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Agronomic and Physiological Efficiency of Hybrid Yellow Corn (*Zea mays* L) Varieties to Different Fertilization Rates

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ABSTRACT

Corn (*Zea mays* L.) is a globally significant cereal crop, widely utilized for food, feed, and industrial purposes. In the Philippines, it ranks second to rice in agricultural significance. This vital crop plays a crucial role in sustaining the livelihoods of Filipino farmers. This study aimed to assess the productivity and efficiency of hybrid corn varieties under varying fertilization rates. The experimental design employed a Factorial Randomized Complete Block Design with three replications. Factor A consisted of five fertilizer treatments: control, 120N-90P2O5-60K2O Kg/ha, 60N-90P2O5-60K2O Kg/ha, 180N-90P2O5-60K2O Kg/ha, and 240N-90P2O5-60K2O Kg/ha. Factor B comprises four hybrid varieties: B118G, P3530THR, Dekalb8899S, and NK6505. The study demonstrated significant effects on agronomic and physiological parameters of corn with varying fertilization rates. Statistically, all hybrid varieties exhibited positive responses to the application of N-P-K. Among the hybrids, NK6505 exhibited notable physiological efficiency and yield. Fertilization rates generally demonstrated a positive influence on plant growth, leading to enhanced yield attributes. The combination of 120N-90P_2O_5-60K_2O Kg/ha, combined with NK6505, yielded the highest net return and return on investment (ROI) of 265.20%. Thus, it is recommended that farmers adopt the combination of NK6505 with 120N-90P_2O_5-60K_2O Kg/ha fertilization rate to enhance the economic profitability of hybrid corn production.

Keywords: agronomic, corn, NPK, physiology, yield

INTRODUCTION

Hybrid yellow corn (*Zea mays* L.) is vital in global agriculture. Known for its impressive productivity, nutritional value, and adaptability to various climates, it’s a go-to crop for both human consumption and livestock feed. Over the years, researchers have developed hybrid varieties with better kernel quality, stronger resistance to diseases, and improved resilience to harsh environmental conditions. These advancements have solidified its importance in ensuring food security and supporting livestock production (Baghdadi et al., 2012; Mandić et al., 2018).

As one of the most widely grown cereals worldwide, hybrid yellow corn dominates agricultural landscapes in countries like the United States, China, and Brazil (Fromme et al., 2019). In the Philippines, it holds the position of the second most important cereal crop, coming right after rice. The southern region of Mindanao stands out as a major production area, thanks to its fertile land and favorable weather. For many Filipino farmers, corn farming isn’t just a source of income—it’s a way of life. It also plays a crucial role in the livestock industry, which makes up about 18.23% of the country’s agricultural gross value output (Biñas, 2021; Ortega, 2021).

However, scientific studies have focused heavily on improving the traits of hybrid yellow corn to boost productivity and sustainability. Key areas of interest include optimizing plant growth, enhancing nutrient absorption, building resistance to diseases, and maximizing photosynthesis efficiency (Khan et al., 2015; Fromme et al., 2019). Beyond its biological advantages, hybrid yellow corn also appeals to farmers because of its economic potential. Factors like input costs, market demand, and global trade trends all contribute to its profitability. Despite challenges such as climate change and market fluctuations, it continues to be a dependable choice, helping farmers sustain their livelihoods and support rural economies.

Nitrogen, an essential nutrient for corn growth, plays a critical role in plant health by aiding in chlorophyll production, protein synthesis, and energy transfer (Mandić et al., 2018). However, managing nitrogen levels is a balancing act. Over-application can lead to serious environmental problems, like water pollution and greenhouse gas emissions, making it essential to adopt precise and sustainable practices (Baghdadi et al., 2012; Ortega, 2021).

Thus, this study aimed to evaluate the agronomic and physiological efficiency of four distinct hybrid corn varieties under different fertilization rates. Specifically, the study seeks to: Determine the optimum nitrogen levels on agronomic traits; Evaluate the physiological responses to nitrogen application; Identify the optimal nitrogen application rates for the yield of each corn variety; and evaluate the economic efficiency of the hybrid corn varieties.

