THE IMPACT OF FOUR NITROGEN LEVELS ON GRAIN-FILLING, AGRONOMIC, AND PHYSIOLOGICAL TRAITS OF DIFFERENT MAIZE (*Zea mays* L.) VARIETIES.

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Bogor, June 2024

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SUMMARY

CASTUS PASCHAL. The Impact of Four Nitrogen Levels on Grain-filling, Agronomic, and Physiological Traits of Different Maize (*Zea mays* L.) Varieties. Supervised by ISKANDAR LUBIS as first SUPERVISOR and Dr. WILLY BAYUWARDI a second SUPERVISOR. As per Xiong et al. (2015), the global population is anticipated to reach 9 billion by 2050, with the substantial population increase expected to occur in Africa and Asia. This increase raises concerns about increased food demand. Maize's role becomes pivotal, contributing to 45% of the global food demand by 2050 (Gao et al. 2023).

This study aims to evaluate the impact of four nitrogen levels on grain filling, agronomic, and physiological traits of different maize (Zea mays L.) varieties. The study adopted a split-plot randomized complete block design with two treatments (factors). The first treatment was nitrogen levels with four levels (0, 46, 138, and 184 kg N ha^{-1}) applied as main plots. The second treatment was maize variety, with three distinct maize varieties (Hybrid-BISI18, Composite-Sukumaraga, and Local-Tambin) assigned as sub-plots**.** Results highlighted significant effects of both treatments on grain filling, agronomic, and physiological traits of maize plants. Specifically, the type of maize variety significantly affected 100-grain weight, cob weight, cob circumference, cob length, weight of grains per cob, number of grains per row, grain yield per 16-plants per plot, plant heights at all weeks of observation, and stem diameter at the 4th and 6th weeks after planting.

Nitrogen application significantly influenced cob circumference, plant height at the 8th week, stem diameter at the 6th week after planting, and photosynthesis rate at silking (R1) stage. Additionally, the interaction between maize variety and nitrogen significantly influenced plant heights at the 6th week after planting, cob circumference, photosynthesis rate at silking (R1) stage, and number of leaves at the silking (R1) growth stage.

In contrast, the 100-grain weight, cob weight, cob length, rows per cob, weight of grains per cob, grains per row, grain yield per 16-plant plot, plant height at weeks 3 and 4, and stem diameter at week 4 were not affected by nitrogen level or interaction. Furthermore, the number of leaves at the V6 stage of growth and stem diameter at week 8 were not affected by the treatments, either separately or in combination.

The study concludes that both maize variety and nitrogen application significantly influence various agronomic and physiological traits, with their interaction further affecting specific growth parameters, highlighting the importance of tailored agronomic practices for enhancing grain-filling potential, and eventually optimizing maize yield.

Key Words: nitrogen fertilization, grain yield, crop performance, non-structural carbohydrate (NSC), agricultural productivity.

RINGKASAN

CASTUS PASCHAL: Pengaruh Empat Kadar Nitrogen Terhadap Pengisian Biji, Sifat Agronomi, dan Fisiologis Berbagai Varietas Jagung (Zea mays L.). Dibimbing oleh ISKANDAR LUBIS sebagai SUPERVISOR pertama dan Dr. WILLY BAYUWARDI sebagai SUPERVISOR kedua. Sesuai Xiong dkk. (2015), populasi global diperkirakan akan mencapai 9 miliar pada tahun 2050, dengan peningkatan populasi yang besar diperkirakan akan terjadi di Afrika dan Asia. Peningkatan ini menimbulkan kekhawatiran akan peningkatan permintaan pangan. Peran jagung menjadi sangat penting karena berkontribusi terhadap 45% permintaan pangan global pada tahun 2050 (Gao et al. 2023).

Penelitian ini bertujuan untuk mengevaluasi dampak empat tingkat nitrogen terhadap pengisian biji, sifat agronomi, dan fisiologis berbagai varietas jagung (Zea mays L.). Penelitian menggunakan rancangan acak kelompok lengkap terbagi dua dengan dua perlakuan (faktor). Perlakuan pertama adalah kadar nitrogen dengan empat taraf (0, 46, 138, dan 184 kg N ha-1) yang digunakan sebagai petak utama. Perlakuan kedua adalah varietas jagung, dengan tiga varietas jagung berbeda (Hibrida-BISI18, Komposit-Sukumaraga, dan Lokal-Tambin) yang ditetapkan sebagai anak petak. Hasilnya menyoroti dampak signifikan dari kedua perlakuan terhadap pengisian biji-bijian, sifat agronomi, dan fisiologis tanaman jagung. Secara spesifik jenis varietas jagung berpengaruh nyata terhadap bobot 100 butir, bobot tongkol, lingkar tongkol, panjang tongkol, bobot gabah per tongkol, jumlah gabah per baris, hasil gabah per 16 petak tanaman, tinggi tanaman pada seluruh minggu pengamatan. , dan diameter batang pada minggu ke-4 dan ke-6 setelah tanam.

Pemberian nitrogen berpengaruh nyata terhadap lingkar tongkol, tinggi tanaman minggu ke-8, diameter batang minggu ke-6 setelah tanam, dan laju fotosintesis pada satage silking (R1). Interaksi varietas jagung dengan nitrogen berpengaruh nyata terhadap tinggi tanaman umur 6 minggu setelah tanam, lingkar tongkol, laju fotosintesis pada tahap silking (R1), dan jumlah daun pada tahap pertumbuhan silking (R1). Sebaliknya bobot 100 butir, bobot tongkol, panjang tongkol, baris per tongkol, bobot gabah per tongkol, gabah per baris, hasil gabah per 16 petak tanaman, tinggi tanaman minggu ke 3 dan 4, serta diameter batang minggu ke 3 dan 4. 4 tidak terpengaruh oleh tingkat nitrogen atau interaksi. Selanjutnya jumlah daun pertumbuhan stadia V6 dan diameter batang minggu ke 8 tidak dipengaruhi oleh perlakuan baik secara terpisah maupun kombinasi.

Studi ini menyimpulkan bahwa varietas jagung dan aplikasi nitrogen secara signifikan mempengaruhi berbagai sifat agronomi dan fisiologis, dan interaksi keduanya selanjutnya mempengaruhi parameter pertumbuhan spesifik, menyoroti pentingnya praktik agronomi yang disesuaikan untuk meningkatkan potensi pengisian biji-bijian, dan pada akhirnya mengoptimalkan hasil jagung.

Kata Kunci : pemupukan nitrogen, hasil gabah, performa tanaman, karbohidrat non-struktural (KNS), produktivitas pertanian.

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CASTUS PASCHAL

Thesis
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6. The author hopes that this scientific work will be beneficial for those in need and for the advancement of science, especially in the field of agriculture.

Bogor, June 2024

Castus Paschal

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I INTRODUCTION

1.1 Background

Maize (*Zea mays*) is a vital cereal crop globally, ranking third after wheat and rice (Sigigaba and Mdoda 2021). The United States, China, and Brazil are the leading producers of maize on a global scale (Cherniwchan and Moreno-Cruz 2019). Maize, serves as a global vital source of food, feed, and raw material for energy (Zhao *et al.* 2020), reflecting the trajectory of human population expansion. According to Xiong *et al.* (2015), the global population is expected to reach 9 billion by 2050. This stimulates rising concerns about food security, where maize's role becomes pivotal, contributing to 45% of the global food demand by 2050 (GAO *et al.* 2023). In regions like Sub-Saharan Africa, maize holds dual significance, serving as both a staple food and a primary income source for smallholder farmers (Sigigaba and Mdoda 2021). In Asian countries such as China, India, Thailand, and Indonesia, maize is predominantly cultivated by small-scale farmers with limited resources, relying on rainfall, this crop plays a significant role in food systems, with these nations collectively accounting for 98% of maize produced in the region, and contributing 26% to the global total (Prasanna *et al*. 2014).

Maize's growth cycle involves the process of grain filling, a stage critical for determining yield and quality, grain filling involves the accumulation of dry matter, and nutrient absorption by the developing grain/kernel(Baillot *et al.* 2018). Grain filling as discussed by, Zhang *et al*. (2013), is a complex process influenced by various factors such as meteorological conditions, plant-related aspects such as sink capacity of grains, assimilate availability, leaf nitrogen dynamics, and soil fertility dynamics. Additionally, according to Ma *et al.* (2023), biological processes like photosynthetic efficiency, starch biosynthesis, transportation of assimilates, and endosperm cell division directly influence grain filling. Indirectly grain filling is influenced by factors such as nutrient availability including nitrogen, phytohormones, and abiotic stresses, among others.

Notably, nitrogen nutrient influences leaf photosynthesis, and biomass production, boosts assimilates accumulation in kernels post-silking, promoting kernel formation, affecting leaf area index (LAI) and chlorophyll levels, this nutrient is essential for synthesizing various enzymes, structures, and proteins essential for photosynthesis efficiency and other metabolic activities, and ultimately improve grain yield and quality (LIU *et al*. 2021; Yue *et al*. 2021; Szulc *et al*. 2023). Despite the importance of nitrogen fertilization in enhancing maize productivity, its excessive use can lead to fertilizer loss, environmental pollution, and low grain yield (Wu et *al*., 2019; Yue et *al*. 2022).

