ISSN 2828-9463

Application of NPK Fertilizer and Chicken Manure for the Growth and Production of Sorghum Plants (*Sorghum bicolor* (L.) Moench)

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Sorghum (Sorghum bicolor (L.) Moench) is a cereal crop that has the potential to be developed as an alternative food source because it is adaptive to suboptimal land. The main obstacle in its development is the management of soil fertility, especially the fulfillment of nutrients nitrogen (N), phosphorus (P), and potassium (K). A combination of organic and inorganic fertilizers is necessary to sustainably increase growth and production. This study aims to analyze the influence of chicken manure and NPK fertilizer and their interaction on the growth and production of sorghum. This study used a two-factorial Group Random Design (RAK) with three replicas. The first factor was chicken manure (control, 5 kg, and 10 kg), and the second factor was NPK fertilizer 16:16:16 (control, 1 g, and 2 g). The parameters observed included plant height, number of leaves, stem diameter, panicle length, seed weight per plant, seed weight per plot, and weight of 100 seeds. The data was analyzed using Minitab version 22 through the General Linear Model (GLM) and the Tukey test at the level of 5%. The results of the study showed that the application of chicken manure, NPK fertilizer, and their interactions had a real effect on the growth and production of sorghum. The combination of K1N1 provided the highest response on most parameters, K2N1 occupied the second-highest position with a relatively stable growth response and yield, and K2N2 excelled at a weight of 100 seeds.
Keywords: Sorghum, Chicken Manure Fertilizer, NPK Fertilizer, Growth, Production.

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1. Introduction

Sorghum (Sorghum bicolor (L.) Moench) is a cereal crop that has the potential to be developed as an alternative food source in supporting food diversification in Indonesia. This plant has extensive adaptability and is tolerant to various suboptimal soil conditions, such as drylands, acidic lands, and lands with limited water availability [1], [2], [3]. In addition, sorghum is able to produce in relatively high environmental stress conditions, making it a strategic commodity in dealing with climate change and limited productive land [4]. Nonetheless, the development of sorghum plants is still very limited, because in general sorghum is not very popular in the community [3], [5].

One of the main limiting factors in sorghum cultivation is the management of soil fertility, especially the fulfillment of macronutrients nitrogen (N), phosphorus (P), and potassium (K), which play an important role in vegetative growth and yield formation [6]. The use of NPK fertilizer has been proven to be able to increase the growth and yield of sorghum significantly [7]. Nevertheless, the continuous use of inorganic fertilizers without being balanced with organic matter can reduce the physical and biological quality of the soil. NPK fertilizers, such as the 16-16-16 formulation, work by providing macronutrients quickly and immediately available to plants, thus providing a relatively rapid growth response. However, this fertilizer does not directly improve the soil structure or increase the activity of soil microorganisms.

On the other hand, chicken manure as an organic fertilizer contains macro and micro nutrients and plays a role in improving soil structure, increasing water holding capacity, and increasing the activity of microorganisms that play a role in the process of decomposition and mineralization of nutrients. In addition, chicken manure has a relatively low C/N ratio, so that its nutrients are available faster than some other types of organic fertilizers [8]. However, the use of organic fertilizers alone is often not able to meet the nutrient needs of plants optimally in a short time, while inorganic fertilizers work quickly but do not directly contribute to improving soil properties. Therefore, the combination of organic and inorganic fertilizers is an approach that has the potential to provide a balance between rapid nutrient availability and sustainable improvement of soil fertility.

Some previous studies have generally examined the effects of NPK fertilizer or manure separately on the growth and production of sorghum. However, studies that specifically evaluated the combination of chicken manure and NPK manure doses in factorial designs to obtain the most effective and consistent combination of growth and yield components are still limited. This study aims to analyze the influence of each and the interaction of chicken manure and NPK fertilizer, as well as the optimal dosage, on the growth and production of sorghum plants. Therefore, this study is unique in integrating organic and inorganic fertilizers both simultaneously and partially, to obtain more effective and sustainable fertilization recommendation.

2. Literature Review

NPK 16:16:16 is an inorganic compound fertilizer containing balanced concentrations of nitrogen (N), phosphorus (P), and potassium (K), each at 16%, which are essential macronutrients required for plant growth and productivity. Nitrogen plays an important role in stimulating vegetative growth through chlorophyll formation, protein synthesis, and leaf and stem development. Phosphorus is involved in root development, cell division, and energy transfer processes, while potassium functions in regulating water balance, enzyme activation, and improving plant tolerance to environmental stress [9] Due to its readily available nutrient composition, NPK fertilizer is capable of rapidly supplying nutrients required during the early stages of plant growth, thereby supporting optimal growth and biomass accumulation.