MATERIALS AND METHODS

Location and Duration of the Study

This research study was conducted at Claveria, Misamis Oriental (latitude 8°35'52"N, longitude 124°49'21"E), situated at an elevation of 510 meters above sea level. It is conducted through a collaborative project between the University of Science and Technology of Southern Philippines, Claveria Campus, and the ACDI Multipurpose Cooperative (External Funder) via the Center for High Value Crops. The study started from July 2023 to September 2023.

Materials

The study utilized a variety of materials, including a tractor for harrowing and plowing, data sheets for recording observations, and a selection of hybrid corn seeds (B118G, P3530THR, Dekalb8899S, and NK6505). Additionally, labels and tags made from bamboo sticks and tags were used for identification purposes. Other equipment includes a weighing scale for fertilizer preparation, a measuring tape for laying out the study area, a bolo for soil sampling, and a knapsack sprayer for herbicide application.

Methods

Experimental Design and Treatments

This study was laid out using a 5x4 Factorial Randomized Complete Block Design (RCBD), replicated three times. Moreover, five different fertilization rates served as Factor A, namely, F_1 - control, F_2 - 120N-90P_2O_5-60K_2O, F_3 - 60N-90P_2O_5-60K_2O, F_4 - 180N-90P_2O_5-60K_2O, and F_5 - 240N-90P_2O_5-60K_2O. On the other hand, four hybrid yellow corn varieties were utilized as Factor B, namely, B118G, P3530THR, Dekalb8899S, and NK6505.

Experimental Layout

An area of 8,760 m2 was utilized in the study. Within this area, each replication measures a plot size of 25 meters in length and 5 meters in width, a planting distance of 50 cm x 25 cm, 1 meter distance between replications, and 1 meter distance between treatments, respectively.

Soil Sampling

Before commencing the experiment to assess soil properties, a comprehensive soil analysis was conducted, collection of at least ten soil samples from various locations within the study area. These samples underwent thorough analysis to provide valuable insights into the soil characteristics and composition, ensuring a well-informed experimental setup.

Land Preparation

Field cleaning was done ahead of time. The land was plowed using a traditional plow and harrowed to pulverize the soil after the field experienced adequate rainfall. This comprehensive process included three passes of mechanized tractor plowing, complemented by manual plowing, to meticulously prepare the experimental site.

Layout Set-up

The study area was meticulously measured, spanning 79 meters in width by 59 meters in length. Within this designated area, individual plots were delineated, each measuring 25 meters in length by 5 meters in width. Replications were strategically spaced 2 meters apart to ensure statistical independence, with a 1-meter separation between adjacent plots to prevent any potential interference. To facilitate accurate identification and tracking of treatments, labels were prominently installed at each plot.

Planting Procedure

A single seed was carefully sown per hill. Seven days post-sowing, vigilant observation was conducted to identify any gaps or instances of multiple plants per hill. If such instances are observed, a proactive thinning and transplanting process is implemented to ensure optimal spacing and uniform plant distribution, thereby maximizing growth potential and overall experimental integrity.

Fertilizer Application

One week before planting, agricultural lime was applied at a rate of 1.25 tons per hectare to prepare the soil. During sowing, chicken manure was incorporated at 2.4 metric tons per hectare, except in the control plots. Fertilizer treatments were applied in three stages: 20% as a basal application at sowing, 30% at 21 days after sowing (DAS), and the remaining 50% at 30 DAS.

Water Management

This study emphasizes the use of rain-fed irrigation for corn cultivation, with a focus on optimizing and maximizing the utilization of rainfall as the primary water source for crop growth.

Herbicide Application

The application of herbicide was judiciously determined based on the weed population observed within the experimental area. Given the tolerance of the corn varieties to Roundup herbicide, commonly used in Roundup Ready crops, its application is deemed both safe and suitable. This decision reflects a careful consideration of both weed management needs and the specific traits of the corn varieties, ensuring effective and responsible agricultural practices.

Pest Management

To safeguard against pest infestations, proactive measures were taken during the vegetative stage to detect any signs of pest presence. Should destructive pests be identified, targeted pesticide applications were deployed as a responsive intervention. This approach underscores our commitment to vigilant monitoring and swift action to protect crop health and optimize yield potential, ensuring a resilient and sustainable agricultural system.