1.2 Problem Statement and Justification

Local and composite maize varieties are popular among small-scale farmers across diverse African regions such as Tanzania, Kenya, Uganda, and South Africa, among others. Additionally, in Indonesia, local and composite maize varieties are widely cultivated in regions like Bone, East Nusa Tenggara, South Sulawesi, Kadu madang in Banten Province, and in Madura (Prasanna *et al.* 2014; Abate *et al*. 2017; Rahayu *et al*. 2021; Sigigaba and Mdoda 2021; Purba and Hadiatry 2022). However, previous research efforts have predominantly focused on the grain-filling process in hybrid varieties despite the widespread cultivation of local and composite varieties. This narrow focus overlooks the broader implications of grain filling in local and composite varieties, which are extensively cultivated by small-scale farmers across multiple regions. Addressing this gap, this study aims to investigate the impact of four nitrogen levels on local, composite, and hybrid varieties across grain-filling, agronomic, and physiological traits of maize.

1.3 Objectives

The objectives of this research are:

a. To evaluate the effect of four nitrogen levels on grain-filling, as well as agronomic and physiological traits of different maize varieties
b. To evaluate the effect of maize varieties on grain filling, agronomic and physiological traits

1.4 Hypothesis

1. Nitrogen application significantly affects grain-filling, agronomic, and physiological traits
2. Type of maize variety significantly affects grain-filling, agronomic, and physiological traits
3. There is the interaction between variety and nitrogen on grain-filling, agronomic, and physiological traits

II LITERATURE REVIEW

2.1 Climatic conditions (rainfall and temperature) and maize cultivation

Maize exhibits extensive phenotypical and genotypic diversity, accounting for its widespread presence in both tropical and temperate regions, variability of temperature and precipitation during the cultivation period are essential for maize production, specifically under the rain-fed system of cultivation (Chemura *et al.* 2022). Additionally, maize is a versatile crop, capable of thriving in diverse agro-climatic environments. This crop is cultivated worldwide, even at elevations up to 300 meters above sea level. Farmers like this crop because it provides highest grain yield among the cereals. Maize serves multiple purposes, providing both grain, raw materials for energy, and fodder. In some regions, maize can perform better within the range of rainfall between 300-500mm which is considered below the average for the enhanced grain yield (Sah *et al.* 2020). According to a study by (Gyamerah *et al.* 2023), a temperature range of 27.9(°C) and 28.1(°C) with rainfall range of 1290 mm to 1390 mm was observed as an optimal for maximizing yield over to 2.0MT/ha.

2.2 Maize growth cycle

Maize growth goes through crucial growth phases, the identification and understanding of these phases is essential in its cultivation. Management practices for enhancing yield in maize align with a better understanding of growth phases, through which potential yield is influenced.

According to the Iowa State University Extension and Outreach website, maize growth is categorized into two major phases: the vegetative phase (V) and the reproductive stage (R) (Iowa State University, n.d.).

Table 1 Growth stages in maize crop

VEGETATIVE STAGES

Symbol	Description
VE	Germination/emergence-shoot emerge from the soil
V1	First leaf appearance- with visible collar and round tip
V2	Second leaf- visible collar is seen, and pointed leaves are observed.
Vn	n^{th} leaf-‘n’- leaf collars are visible, appearances of 8-12 leaves for hybrid
VT	Tassel- lowest branch of tassel is observed

REPRODUCTIVE STAGE

R1	R1-Emergence of silks out of the maize husk
R2	Blister stage-kernel/grain has developed alike blisters with clear liquid
R3	Milk- milky fluid is observed in kernel
R4	Dough –dents are formed on kernel, with milk mark extends to the kernel tips
R6	Physiological maturity – Kernel/grain reaches the fullest dry matter accumulation, with a black layer visible at the base of kernel

2.3 Agronomic practices in maize cultivation

Table 2 Some agronomic practices in maize cultivation

Agronomic practice	Description
Plant density	Optimum range of plant per unit area is an essential agronomic practices which determine yield and yield components of maize plant, plant density significantly affect overall yield and number of cobs, high plant population beyond the recommendation tend to reduce grain yield
Maize variety	Yield in maize is extensively influenced by the type of variety/seed cultivated, the choice of maize variety can account for up to 20% of maize yield gap, maize variety selection is a key strategy to enhance maize yield and reduce the yield gap.
Fertilizer application	Poor soil fertility is an important factor which limits the productivity in maize. Nitrogen and phosphorus are the most limiting nutrients in (crops) maize productivity

Source: Tesfaye et al. 2019

2.4 Definitions of maize varieties

a) Hybrids maize varieties

Hybrid varieties are the first-generation offspring resulting from the crossbreeding of inbred line parents, open- pollinated varieties (OPVs), and other populations that are commonly used in commercial agriculture(Olisa *et al.* 2021). This breeding approach combines desirable traits such as higher yield, disease resistance and adaptability to specific environmental conditions. Hybrid vigor, which enhances yield, is a notable advantage of this method (Xu *et al.* 2021), the utilization of heterolysis in hybrid breeding plays a crucial role in boosting maize yield and can enhance yield up to 35%

b) Composite varieties

Composite varieties are a group of interbred cultivars that can be utilized as Open-Pollinated (OP) cultivars. They are randomly mated and can provide a quick method to enhance OP cultivar performance (Kutka 2011). The production of composite cultivar goes through a special method as stated by (San *et al.* 1993), composite mass selection a breading technique that involves selecting individual plants based on their physical characteristics, and then combing the seeds from these plants to create the generation. This method is distinct from other selection methods because it focuses on multiples traits at once and preserves genetic diversity.

c) Local /Landrace varieties

Local varieties also referred as landraces are maize varieties that are open-pollinated and have been improved through the selection and production processes conducted by family farmers. Local varieties are widely spread among small-scale farmers, and provide an opportunity for farm-saved seed source (Hebinck *et al.*

2015; Almekinders *et al*. 2021). These varieties are characterized by their origin within the local community and their adaptation to local conditions through traditional farming practices. Maize landrace populations are indigenous plant varieties that have not undergone formal breeding programs like modern varieties. These maize types are cultivated by farmers on their own land over several generations, where seeds are saved annually. These landraces possess distinct characteristics. Moreover, maize Landraces consist of highly diverse groups, exhibiting variations both and withinpopulations (Hosang *et al*. 2020).

2.5 Crops productivity, Fertilizer application and Non-structural carbohydrate (NSCs) relationships

Plants produce two types of carbohydrates - structural and non-structural (NSCs). NSCs such as glucose and starch are essential for plant metabolic processes and can indicate the plant's growth and response to external stress. The production and reuse of NSCs are critical to achieving high crop yields in the face of climate change. Nitrogen addition can increase or decrease NSC levels in plants depending on its assimilation and impact on the photosynthetic system.(Wu *et al*. 2019).The filling of rice grains depends on photosynthesis and mobilization of stored non-structural carbohydrates (NSC) in stems. Up to 28% of the final rice yield can come from stems, and enhancing the transfer of NSC from stems to grains can increase yield. Environmental stress reduces NSC movement and buildup, while low nitrogen levels increase NSC buildup and movement. Excessive nitrogen does not improve NSC buildup or movement and does not maximize crop production (Li *et al*. 2018). Under stressful conditions, cereal crops rely heavily on stored non-structural carbohydrates (NSC) to produce grain yield, which can make up over 50% of the total yield. However, in non-stressful conditions, the contribution of stored NSC to grain yield is much lower, ranging from 5% to 33% (Kumari *et al*. 2020) .The storage and release of NSC are vital for plants to cope with changes in their environment. When plants produce more carbohydrates than needed for growth, they store the excess as soluble sugars and starch. These NSC can be used later to support growth and metabolic functions when the supply of carbohydrates is limited. Hence, the redistribution of recently assimilated carbon from leaves to different sinks such as storage, defense, growth, and metabolic maintenance is a critical process in many plant species (Zepeda *et al*. 2022)

III METHODOLOGY

3.1 Research location and time

The study was conducted at the Leuwikopo station, IPB University, Bogor District, from June to September 2023. Soil samples before the experiment were collected and sent for analysis to the soil Laboratory Department ofAgronomy and Horticulture, IPB University on 30th March, 2023.

3.2 Materials and tools

The Planting material was maize seeds of the three varieties Hybrid-BISI 18, Composite-SUKMARAGA and Local-TAMBIN obtained from the certified sources, nitrogen fertilizer (46%N), SP- 36 (36%), and 50 kg. ha−1 KCl (60%), agricultural lime, cow manure, insecticides (active ingredient; abamectin), fungicide (active ingredient; mancozeb 80%), and bactericides (active ingredient; streptomycin 20%). Tools and equipment used were weighing balance/digital scale, permanent mark pen, plastic tag, small pole, and measuring tape, insecticides, Licor Li-6400XT, and moisture meter.

3.3 Experimental Design

The experiment employed a split-plot randomized complete block design, with two treatments (factors). The first factor was nitrogen levels with four levels i.e., 0, 46, 138, and 184 kg N ha^{-1} applied as main- plots, and the second treatment factor was maize varieties, with three distinct maize varieties i.e., Hybrid-BISI18, Composite-Sukumaraga, and Local-Tambin allocated as sub-plots. The experimental area was replicated thrice, with a total of 36 sub-plots, each sub-plot with a size of 4m by 4m.

3.4 Work Procedure

3.4.1 Stages of research activities/implementation

a. Land Preparation

Land preparation began one month before the implementation of the research experiment, the preparation included clearing vegetation, debris of obstacles from the land to create a clean experimental area, ploughing and lastly the area was harrowed into seedbed with smooth soil for easy seed-soil contact to enhance quick germination. Finally, the experimental area was plotted following the recommended experimental design, with three replications, each with three main-plots and each main-plot with three sub-plots, the size of each sub-plot was 4m by 4m.

b. Planting

Seeds of each variety were prepared in a separate container and carefully labeled, two seeds were planted carefully following the experimental lay-out and the labels of treatment identification, and after three weeks, one maize plant was thinned out to remain with one healthy plant.

c. Fertilizer application

Nitrogen fertilizer (46%) was split-applied during sowing and at the knee height stage of the crop. Additionally, 50 kg ha−1 of SP-36 (36%) and 50 kg ha−1 of KCl (60%) were applied during sowing.

d. Management Practices

Day- to-day observations were conducted and recorded. Key operations included weed management, which was done in the third week after planting to prevent weeds from competing with the crops for nutrients, water, air, and sunlight. Earthing-up was also performed in the third week after planting to encourage root growth and provide better support for the plants.

