

The Growth and Yield Of Aluminium Tolerant Maize Varieties With The Addition Of Cow Manure

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ABSTRACT

Maize (*Zea mays* L.) is a strategic food commodity that supports food security and the national economy. However, maize productivity on suboptimal land is often limited by low soil fertility, particularly due to soil acidity and aluminum (Al) toxicity. This study aimed to identify aluminum-tolerant maize varieties under $AlCl_3$ stress conditions and evaluate their growth and yield on suboptimal land experiencing aluminum (Al) stress with the addition of cow manure. This study was conducted in two stages. The first stage involved selecting aluminum-tolerant maize varieties using nutrient culture in a factorial Completely Randomized Design (CRD) with six maize varieties and two $AlCl_3$ concentrations (0 ppm and 180 ppm). The results of the first stage showed that the varieties P32, Bisi 18, and Lamuru were classified as aluminum-tolerant, while the variety Sukmaraga was classified as sensitive but described as adaptive to acidic soils. The second stage was a field test on suboptimal soil experiencing aluminum stress using a factorial Randomized Block Design (RBD) with four selected maize varieties and three doses of cow manure. The data were tested for F at the 5% significance level; if the F_{hit} value exceeded the F table value, the data were analyzed using Duncan's Multiple Range Test (DMRT). The results showed that two maize varieties (P32 and Bisi 18) at a manure dose of 10 tons/ha provided the best growth, and these results were seen from the length of the cob, the number of cobs, the weight of the peeled cob, and the potential yield per hectare

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1. Introduction

Maize (*Zea mays* L.) is one of the most important food commodities, capable of driving national economic growth. Maize contains 73.7 g of carbohydrates, 320 calories, 3.90 g of fat, 8.28 g of protein, 10 mg of calcium, 256 mg of phosphorus, and 2.4 mg of iron (Panikkai 2017). Besides being used as food, maize is also used as animal feed and as an industrial raw material (Gomez *et al.*, 2017; Ilyas *et al.*, 2014). By 2024, maize production in Indonesia will reach 20.48 million tons. Nevertheless, national maize production can still be increased through efforts to expand planted areas (extensification) and increase the productivity of existing land (intensification). However, these efforts are often hampered by various environmental factors, such as soil acidity and aluminum (Al) phytotoxicity. Indonesia has 144.47 million hectares of suboptimal dryland, with acidic soils accounting for 74.3% (107.36 million hectares) of the total dryland area (BRIN 2024). Acidic soils exhibit deficiencies of Ca,

Mg, P, K, and N, as well as symptoms of Al toxicity. An excess of H^+ , Mn^{2+} , Fe^{3+} , and Al^{3+} , with a deficiency of Ca^{2+} and Mg^{2+} , is characteristic of acidic soils. The main obstacle to the use of acidic soils is Al toxicity (Bojórquez-Quintal *et al.*, 2017).

Aluminum is one of the most abundant metallic elements found in the earth's crust. (Cunha *et al.*, 2018). High aluminum content in soil is a major factor affecting plant growth (Brunner & Sperisen, 2013). Aluminum in the form of $Al(H_2O)_6^{3+}$ or Al^{3+} is highly toxic to plants (Mukhopadyay *et al.*, 2012). Furthermore, soils with a pH <5.0 contain dissolved Al in mobile ionic forms, such as Al^{3+} . Al^{3+} is considered a major limiting factor for plant growth in acidic soils (Sun *et al.*, 2020). Excess aluminum in the soil can inhibit maize growth and yield. Furthermore, aluminum can also bind phosphorus (P) and molybdenum (Mo).

The initial and most visible symptoms of Al toxicity are inhibited root growth and changes in root morphology. Application of Al (400 μM) to *Triticum aestivum* and *Camellia sinensis* can inhibit root growth by reducing root volume and the number of lateral roots (Hossain *et al.*, 2006). Plants experiencing aluminum toxicity can experience problems absorbing, transporting, and utilizing nutrients, as well as inhibiting enzyme activity and hormone balance (Pidjath *et al.*, 2021; Yamamoto, 2019). Highly acidic soils in tropical regions can reduce maize yields by 38-80% (Gracen, 2018). Maize grown in acidic soils with Al saturation of 45-70% has a very low potential yield, ranging from 1.55 to 3.76 t ha⁻¹ (Evans *et al.*, 2013; P. . Hayati *et al.*, 2014). The use of resistant varieties and land improvement in acidic soils with high Al saturation is one way to increase maize growth and productivity. Currently, many maize varieties are available, each with its own advantages. Maize varieties differ in their physiological and agronomic responses to aluminum stress, which affects their productivity under acidic conditions. In addition, land improvement by adding organic matter can help address soil acidity and increase soil pH. Organic matter acts as an electron donor to reduce metal reactions (Ch'Ng *et al.*, 2014; Olafisoye *et al.*, 2016)