In addition to inorganic fertilizer, chicken manure is recognized as an organic fertilizer with relatively high nutrient content and rapid decomposition characteristics. Chicken manure contributes not only to nutrient supply but also to the improvement of soil physical, chemical, and biological properties. The application of chicken manure increases soil organic matter, improves soil structure and aeration, enhances water holding capacity, and stimulates microbial activity in the soil [10] Furthermore, the nutrient content of chicken manure supports chlorophyll formation, root development, and plant metabolic activities, which ultimately influence vegetative and generative growth. Previous studies reported that chicken manure application significantly increased plant height, leaf number, and plant biomass [11].

The integration of organic and inorganic fertilizers has been widely considered an effective and sustainable fertilization strategy. Inorganic fertilizers such as NPK provide nutrients rapidly and directly to plants, whereas organic fertilizers function as nutrient buffers capable of gradually releasing nutrients through decomposition processes. Organic matter from chicken manure also improves nutrient retention and reduces nutrient loss through leaching, thereby increasing fertilizer use efficiency. Therefore, the combined application of NPK fertilizer and chicken manure is expected to create a more stable nutrient supply, improve soil fertility, and optimize sorghum growth and production.

Several previous studies have investigated the effects of organic and inorganic fertilizers on sorghum plants under different environmental conditions and treatment approaches. [14) evaluated sorghum productivity based on varietal response to organic and inorganic fertilizers, while [13] examined the effect of chicken

ISSN 2828-9463

manure and NPK fertilizer under acidic soil conditions. Other studies mainly focused on single fertilizer application, fertilizer micro-dosing strategies, genetic variability, or stress tolerance responses [12] [7] [22]. However, studies specifically evaluating the combined effects of chicken manure and NPK fertilizer under relatively neutral soil conditions remain limited. In addition, limited information is available regarding the most effective dosage combination capable of optimizing both sorghum growth and production simultaneously.

Based on these considerations, this study was conducted to analyze the effects of chicken manure and NPK fertilizer on the growth and production of sorghum plants, evaluate the interaction between both fertilizers, and determine the most effective dosage combination for sorghum cultivation. Hypothetically, the application of chicken manure and NPK fertilizer is expected to significantly affect sorghum growth and production, and the interaction between both fertilizers is predicted to provide better responses compared to single fertilizer application.

3. Method

Place and Time of Research

This research was carried out on garden land with sandy soil structure, Senayan village, Touluaan District, Southeast Minahasa Regency, from May to August 2025.

Tools and Materials

The tools used in this study are: meters, ordinary scales (carl schilieper with a capacity of 5 kg), digital scales (Joil: max 3 kg and min 0.1 g) and digital scales (Acas: maximum: 40 kg and minimum: 200 g), pH measuring instruments (Lavios VT-05), digital calipers (max 150 mm and min 0.1 mm) hoes, shovels, buckets, gallons, dippers, cameras, labels, rulers, books and stationery.
The materials used are: super variety 6 sorghum seeds, chicken manure, NPK 16-16-16 fertilizer, and contact herbicide 486 SL.

Research Procedure

The research began with land preparation by cleaning weeds manually and then continued using contact herbicide 486 SL. The soil is then cleaned of weeds and loosened using a shovel and hoe, and then an experimental plot is made according to the predetermined size. Chicken manure is applied and mixed into the soil on a predetermined plot according to the treatment dose.

Sorghum seeds are first soaked for 2 days until they germinate, with water replacement every 8 hours to prevent spoilage. Planting is done manually with a depth of ±5 cm; each hole is filled with 2–3 seeds with a planting distance of 30 cm. After planting, water evenly. Plant maintenance includes watering according to weather conditions (because during the study rainfall tends to be stable, watering is not often done to avoid excess water and the fertilizer given is not easy to wash), fertilization of NPK at the age of 2 weeks after planting according to the treatment dose with a distance of ±3 cm from the base of the stem, weeding weeding and mulching is carried out weekly, mulching in the generative phase to prevent collapse, as well as manual control of plant pest organisms without the use of chemicals.