Supplemental irrigation using sprinklers was employed during dry periods to ensure adequate soil moisture. To protect the crop from pests and diseases, insecticides (active ingredient: abamectin), fungicides (active ingredient: mancozeb 80%), and bactericides (active ingredient: streptomycin 20%) were applied. Additionally, drainage management was conducted to prevent waterlogging in the field.

3.4.2 Procedures for Data recording

Observations carried out included soil and nutrient analysis, agronomic/yield, physiological parameters, and climatic conditions.

a) Soil analysis

Soil sampling was conducted to obtain representative samples of the entire experimental area before the experiment and was sent to the soil Laboratory Department of Agronomy and Horticulture, IPB University for the analysis of soil pH, organic carbon, nitrogen total, available phosphorus, potential phosphorus, and potassium.

b) Traits/parameters studied.

1) Number of leaves: Counted during the sixth leaf (V6) and silking (R1) growth stages
2) Time to 50% Tasseling: Days counted from planting until 50% of plants in each subplot produced tassels.
3) Time to 50% Silking. Days counted from planting until 50% of plants in each sub-plot had silks emerged
4) Plant Height (cm): Measured using a measuring tape at 3, 4, 6, and 8 weeks after sowing.
5) Stem Diameter (mm): Measured using a vernier caliper at 4, 6, and 8 weeks after sowing.
6) Days to Harvesting: Determined by physiological maturity indicators, such as kernel moisture content (30-35%), change in cob color, and kernel denting. Days from planting to the observation of maturity indices were recorded.
7) Photosynthesis Rate (μmol CO_2 m^{-2} s^{-1}): Measured on one leaf from two randomly selected plants in each subplot during the silking stage (R1) using an LI-6400/XT portable photosynthesis system. Measurements were taken around 9:00-10:00 AM WIB.
8) Soluble Sugar and Starch Content (mg g^{-1}): Two plants were randomly

collected from each subplot. Leaves and stems were separated, oven-dried at 80°C for 48 hours, milled, sieved, and analyzed at the IPB University laboratory.

9) Crop Growth Rate (CGR): Measured in grams. Calculated using the formula by Tanveer et al. (2014): CGR = (W2 - W1) / (t2 - t1), where W1 is dry matter at the first harvest (V6), W2 is dry matter at the second harvest (R2), t1 is days of observation at the first harvest, and t2 is days of observation at the second harvest.
10) Grain Yield per 16 Plants per Plot (kg): Measured from mature cob.
11) Fresh Weight Grain Filling Rate (g day^{-1}): After the blister (R2) growth stage, fresh grains from immature cobs were weighed using a digital scale over three weeks.
12) Grain Filling Duration: Calculated by subtracting days to harvest from days to silking.
13) 100-Grains Weight (g): 100 grains from the middle part of a physiologically mature cob were weighed using a digital scale.
14) Cob Weight (g): Matured cobs were weighed using a digital scale.
15) Cob Length (cm): The length of mature cobs was measured and recorded.
16) Grains Weight per Cob (g): All grains from a mature cob were weighed using a digital scale.
17) Grains per Row: The longest row per cob was marked and grains were counted.
18) Rows per Cob: Rows on a mature cob were counted.
19) Cob Circumference (mm): Measured using a measuring tape

c) Climatic condition

Climate conditions specifically, rainfall and temperatures of the experimental area were determined following the reference from the West Java Climatology station (Stasiun Klimatologi Jawa Barat).

3.5 Data analysis

Data normality and homogeneity were checked using Minitab 16 software. Significant differences between the mean values were tested using Analysis of variance (ANOVA) with Tukey Honestly Significant Difference HSD test at a 5% level of probability with Statistical Analysis System (SAS) software 9.4.

IV RESULTS AND DISCUSSION

4.1 Experimental area's soil condition and the Climate

According to (Kriteria Penilaian Sifat Kimia Tanah 2000), the soil analysis before results (Table 3) indicated that soil pH= rated as medium and described as slightly acidic, C-organic = low, Nitrogen total=low, available P= high. 2ton/ha of agricultural lime was applied in order to assist in raising soil pH to a more neutral point, to enhance nutrient availability. Moreover, 1ton/ha of cow manure was applied to the experimental area to increase soil organic carbon content for enhancing soil structure, water holding capacity, and nutrient retention.

Table 3 Results of soil analysis before the experimentation

Soil parameters	**Results/Status**	**Extraction method**
pH H_20	5,51	pH meter
pH KCl	4,81	pH meter
C-organic	1,60%	Spectrometry
N-Total	0,20%	Kjeldahl method
Available- P	54,00 ppmP_2O_5	Spectrometry
Potential-P	132,02 mg P_2O_5/100g	Spectrometry
Potential-K	31,58 mgK_2O/100g	AAS

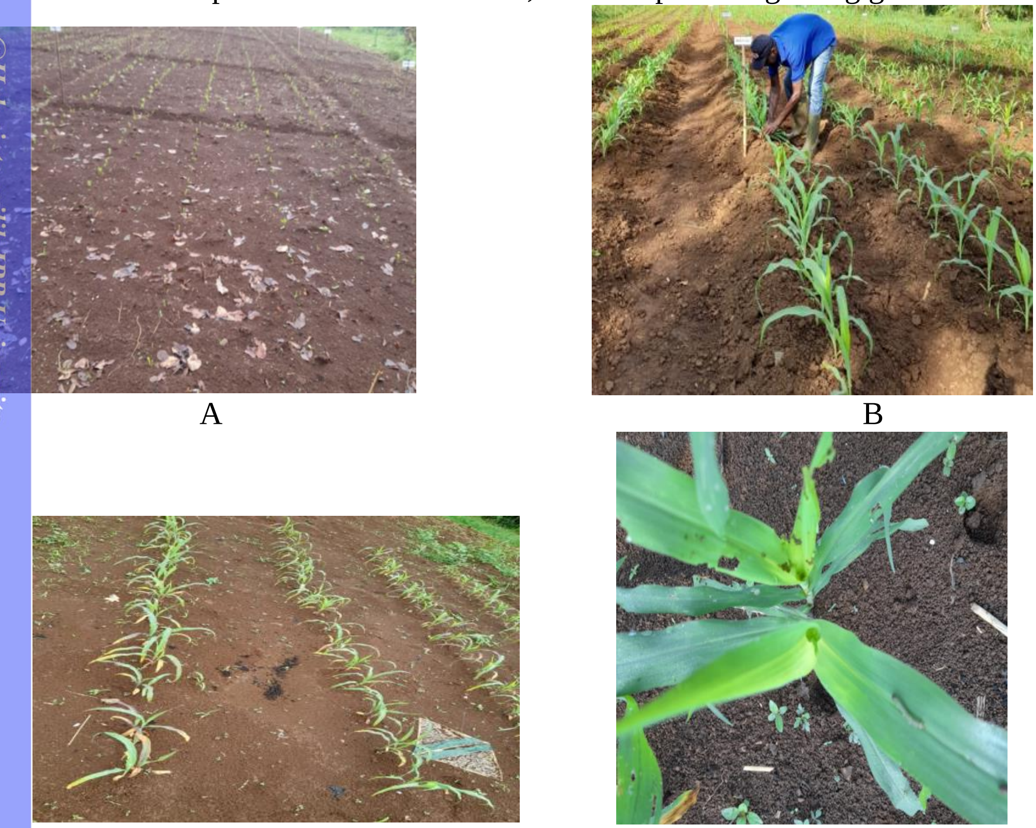
The average temperature ranged around 27.1^o C, with a maximum of 32.1^{o}C, and the minimum temperature was 23.6^{o}C (Table 4). The rainfall conditions ranged from 5.2 to 15.1mm per month (BMKG, 2023). Apart from other factors, maize production is highly dependent on rainfall and temperature, and during the experiment period, the precipitation was considered very low.
To mitigate this, a sprinkler irrigation system was used during dry spells to enhance soil moisture.

Table 4 Climate data during May until September 2023 at Leuwikopo Experimental station.

Month	**T min (˚C)**	**Tmax (˚C)**	**Tavg (˚C)**	**Rainfall (mm per month)**
May	23,63	32,95	27,07	14,00
June	23,06	32,51	26,51	15,53
July	22,51	32,28	26,35	11,2
August	21,91	33,13	26,38	11,13
September	21,56	33,72	26,78	5,18

Note: Climate data from Bogor Climatology Station (BMKG), May-September2023. T min: Minimum temperature, T max: Maximum temperature, Tavg: average temperature.

The germination rate for all the varieties ranged between 85-90%. The condition of the plants was generally good during the first week of planting (fig 4.3). In the 13th week after planting, plants exhibited symptoms where the first, second, and third leaves from above the ground turned yellow to purple color, and eventually dried out. This condition was observed in most of the sub-plots of different varieties and under different nitrogen levels as well. Insecticides (active ingredient; abamectin), fungicide (active ingredient; mancozeb 80%), and bactericides (active ingredient; streptomycin 20%) were sprayed twice a week. The condition improved after three weeks, with the plants regaining good health.



A B C D

Figure 1 Symptoms of diseases and pests, germination, and plant improvement. A=germination B =plants improvement after management and C and D= maize plant condition after the diseases and pest attaches.