Cow manure is an organic material that significantly reduces Al content in acidic soils and can also increase soil pH. The application of cow manure is known to increase soil pH, increase microorganism activity, and release various organic compounds, such as malic, citric, and tartaric acids, which can bind Al in an inactive form and reduce the level of Al-dd (Kulesh *et al.*, 2025). The increase in cow manure dose is highly linear with soil pH (Fikdalillah *et al.*, 2016; Indriyati *et al.*, 2022). In the study by Saragih *et al.* (2019), the use of 30 tons/ha of cow manure and SP-36 fertilizer increased soil pH. Using cow manure can also increase crop production. The study of Jamidi *et al.*, (2022) reported that the use of 15 tons/ha of cow manure can increase the growth of stem diameter, number of leaves, weighted cob weight, weighted cob length, unweighted cob length, and 1000 seed weight. Based on previous research results, no study has combined genetic strategies and soil management by screening aluminum-tolerant corn varieties using nutrient cultures subjected to $AlCl_3$ stress, followed by field testing on acidic soils with several doses of cow manure. Therefore, this study was conducted to obtain aluminum-tolerant corn varieties through screening, then to evaluate their growth responses and yields under acidic soil conditions with various doses of cow manure. This study also aims to determine the best dose of cow manure to support corn growth and yield in soils experiencing aluminum stress.

2. Methodology

2.1 Place and Experimental Materials

This research was conducted in the Tissue Culture Laboratory, Greenhouse, and experimental field of the Faculty of Agriculture, Andalas University, and in Sitiung District, Dharmasraya Regency. The first phase of the research lasted one month, from September to November 2024, while the second phase lasted from December to April 2025. The corn seeds used included six hybrid varieties: P32, JH37, Nasa 29, Bisi 18, Lamuru composite variety, and Sukmaraga. Other materials used included cow manure and chemical reagents used to prepare Hoagland nutrient solutions, such as NaOCl (0.5%), CaCl₂, K₂SO₄, MgSO₄, NH₄Cl, NH₄NO₃, AlCl₃·6H₂O, NaOH (0.1 N), HCl (0.1 N), sterile sand, and distilled water.

2.2 Treatments

2.2.1 *Stage 1: Screening of Aluminum-Tolerant Corn Varieties Through Nutrient Culture Treatment Design and Structure*

This study used a factorial design with two factors in a Completely Randomized Design (CRD). The first factor was variety, with six levels: JH37, P32, Nasa 29, Bisi 18, Lamuru, and Sukmaraga. The second factor was AlCl₃ concentration, consisting of two levels: 0 ppm and 180 ppm. There were 12 treatments in this experiment, each replicated three times, resulting in 36 experimental units. The experimental units were seedbeds, resulting in 36 in total.

Experimental Units and Replication

Corn seeds of each variety were germinated in sand using mica boxes for 7 days. Sprouts with uniform growth on sand media were selected from each variety, up to 16 seeds, to be planted in nutrient culture media containing Hoagland nutrient solution and 180 ppm AlCl₃ as a treatment. The treatment with 180 ppm AlCl₃ in nutrient culture media is equivalent to 2 Al₂O₃ (2 me/100 g) in soil analysis results. Planting was carried out on each seedbed using Styrofoam, which was placed on top of the seedbed, perforated with up to 16 holes, and cotton was inserted. In the middle of the cotton, the seeds were inserted until the roots reached the solution prepared. Then, each seedbed filled with nutrient solution was flushed with an aerator to prevent oxidation of the solution. Planting in nutrient culture media was carried out for 3 weeks. The nutrient culture with the 180 ppm AlCl₃ treatment must have a pH of 5. If the pH was found to be less than 5 during the study, it was increased by adding a few drops of 0.1 N NaOH solution until the pH reached 5. pH measurements were made using a digital pH meter.

Observation Parameters

The first stage of this study included observations of relative root length, root volume, root dry weight, and shoot dry weight. All parameters were calculated after harvest and analyzed to determine the level of plant tolerance to aluminum stress using the MFV Membership Function Value.

2.2.2 *Phase 2: Field Trial*

Treatment Design and Structure

The experiment was conducted on acidic soil with aluminum stress and several doses of cow manure were added. The experiment followed a Randomized Block Design (RBD) with two factors. The first factor was the results of screening Al-tolerant varieties that had been analyzed for tolerance using Membership Function Value (MFV) calculations. These factors

included three varieties (P32, Bisi 18, and Lamuru), as well as an additional variety described as tolerant to acidic soils (sukmaraga). The second factor was the cow manure dose, namely 0 tons/ha, 5 tons/ha, and 10 tons/ha. In this experiment, there were 12 treatments, each replicated three times.