Harvesting is carried out at the age of 100–105 days after planting, or when the sorghum seeds have completely hardened, golden yellow, the leaves begin to turn yellow, and buds begin to appear between the stem and the base of the stem. It is then dried in the sun 1–3 times before being cleaned manually using a simple alternative tool namely a grater and trash to separate the seeds from the husks and panicle stalks. After cleaning, the seeds are weighed using a digital scale.

Experimental Design

This study uses an experimental method with a two-factor Group Random Design (RAK). The first factor is chicken manure, which consists of three levels, namely K0 (control or no treatment), K1 (5 kg per plot), and K2 (10 kg per plot). The second factor is NPK fertilizer, which consists of three levels, namely N0 (control or no treatment), N1 (1 g per plant), and N2 (2 g per plant). The combination of these two factors resulted in 9 treatment combinations, namely K0N0, K0N1, K0N2, K1N0, K1N1, K1N2, K2N0, K2N1, K2N2, with 3 repetitions, so that 27 test plots were obtained. The distance between groups is 50 cm, the distance between plots is 40 cm, the distance between plants is 50 cm, and the distance between rows is 30 cm. Each plot consists of 8 plants with 4 plants as observation samples, so that the total number of sample plants is 108 plants out of a total of 216 plants. The size of each plot is 120 × 105 cm with a research area of 9.8 × 8.36 m.

Observation Parameters

The observation parameters are grouped based on two phases, namely, the vegetative phase and the generative phase. The vegetative phase is: plant height, number of leaves, and stem diameter while the generative phase includes: panicle length, seed weight per sample, seed weight per plot, and weight of 100 seeds.

Plant Height (cm): Measurements are carried out starting from 2-4 weeks after planting, by measuring from the base of the stem to the tip of the shoots that are growing the highest, using a meter. Number of Leaves (Strands): Measurements are made from 2-4 weeks after planting, by counting the number of leaves that grow. Stem diameter (mm): Measurements are made from 2-4 weeks after planting, by measuring from the bottom two segments of the stem, using calipers.

Panicle Length (cm): Measurement is carried out only once during the harvest period, by measuring from the base of the panicle to the tip of the panicle using a meter. Seed Weight Per Sample (g): Weighing is carried out at the end of harvest and sun-drying, by weighing the sample plants one by one using a digital scale with an accuracy level of up to 0.1 g. Seed Weight Per Plot (g): Weighing is carried out at the end of harvest and sun-drying, by weighing the weight of the seeds on each plot/plot, using a digital scale (maximum: 40 kg and minimum: 200 g). Weight of 100 Seeds Per Plot (g): Weighing is carried out at the end of harvest and sun-drying, by weighing the weight of 100 seeds in each plot/plot, using a digital scale with a high level of accuracy up to 0.1 g.

Data Analysis

The data obtained from the observation results were analyzed using variety analysis (ANOVA) through the General Linear Model (GLM) at the level of 5% to test the main influence of NPK fertilizer and chicken manure, as well as the interaction of both on the growth and production of sorghum plants and if the effect was real/significant, then followed by the Tukey test at the level of 5%, to determine which treatment groups were significantly different. using the statistics software Minitab Version 22 for Windows.

4. Results And Discussion

Results

Vegetative Phase

Plant Height

To determine the tendency of high response of sorghum plants due to the combination of chicken manure and NPK fertilizer treatment at each observation age, the average plant height is presented in Table 1.

Table 1. Average Plant Height

Treatment	2 MST	4 MST	6 MST	8 MST
K0N0	11,12 d	41,61 d	71,86 d	124,48 c
K0N1	13,37 bcd	56,92 ab	111,79 a	156,33 a
K0N2	10,54 d	39,84 d	86,68 bcd	143,59 abc
K1N0	13,25 cd	45,90 bcd	79,93 cd	129,51 bc
K1N1	15,08 bc	66,22 a	113,85 a	159,09 a
K1N2	16,12 bc	46,06 bcd	96,80 abc	147,75 ab
K2N0	17,12 b	54,42 abc	99,46 ab	144,42 ab
K2N1	20,95 a	55,66 abc	104,46 ab	155,71 a
K2N2	22,95 a	43,93 cd	99,40 ab	144,29 ab

Remarks: The number followed by the same letter shows no real difference based on Tukey's follow-up test at the real level of 5%.