Sampling Period and Data Gathering

Sampling and data gathering were done based on the following schedules: a two-week interval from 14 DAS to 70 DAS for agronomic and physiological parameters and yield parameters at harvest (120 DAS).

Harvesting

Harvesting was done 120 days post-sowing, employing a mechanized harvester primarily for non-data sampling purposes. In addition, manual harvesting of ten randomly selected samples was meticulously conducted to ensure accurate data collection. This comprehensive approach blends efficiency with precision, allowing for thorough evaluation of crop performance and yield potential.

Data Gathered

A. Agronomic Parameters

1. Plant Height (cm). This was measured by taking the length of the plant from the soil level to the tip of the longest leaf. The data will be gathered at 14, 28, 42, 56, and 70 days after sowing (DAS) with ten randomly selected sample plants.
2. Number of Leaves. The number of leaves was determined by visually counting the fully expanded leaves on the main stem of each plant. This assessment selected ten random plant samples from each plot at intervals of 14, 28, 42, 56, and 70 DAS.
3. Stem Diameter (mm). This was determined by measuring the stem using a vernier caliper. This measurement was conducted on ten randomly selected plant samples in each plot at intervals of 14, 28, 42, 56, and 70 DAS.

B. Physiological Parameters

1. Relative Chlorophyll Content (RCC). Total chlorophyll values were taken from five randomly selected plant samples in every plot using a Minolta Chlorophyll Meter (SPAD-502) at 14, 21, 28, 42, 56, and 70 DAS. The upper, middle, and lower parts of three fully expanded leaves were measured between 5:00 am and 8:00 am and were recorded as the mean of three measurements of each selected individual leaf.
2. Leaf Area Index (LAI). The leaf area index was measured manually by tracing the outline of each leaf using a ruler to calculate the leaf area. The LAI was calculated as the total leaf area per unit of ground area. This was collected at 14, 28, 42, 56, and 70 DAS, respectively.

C. Yield and Yield Components

1. Cob Length (cm). This was gathered by measuring the cob length from the tip of the base up to the top of the cob of the 10 samples in each treatment.
2. Cob Weight (g). The data were gathered by weighing the average of 10 samples in each treatment.
3. Weight of Kernels (g). Measurements were taken from ten samples in each treatment per replication using a weighing scale.
4. Weight of 1000 Kernels (g). Measurements were taken from 1000 grains of every treatment per replication using a weighing scale.
5. Grain Yield (t ha^{-1}). This was taken by weighing the total grain harvested from the plots after shelling and reported as 14% moisture content, with a unit of tons/ha.

D. Cost and Return Analysis

The cost and return analysis was computed based on the actual records of the cost and the gross sales on the prevailing price of corn in the market. The formula for calculating the Return on Investment is as follows:

Statistical Analysis

Statistical analysis was determined using the Analysis of Variance in a 5x4 Factorial in Randomized Complete Block Design (RCBD) for all the parameters obtained, and Tukey’s Test (HSD) at 5 % & 1% was used to test the differences among treatments

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RESULTS AND DISCUSSION

Agronomic Parameters

Plant Height (cm)

Plant height across various hybrid corn varieties showed a highly significant difference in response to different fertilizer applications throughout the growth stages, except at 14 DAS, as presented in Table 1. The data indicate that the control treatment consistently exhibited the lowest plant height at 28 DAS (88.39 cm), 42 DAS (160.69 cm), and 56 DAS (166.96 cm). In contrast, treatments 120N-90P_2O_5-60K_2O, 60N-90P_2O_5-60K_2O, 180N-90P_2O_5-60K_2O, and 240N-90P_2O_5-60K_2O demonstrated statistically similar results, with significantly greater plant heights compared to the control across these time points.