Experimental and Replication Units

Planting was carried out on acidic soil following soil analysis, as shown in Table 1. The land was cultivated using a hoe, and beds measuring 1.4 x 2.8 m were made. Each bed was labeled according to the treatment. Each bed received a manure treatment according to the specified dose. Manure was applied 1 week before planting. Before planting, soil samples were taken for soil analysis after manure application (Table 2). Planting was carried out in a trial plot with a spacing of 70 cm x 20 cm. This resulted in 28 plants, with 6 sample plants. In the corn planting process, fertilization was carried out twice, namely at the age of 12 days after planting with a dose of 100 kg/ha of urea fertilizer and 350 kg/ha of NPK, then at the age of 45 days after planting with a dose of 250 kg/ha of urea fertilizer. Other treatments included watering and controlling corn pests and diseases.

Observation Parameters

Observation parameters at this stage include the time of emergence of female corn flowers and male corn flowers, plant height growth observed every 2 weeks until entering the generative phase, namely at the age of 6 weeks after planting, and several parameters of corn yield components including cob diameter, cob length, number of cobs, weight of 1000 seeds, cob weight, and potential yield per hectare observed after harvest.

Table 1. Soil Chemical Characteristics Before Treatment

No.	Jenis Analis	Value (0 tons/ha)	criteria
1	pH H ₂ O (1:5)	5.03	acid
2	N-Total (%)	0.14	low
3	P-Tersedia (ppm P ₂ O ₅)	3.14	low
4	K-Total (mg K ₂ O/100 g)	2.07	Very low
5	Al-dd (me/100 g)	2.13	acid

Sumber: PT. Wiwiadi Bintang Sains WBS Laboratory

Table 2. Soil Chemical Properties After Cow Manure Treatment

No.	Types of Analysts	5 tons/ha	10 tons/ha
1	pH H ₂ O (1:5)	5.98	6.21
2	N-Total (%)	0.38	0.60
3	Available P (ppm P ₂ O ₅)	10.62	13.35
4	K-Total (mg K ₂ O/100 g)	17.07	17.49
5	Al-dd (me/100 g)	1.45	0.83

Sumber: PT. Wiwiadi Bintang Sains WBS Laboratory

2.3 Assessment of Stress Tolerance

The level of tolerance of maize plants to aluminium stress under nutrient culture can be evaluated using the Membership Function Value (MFV) (Li *et al.*, 2020; Mohamed *et al.*, 2020). Membership Function Value (MFV) calculation includes observations of relative root length, root volume, root dry weight, and shoot dry weight. To calculate the MFV value, the

Stress Tolerance Index (STI) is needed from the character value under no AlCl₃ stress; when there is AlCl₃ stress, it is calculated using the formula.

$$STI = \frac{\text{Average value of character } i \text{ under AlCl}_3 \text{ stress conditions}}{\text{Average value of character } i \text{ under normal conditions}} \times 100 \%$$

Based on the STI value, the MFV value is calculated using the formula:

$$MFV = \frac{(X_i - X_{\min})}{(X_{\max} - X_{\min})}$$

Where X is the STI value of the *i*th trait, X max, and based on these calculations, a Membership Function Value (MFV) value will be obtained, which ranges from 0-1. Then, the average and standard deviation of the MFV values can be calculated as criteria that group varieties into several classes (Li *et al.*, 2020). These criteria include:

MFV Value Criteria

Very Tolerant	$X_i \geq \bar{x} + 1,64SD$
Tolerant	$\bar{x} + 1,64SD > X_i \geq \bar{x} + 1SD$
Fairly Tolerant	$\bar{x} + 1SD > X_i \geq \bar{x} - 1SD$
Sensitive	$\bar{x} - 1SD > X_i \geq \bar{x} - 1,64SD$
Very Sensitive	$X_i < \bar{x} - 1,64SD$

Where \bar{x} is the average MFV, SD is the standard deviation of MFV, and X_i is the MFV value of the *i*-th accession.

2.4 Statistical Analysis

Data from the field experiment (Stage 2) were analyzed using analysis of variance (ANOVA) to determine the effects of maize variety and cow manure application. If significant differences were detected ($F_{\text{calculated}} > F_{\text{table}}$), the results were further tested using Duncan's Multiple Range Test (DMRT) at the 5% significance level, employing the STAR software.

3. Results and Discussion

3.1. Aluminium Tolerance

The level of maize tolerance to aluminum stress was evaluated through nutrient culture using the Membership Function Value (MFV) as presented in Table 3.