4.2 Analysis of variance (ANOVA) of key agronomic and physiological traits of maize varieties under different nitrogen levels.

The results of the ANOVA summary in Table 5 showed a coefficient of variation ranging from 0.19% to 19.27%, indicating that the experiment was sufficiently reliable. This reliability enhances the validity of the conclusions drawn, implying minimal variability due to external factors (Table 5).

Significant influences of treatments on key agronomic traits were observed. Maize variety significantly affected 100-grain weight, cob weight, cob circumference (cm), cob length, weight of grains per cob, number of grains per row, and grain yield per 16 plants plot at a 0.01 significance level, highlighting genetic variability among maize varieties in terms of grain filling potential. Nitrogen levels significantly influenced cob circumference, indicating their crucial impact on cob size and structure, and the quantity and quality of rows on the cob. The interaction effect between maize varieties and nitrogen levels significantly influenced cob circumference, suggesting that the response of cob diameter to nitrogen levels varies depending on the maize variety, highlighting a complex relationship between genetic factors and nitrogen fertilizer input.

Maize varieties significantly influenced plant height at multiple observation times (3rd, 4th, 6th, and 8th weeks after planting), indicating genetic differences in growth patterns. Similarly, stem diameter was significantly influenced by maize variety in the 4th and 6th weeks after planting, indicating potential variations in stem development during early growth stages. Nitrogen levels significantly influenced plant height in the 8th week and stem diameter in the 6th week, emphasizing the crucial role of nitrogen in both late-stage plant growth and early stem growth. The interaction between maize variety and nitrogen significantly influenced plant height at the 6th week after planting. Additionally, maize varieties significantly influenced the number of leaves at the silking (R1) growth stage. Photosynthesis performance was significantly affected by both nitrogen availability and maize varieties.

Table 5 Summary of ANOVA on agronomic and physiological traits of maize varieties under different nitrogen levels

Traits	Nitrogen	Variety	Variety X Nitrogen	CV (%)
100 -grains weight (g)	ns	**	ns	5.66
Cob Weight (g)	ns	**	ns	19.34
Cob circumference(cm)	*	**	*	2.62
Cob Length (cm)	ns	**	ns	2.73
Rows per cob	ns	**	ns	4.05
Weight of grains per cob (g)	ns	**	ns	15.46
Grains per row	ns	**	ns	3.41
Yield per 16 plants plot^{-1} (kg)	ns	**	ns	16.94
Plant Height at week 3	ns	**	ns	8.49
Plant Height at week 4	ns	**	ns	7.85
Plant Height at week 6	ns	**	*	0.19
Plant Height at week 8	*	*	ns	6.73
Stem diameter at week 4	ns	**	ns	13.11
Stem diameter at week 6	*	**	ns	5.49
Stem diameter at week 8	ns	ns	ns	6.23
Photosynthesis rate during R1 stage	**	ns	**	7.7
Number of leaves at V6 stage	ns	ns	ns	7.4
Number of leaves at R1 stage	ns	ns	*	9.7

Note: * = significant at α=0.05, ** = significant at α=0.01, ns = not significant, CV = coefficient of Variation.

4.3 Effect of maize varieties and nitrogen levels on leaf count at silking (R1) growth stage and dry matter accumulation (g) at both silking (R1) and sixth leaf (V6) growth stages.

I. Effect on number of Leaves during silking (R1) stages

In Table 6, a significant interaction was observed between maize varieties and nitrogen levels on the number of leaves during the silking growth stage (R1). The local variety (Tambin) produced more leaves (10.33) at 138 kg N ha^{-1} compared to the control conditions (9.83) and the highest nitrogen dose of 184 kg N ha^{-1} (8.5). Higher leaf count under 138 kg N ha^{-1} nitrogen dose did not differ significantly from the rest of the nitrogen levels.
In contrast, the composite variety (Sukumaraga) showed the highest leaf count (12.5) under the highest nitrogen dose (184 kg N ha^{-1}) compared to the control conditions (11 leaves). This variety also showed a high leaf count under 138 kg N ha^{-1} (11.6), but this did not differ significantly from the leaf count under 184 kg N ha^{-1}. A number of leaves of the hybrid variety (BISI18) during the R1 stage did not differ significantly across nitrogen levels, but there was a tendency to produce more leaves (11) when treated with 138 kg N ha^{-1}.
Nitrogen is a critical nutrient for plant growth, influencing the development of vegetative structures such as leaves. Higher nitrogen availability often promotes increased leaf production due to enhanced chlorophyll content and photosynthetic activity; likewise, different maize varieties have varying genetic capacities for nitrogen uptake and utilization. Hybrid varieties often have improved genetic traits for efficient nitrogen use, leading to higher leaf counts under optimal and high nitrogen conditions compared to local varieties. This explains why the hybrid variety (BISI18) showed higher leaf counts under moderate nitrogen dose 46 kg N ha^{-1} compared to the local variety and composite varieties.

Table 6 Interaction between maize varieties and nitrogen leaf count at R1

Variety	Nitrogen levels (kg.ha^{-1})	Number of leaves R1 Stage
Local	0	9.83ab
	46	7.33b
	138	10.33ab
	184	8.50ab
Composite	0	11ab
	46	9.67ab
	138	11.67ab
	184	12.50a
Hybrid	0	9.50ab
	46	10.83ab
	138	11.00ab
	184	9.89ab

Note: Numbers followed by the same letter in the same column were not significantly different based on Turkey HSD.

4.4 Impact of nitrogen levels and maize varieties on plant height (cm) and stem diameter (mm).

Table 7 shows that plant height differed significantly across nitrogen levels at week 6 after planting. Generally, nitrogen application influences plant height and other growth parameters of maize plants(Ariraman *et al.* 2020). Results in Table 7 displays that the application of 46 kg N ha^{-1} resulted in taller plants (230.4 cm) compared to the control conditions (202.7 cm) and both higher and highest nitrogen doses. Notably, the application of 138 kg N ha^{-1} also enhanced plant height (222 cm), although this was not significantly different from the plant height recorded under 46 kg N ha^{-1}. Moderate nitrogen levels often optimize plant height due to balanced nutrient availability, which promotes vigorous vegetative growth without causing excessive foliage or nutrient imbalances. This explains why plants treated with 46 kg N ha^{-1} were taller than those under control conditions or higher nitrogen doses, excessive nitrogen application can lead to a diminishing returns effect, where additional nitrogen does not proportionally increase plant height. This is often due to potential nutrient imbalances or luxury consumption, where plants absorb more nitrogen than they can efficiently utilize (Gheith et *al*. 2022). This supports the finding that 138 kg N ha^{-1} enhanced plant height but did not significantly differ from the effect of 46 kg N ha^{-1}.

Table 7 Effect of nitrogen levels on plant height at week 6th week after planting

Variable	Weeks After Planting 8 --- plant height (cm) ---
Nitrogen levels (kgN/ha)	
0	202.772b
46	230.452a
138	222.010ab
184	221.347ab

Note: Number followed by the same letter in the same column were not significantly different according to HSD 5% level.

Plant height plays a crucial role in defining plant architecture, and plant growth, and can be influenced by factors like nutrient availability, and genetic make-up, among others(Li. *et al*, 2024). In Table 8, plant height at the 3rd, 4th, 6th, and 8th weeks after planting differed significantly. The local variety 'Tambin' was significantly taller during the 3rd (64 cm), 4th (105.4 cm), and 6th (205.5 cm) weeks after planting compared to the hybrid variety 'BISI-18', which recorded plant heights of 53.3 cm at the 3rd week, 84.5 cm at the 4th week, 178.6 cm at the 6th week, and 229.1 cm at the 8th week. The composite maize variety 'Sukumaraga' was the shortest among the tested maize varieties during the 3rd (38.9 cm), 4th (65.4 cm), 6th (151.3 cm), and 8th (209 cm) weeks after planting.
The observed trends in plant height across the different maize varieties suggest distinct growth patterns influenced by genetic factors. The local variety 'Tambin' exhibited the most rapid early growth, as evidenced by its significantly greater height at the 3rd, 4th, and 6th weeks after planting. This early vigor may confer advantages in resource competition and stress resilience during critical early

developmental stages. In contrast, the hybrid variety 'BISI-18' showed a slower initial growth rate but surpassed 'Tambin' in height by the 8th week. This growth pattern indicates a potential for prolonged vegetative growth and possibly higher final biomass accumulation, which could be beneficial under certain agronomic conditions.

The composite maize variety 'Sukumaraga' consistently demonstrated the shortest plant height at all observed intervals. This trend may reflect a more compact growth habit or genetic traits favoring resource allocation to other physiological processes. While shorter stature could be disadvantageous in terms of light competition, it may offer benefits such as reduced lodging risk and suitability for high-density planting.

Table 8 Effect of maize varieties on plant height during the 3rd, 4th, 6th and 8th weeks after planting

Variable	Weeks After Planting			
	3	4	6	8
	--- plant height (cm) ---			
Type of Maize				
Local	64.087^{a}	105.441^{a}	205.555^{a}	
Composite	38.935^{c}	65.483^{c}	151.389^{c}	209.094^{b}
Hybrid	53.372^{b}	84.546^{b}	178.645^{b}	229.196^{a}

Note:Number followed by the same letter in the same column were not significantly different to HSD 5% level.

The interaction between nitrogen levels and maize varieties (Table 9) on plant height differed significantly during week 6 after planting. The local variety 'Tambin' showed a positive response to nitrogen fertilization, particularly at 138 kg N ha^{-1}, exhibiting higher plant heights (213.8 cm) during the 6th week of observation compared to the control treatment with plant heights of 208.2 cm. While the highest plant heights of the local variety 'Tambin' did not differ significantly with the highest nitrogen dose (184 kg N ha^{-1}), it did differ significantly from those under moderate dose of 46 kg N ha^{-1}.

