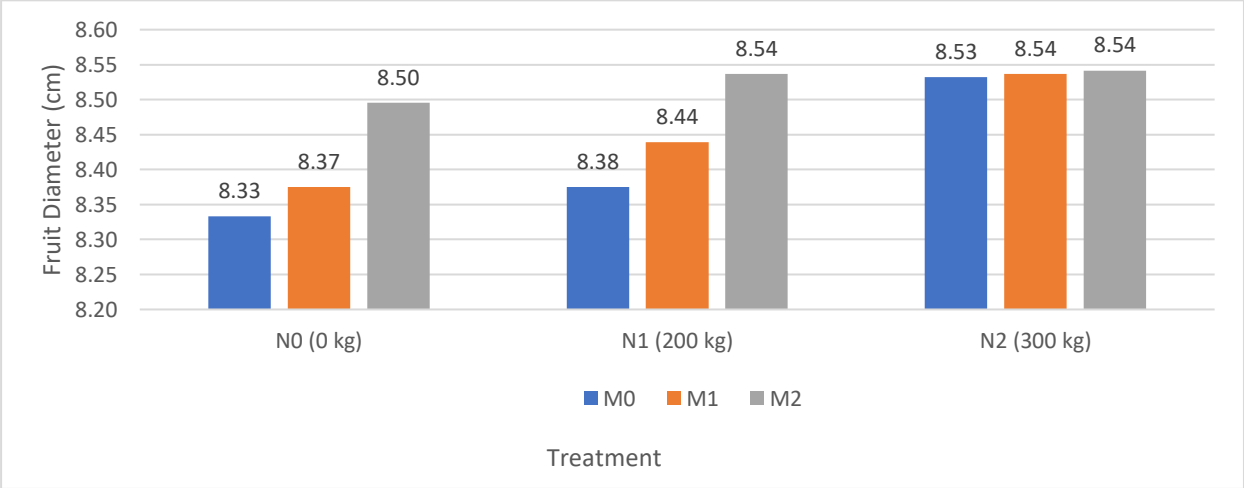

Figure 4. Average fruit diameter of cucumber (cm) under NPK fertilization and mulch application.

Figure 4 The interaction between NPK fertilizer dosage (N) and mulch type (M) significantly affected fruit diameter, as evidenced by the observed results. In the treatment without fertilizer (N0), fruit diameter ranged from 8.33 cm (M0) to 8.50 cm (M2), indicating that mulch application particularly M2 can have a positive impact on fruit development even in the absence of nutrient supplementation. This finding aligns with Guo et al. (2024), who reported that effective mulching not only improves soil physical properties but also enhances fruit quality. The increased fruit diameter observed in the N0M2 treatment suggests that mulch can create a favorable microenvironment for fruit growth, as it plays a key role in retaining soil moisture and regulating temperature both of which are critical for optimal fruit development (Amare & Desta, 2021).

Applying a moderate fertilizer dosage of 200 kg/ha (N1) further increased fruit diameter, ranging from 8.38 cm (M0) to 8.54 cm (M2). This improvement highlights the synergistic effect of mulching and fertilization on fruit quality. The N1M2 combination, which produced the largest fruit diameter, illustrates the potential of certain mulch types to enhance nutrient availability and fruit development (Beelagi et al., 2023). Previous studies have shown that such combinations can optimize not only fruit diameter but also overall yield performance, reinforcing the importance of integrated nutrient management in agricultural practices (Shao-ping et al., 2022).

At a higher fertilizer dosage of 300 kg/ha (N2), fruit diameter remained relatively stable with minimal variation among mulch types 8.53 cm (M0) and 8.54 cm (M1 and M2). The observation that increasing the fertilizer dosage from 200 to 300 kg/ha did not significantly improve fruit diameter suggests the presence of a nutrient application threshold, beyond which additional inputs no longer provide meaningful benefits. This finding is consistent with studies indicating that optimal growth conditions can be achieved without excessive fertilization, as nutrient oversupply may lead to saturation and inefficient resource use (Horimoto et al., 2022).