Table 3. Aluminium tolerance classification of maize varieties based on Membership Function Value (MFV)

Variety	Relative Root Length		Root Volume		Root dry weight		Header dry weight	
	MFV value	Criteria	MFV value	Criteria	MFV value	Criteria	MFV value	Criteria
Jh37	0	Very Sensitive	0	Sensitive	0	Sensitive	0.08	Fairly Tolerant
P32	1	Tolerance	1	Tolerance	0.68	Fairly Tolerant	0.30	Fairly Tolerant
Nasa 29	0.56	Fairly Tolerant	0.41	Fairly Tolerant	0.12	Fairly Tolerant	0	Fairly Tolerant
Bisi 18	0.71	Fairly Tolerant	0.39	Fairly Tolerant	0.47	Fairly Tolerant	0.89	Tolerance
Lamuru	0.84	Fairly Tolerant	0.93	Tolerance	1	Tolerance	1	Very Tolerant
Sukmaraga	0.50	Fairly Tolerant	0.11	Fairly Tolerant	0.14	Fairly Tolerant	0.06	Fairly Tolerant

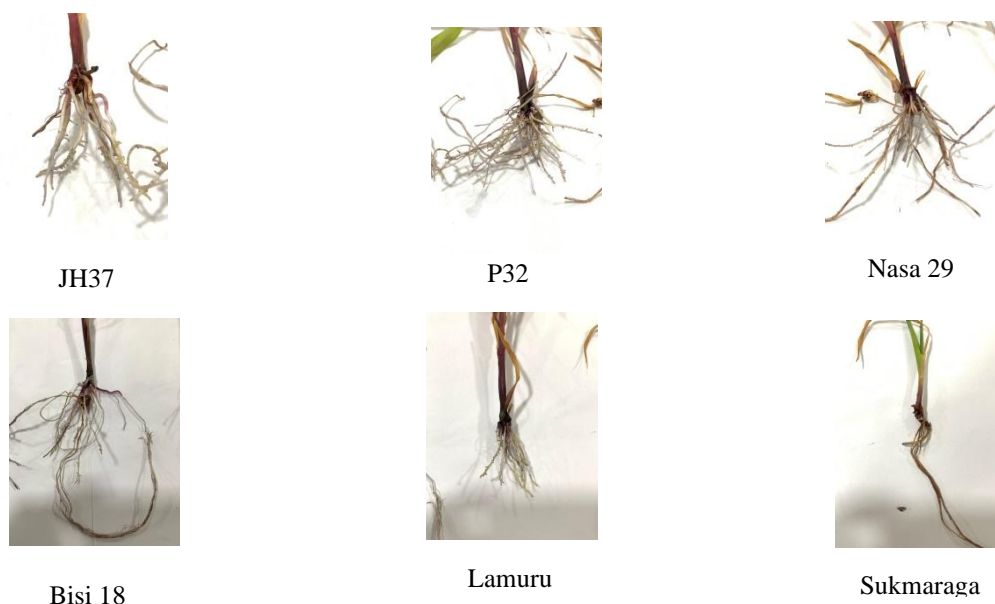


Figure 1. Root Appearance Of Each Variety

Based on root length and volume parameters, the P32 variety met the tolerance criteria. These results indicate that the P32 variety can adapt to Al stress. Root length is used as a selection index because it is easier to distinguish tolerant varieties from those sensitive to Al (Herawati *et al.*, 2021). Sensitive varieties will have shorter roots. Root shortening is one of the results of Al inhibition, so that the root structure appears shorter and fatter, and the branching is reduced, while the adventitious roots grow more. Plants under Al stress can experience root damage. This occurs because, at pH four below 5.5, Al is in the form of Al³⁺, which is toxic to plant roots, especially in the area from the root tip, which includes the meristem zone and root elongation so that this area will experience thickening and roots grow shorter (Roslim *et al.*, 2012).

The P32 and Lamuru varieties have root volumes within the tolerance criteria. Varieties classified as tolerant have a larger root volume compared to sensitive criteria. The root tip is

the part of the plant that has an important role in detecting aluminium poisoning. This part is the most prominent plant organ and functions as a distal transition zone between the apical meristem and the root elongation zone, allowing adventitious roots to grow further to obtain nutrients (Fan *et al.*, 2020; Liu *et al.*, 2022; Sun *et al.*, 2020). Aluminium affects cell division and elongation in root tips, leading to thickened root cell walls and abnormal cell organization. This, in turn, can affect root volume. (Liu *et al.* 2022)

The dry weight of the roots of the Lamuru variety is also superior to other varieties. The dry weight of the roots of the Lamuru variety is also superior to that of other varieties. The dry weight of Lamuru roots is included in the tolerance criteria. According to the statement, tolerant varieties are more adaptable than sensitive varieties (Evans *et al.*, 2013). Varieties with higher root dry weight are more adaptable to Al stress. In intolerant genotypes, the entry of aluminium can be prevented at the plasma membrane, so it does not enter the symplast or the sensitive area at the root tip of the cytoplasm. The uptake of aluminium by root cell walls is relatively low, and the role of cell wall membrane permeability in the external tolerance mechanism has been reported (Herawati *et al.*, 2021).