For the hybrid variety 'BISI-18', a trend of increasing plant heights was observed with nitrogen application, peaking at 46 kg N ha^{-1}, with the highest observed plant heights of 198.6 cm. This differed significantly from the plant heights under the control conditions. Notably, there was a diminishing return with higher nitrogen doses, suggesting a potential threshold effect beyond which additional nitrogen may not yield further growth benefits.

Likewise, the composite maize variety 'Sukumaraga' displayed a significant increase in plant heights with increased nitrogen levels, particularly at 46 kg N ha^{-1}, which influenced the highest plant heights (161.7 cm) compared to the control treatment (143.4 cm) and higher doses of 138 kg N ha^{-1} (156.8 cm) and 184 kg N ha^{-1} (143.5 cm), respectively. Both composite and hybrid varieties exhibited higher plant heights under 46 kg N ha^{-1} compared to the control treatments. The hybrid variety, in particular, demonstrated superior growth characteristics with optimal nitrogen application levels. It is noteworthy that while the hybrid variety 'BISI-18' reached its maximum plant height (198.6 cm) under

46 kg N ha^{-1} during the 6th week of observation, a previous study by Adhikari *et al*. (2021) noted optimal nitrogen levels of 220 kg N ha^{-1} for maximum plant height in various hybrid varieties.

Table 9 Interaction between maize varieties and nitrogen levels on plant height (cm) during six weeks after planting.

Variable		**Weeks after planting**
		6 **--- Plant height (cm) ---**
Local	0	208.2^{a}
	46	189.4^{bc}
	138	213.8^{a}
	184	210.6^{a}
Composite	0	143.4^{e}
	46	161.7^{cde}
	138	156.8^{de}
	184	143.5^{e}
Hybrid	0	154.2^{de}
	46	198.6^{ab}
	138	178.5^{bcd}
	184	183.1^{bc}

Note: Number followed by the same letter in the same column was not significantly different based on HSD 5% level.

Results in Table 10, show that stem diameter differed significantly during both the 4th and 6th weeks after planting among the maize varieties. During the 4th week, the local variety 'Tambin' demonstrated the thickest stem (12.6 mm), followed by the hybrid variety 'BISI-18' (11.1 mm), with the composite variety 'Sukumaraga' being the least (8.4 mm).

During the 6th week of observation, the hybrid variety 'BISI-18' had the thickest stem (22.5 mm), followed by the composite variety 'Sukumaraga' (21.8 mm), and the local variety 'Tambin' produced the thinnest plant stems (18.3 mm). Additionally, the stem thickness of the local variety during the 4th week differed significantly from that of the composite variety 'Sukumaraga', but not from that of the hybrid variety 'BISI-18'. Similarly, the stem thickness of the local variety 'Tambin' during the 6th week after planting differed significantly from both the composite and hybrid varieties. Generally, the observed trends in stem diameter across the different maize varieties highlight the influence of genetic factors and growth stages on plant structural development. During the 4th week after planting, the local variety 'Tambin' demonstrated the thickest stems, suggesting an early allocation of resources to structural growth, which may enhance stability and support for further vegetative growth. This characteristic could provide advantages in environments prone to lodging or mechanical damage.

The hybrid variety 'BISI-18', while initially having thinner stems than 'Tambin' during the 4th week, exhibited the thickest stems by the 6th week. This trend indicates a different growth strategy, where the hybrid variety may initially prioritize other physiological processes before investing in structural robustness. The significant increase in stem thickness of 'BISI-18' by the 6th week suggests a potential for greater resilience and mechanical strength as the plant matures.

The composite variety 'Sukumaraga', which consistently showed the thinnest stems during the 4th week, displayed a substantial increase in stem thickness by the 6th week, surpassing the local variety 'Tambin'. This suggests that 'Sukumaraga' may have a delayed but effective response in structural growth, potentially balancing early vegetative growth with later structural development.

The significant differences in stem thickness among the varieties at both observation stages highlight the importance of variety selection based on specific agronomic needs.

Table 10 Effect of maize varieties on stem diameter during week 4th and week 6th after planting

Variable	Weeks After Planting	
	4	6
	---stem diameter (mm) ---	
Type of Maize		
Local	12.636a	18.350b
Composite	8.493b	21.813a
Hybrid	11.191a	22.542a

Note:Number followed by the same letter in the same column were not significantly different to HSD 5% level.

Table 11 demonstrates that nitrogen application significantly affected stem thickness in maize plants, which differed significantly across weeks 4 and 6. Plants treated with a moderate dose of 46 kg N ha^{-1} developed thicker stems (22 mm) compared to those under control conditions (19.4 mm), and higher doses of 138 kg N ha^{-1} (21.1 mm) and 184 kg N ha^{-1} (21 mm). The thicker plant stems recorded under the moderate nitrogen dose differed significantly from those under control conditions but did not differ significantly from those under higher nitrogen doses. The results indicate that moderate nitrogen application (46 kg N ha^{-1}) significantly enhances the stem thickness of the varieties evaluated compared to control conditions, suggesting an optimal dose for structural growth. Interestingly, higher nitrogen doses did not result in significantly thicker stems than the moderate dose, implying a potential threshold beyond which additional nitrogen does not further benefit stem development.

These findings are consistent with the observation by (Ali and Anjum 2017), that maximum stem diameter (3.68 cm) was achieved with the highest nitrogen dose of 180 kg ha^{-1}, followed by 160 kg ha^{-1} (3.51 cm) and 130 kg ha^{-1} (3.46 cm), while the smallest diameter (2.58 cm) was recorded with no fertilizer, and 70 kg ha^{-1} resulted in a diameter of 2.89 cm. This suggests that an increased nitrogen supply may promote cell division, leading to consistent stem diameter expansion.

Table 11 Effect of nitrogen levels on stem diameter during week 6 after planting

Variable	Weeks After Planting
	6
	---stem diameter (mm) ---
Nitrogen level (kgN/ha)	
0	19.434b
46	22.013a
138	21.129a
184	21.028a

Note:Number followed by the same letter in the same column were not significantly different to HSD 5% level.

4.5 Effects of maize variety and nitrogen levels on yield components traits.

I. Effects on 100-grain weight (g), cob weight (g) and cob length (cm)

Results in Table 12 show that 100-grain weight (g), cob weight (g), and cob length (cm) differed significantly among maize varieties. The hybrid variety 'BISI-18' exhibited the heaviest 100-grain weight (40.3 g), followed by the composite variety 'Sukumaraga' (34.6 g), and the local variety 'Tambin' with 30.9 g. In terms of cob weight, 'BISI-18' continued to perform the best, yielding 206.3 g, followed by 'Sukumaraga' with 184.4 g, and 'Tambin' with the least at 118.4 g. Regarding cob length, 'BISI-18' also produced the longest cobs at 25.2 cm, followed by 'Sukumaraga' achieved 24.5 cm, while 'Tambin' had the shortest cobs measuring 20.1 cm.

Hybrid'BISI-18' demonstrated superior performance in grain weight and cob dimensions, suggesting potential advantages for yield enhancement strategies. Generally, the variation exhibited in cob length among varieties, with 'BISI-18' producing the longest cobs and 'Tambin' the shortest, indicates genetic variability in ear development, which is crucial for optimizing harvest efficiency and yield stability. Based on Gheith *et al*.(2022), there was an increase in 100-kernel weight and cob length in both study seasons (2019 and 2020) corresponded with higher nitrogen levels, with the highest nitrogen dose of 366kg N/ha enhanced the highest values of 100-kernel weight (45.8 and 42.2g) and cob length (16.7 and 16.6cm), respectively. Although this study found that only maize varieties significantly influenced the parameters studied. The superior performance of 'BISI-18' in grain weight and cob dimensions may indicate that this hybrid variety possesses inherent traits that optimize these parameters, independently of nitrogen levels. This observation aligns with the enhanced effects of higher nitrogen application reported by Gheith et al. (2022), suggesting that genetic factors play a crucial role in optimizing yield parameters.

II. Effects on grains weight per cob (g), grains per row, and rows per cob

Grain weight per cob, grains per row, and rows per cob differed significantly across maize varieties (Table12). The composite variety (Sukumaraga) produced the most rows per cob (14.9), followed by the hybrid variety (BISI-18) (14.1 rows), and the local variety Tambin had the least with 10.9 rows per cob. The rows per cob counted in composite differed significantly from that of both local and hybrid varieties. Notably, the hybrid variety BISI18 yielded the highest grain weight per cob (165 g) and grains per row (37), followed by the composite variety (Sukumaraga) producing 144.9 g and 36.5 grains per row, respectively. The local variety -Tambin performed moderately better compared to the other two varieties, recording a grain weight per cob of 71.7 g and 24 grains per row. (Gheith et *al.* 2022), noted that more kernels weight per ear, number of grains per ear, and number of grains per row peaked under the highest nitrogen dose of 366kg N/ha.

III. Effects on cob circumference (cm), fresh weight grain filling rate (FWGFR) (g.day^{-1}) and yield per 16plants plot^{-1} (kg).

The hybrid variety (BISI18) recorded the largest cob circumference (18.9 cm), the highest grain yield per 16 plants per plot (33.7 kg), and fresh weight grain filling rate (9.59 g.day^{-1}), the values of BISI-19 were significantly different from the values of composite and local varieties, with the exception of the value of fresh weight grain filling rate which differed significantly from local variety-tambin only. Notably, the composite variety (Sukumaraga) was the second best, with a cob circumference of 17.8 cm, a fresh weight grain filling rate of 7. g.day^{-1}, and a grain yield per 16-plant per plot of 23.8 kg. The local variety Tambin had the lowest performance, with a cob circumference of 16.9 cm, fresh weight grain filling rate of 5.51 g.day^{-1}, and a grain yield per 16-plant plot of 9.2 kg.