Based on Table 1, sorghum plant height increases consistently across treatment combinations from 2 to 8 MST. However, the magnitude of the growth response differs between treatment combinations. At age 2 MST, K2N2 (22.95 cm) and K2N1 (20.95 cm) showed the highest plant height and did not differ significantly from each other, but differed significantly from the control treatments K0N0 (11.12 cm) and K0N2 (10.54 cm), which had the lowest average. Entering the age of 4 MST, the combination of K1N1 produced the highest average (66.22 cm) and was not significantly different from several other treatments, including K0N1 (56.92 cm), but significantly different from K0N0 (41.61 cm).

This trend continued at the age of 6 and 8 MST, where K1N1 reached 113.85 cm and 159.09 cm, respectively, and was in the highest group. In contrast, K0N0 consistently showed the lowest values throughout the entire observation time. In general, the combination of chicken manure and NPK fertilizer provides better growth than without fertilization, especially in the active growth phase.

Number of Leaves

To determine the response tendency of the number of leaves of sorghum plants due to the combination of chicken manure and NPK fertilizer treatment at each observation age, the average number of leaves is presented in Table 2.

Table 2. Average Number of Leaves

Treatment	2 MST	4 MST	6 MST	8 MST
K0N0	4 cd	5 c	7 c	9 c
K0N1	5 abc	6 ab	9 ab	10 ab
K0N2	4 d	5 c	8 b	10 b
K1N0	4 bcd	6 abc	8 b	9 bc
K1N1	4 bcd	7 a	10 a	11 a
K1N2	5 abc	6 abc	9 ab	11 ab
K2N0	5 ab	5 bc	9 b	10 b
K2N1	5 a	6 abc	9 b	10 ab
K2N2	5 abc	6 abc	8 b	10 ab

Remarks: The number followed by the same letter shows no real difference based on Tukey's follow-up test at the real level of 5%.

Based on Table 2, the number of sorghum leaves increases as the plant ages across all treatment combinations. However, the average difference between treatments began to be seen from the early phase

 ISSN 2828-9463

of growth. At the age of 2 MST, the combination of K2N1 produced the highest number of leaves (5 leaves) and was significantly different from K0N2 (4 leaves).

At ages 4 to 8 MST, K1N1 combinations consistently showed the highest average number of leaves: 7, 10, and 11 leaves, respectively. This value is significantly different from the K0N0 control treatment, which results in a lower number of leaves, namely 5, 7, and 9 leaves. In general, these results suggest that the combination of chicken manure and NPK fertilizer provides a better response to leaf formation than without fertilization.

Rod Diameter

To determine the response tendency of the stem diameter of sorghum plants due to the combination of chicken manure and NPK fertilizer treatment at each observation age, the average stem diameter is presented in Table 3.

Table 3. Average Rod Diameter

Treatment	2 MST	4 MST	6 MST	8 MST
K0N0	4,62 def	7,95 c	13,51 c	23,88 c
K0N1	5,94 cde	10,48 bc	16,12 c	35,08 ab
K0N2	4,47 ef	7,70 c	13,58 c	31,64 ab
K1N0	4,01 f	9,98 bc	14,62 c	30,41 b
K1N1	6,27 bcd	14,68 a	25,99 a	36,72 a
K1N2	6,77 bc	12,52 ab	21,15 b	31,29 b
K2N0	7,82 ab	11,66 b	21,75 ab	33,74 ab
K2N1	9,05 a	12,70 ab	24,34 ab	34,72 ab
K2N2	9,04 a	11,82 b	24,04 ab	34,20 ab

Remarks: The number followed by the same letter shows no real difference based on Tukey's follow-up test at the real level of 5%.

Based on Table 3, the stem diameter increases as the plant ages in all treatment combinations. Nonetheless, the differences between the combinations were evident at each observation time.

At age 2 MST, K2N1 (9.05 cm) and K2N2 (9.04 cm) showed the highest stem diameters, while K1N0 (4.01 cm) and K0N2 (4.47 cm) produced the lowest values. Entering the age of 4 MST, the K1N1 combination began to show superiority with an average of 14.68 cm and was in the highest group compared to other treatments, especially the control without fertilization.

The pattern continued at ages 6 and 8 MST. At 6 MST, K1N1 reached 25.99 cm and remained the highest, followed by K2N1 (24.34 cm) and K2N2 (24.04 cm), while K0N0 showed the lowest value (13.51 cm). At the end of observations (8 MST), K1N1 again provided the largest rod diameter (36.72 cm), while K0N0 remained the lowest (23.88 cm).