Disruption of root absorption will affect plant nutrient uptake. In maize, (Mariano *et al.*, 2015) used a divided-root-chamber technique to show that aluminium altered root nutrient uptake, significantly reducing the net uptake of calcium (Ca) and magnesium (Mg). In addition, phosphorus (P) deficiency is a significant concern in acidic soils due to the high affinity of aluminium for P, which causes the formation of insoluble Al-P compounds in the soil (Magalhaes *et al.*, 2018).

The decrease in shoot dry weight is caused by the unavailability of nutrients for optimal growth, resulting from disturbances in the absorption and transport of minerals in the roots (Kochian *et al.*, 2015). The shoot dry weight of the Lamuru and Bisi 18 varieties was classified as very tolerant and tolerant. In sensitive varieties, inhibition of shoot growth occurs as a secondary effect due to nutrient deficiencies, especially magnesium (Mg), calcium (Ca), and phosphorus (P), as well as limitations in water absorption, which cause stunted rice growth (Ma *et al.* 2014).

3.2 Maize Yield components

The maize yield components for the variety treatment and cow manure dose are presented in Table 4. The results of the analysis show that none of the yield component parameters exhibit a significant interaction between variety and cow manure dose, but are influenced by a single factor. Variety significantly influences cob diameter, number of cobs, weight of 1000 seeds, shelled cob weight, and potential yield per hectare. However, there was no visible effect of giving a dose of cow manure on the parameters of cob diameter, number of cobs, and weight of 1000 seeds.

Table 4. Effect of Varieties on Corn Yield Components

Factor	Cob diameter (cm)	Cob length (cm)	number of cobs (fruit)	Weight of 1000 seeds	Cob weight (g)	Potential yield per hectare (ton/ha)
Varietas						
P32	4.61 b	18.33	27.00 a	297.62 b	5.19 a	8.27 a
Bisi 18	5.07 a	17.85	26.44 a	332.07 a	5.47 a	8.41 a
Lamuru	5.02 a	17.25	24.78 b	343.61 a	4.44 b0	6.16 b
Sukmaraga	4.94 a	17.58	26.00 a	348.51 a	4.82 ab	6.90 b
Cow manure fertilizer dosage (ton ha⁻¹)						
0	4.76 a	17.28 a	25.74 a	323.54 a	4.49 b	6.58 b
5	4.88 a	17.34 a	25.91 a	328.87 a	4.91 a	7.18 b
10	5.07 a	18.48 a	25.49 a	338.69 a	5.54 a	8.54 a
CV	6.05%	4.53%	4.45%	7.08%	14.75%	15.92%

Description: Values followed by the same letter in the same column indicate no significant difference based on the DMRT test at the 5% level. Data are the average values from three replicates with seven sample plants in each replicate. The analysis of variance results showed no significant interaction between variety and cow manure dose, so the table presents the main effects of each factor.

The study found no significant interaction between variety and cow manure dosage. This indicates that various doses of cow manure elicited relatively similar responses across the varieties tested. Therefore, an increase in the cow manure dosage is necessary. As explained in the study by Gumawang *et al.* (2025), the application of cow manure in effective and efficient amounts can support the maximum vegetative phase of plants, indicating a close relationship between organic fertilizer supply and plant development.

Variety significantly affects the diameter of maize cobs. The maize cob diameters of several varieties showed the same results: Bisi 18, Lamuru, and Sukmaraga in the range of 4.94-5.07, except for the P32 variety, which had a smaller cob diameter. Each variety can produce large ear diameters when sufficient nutrients are available. These results align with research by (Sirappa & Nurdin, 2010), which shows that different genotypes can respond differently, even in the same environment. Genetic factors have a more significant influence than environmental factors. According to the study by (Hayati *et al.*, 2016), most of the characters in the tested maize varieties were controlled by distinct genes, resulting in differences in cob diameter.

Cob length did not significantly influence either the variety or the dose of cow manure. The length of the cob has no real influence; it is suspected that the ability of each variety to produce long cobs with the addition of Cow dung has not been proven effective in increasing cob length. In research, Jayanti *et al.* (2021) stated that the length of maize cobs is more influenced by genetic factors, whereas the ability of plants to express their genetic characteristics is influenced by environmental factors.

The ability of a variety to produce good results is also seen in the number of cobs. Varieties have a significant effect on the number of maize cobs. The varieties P32, Bisi 18, and Sukmaraga have more cobs than the Lamuru variety. The lamuru variety has the fewest cobs, indicating it has not adapted to these environmental conditions. According to Rosliana *et al.* (2018), the number of cobs is a trait influenced by genetic and environmental factors.

Varieties have a significant effect on the weight of 1000 seeds. The P32 variety has the lowest weight per 1000 seeds among the Bisi 18, Lamuru, and Sukmaraga varieties. Varieties with a higher 1000-seed weight indicate greater yield potential. As stated by Herawati *et al.* (2023), the characteristics of the yield components include cob diameter, cob length, number of rows per cob, number of seeds per row, and weight of 100 seeds.