Overall, the results of this study underscore the importance of both fertilization and mulching in enhancing fruit diameter, particularly when combined with M2 mulch. The best treatments N1M2 and N2M2

both resulted in a maximum fruit diameter of 8.54 cm, emphasizing the value of selecting the appropriate mulching strategy alongside fertilizer application to maximize yield parameters. The synergy between these two factors suggests that integrated management practices combining mulching with optimal fertilization can substantially improve fruit quality in horticultural crops (Strik & Davis, 2021).

5. Number of Fruits per Plant

The observation results on the number of cucumber fruits per plant under NPK fertilizer application and mulch treatment, along with the analysis of variance, are presented in the table below. The results indicate that NPK fertilizer application had a highly significant effect, while the type of mulch and the interaction between NPK fertilizer and mulch had no significant effect on the number of fruits per plant.

Table 2. Average number of cucumber fruits per plant under NPK fertilization and mulch application.

NPK Fertilizer	Mulch Type			Average
	K0	K1	K2	
P0	9.67	10.00	10.00	9.89[b]
P1	11.00	10.00	10.67	10.56[a]
P2	10.00	11.00	11.00	10.67[a]
LSD 5%	0,45			

Note: Least Significant Difference at the 5% significance level Means followed by different letters in the same column are significantly different based on LSD test at the 5% level.

Based on Table 2, the application of NPK fertilizer significantly increased the number of cucumber fruits per plant compared to the control (no fertilization). Fertilizer dosages of 200 kg/ha and 300 kg/ha resulted in higher fruit counts (10.56 and 10.67 fruits per plant, respectively) than without fertilizer (9.89 fruits per plant), although no significant difference was observed between the two fertilized treatments. Mulching also influenced yield, but the primary effect stemmed from NPK fertilization.

The presented findings highlight the significant impact of NPK fertilizer dosage and mulch type on cucumber yield, particularly in terms of the average number of fruits produced per plant. When comparing cucumber yield at different NPK levels, it is evident that fertilizer application markedly increases fruit production. Specifically, cucumber plants without NPK produced an average of 9.89 fruits per plant, while 200 kg/ha and 300 kg/ha applications increased this to 10.56 and 10.67 fruits per plant, respectively. This indicates a positive correlation between fertilizer dosage and fruit yield, aligning with previous research showing that NPK fertilizers improve growth characteristics and yield in various crops, including cucumber (Musa et al., 2021; Aluko, 2021).

Furthermore, mulch type also plays an important role in influencing fruit yield. In this study, both silver-black plastic mulch and straw mulch contributed similarly to average fruit yield at respective NPK levels, while the no-mulch treatment consistently produced lower yields. This supports earlier studies emphasizing the importance of mulch in improving water retention and nutrient availability, both of which are critical for optimal plant growth and yield (Fasina et al., 2021; Bello et al., 2023). The significant increase in average fruit count per plant in mulched treatments reinforces the idea that mulching improves the plant microenvironment, thereby enhancing nutrient absorption and overall productivity (Sallam et al., 2021).

The observation that the average number of fruits per plant at 200 kg/ha and 300 kg/ha NPK dosages did not differ significantly suggests a possible yield saturation point at a certain fertilizer level. The Least Significant Difference (LSD) value of 0.45 at the 5% significance level indicates that although both fertilized treatments outperformed the control, increasing the fertilizer rate beyond 300 kg/ha may not result in further yield gains. These findings emphasize the need for precise fertilizer management to avoid unnecessary inputs and to mitigate the potential environmental impacts of over-fertilization, such as nutrient leaching and soil degradation (Chotangui et al., 2022; Orouji et al., 2023).

In conclusion, the significant increase in cucumber yield due to NPK fertilizer application confirms the importance of this input in agricultural practices aimed at optimizing fruit production. Supported by various studies, the integration of NPK fertilization with proper mulching techniques is essential for enhancing cucumber productivity, thereby justifying the need for further research and wider adoption of these practices in sustainable agriculture (Aluko, 2021; Fasina et al., 2021; Bello et al., 2023).

6. Number of Fruits per Plot

The observation results on the number of cucumber fruits per plot under NPK fertilizer application and mulch treatment, along with the analysis of variance, are presented in the table below. The results indicate that NPK fertilizer application had a highly significant effect, while the type of mulch and the interaction between NPK fertilizer and mulch had no significant effect on the number of fruits per plot.