In general, the combination of chicken manure and NPK fertilizer results in a larger stem diameter than without fertilization, and the difference becomes more pronounced in the advanced vegetative phase.

Generatif Phase

Long Panicle

To determine the tendency of the long response of panicles in sorghum plants due to the combination of chicken manure and NPK fertilizer treatment, the average panicle length is presented in Table 4.

Table 4. Average Length of Panicles

Treatment	Average
K0N0	50,63 a
K0N1	49,43 a
K0N2	52,45 a
K1N0	50,48 a
K1N1	48,67 a
K1N2	49,62 a
K2N0	49,45 a
K2N1	51,38 a
K2N2	51,19 a

Description: Numbers followed by the same letter shows no real difference based on advanced tests Tukey at a real level of 5%.

Based on Table 4, the length of sorghum panicles across all treatment combinations showed a relatively uniform range of values. The highest average was obtained at K0N2 (52.45 cm), followed by K2N1 (51.38 cm) and K2N2 (51.19 cm), while the lowest value was found at K1N1 (48.67 cm).

Although there was an average variation between treatments, the results of the analysis showed that all combinations did not significantly differ in panicle length. This shows that the application of chicken manure, NPK fertilizer, or a combination of the two has not had a significant effect on the length of panicles in this study condition.

Weight of Seeds Per Sample

To determine the tendency of the response of seed weight per sample of sorghum plants due to the combination of chicken manure and NPK fertilizer treatment, the average weight of seeds per sample is presented in Table 5.

Table 5. Average Weight of Seeds Per Sample

Treatment	Average
K0N0	94,29 cd
K0N1	99,50 bcd
K0N2	99,49 bcd
K1N0	90,87 d
K1N1	114,64 a
K1N2	105,87 abc
K2N0	99,09 bcd
K2N1	105,70 abc
K2N2	109,80 ab

Description: Numbers followed by the same letter shows no real difference based on advanced tests Tukey at a real level of 5%.

Based on Table 5, the weight of the seeds per sample shows variation between treatment combinations. The highest value was obtained in the combination of K1N1 (114.64 g), followed by K2N2 (109.80 g), and K1N2 and K2N1, which reached 105.87 g, respectively. In contrast, treatment without a balanced combination of fertilizers, such as K0N0 (94.29 g) and K1N0 (90.87 g), results in lower seed weight.

In general, the increase in seed weight per sample was more noticeable in the combination of chicken manure and NPK fertilizer than in single or no fertilization treatment, suggesting that the balance between organic and inorganic fertilizers played a role in improving sorghum seed yields.

Weight of Seeds Per Plot

To determine the tendency of the response of seed weight per plot of sorghum plants due to the combination of chicken manure and NPK fertilizer treatment, the average weight of seeds per plot is presented in Table 6.

Table 6. Average Weight of Seeds Per Plot

Treatment	Average
K0N0	471,26 c
K0N1	742,40 ab
K0N2	669,60 abc
K1N0	564,46 bc
K1N1	796,40 a
K1N2	704,73 ab
K2N0	613,86 abc
K2N1	787,13 a
K2N2	782,16 a

Description: Numbers followed by the same letter shows no real difference based on advanced tests Tukey at a real level of 5%.

Based on Table 6, the weight of seeds per plot shows the difference between treatment combinations. The combination of K1N1 yielded the highest value (796.40 g), followed by K2N1 (787.13 g) and K2N2 (782.16 g). In contrast, the treatment without fertilization (K0N0) showed the lowest value (471.26 g).

In general, treatments that received NPK fertilizer (N1 and N2) at each dose of chicken manure tended to result in a higher seed weight per plot than treatments without NPK (N0). This suggests that the application of NPK fertilizer plays an important role in increasing seed yields, and that the response becomes better when combined with chicken manure at a certain dose.

Weight 100 Pieces

To determine the tendency of the response of the weight of 100 seeds per plot of sorghum plants due to the combination of chicken manure and NPK fertilizer treatment, the average weight of 100 seeds per plot is presented in Table 7.

Table 7. Average weight of 100 pieces

Treatment	Average
K0N0	2,50 b
K0N1	2,83 a
K0N2	2,40 b
K1N0	2,26 b
K1N1	2,30 b
K1N2	2,40 b
K2N0	2,43 b
K2N1	2,10 b
K2N2	3,50 a

Description: Numbers followed by the same letter shows no real difference based on advanced tests Tukey at a real level of 5%.