The cob weight yield is directly proportional to the potential yield of several varieties. The weight of peeled cobs and the potential yield per hectare are strongly influenced by both the variety and the dose of cow manure. The weight of peeled cobs increased along with increasing cow dung dosage. Increasing the dose of cow manure can reduce the acidity level in the soil; it is proven that the soil pH was originally 5.03 after adding cow manure in the 5 ton/ha treatment increased to 5.98, and in the 10 ton/ha treatment, it increased to 6.21, but the pH increased in this study, the soil was still in the acid category or had a pH <7. The soil analysis results after processing are shown in Table 2: the increase in soil pH. Applying manure to acidic soil provides the nutrients and organic material needed for plant growth. It reduces soil acidity, increases the availability of manure and phosphorus, and reduces aluminium toxicity (Agustini & Wahdaniyah, 2017). Cow dung significantly affects the total N amount of soil (Agustini & Wahdaniyah, 2017). Adding 10 tons/ha of cow manure yields the greatest weight and yield potential compared to other doses. These results show that increasing the dose of cow manure increases maize production. Variety also has an important role in providing the potential for great results.

Plant variety has been proven to significantly influence the weight and potential yield per hectare of maize plants. The highest cob weight and yield potential per hectare of maize are found in the Bisi 18 and P32 varieties. The ability of the Bisi 18 and P32 varieties to increase crop yields is influenced by genetic factors. This variety shows better growth and development than others. Apart from that, this variety is also tolerant, as it grows and develops well in acidic conditions. Tolerant varieties can reduce yield reduction under Al stress conditions (Vasconcellos *et al.* 2021). Meanwhile, in sensitive varieties, Vasconcellos *et al.* (2021) found that Al poisoning reduced maize yields by 18.7%. The entry of aluminium into root cells can inhibit and disrupt the absorption and transport of P, Ca, Mg, and K, and can cause lipid peroxidation or oxidative fat degradation.

3.3 Maize Morphology

The emergence times of female and male flowers in various maize varieties are presented in Figures 2 and 3, respectively. Observations show that all varieties exhibit different emergence periods. Male flower emergence ranges from 52–55 days after planting (DST), while female flowers generally emerge slightly later, around 54–59 DST, depending on the variety and treatment.

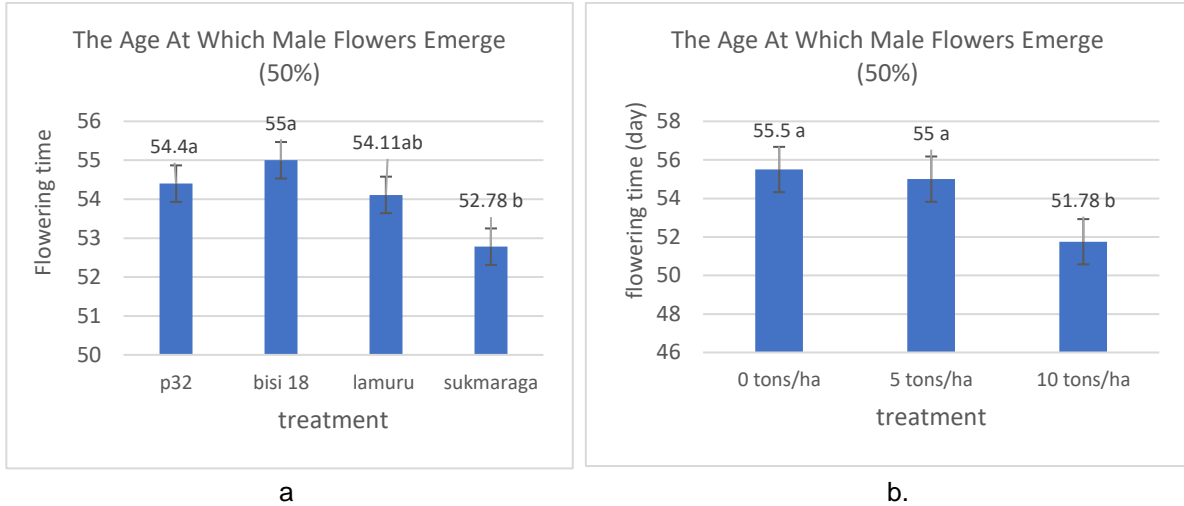


Figure 2. Age of emergence of male flowers (50%) in several corn varieties. Values shown are the average of three replicates. Different letters above the bars indicate significant differences based on the DMRT test at the 5% level. The graph shows: a) the main effect of variety, b) the main effect of fertilizer dose