Table 3. Average number of cucumber fruits per plot under NPK fertilization and mulch application.

NPK Fertilizer	Mulch Type			Average
	K0	K1	K2	
P0	57.67	60.00	59.33	59.00[b]
P1	64.33	59.67	62.33	62.11 [a]
P2	61.33	65.00	64.00	63.44 [a]
LSD 5 %	2.03			

Note: Least Significant Difference at the 5% significance level Means followed by different letters in the same column are significantly different based on LSD test at the 5% level.

The analysis of the data presented in Table 3 confirms the significant impact of NPK fertilizer application on cucumber yield. Specifically, the application of NPK at dosage levels of 200 kg/ha and 300 kg/ha resulted in a notable increase in the average number of fruits per plot compared to the control treatment with 0 kg/ha. This result aligns with existing literature, which indicates that NPK fertilizers enhance growth parameters and fruit yields in various horticultural crops, including cucumbers (Abidemi et al., 2021; Lee et al., 2024).

In detail, the findings reveal that while the increase from 0 kg/ha to higher NPK doses significantly affected fruit yield, there was no statistically significant difference between the yields obtained from 200 kg/ha and 300 kg/ha. This observation suggests the potential economic efficiency of applying the lower dose of 200 kg/ha, which may already be sufficient to achieve maximum yield without incurring the additional costs associated with higher fertilizer applications. Previous studies have documented similar trends, showing that optimized fertilizer application rates can provide economic benefits by reducing input costs without compromising crop yields (Lee et al., 2024; Chotangui et al., 2022).

The type of mulch used also deserves attention in this discussion. Although variations in mulch application influence crop yield, the dominant effect of NPK fertilizer on yield improvement indicates that fertilization is a more critical factor in determining cucumber productivity. Research supports this view, showing that although organic and biodegradable mulches can positively contribute to soil moisture retention and fruit quality, the primary driver of growth improvement typically stems from the availability of nutrients through adequate fertilization (Orouji et al., 2023; Joshi et al., 2022). Therefore, mulching should be regarded as a complementary practice that enhances the benefits of fertilizer application, rather than a standalone solution.

The importance of optimizing fertilizer management and mulching strategies cannot be overlooked in agricultural practices. As highlighted in various studies, improper fertilizer use can lead to environmental issues such as nutrient leaching and soil degradation (Hou et al., 2023; Nwachukwu et al., 2023). Thus, further research and field trials are needed to develop a balanced approach that ensures high yields while maintaining environmental sustainability.

7. Fruit Weight per Plant

The observation results on cucumber fruit weight per plant under NPK fertilizer application and mulch treatment, along with the analysis of variance, are presented in the table below. The results show that the type of mulch had a highly significant effect, while NPK fertilizer application and the interaction between NPK fertilizer and mulch did not have a significant effect on fruit weight per plant.

Table 4. Average fruit weight per cucumber plant (g) under NPK fertilization and mulch application.

NPK Fertilizer	Mulch Type		
	K0	K1	K2
P0	3472.90	3749.70	3767.67
P1	3974.67	3698.67	4045.77
P2	3513.00	3994.83	3997.77
Average	3653.52[b]	3814.40[a]	3937.07[a]
NP BNT 0,05 %	8,60		

Note: Least Significant Difference at the 5% significance level Means followed by different letters in the same row are significantly different based on the LSD test at the 5% level.

The results presented in Table 4 clearly demonstrate a significant increase in the average fruit weight per cucumber plant when mulch is applied. Specifically, the average fruit weight in plots without mulch was 3,653.52 g, which was significantly lower compared to the weight observed with silver-black plastic mulch (3,814.40 g) and straw mulch (3,937.07 g). These findings confirm the positive impact of mulching on cucumber production, consistent with agricultural literature indicating that mulching can enhance plant performance. Mulch generally helps retain soil moisture, regulate soil temperature, and suppress weed growth factors that contribute to improved plant growth and fruit development (Kehinde-Fadare et al., 2022; Chotangui et al., 2022).