(Adhikari *et al*. 2021) have demonstrated that increasing nitrogen levels can significantly enhance grain yield in maize. This aligns with the current findings where maize varieties, particularly hybrid BISI18, showed higher grain yield per 16 plants per plot compared, and fresh weight gain filling rate to other varieties. While this study did not find the significances of nitrogen in this aspect, the general principle that nitrogen fertilization enhances yield supports the idea that optimal nitrogen application could further benefit the top-performing maize variety (BISI18) even more. Similarly, Fu *et al.* (2020) noted improvements in growth parameters alongside grain yield with increased nitrogen levels. In this study, although nitrogen levels weren't significant against these traits, the differences observed in cob circumference and grain filling rate among maize varieties could be influenced by inherent differences in nitrogen use efficiency or other growth responses to soil nitrogen availability. Under varying nitrogen conditions (as observed in previous studies), the performance gaps between maize varieties might widen or diminish, depending on their responsiveness to nitrogen.

Table 12 Effect of maize varieties on yield components

Variable	100 grain weight (g)	Cob weight (g)	Cob length (cm)	Cob circumference (cm)	Rows Per cob
Maize variety					
Local	30.965[c]	118.44[b]	20.114[b]	16.93[c]	10.9[c]
Composite	34.696[b]	184.40[a]	24.574[a]	17.88[b]	14.9[a]
Hybrid	40.303[a]	206.36[a]	25.248[a]	18.91[a]	14.1[b]
Maize variety	**Grains weight per cob(g)**	**Grain per row**	**Yield per 16plants per plot**	**Fresh weight grain filling rate(gd^{-1})**	**Grains weight per cob(g)**
Local	71.72[b]	24.0[b]	9.22[c]	5.516[b]	71.72[b]
Composite	144.94[a]	36.5[a]	23.89[b]	7.091[ab]	144.94[a]
Hybrid	165.00[a]	37.0[a]	33.79[a]	9.593[a]	165.00[a]

Note: Numbers followed by the same letter in the same column were not significantly different based on HSD 5% level.

The interaction between maize varieties and nitrogen levels on cob circumference differed significantly (Table 13). The local variety -Tambin planted under 184 kg N/ha produced cobs with the largest circumference (17.8 cm) compared to control conditions (16.4 cm), which was significantly different from both the control nitrogen condition (0 kg N/ha) and the moderate nitrogen level (46 kg N/ha). The composite variety (Sukumaraga) recorded a larger cob circumference (18.5 cm) when treated with 46 kg N/ha nitrogen dose compared to both control conditions and higher nitrogen levels. Notably, the hybrid variety (BISI18) produced the largest cob circumference (19.4 cm) under a high nitrogen dose of 138 kg N/ha compared to control conditions (18.5 cm) and the highest dose (18.8 cm). In all varieties, a diminishing returns effect was observed. The study by Adhikari *et al*.2021, corroborates the influence of nitrogen fertilization on yield-related aspects like cob circumference.

Table 13 Interaction between maize varieties and nitrogen levels on cob circumference (cm)

Variety	**Nitrogen levels ($kg.ha^{-1}$)**	**Cob circumference (cm)**
Local	0	16.44^{ef}
	46	15.81^{e}
	138	17.61^{cd}
	184	17.86^{bcd}
Composite	0	17.29^{de}
	46	18.54^{abc}
	138	17.67^{cd}
	184	18.03^{bcd}
Hybrid	0	18.52^{abc}
	46	18. 78^{abc}
	138	19.48^{a}
	184	18.87^{ab}

Note: Numbers followed by the same letter in the same column were not significantly different based on HSD 5% level.

4.6 Effect of nitrogen levels and maize varieties on a range of agronomic and physiological traits.

I. Effect on days to tasseling (days) and days to silking (days)

The results in Table 14 shows that both days to tasseling and days to silking did differ significantly among maize varieties. The hybrid variety 'BISI-18' had the longest duration to tasseling (53.7 days) and days to silking (57.7 days) compared to the composite variety 'Sukumaraga,' which recorded 53.5 days to tasseling and 56 days to silking. The local variety 'Tambin' demonstrated the shortest duration, with 44.5 days to tasseling and 48.4 days to silking. The significant differences in days to tasseling and silking among maize varieties highlight the genetic variability in flowering time, which is crucial for optimizing planting schedules and improving yield predictability.
While an extended duration to tasseling and silking observed in the hybrid variety 'BISI-18' suggests it might be better suited for longer growing seasons, providing a longer period for grain filling and potentially higher yields, the shorter duration to tasseling and silking in the local variety 'Tambin' indicates its potential advantage in areas with shorter growing seasons or where early maturation is desired to avoid late-season environmental stresses. Adhikari *et al.* (2021) corroborates this study's results by emphasizing the complex interplay between genetic factors and agronomic practices in maize development. While the previous study demonstrated that nitrogen levels significantly influenced tasseling and silking in hybrid maize, this study's observation that maize varieties significantly impacted these variables suggests that genetic differences play a crucial role in determining flowering time. This genetic variability, as seen in the varying

durations to tasseling and silking among the hybrid, composite, and local varieties in this study, might overshadow the effects of nitrogen under certain conditions. Thus, the current findings align with the notion that optimizing maize growth and yield requires considering both genetic traits and environmental management practices.

II. Effects on crop growth rate (g.day^{-1}), grain filling duration (days), and days to harvesting (days)

Table 14 reveal that crop growth rate, grain filling duration, and days to harvesting differed significantly. The hybrid variety 'BISI-18' achieved the highest growth rate, recording 4.1 g/day, which differed significantly from the other two varieties. The local variety 'Tambin' had the second-highest growth rate (2.6 g/day), while the composite variety 'Sukumaraga' was the slowest, growing at a rate of 2.6 g/day. The significant differences in growth rates among maize varieties highlight the genetic variability in growth performance, with 'BISI-18' exhibiting the highest daily growth rate, suggesting its potential for higher biomass accumulation and yield. Concerning days to harvesting, the composite variety recorded more days to harvest (125days), followed by hybrid variety-BISI18 (124.7days), local variety-tambin took short days to harvesting (103.9days) compared to the rest of the varieties, and was a significant difference from other two varieties.

On the other hand, the composite variety 'Sukumaraga' had the longest grain filling duration (68.5 days), followed by the hybrid variety 'BISI-18' with 67.3 days. Notably, the local variety 'Tambin' had the shortest grain-filling duration (55.5 days). Generally, the composite variety had the statistically longest grain filling duration compared to the other varieties, which is crucial for accumulating more starch and nutrients, impacting the overall grain size, quality, and yield. The extended grain filling duration observed in 'Sukumaraga' indicates its potential for producing larger and higher-quality grains, as a longer grain-filling period allows for more starch and nutrient accumulation. (Li *et al.* 2020), found that application of nitrogen fertilizer enhanced the population grain-filling rate among two different hybrid varieties , with variety XY508 strongly affected compared to variety ZH311, these findings support the current observation by demonstrating that different maize varieties respond uniquely to nitrogen application, which enhances the grain filling rate. This highlights the role of genetic differences among varieties in determining grain-filling characteristics. While nitrogen did not significantly affect grain filling duration in this study, it remains crucial for grain-filling efficiency, aligning with the observed significant influence of maize varieties on grain-filling duration.

III. Effects on soluble sugar (mg g^{-1}) and starch content (mg g^{-1}) during silking stage (R1)

Generally, the composite variety (Sukumaraga) produced the most soluble sugar content (3.96 mg/g). The hybrid variety also performed competitively well, accumulating 3.91 mg/g of soluble sugar content, and both were not significantly different from one another. In contrast, the local variety had the lowest soluble sugar content (1.52 mg/g) during the R1 stage, which differed significantly from the rest varieties. In terms of starch content, the hybrid variety (BISI18) produced the most starch (1.49 mg/g), followed by the composite variety (Sukumaraga) (1.45 mg/g). The local variety demonstrated the least starch content (0.65 mg/g). According to Wu *et al*. (2019), in two hybrid cultivars, it was noted that a reduction in nitrogen fertilizer stimulates the activities of sucrose phosphate synthase, which promotes the accumulation of soluble sugar and starch content. Conversely, the addition of fertilizer within a specific range tends to improve photosynthesis efficiency, thereby enhancing the production of soluble sugar and starch content (non-structural carbohydrates). This study also observed that during the V6 to R1 stages, under nitrogen levels ranging from 150 to 450 kg/ha, the starch content in the ZH311 variety decreased by 25.55%. Specifically, at the R1 stage, the starch content in the stem of ZH311 decreased by 10.95% under 150 kg/ha and by 23.17% under 300 kg/ha compared to that under 0 kg/ha over two years. The soluble sugar content of XY508 under 0-450 kg/ha during V6 to R1 decreased by 30.22% and increased by 42.31% during the R1 and R5 stages. During the R1 stage, the soluble sugar content in the stem of ZH311 decreased by 20.40% under 150 kg/ha and by 67.77% under 300 kg/ha compared to 0 kg/ha.