However, at 70 DAS, the trend shifted, with the highest level of nitrogen application of 240N-90P_2O_5-60K_2O resulting in the shortest plant height, measuring 220.03 cm, followed by the control treatment at 235.73 cm. On the other hand, 60N-90P_2O_5-60K_2O recorded the tallest plant height at 255.93 cm. Statistically, 120N-90P_2O_5-60K_2O, 60N-90P_2O_5-60K_2O, and 180N-90P_2O_5-60K_2O demonstrated similar results.

Table 1. Plant height (cm) of agronomic and physiological efficiency of hybrid yellow corn varieties to different fertilization rates

TREATMENTS	PLANT HEIGHT (cm)				
	14 DAS	28 DAS	42 DAS	56 DAS	70 DAS
Fertilizer Application					
F_1– Control	35.25	88.39^{b}	160.69^{b}	166.96^{b}	235.73^{ab}
F_2– 120N-90P_2O_5-60K_2O	36.69	94.96^{ab}	173.28^{a}	188.98^{a}	251.12^{a}
F_3– 60N-90P_2O_5-60K_2O	37.14	99.93^{a}	178.01^{a}	191.29^{a}	255.93^{a}
F_4– 180N-90P_2O_5-60K_2O	37.12	98.87^{a}	177.58^{a}	192.66^{a}	253.64^{a}
F_5– 240N-90P_2O_5-60K_2O	36.23	96.94^{a}	178.20^{a}	190.26^{a}	220.03^{b}
F-test	ns	**	**	**	**
Variety					
V_1 - B118G	37.79^{a}	97.39^{a}	170.47	187.33^{a}	239.78
V_2 - P3530THR	35.21^{b}	95.61^{ab}	176.72	193.45^{a}	245.49
V_3 - Dekalb8899S	36.52^{ab}	98.58^{a}	172.41	190.15^{a}	244.56
V_4 - NK6505	36.43^{ab}	91.69^{ab}	174.61	173.21^{b}	243.32
F-test	*	*	ns	**	ns
Fertilizer Application x Variety					
F-test	ns	ns	ns	ns	ns
CV (%)	6.16	6.63	5.75	7.14	8.29

Means in a column with the same letters are not significantly different at 5% level using Tukey’s test.

** - significant at a level of 1% of probability ($p < 0.01$)

* - significant at a level of 5% of probability ($0.01 =< p < 0.05$)

ns - non-significant ($p >= 0.05$)

DAS - Days After Sowing

These results align with findings from prior research, showing the critical role of balanced fertilizer application in corn growth. Yukui et al. (2012) demonstrated that applying approved nitrogen (N) fertilizer rates optimizes

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plant height and stem perimeter compared to excessive or insufficient N treatment. Similarly, Bakhmanly (2023) found that complex fertilizers combining nitrogen, phosphorus, and potassium (N, P, K) significantly enhance maize plant height, with fertilized variations consistently outperforming unfertilized maize.

Moreover, when assessing various hybrid corn varieties subjected to different nitrogen levels, the data revealed significant differences in plant height at 14, 28, and 56 DAS, while no significant differences were observed at 42 and 70 DAS. At the early growth stage (14 DAS), B118G exhibited the tallest plant height, measuring 37.79 cm, while P3530THR recorded the shortest height at 35.21 cm. However, by 28 DAS, Dekalb8899S achieved the greatest plant height of 98.58 cm, whereas NK6505 was the shortest at 91.69 cm. At 56 DAS, NK6505 again recorded the lowest plant height at 173.21 cm among all varieties.

These findings are consistent with previous studies highlighting the impact of nitrogen-phosphorus-potassium (NPK) fertilization on plant growth and the variability in response across different hybrid corn varieties. Pusparini et al. (2018) and Asghar et al. (2010) reported that increasing NPK doses promote taller plants and higher yields, though the optimal dosages vary depending on the hybrid. Musa et al. (2023) and Awdalla et al. (2018) further emphasized the variability in hybrid performance, noting that some cultivars, such as white single-cross hybrids, respond more favorably to NPK fertilization than others, such as yellow three-way cross hybrids (Awdalla et al., 2018).