Both silver-black plastic mulch and straw mulch contributed similarly to the increase in fruit weight, indicating that either type can be effectively used to improve yield. The absence of a significant difference between the two mulch types suggests that farmers can make decisions based on availability and cost-efficiency, rather than solely on effectiveness. Previous studies have emphasized the importance of mulch material selection, especially in terms of moisture conservation and enhancing nutrient availability (Chotangui et al., 2022; Raj et al., 2023). For instance, silver-black plastic mulch is known for warming the soil and accelerating plant growth, while straw mulch increases soil organic matter and microbial activity, ultimately improving fruit quality (Abidemi et al., 2021).

The significance of the Least Significant Difference (LSD) value of 8.60 at the 5% level reinforces the statistical reliability of these results. Both mulching treatments significantly increased fruit weight compared to the no-mulch control, supporting the hypothesis that proper mulching practices can provide tangible agronomic benefits. This finding is consistent with prior studies showing that nutrient uptake and fertilizer efficiency can be maximized through appropriate cultivation practices such as mulching (Anjum et al., 2024).

Furthermore, the positive correlation between mulch use and increased fruit weight suggests that mulching should be widely promoted among cucumber farmers. The integration of mulch with optimized fertilization strategies may offer even greater benefits, as evidenced by various studies (Musa et al., 2021). Therefore, adopting mulching as a routine practice in cucumber cultivation can serve as a sustainable approach to improving crop yields while enhancing soil health.

8. .Fruit Weight per Plot

The observation results on fruit weight per plot of cucumber under NPK fertilizer application and mulch treatment, along with the analysis of variance, are presented in the table below. The results indicate that NPK fertilizer application had a significant effect, while the type of mulch and the interaction between NPK fertilizer and mulch did not have a significant effect on the fruit weight per plot of cucumber.

Table 5. Average fruit weight per plot of cucumber (kg) under NPK fertilization and mulch application.

NPK Fertilizer	Mulch Type			Average
	K0	K1	K2	
P0	18.37	18.90	19.13	18.80[b]
P1	20.51	19.25	20.16	19.98[a]
P2	19.80	19.74	21.98	20.51[a]
LSD 5 %	1.06			

Note: Least Significant Difference at the 5% significance level Means followed by different letters in the same column are significantly different based on LSD test at the 5% level.

The data presented in Table 4 show a significant increase in cucumber fruit weight as a result of NPK fertilizer application, with average fruit weight per plot rising from 18.80 kg without fertilizer to 19.98 kg at a dosage of 200 kg/ha and 20.51 kg at 300 kg/ha. This notable increase underscores the crucial role of NPK fertilizer in enhancing yield potential in cucumber cultivation. Statistical analysis, with an LSD value of 1.06 at the 5% significance level, indicates no significant difference in fruit weight between the 200 kg/ha and 300 kg/ha fertilizer dosages, suggesting that 200 kg/ha is already sufficient for optimal growth without incurring additional costs from higher fertilizer inputs (Sharma et al., 2023).

Previous studies support these findings, demonstrating that NPK fertilizer enhances cucumber growth indices, including fruit weight, through improved nutrient availability (Musa et al., 2021; Kehinde-Fadare et al., 2022). These results reflect a similar trend observed in other studies evaluating varying fertilizer applications, confirming the critical roles of nitrogen, phosphorus, and potassium in achieving optimal cucumber yields (Chotangui et al., 2022). When NPK dosages are optimized, significant increases in fruit weight can be achieved, indicating efficient resource use in cucumber farming aligning with sustainable agriculture methodologies that aim to maximize yield while minimizing waste (Lee et al., 2024).

Moreover, the data indicate that an NPK dosage of 200 kg/ha may be considered the economically optimal threshold for cucumber production. This aligns with practical farming strategies where growers aim to balance effectiveness and cost-efficiency, as high input costs may hinder farm sustainability (Almadiy et al., 2023). Furthermore, applying NPK fertilizer in combination with other cultural practices such as mulching or organic amendments may yield better results in terms of fruit weight and overall plant health (Frimpong et al., 2021).

The lack of statistically significant differences between the 200 kg/ha and 300 kg/ha fertilizer treatments highlights the need for farmers to consider economic limitations in addition to agronomic recommendations. This reinforces the importance of further research to explore interactions between various fertilization practices and environmental conditions to optimize yields with lower fertilizer inputs (Kehinde-Fadare et al., 2022).