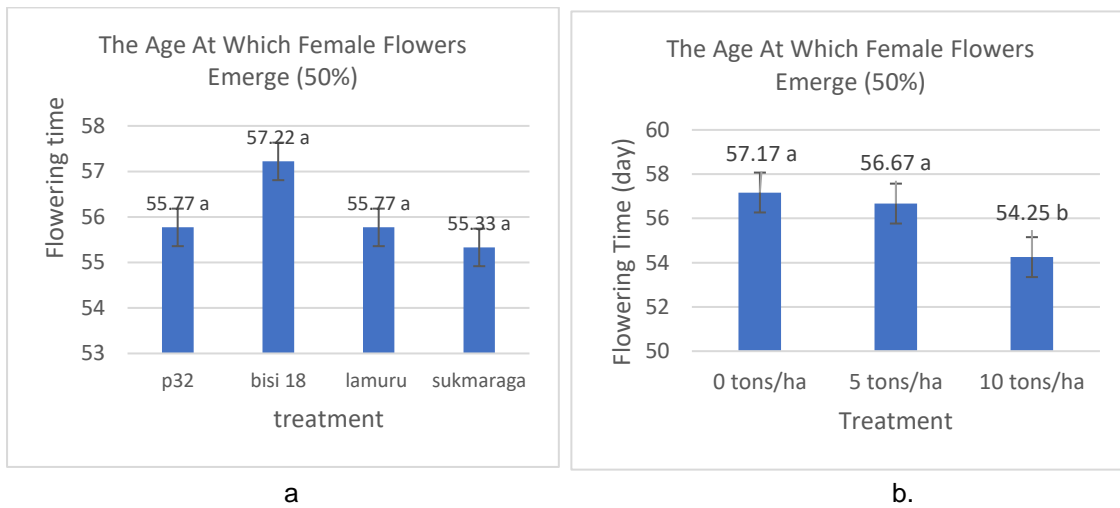


Figure 3. Age of emergence of female flowers (50%) in several corn varieties. Values shown are the average of three replicates. Different letters above the bars indicate significant differences based on the DMRT test at the 5% level. The graph shows: a) the main effect of variety, b) the main effect of fertilizer dose.

The Sukmaraga variety exhibited the earliest emergence of both male and female flowers among the varieties. This indicates a genetic advantage that accelerates the flowering phase. These results align with those of Jamidi *et al.* (2022), who found that genetic factors contribute significantly to flowering speed in the Sukmaraga variety. This genetic advantage is reflected in the synchronization and acceleration of male and female flower emergence, potentially supporting pollination efficiency.

In addition to variety factors, increasing the dose of cow manure (up to 10 tons ha⁻¹) accelerated the emergence of both male and female flowers compared to other doses. This condition is thought to be related to the increased availability of essential nutrients that

support early vegetative growth and the transition to the generative phase. According to (Azwarda, 2020), cow manure can provide nutrients that stimulate flowering and improve soil physical and biological conditions, thereby accelerating the plant's reproductive phase.

Overall, the variation in the age of male and female flower emergence in this study was influenced by a combination of genetic factors of the variety and nutrient availability from cow manure. Varieties with earlier flowering characteristics, such as Sukmaraga, demonstrated good adaptation potential to suboptimal environmental conditions, especially when supported by adequate organic fertilization.

The growth of maize plants in various varieties and doses of cow manure is presented in Figure 4. All plants showed height variation and experienced increased growth from 2 weeks after planting (WAP) until entering the generative phase at 6 WAP. The results showed that the Lamuru variety in the treatment without cow manure (0 tons ha⁻¹) experienced the slowest growth compared to other varieties. This condition indicates that the Lamuru variety is less able to grow optimally in soil without the addition of organic matter. The addition of cow manure improves soil structure and increases nutrient availability, thereby supporting root nutrient absorption and stimulating root growth and development. Good root development then encourages the growth of vegetative organs, such as stems and leaves. This finding is consistent with Santoro *et al.* (2018), who reported that manure application significantly affected plant height, leaf area index, root biomass, and shoot biomass. Increased leaf area contributes to greater photosynthetic activity, as leaves are the main organs where photosynthesis occurs.