Based on Table 7, the weight of 100 seeds shows the difference between the treatment combinations. The highest values were obtained in K2N2 combinations (3.50 g), while other combinations tended to produce lower values and were relatively close together. K0N1 also showed a fairly high weight of 100 seeds, although it was still below K2N2.

In contrast, the combination of K1N0, K2N1, K1N1, K0N2, and K0N0 resulted in a weight of 100 seeds that were 100 seeds lower and not much different from each other. These results suggest that the seed weight response is affected by certain combinations of treatments, especially at higher doses of fertilizer.

Discussion

The environmental conditions during the study were classified as favorable for the growth of sorghum plants, characterized by stable rainfall, sufficient light intensity, and relatively moist and fertile soil conditions. Soil pH is in the range of 6-7, which is the optimal range for the availability of nutrients, especially N, P, and K [13]. With these favorable environmental conditions, the variation in growth and yield obtained more reflects the influence of fertilization treatment.

The results showed that the height of sorghum plants responded differently to fertilizer treatment at each stage of growth. At the ages of 2, 4, and 6 MST, chicken manure, NPK fertilizer, and the interaction of both have a real effect on plant height. This shows that in the early to mid-vegetative phase, plants are still heavily influenced by the availability of nutrients in the soil.

The high growth of plants in this phase is closely related to the availability of macronutrients, especially nitrogen, which play a role in the division and elongation of stem cells. [14] stated that the adequacy of nitrogen in the vegetative phase will encourage faster and stronger stem growth. The results of this study show a similar pattern, where a balanced combination of fertilizers results in better height growth compared to without fertilization or a single treatment.

The combination of organic and inorganic fertilizers allows plants to obtain nutrients more stably. Chicken manure helps improve soil conditions, while NPK fertilizer provides nutrients that are quickly available to plants. In the initial vegetative phase, the integration of these two types of fertilizers supports plant growth more optimally, as reported by [15].

Entering the age of 8 MST, the influence of chicken manure and its interactions is no longer real, while NPK fertilizer is still a real effect. This indicates that the plant is starting to approach the phase of seed formation and filling, so the plant's height gain tends to slow down. [13] explained that when plants have approached their maximum growth potential, the response to organic fertilizers generally decreases, and the influence of inorganic fertilizers becomes more visible.

The number of leaves of sorghum plants shows a different response to fertilizer treatment in each growth phase. At the age of 2 MST, the number of leaves was significantly affected by chicken manure and its interaction with NPK fertilizer, while NPK fertilizer alone did not show a significant effect. This shows that in the early stages of growth, leaf formation is more influenced by the conditions of the growing medium and the improvement of soil properties due to the addition of organic matter. [12] stated that organic matter plays a role in improving the physical, chemical, and biological properties of the soil so as to support early vegetative growth. [14] also explained that in the early phase, the availability of nutrients that are gradually released from organic fertilizers plays a greater role in leaf formation.

At age 4 MST, chicken manure and NPK fertilizer had a significant effect on leaf count, respectively, but the interaction between the two did not show a noticeable effect. This condition shows that at this stage, each fertilizer has been able to support leaf growth independently, but the combination of the two has not yet exerted an additional real effect [16].

Entering the age of 6 MST, both chicken manure, NPK fertilizer, and their interactions have a real effect on the number of leaves. This shows that in the active vegetative phase, plants are able to utilize nutrients from both fertilizer sources more effectively. Increasing nutrient availability at this stage plays an important role in the formation of leaves as the main organ of photosynthesis [17].

At the age of 8 MST, the influence of the two types of fertilizers and their interactions is still evident. Even though the plant is starting to enter an advanced phase of growth, the availability of nutrients still plays a role in maintaining the number of leaves. Organic fertilizers help maintain soil fertility so that vegetative growth can be maintained more stable [18].

The stem diameter of the sorghum plant showed a consistent response to fertilizer treatment throughout the observation time. At the age of 2, 4, 6, and 8 MST, chicken manure, NPK fertilizer, and the interaction of the two have a real effect on stem growth. This shows that the development of stem diameter is greatly influenced by the availability of nutrients and the conditions of the growing medium from the initial vegetative phase to the advanced growth phase.