9. Productivity

The observation results on cucumber crop productivity under NPK fertilizer application and mulch treatment, along with the analysis of variance, are presented in the table below. The results indicate that NPK fertilizer application had a significant effect, while the type of mulch and the interaction between NPK fertilizer and mulch did not have a significant effect on cucumber productivity.

Table 5. Average fruit weight per plot of cucumber plants (kg) under NPK fertilization and mulch application.

NPK Fertilizer	Mulch Type			Average
	K0	K1	K2	
P0	153.07	157.49	159.42	156.66[b]
P1	170.92	157.91	167.96	165.60[a]
P2	164.98	164.49	183.18	170.88[a]
LSD 5 %	8.42			

Note: Least Significant Difference at the 5% significance level Means followed by different letters in the same column are significantly different based on LSD test at the 5% level.

The findings from Table 5 illustrate the significant effect of NPK fertilizer application and mulch use on the average fruit weight per plot of cucumber plants. At a fertilizer dose of 0 kg/ha, the recorded average fruit weight was 153.07 g without mulch, 157.49 g with silver-black plastic mulch, and 159.42 g with straw mulch, resulting in an overall average of 156.66 g. When the NPK dose was increased to 200 kg/ha, a noticeable improvement was observed: 170.92 g without mulch, 157.91 g with silver-black plastic mulch, and 167.96 g with straw mulch, yielding an overall average of 165.60 g. A further increase in dosage to 300 kg/ha resulted in average fruit weights of 164.98 g (no mulch), 164.49 g (silver-black plastic mulch), and 183.18 g (straw mulch), with an overall average of 170.88 g. The Least Significant Difference (LSD) value at the 5% significance level was 8.42, indicating that while both the 200 kg/ha and 300 kg/ha fertilizer doses significantly improved fruit weight compared to the control, there was no significant difference between the two fertilizer levels.

These results align with previous studies that demonstrate a positive correlation between NPK fertilizer application and increased fruit weight in cucumber plants. The essential nutrients provided by NPK—particularly nitrogen, phosphorus, and potassium—support vegetative growth and fruit development by enhancing photosynthesis and plant metabolic processes (Chotangui et al., 2022). For instance, nitrogen plays a key role in the synthesis of amino acids and proteins, which are fundamental to plant growth and fruit formation (Muhamad, 2023). Phosphorus contributes to root development and energy transfer within the plant, both of which are critical during fruit setting (Okebalama et al., 2022).

Furthermore, mulch type also interacts with fertilizer application in influencing fruit weight. Although increasing NPK dosage significantly enhanced yield, mulching practices independently contributed to maintaining soil moisture and regulating soil temperature, which positively affected plant health and fruit production. The data indicate that while silver-black plastic mulch and straw mulch resulted in different fruit weights, their interaction with higher fertilizer doses appeared less critical, as both types performed well at the tested NPK levels (Pan et al., 2022).

This analysis also highlights that a 200 kg/ha dosage may be more financially beneficial, as it did not result in a statistically significant increase in fruit weight compared to the 300 kg/ha dosage. Thus, it may serve as a more cost-effective option for farmers. This finding aligns with sustainable agricultural practices that emphasize efficient nutrient management, providing sufficient fertilization while minimizing costs and environmental impacts associated with excessive fertilizer use (Ofoe et al., 2024).

CONCLUSIONS

The application of NPK fertilizer at a dose of 6 g/plant (equivalent to 300 kg/ha) produced the best results in terms of productivity, yielding 170.88 tons/ha, fruit weight per plot of 20.51 kg, number of fruits per plant of 10.67, and number of fruits per plot of 63.44. The use of straw mulch resulted in the highest fruit weight per plant, reaching 3,973.07 g. Although the interaction between NPK fertilization and mulch application did not show a statistically significant effect, a positive trend was observed in the treatment combining 6 g/plant (300 kg/ha) of NPK fertilizer with straw mulch. This combination tended to enhance plant height, flowering time, fruit length, fruit diameter, and overall productivity.

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