Number of Leaves

Table 2 reveals significant statistical differences in leaf count across different fertilizer applications at 28, 42, 56, and 70 DAS. The control treatment consistently recorded the lowest number of leaves, with averages of 7.59 at 28 DAS, 11.22 at 42 DAS, 10.72 at 56 DAS, and 13.50 at 70 DAS. Specifically, 240N-90P2O5-60K2O showed the highest average number of leaves at 8.11 at 28 DAS. Statistically, 120N-90P2O5-60K2O, 60N-90P2O5-60K2O, and 180N-90P2O5-60K2O exhibited the same values at 42, 56, and 70 DAS, to which 120N-90P2O5-60K2O showed the greatest number of leaves.

Additionally, among hybrid corn varieties subjected to different nitrogen levels, no significant effects on leaf count were observed during the early stages (14, 28, and 42 DAS). However, at 56 and 70 DAS, B118G recorded the lowest number of leaves, with 10.70 and 13.75 leaves, respectively, significantly lower than other hybrids. At 56 DAS, P3530THR significantly demonstrated a higher number of leaves than the other hybrids, while at 70 DAS, P3530THR, Deklab8899S, and NK6505 revealed statistically the same values.

Nitrogen impacts the growth as it is a key component of chlorophyll, amino acids, and proteins. Jones et al. (2018) demonstrated that higher nitrogen levels during the vegetative phase enhance leaf output by boosting photosynthetic activity, which supports overall plant vigor. However, excessive nitrogen application can delay maturity and reduce yield efficiency, underscoring the need for balanced nutrient management.

The observed variations in leaf count among treatments align with research on the impact of NPK fertilizers on maize leaf development. Some studies (Pantas Simanjuntak et al., 2021; Yoskader et al., 2023) reported no discernible effect on leaf number, while others (Lolita Dewi Pertaminingsih et al., 2018; Law-Ogbomo & Law-Ogbomo, 2009) found that NPK treatment increased leaf counts. The consistent differences in leaf numbers in this study, especially in fertilized treatments, support the latter findings, highlighting the benefits of optimized NPK application.

Furthermore, these results also align with Wang et al. (2022), who noted that hybrid corn varieties often display enhanced vegetative growth due to genetic traits that promote photosynthesis and leaf production. Efficient nutrient utilization and adaptability to environmental conditions further contribute to increased leaf yield in hybrids. Additionally, studies by Enujeke (2013) confirm that hybrid cultivars exhibit wide variability in growth traits, including leaf number and area, which are closely linked to maturity classification. These findings emphasize the interplay between genetics and nutrient management in optimizing leaf development and overall maize productivity.

Table 2. Number of leaves of agronomic and physiological efficiency of hybrid yellow corn varieties to different fertilization rates

TREATMENTS	NUMBER OF LEAVES				
	14 DAS	28 DAS	42 DAS	56 DAS	70 DAS
Fertilizer Application					
F_1– Control	4.82	7.59^{b}	11.22^{b}	10.72^{b}	13.50^{b}
F_2– $120N\text{-}90P_2O_5\text{-}60K_2O$	4.94	7.82^{ab}	12.55^{a}	11.58^{a}	14.26^{a}
F_3– $60N\text{-}90P_2O_5\text{-}60K_2O$	5.09	8.03^{ab}	12.38^{a}	11.28^{ab}	14.33^{a}
F_4– $180N\text{-}90P_2O_5\text{-}60K_2O$	4.98	8.00^{ab}	12.50^{a}	11.24^{ab}	14.33^{a}
F_5– $240N\text{-}90P_2O_5\text{-}60K_2O$	4.97	8.11^{a}	12.02^{ab}	11.29^{ab}	14.41^{a}
F-test	ns	*	**	**	**
Variety					
V_1 - B118G	5.02	7.94	11.99	10.70^{c}	13.75^{b}
V_2 - P3530THR	5.07	8.03	12.51	12.03^{a}	14.38^{a}
V_3 - Dekalb8899S	4.91	7.85	12.20	11.29^{b}	14.19^{a}
V_4 - NK6505	4.84	7.82	11.84	10.86^{bc}	14.34^{a}
F-test	ns	ns	ns	**	**
Fertilizer Application x Variety					
F-test	ns	ns	ns	ns	ns
CV (%)	5.09	5.31	5.76	4.85	2.34

Means in a column with the same letters are not significantly different at 5% level using Tukey's test.