The effect of chicken manure on stem diameter is related to its role in improving soil structure and aeration, so that the root system develops better and nutrient absorption becomes more effective. Healthy roots allow photosynthetic results to be optimally allocated for stem tissue formation and enlargement.[19] reported that chicken manure can increase vegetative growth, including stem diameter, because it is able to improve the growing environment and provide nutrients gradually.

NPK fertilizer also plays a real role in increasing the diameter of the stem. Nitrogen supports cell division and elongation, phosphorus plays a role in the formation of energy and tissue, while potassium helps strengthen stem tissue and supports translocation of photosynthetic results [14]. [7] stated that the adequacy of macronutrients through NPK fertilization contributes directly to increasing the vegetative growth of sorghum plants.

The influence of the interaction between chicken manure and NPK fertilizer shows that the two types of fertilizers complement each other in supporting stem enlargement. Improving soil conditions with organic fertilizers increases the utilization of nutrients from inorganic fertilizers, so that the formation of stem tissue takes place better. The results of this study are in line with the findings of [9] who explained that the combination of organic and inorganic fertilizers provides better vegetative growth results than the use of one type of fertilizer alone.

Chicken manure, NPK fertilizer, and the interaction of the two did not have a real effect on panicle length. This suggests that panicle length is relatively stable and less responsive to fertilization variations, especially in favorable growing environmental conditions.

The length of panicles in sorghum is more influenced by genetic factors than by fertilization treatment. [20] stated that the generative morphological character of sorghum tends to be controlled by the genetic traits of the variety, so changes in nutrient inputs are not always followed by noticeable changes in panicle size. A similar thing is explained by [21], who stated that the formation of reproductive organs in cereal plants has been determined from the early stages of development.

[14] also reported that the difference in panicle length is more related to the character of the variety than the fertilizer treatment. In addition, variations in the ability of genotypes to utilize nitrogen can affect plant responses to fertilization [22]. Thus, the absence of a significant difference in panicle length in this study suggests that these components reflect more of the plant's genetic potential than the direct influence of fertilization.

ISSN 2828-9463

Although panicle length included a generative component, the lack of panicle length between treatments showed that the character was relatively stable under the conditions of this study. The formation of panicles occurs before the seed filling phase, so its size is determined more by the genetic potential of the variety and the initial conditions of growth than by the addition of nutrients in the next phase. Using the same variety (Super 6), the variation in panicle length tends to be limited despite the differences in fertilization. In addition, the results of this study showed that the increase in yield was more reflected in the weight of the seeds than in the length of the panicles, which indicated that fertilization played a greater role in supporting the seed filling process than in prolonging the size of the panicles.

The weight of seeds per sample is significantly influenced by chicken manure, NPK fertilizer, and the interaction of both. This shows that the resulting component in the form of seed weight is very sensitive to the availability of nutrients during the generative phase, especially at the seed filling stage. In this phase, the results of photosynthesis that were formed earlier begin to be allocated to the seeds, so that the adequacy of nutrients is an important determinant in the formation of the final weight of the seeds.

NPK fertilizer plays a role in supporting the seed filling process through the provision of macronutrients that are quickly available, while chicken manure helps improve soil conditions and maintain a more stable availability of nutrients [7]. The combination of the two yields better than a single treatment because better soil conditions allow the nutrients from NPK fertilizer to be utilized more efficiently by plants.

In addition to fertilization factors, yield components such as seed weight are also influenced by the genetic character of the variety. [23] mentioned that genetic variation can cause differences in outcome responses to nutrient treatments. [24] also emphasized that sorghum crop yields are greatly influenced by the interaction between fertilization and growing environmental conditions. Thus, the increase in seed weight in this study reflects the important role of nutrient balance during the seed filling phase.

The weight of seeds per plot was significantly affected by chicken manure and NPK manure, but the interaction between the two showed no noticeable difference. This shows that the increase in yield on the map scale is more determined by the influence of each type of fertilizer independently.

The effect of chicken manure on the weight of seeds per plot is related to its role in improving soil conditions. Improvements in the physical and biological properties of the soil improve the soil's ability to retain water and nutrients, resulting in better plant growth in a plot and higher accumulated yields [11]. On the other hand, NPK fertilizers provide the necessary macronutrients during the generative phase. Nitrogen supports the formation of biomass, phosphorus plays a role in the process of seed formation and filling, while potassium helps translocate photosynthesis results to seeds [14]. The adequacy of these elements allows for a more pronounced increase in yields, as also reported by [7].