Table 14 Effect of maize varieties on agronomic and physiological traits

Variable	**Soluble Sugar(mg g^{-1}) content at R1 stage**	**Starch content(mg g^{-1}) at R1 stage**	**Grain filling duration**	**Crop growth rate (gday^{-1})**
Maize varieties				
Local	1.523^{b}	0.65^{b}	55.50^{b}	2.687^{b}
Composite	3.964^{a}	1.45^{a}	68.58^{a}	2.638^{b}
Hybrid	3.913^{a}	1.49^{a}	67.30^{a}	4.191^{a}
Maize varieties	**Days to tasseling(day)**	**Days to silking(days)**	**Days to harvesting (days)**	**Days to tasseling (day)**
Local	44.58^{b}	48.41^{b}	103.92^{b}	44.58^{b}
Composite	53.51^{a}	56.14^{a}	125.08^{a}	53.51^{a}
Hybrid	53.75^{a}	57.77^{a}	124.72^{a}	53.75^{a}

Note: Number followed by the same letter in the same column were not significantly different to HSD 5% level.

Results in Table 15 reveal that nitrogen levels significantly affected photosynthesis performance in maize plants. Generally, the nitrogen dose of 138 kg N/ha^{-1} promoted higher photosynthetic efficiency measuring (26.89 µmol CO2 m²/s) compared to the control conditions and highest nitrogen dose. Additionally, the application of a moderate nitrogen dose of 46 kg N/ha^{-1} significantly improved photosynthesis rate, although it did not differ significantly from the highest recorded photosynthesis performance. According to Su *et al.* (2020), it was observed that the application of nitrogen rate of (N255) was effective in terms of photosynthesis rate compared to lower dose (N150) and higher rates (N300), which corresponds to this study's observations.

Table 15 Effect of nitrogen levels on Photosynthesis rate (µmol CO2 m²/s)

Variable	**Photosynthesis Rate**
Nitrogen levels(kgN/ha)	
0	24.45[b]
46	24.82[ab]
138	26.89[a]
184	23.11[b]

Note: Number followed by the same letter in the same column were not significantly different to HSD 5% level.

The interaction between maize varieties and nitrogen levels on photosynthesis rate differed significantly (Table 16). Local variety Tambin treated with 138 kg N/ha^{-1} showed higher efficiency in terms of the rate of photosynthesis (27.84 µmol CO2 m²/s), compared to the control conditions (24.27 µmol CO2 m²/s) and the highest nitrogen dose of 184 kg N/ha^{-1} (23.33 µmol CO2 m²/s). The highest photosynthesis rate observed at 138 kg N/ha^{-1} differed significantly from that at the highest nitrogen level of 184 kg N/ha^{-1}.

Similarly, the application of 138 kg N/ha^{-1} on the composite variety (Sukumaraga) resulted in the highest photosynthesis rate (27.06 µmol CO2 m²/s), compared to the control conditions (25.06 µmol CO2 m²/s) and the highest nitrogen dose (23.09 µmol CO2 m²/s). This highest photosynthesis rate differed significantly from the rate observed under the highest nitrogen dose.

Notably, the hybrid variety had the lowest photosynthesis rate (25.79 µmol CO2 m²/s) when planted under 138 kg N/ha. Despite the lower photosynthesis rate under the same nitrogen treatment level as the other varieties, the hybrid variety still performed better in terms of grain yield. This may be explained by the heterosis feature of the hybrid variety, which allows it to produce more grains and achieve a higher fresh weight of grains even with a lower photosynthesis rate compared to the other varieties.(Yue *et al.* 2021), corroborate the positive influence of nitrogen on photosynthetic traits, correlating with our current study's observations.

Table 16 Effect of interaction between maize varieties and nitrogen levels on photosynthesis rate (µmol CO2 m²/s) at silking (R1) stage

Varieties	Nitrogen levels (kg/ha)	Photosynthesis rate (µmol CO2 m²/s) at R1
Local	0	24.27abc
	46	24.40abc
	138	27.84a
	184	23.33bc
Composite	0	25.06abc
	46	26.01abc
	138	27.06ab
	184	23.09c
Hybrid	0	23.83bc
	46	24.04bc
	138	25.79abc
	184	22.90c

Note: Numbers followed by the same letter in the same column were not significantly different based on HSD 5% level.

4.7 Correlation studies

Figure 2 shows the results of correlation analysis between key grain-filling, agronomic, and physiological traits measured during the experiment. Statistically, it was found that starch content and soluble sugar, significantly correlated with yield components (cob weight, cob length, cob diameter, number of grains per row, grain weight, and number of grains per cob). High starch implies better energy reserve within the grains, essential for increased grain weight, soluble sugar content indicates the resource for grain development and yield formation. Notably, days to tasseling, and days to silking positively correlated with yield component, highlighting that extended durations of silking and tasseling could result in uniform pollination and fertilization, leading to increased grain set. Additionally, grain filling duration positively correlated with yield components, suggesting that a longer grain filling duration allows for prolonged grain development and accumulation, leading to higher grain weights and eventually increased yield. Similar results were documented by (Yue *et al.* 2022), where 100 grains weight, grains per plant, and ears ha^{-1} showed a positive correlation with yield of maize.

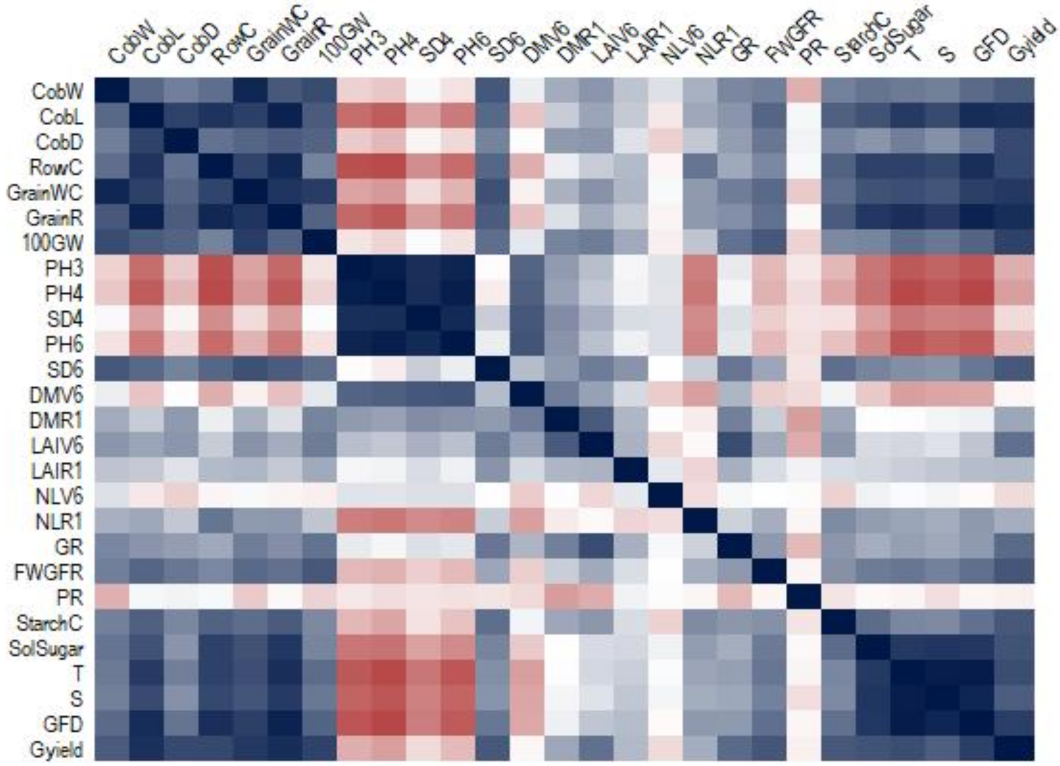


Figure 2. Correlation analysis of grain filling parameters, morphology and physiological traits using Minitab 16 software.

The color indicates the strength of correlation. Red color indicates a negative correlation and blue color indicates positive correlation and white color indicates no correlation. The darker color of each category (positive or negative) shows e higher coefficient of correlation (Close to 1 or -1). RowC= Number of rows per cob, GrainWC=Grain weight per cob (g), GrainR=Number of grain per row,100GW= 100-grain weight (g), PH3= Plant height (cm) at week3,PH4= Plant height(cm) at week4,PH6= Plant height (cm) at week6, SD4= Stem diameter(mm) at week 4, SD6= Stem diameter (mm) at week 4, DMV6= Dry matter production (g) at sixth leaf stage (V6) stage,DMR1-Dry matter production (g) at silking (R1) stage,LAIV6= Leaf area index at sixth leaf stage (V6) stage, LAIR1= Leaf area index at silking (R1) stage,NLV6= Number of leaves at sixth leaf stage (V6) stage,NLR1= Number of leaves at silking (R1) stage, GR=Growth rate,FWGFR=Fresh weigh grain filling rate(g.day^{-1}),PR=Photosynthesis rate (µmolCO2m^-2s^-1) at at silking (R1) stage, StarchC= Starch content (mg g^{-1}), SolSugar=Soluble sugar content(mg g^{-1}) , T= Days to tasseling,S=Days to silking,GFD=Grain filling duration, Gyield= Grain yield per 16-plant plot^{-1} (kg).

V. CONCLUSION AND RECOMMENDATION

3.1 Conclusion

Based on the findings of this research, it is evident that both maize varieties and nitrogen levels significantly influence various agronomic and physiological traits, such as plant height, cob weight, and photosynthesis rate. The interaction between nitrogen levels and maize varieties also significantly affects specific parameters, highlighting the need for tailored agronomic practices. For instance, hybrid maize varieties-BISI 18, local variety-Tambin and composite variety-Sukumaraga combined with high nitrogen levels (i.e, 138 to 184kg N ha^{-1}) demonstrated higher photosynthetic efficiency (a basic source of assimilates), better dry matter production (a resource necessary for grain filling), and the highest cob circumference (a critical parameter of grain filling), indicating a higher potential number of kernels, which could lead to higher yield, emphasizing the importance of selecting the appropriate combination for specific growing conditions.