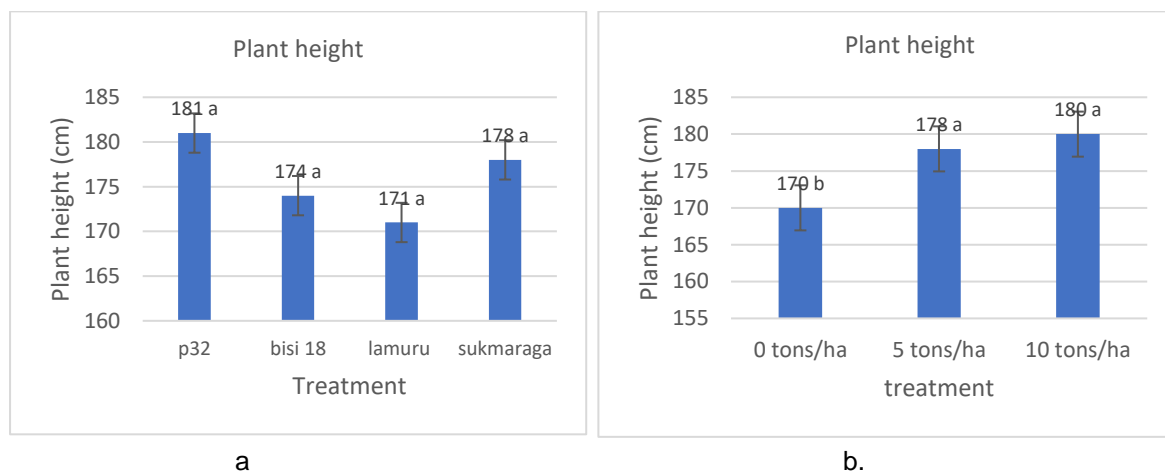


Figure 4. Plant height of several corn varieties. Values shown are the mean of three replicates. Different letters above the bars indicate significant differences based on the DMRT test at the 5% level.

The graph shows a. the main effect of variety, b. the main effect of fertilizer dose.

4. Conclusion

Based on the results obtained, the following conclusions can be drawn from the first stage of the experiment using nutrient culture media with varying AlCl₃ concentrations. Tolerant corn varieties are P32, Bisi 18, and Lamuru. These results were obtained from the calculation of Membership Function Value (MFV), which shows that the P32 variety has tolerance criteria for relative root length and root volume, the Bisi 18 variety has tolerance criteria for dry shoot weight, and the Lamuru variety has tolerance criteria for root volume and

dry root weight. In the second stage of the experiment, using 4 corn varieties and applying several doses of cow manure on acidic land, no significant interaction between the corn varieties and the cow manure doses was observed. However, the application of 10 tons/ha of cow manure produced the best results for corn growth and yield, as observed through the age of male flowers (50%), the age of female flowers (50%), the weight of peeled cobs, and potential yield per hectare. Among the varieties tested, P32 and Bisi 18 showed the highest results for cob length, number of cobs, peeled cob weight, and overall yield potential.

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Attachment

Variety	Cob Diameter			
	Manure Dosage			Main Effect of Variety
	0 tons	5 tons	10 tons	
P32	4.30	4.67	4.86	4.61 b
Bisi 18	5.00	5.08	5.11	5.07 a
Lamuru	4.70	5.08	5.28	5.02 a
Sukmaraga	5.07	4.69	5.06	4.94 a
KK = 6.05%				

Variety	length of corn cob			Main Effect of Variety
	Manure Dosage			
	0 tons	5 tons	10 tons	
P32	17.31	17.69	19.39	18.13
Bisi 18	17.57	17.26	18.73	17.85
Lamuru	16.33	17.45	17.97	17.25
Sukmaraga	17.91	16.97	17.86	17.58
Pengaruh utama dosis				
KA= 4.53%				

Variety	number of cobs			Main Effect of Variety
	Manure Dosage			
	0 tons	5 tons	10 tons	
P32	27.33	26.33	27.33	27.00 a
Bisi 18	27.00	26	26.33	26.44 a
Lamuru	23.00	25	26.33	24.78 b
Sukmaraga	25.66	26.33	26.00	26.00 a
KK = 4.45%				

Varietas	Weight 1000 seeds			Main Effect of Variety
	Manure Dosage			
	0 tons	5 tons	10 tons	
P32	282.02	303.98	306.86	297.62 b
Bisi 18	319.74	329.32	347.13	332.07 a
Lamuru	330.70	350.12	350.01	343.61 a
Sukmaraga	361.70	332.06	350.76	348.51 a
KK = 7.08%				

Variety	Weight of Peeled Tuna
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	Manure Dosage			Main Effect of Variety
	0 tons	5 tons	10 tons	
P32	4.90	4.80	5.80	5.19 a
Bisi 18	5.48	5.13	5.80	5.47 a
Lamuru	3.18	4.89	5.24	4.44 b
Sukmaraga	4.37	4.82	5.20	4.82 ab
Pengaruh utama dosis	4.49B	4.91A	5.54A	
KK = 14.75%				

Variety	Potential Yield Per Hectare			Main Effect of Variety
	Manure Dosage			
	0 tons	5 tons	10 tons	
	-----ton/ha-----			
P32	7.68	7.58	9.54	8.27a
Bisi 18	3.33	7.56	9.32	8.41a
Lamuru	4.10	6.71	7.67	6.16 b
Sukmaraga	6.22	6.86	7.61	6.90 b
Pengaruh utama dosis	6.58 B	7.18 B	8.54 A	
KA= 15.92%				