The absence of the effect of interaction showed that at the plot scale, the nutrient needs of the plants had been met by each treatment so that the combination of the two no longer provided additional real results. A similar thing was also reported by [23], who stated that outcome responses are often more influenced by primary nutrient adequacy than by the effects of treatment combinations.

The weight of 100 seeds was significantly affected by NPK fertilizer and the interaction between chicken manure and NPK fertilizer, while chicken manure independently showed no noticeable effect. This shows that the weight of 100 seeds is more determined by the availability of nutrients that are quickly available during the seed filling phase.

The fact that the effect of chicken manure alone shows that the release of nutrients from organic fertilizers that takes place gradually is not fully able to meet the nutrient needs at the time of seed filling. Organic fertilizers play a greater role in improving soil conditions and providing nutrients indirectly, so their effect on seed weight is often invisible without the support of inorganic fertilizers [11].

On the other hand, NPK fertilizer has a real effect on the weight of 100 seeds. Phosphorus plays a role in the formation and filling of seeds, while potassium helps the process of transferring photosynthetic results to seeds [14]. The availability of sufficient macronutrients in the generative phase allows the filling of seeds to take place more optimally, so that the weight of the seeds increases.

The influence of interaction shows that the improvement of soil conditions by chicken manure supports the use of nutrients from NPK fertilizer more effectively. The combination of these two types of fertilizers is able to improve yield quality, as also reported by [9]. Overall, the combination of K1N1 (5 kg of chicken manure + 1 g of NPK) showed the highest and most consistent average on most parameters of sorghum growth and production. This shows that the combination of organic and inorganic fertilizers in moderate doses is able to create soil conditions and nutrient availability that are at optimal levels. These findings are in line with [25], who reported that the combination of chicken manure and NPK provided better growth response and yield than single or no fertilization treatment.

Chicken manure plays a role in increasing soil organic matter, improving structure, and supporting the efficiency of nutrient absorption by roots. [26] also reported that the application of chicken manure was able to increase soil biological activity and sorghum growth compared to controls. On the other hand, NPK fertilizers provide rapidly available macronutrients, especially nitrogen for the formation of chlorophyll and proteins, phosphorus for energy, and potassium for translocation of photosynthetic results [7], The balance of these two nutrients explains why K1N1 provides the most effective response.

The combination of K2N1 (10 kg of chicken manure + 1 g of NPK) showed the second-best results, especially on the yield parameters per plot, indicating that the increase in organic matter still provides advantages in water and nutrient retention [11]. However, an increase in fertilizer dosage is not always followed by a linear increase in yield. This supports the principle of the optimal point of fertilization, as reported by [24].

The combination of K2N2 showed the highest average at 100 seed weights, indicating that increased NPK doses play a role in supporting the seed replenishment process through increased photosynthetic translocation. These findings are in line with [9], although [16] caution that excess nitrogen doses do not necessarily improve overall outcomes. This suggests that the response to high doses can be specific to certain parameters.

In contrast, K0N0 control treatments consistently showed the lowest average on almost all parameters, confirming that without additional nutrients, sorghum plant growth and yield were not optimal [26].

In general, the response pattern of this study suggests that fertilization effectiveness is determined by the balance between improving soil properties through organic fertilizers and the rapid nutrient supply of inorganic fertilizers, rather than solely by increasing doses.

5. Conclusion

The combination of K1N1 treatments (K1 = 5kg chicken coop and N1 = 1g NPK) was the best and most consistent combination, as it provided the highest response or was in the highest group on most growth and production variables. The interaction between chicken manure and NPK fertilizer had a noticeably different effect on plant height (2,4,6 MST), number of leaves (2,6,8 MST), stem diameter, seed weight per sample, and weight of 100 seeds. But there was no noticeable difference in plant height (8 MST), number of leaves (4 MST), panicle length, and seed weight per plot.

6. Recommendation

Future studies are recommended to conduct comprehensive soil analysis, including macro- and micronutrient analysis prior to planting, in order to better understand soil fertility conditions and nutrient availability during sorghum cultivation. In addition, chlorophyll analysis and plant tissue analysis during the maximum vegetative growth phase are also recommended to provide more detailed information regarding nutrient absorption efficiency and the physiological responses of sorghum plants to the application of chicken manure and NPK fertilizer. Further research involving different environmental conditions and wider dosage combinations is also necessary to obtain more comprehensive information regarding the effectiveness of integrated organic and inorganic fertilization in supporting sorghum growth and production.

7. References

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