3.2 Recommendation

Therefore, it is recommended that maize farmers and agronomists optimize their nitrogen management practices and maize variety selection to maximize grain-filling potential and overall yield. Future research should further explore the interactions between environmental factors and maize varieties to develop comprehensive agronomic practices that ensure sustainable maize production. Additionally, beyond nitrogen management, other agronomic practices such as planting density, irrigation, and pest control should be integrated to create a holistic management plan. The interactions between these factors can significantly influence maize growth and yield.

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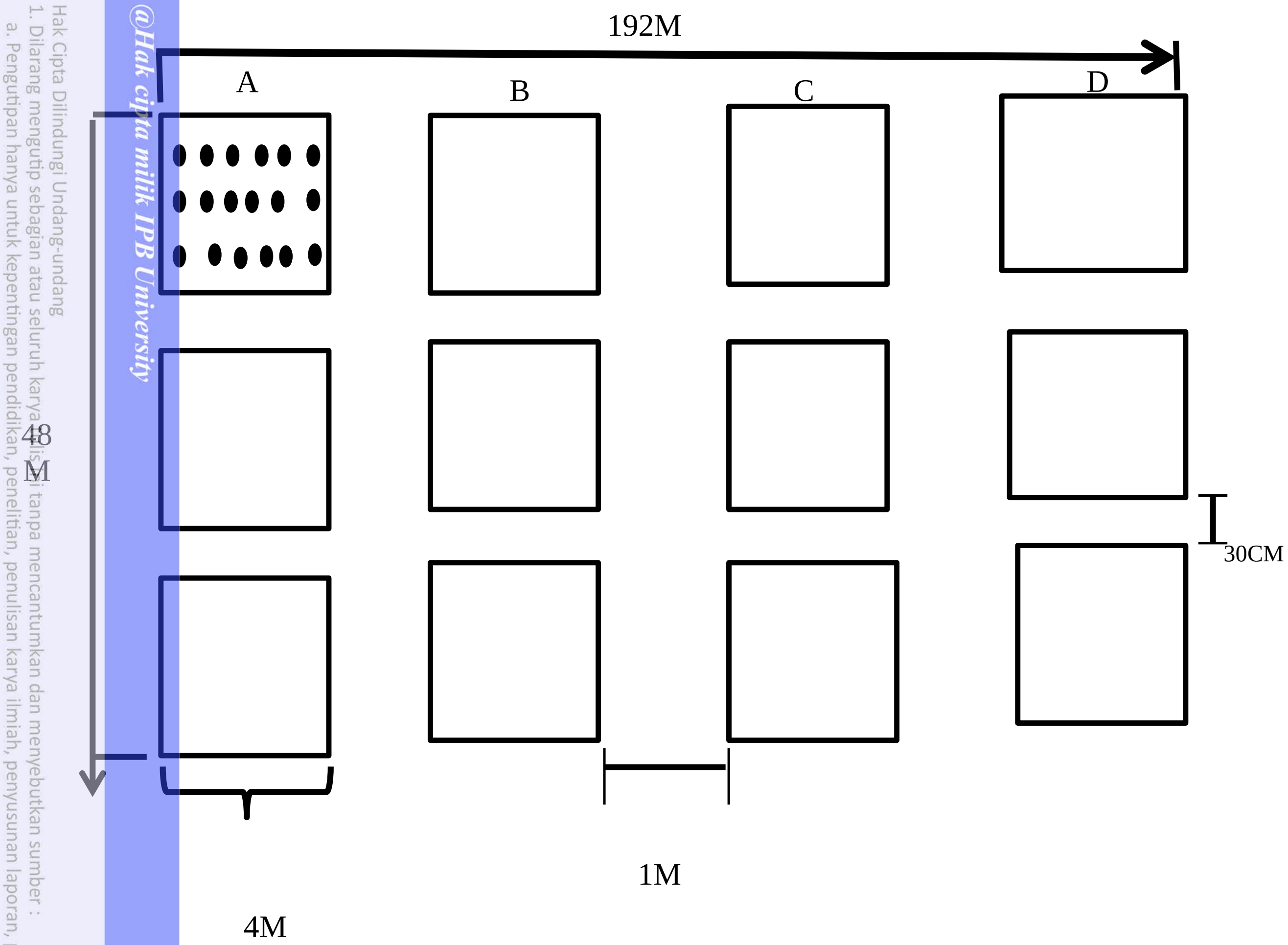
ATTACHMENT

Appendix 1. Randomization of treatments in the experimental field.

REPLICATION1				REPLICATION TWO				REPLICATION 3			
Main-plot 1	Main-plot 2	Main-plot 3	Main-plot 4	Main-plot 1	Main-plot 2	Main-plot 3	Main-plot 4	Main-plot 1	Main-plot 2	Main-plot3	Main-plot4
0 LCH	184 HLC	46 LCH	138 CHL	138 LHC	184 HCL	0 CLH	46 LHC	46 LCH	138 HLC	0 CHL	184 LCH

Appendix 2. Lay –out of the experimental replication



Where, A: Main-plot number 1
B: Main-plot number 2

C: Main-plot number 3

D: Main-plot number 4

Appendix 3. Description of Local Variety (Tambin)

- Origin: East Java (Madura)
- Average plant height: 158.77cm
- Number of leaves: 9.83
- Number of leaves above the ear: 4.27
- Leaf width: 6.40cm
- Leaf length: 71.63cm
- Average height of the ear: 76.77cm
- Ear length: 8.78cm
- Ear diameter : 2.76cm
- Cob diameter : 1.51cm
- 1000grain weight: 230.91g
- Yield per hectare : 3482.00 kg/ha(Amzeri 2009)

Appendix 4. Description of Hybrid Variety (BISI18)

- **Breeders**

Nasib W.W., Putu Darsana, M.H. Wahyudi, and Purwoko

- **Maturity:**

50% silking
- ✓ Low land= 57 days
- ✓ Highlands= 70 days

Physiological maturity
- ✓ Low land= 100 days
- ✓ High land= 125days

- ✓ Stem
  - ✓ Size= large strong and sturdy
  - ✓ Color= Green
  - ✓ Plant height= 230cm
- ✓ Leaves
  - ✓ Size= medium and upright
  - ✓ Color= Dark green
  - ✓ Plant Uniformity= uniform
- Ears

- ✓ Shape: Compact and slightly upright
- ✓ Husk color: Greenish-purple
- ✓ Anther color: Reddish-purple
- ✓ Silk color: Reddish-purple
- ✓ Ear height: Approximately 115 cm
- ✓ Husk cover: Covers the ear adequately

- **Grain**
- ✓ Type: Semi-flint
- ✓ Color: Orange-yellow
- ✓ Number of rows per ear: 14-16 rows
- ✓ 1000 kernel weight: Approximately 303 g
- **Yield**
- ✓ Average yield: 9.1 t/ha of dry shelled corn
- ✓ Potential yield: 12 t/ha of dry shelled corn

- **Suitable Growing Conditions**
- ✓ Suitable for planting in lowlands up to 1000 meters above sea level

- **Roots**

✓ Good

- **Lodging resistance**

✓ Resistant

- **Disease Resistance**

✓ Resistant to leaf rust and leaf spot

Appendix 5. Description of Composite Variety (Sukmaraga)

- **Breeders**

✓ Firdaus Kasim, M. Yasin HG., M. Basir, Wasmo Wakman, Syafruddin, A. Muliadi, Nurtitayani, and Adri

- **Maturity**

✓ 50% silking: Approximately 58 days
✓ Physiological maturity: Approximately 105-110 days

- **Stem**

✓ Structure: Upright
✓ Color: Green
✓ Plant height: Approximately 195 cm (range 180-220 cm)

- **Leaves**

✓ Size: Long and wide
✓ Color: Light green
✓ Plant uniformity: Moderately uniform

- **Roots**

✓ Deep, strong, and well-developed

- **Lodging resistance**

✓ Moderately resistant

- **Ears**

✓ Shape: Semi-compact
✓ Silk color: Purplish-brown
✓ Ear shape: Long cylindrical
✓ Ear height: Approximately 195 cm (90-100 cm)
✓ Husk cover: Well covered (85%)

- **Grain**

✓ Type: Semi-flint
✓ Color: Deep yellow
✓ Row arrangement: Straight and dense
✓ Number of rows per ear: 12-16 rows
✓ 1000 kernel weight: Approximately 270 g

- **Yield**

✓ Average yield: 6.0 t/ha of dry shelled corn
✓ Potential yield: 8.50 t/ha of dry shelled corn

- **Disease Resistance**

Moderately resistant to downy mildew (P. maydis), leaf spot (H. maydis), and leaf rust (Puccinia sp.)

- **Suitable Growing Conditions**

Lowlands up to 800 meters above sea level, adaptive to acidic soils

BIOGRAPH

The author was born in Kasulu District-Kigoma region Tanzania in 12, December1989, the mother of the author is Dafroza Nsanila and Father is Paschal Ngati. The author is the second and last born in the family of two children. The author graduated with Bachelor of Science (B.Sc) in applied agricultural extension from the Department of agricultural extension and community development in the Faculty of Agriculture at Sokoine University of Agriculture in Morogoro region Tanzania, after graduation the author worked one year as assistant section manager at Kagera sugar limited in Misenyi District in Tanzania. The author continued Master's degree in Agronomy and Horticulture offered by the Department of Agronomy and Horticulture in Faculty of Agriculture at IPB University Indonesia under the Indonesian Government Scholarship (KNB).