** - significant at a level of 1% of probability ($p < 0.01$)

* - significant at a level of 5% of probability ($0.01 =< p < 0.05$)

ns - non-significant ($p >= 0.05$)

DAS - Days After Sowing

Stem Diameter (mm)

Stem diameter is an indicator of inter-plant competition and resource allocation, serving as the primary conduit for water and nutrients while facilitating the translocation of photo assimilates. It determines the crop's biological and stalk yield (Ijaz et al., 2015). Table 3 reveals that nitrogen fertilizer application significantly influenced the stem diameter of hybrid corn at 28, 42, and 70 DAS, while no significant differences were observed at 14 and 56 DAS. Treatments without fertilizer consistently recorded the smallest stem diameters, with measurements of 13.27 cm at 28 DAS, 15.22 cm at 42 DAS, and 17.16 cm at 70 DAS. Conversely, $120N\text{-}90P_2O_5\text{-}60K_2O$ and $240N\text{-}90P_2O_5\text{-}60K_2O$ statistically do not differ from each other, which had larger stem diameters compared to other treatments at 42 DAS. However, at 70 DAS, $180N\text{-}90P_2O_5\text{-}60K_2O$ and $240N\text{-}90P_2O_5\text{-}60K_2O$ illustrated similar values and were noted to acquire larger stem diameters.

The results align with findings by Machfud et al. (2019), Simanjuntak et al. (2021), and Afrillah et al. (2023), which demonstrate that NPK application enhances critical growth parameters, including stem diameter, plant height, and cob dimensions. Additionally, Ahmad Raksun et al. (2021) and Law-Ogbomo & Egberanwen et al. (2009) reported that NPK fertilizer treatments consistently resulted in significantly larger stem diameters compared to unfertilized controls.

Moreover, significant differences in stem diameter were observed among hybrid corn varieties at 28 and 56 DAS, with no significant differences at 14, 42, and 70 DAS. B118G consistently recorded the highest stem diameter during the early stage, measuring 17.21 cm at 28 DAS followed by the other varieties, which are statistically similar. At 56 DAS, P3530THR had the largest stem diameter at 19.84 cm, while B118G and NK6505 demonstrated statistically similar results. Additionally, no significant differences were observed in the

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interaction between nitrogen application and hybrid corn varieties, indicating that the effects of nitrogen and hybrid traits operate independently.

Table 3. Stem diameter (cm) of agronomic and physiological efficiency of hybrid yellow corn varieties to different fertilization rates

TREATMENTS	STEM DIAMETER (mm)				
	14 DAS	28 DAS	42 DAS	56 DAS	70 DAS
Fertilizer Application					
F_1– Control	4.91	13.27^{b}	15.22^{b}	18.77	17.16^{b}
F_2– 120N-90P_2O_5-60K_2O	5.17	15.82^{a}	16.93^{a}	18.98	18.51^{ab}
F_3– 60N-90P_2O_5-60K_2O	5.42	15.99^{a}	16.26^{ab}	19.00	18.63^{ab}
F_4– 180N-90P_2O_5-60K_2O	5.15	16.48^{a}	16.09^{ab}	18.40	18.68^{a}
F_5– 240N-90P_2O_5-60K_2O	5.04	15.30^{ab}	16.97^{a}	18.97	18.99^{a}
F-test	ns	**	**	ns	*
Variety					
V_1 - B118G	5.52	17.21^{a}	16.36	18.54^{ab}	18.16
V_2 - P3530THR	5.11	14.65^{b}	16.64	19.84^{a}	18.77
V_3 - Dekalb8899S	4.84	15.37^{b}	15.91	18.05^{b}	18.31
V_4 - NK6505	5.09	14.27^{b}	16.26	18.87^{ab}	18.33
F-test	ns	**	ns	*	ns
Fertilizer Application x Variety					
F-test	ns	ns	ns	ns	ns
CV (%)	13.15	11.35	6.62	9.64	6.96

Means in a column with the same letters are not significantly different at 5% level using Tukey's test.

** - significant at a level of 1% of probability ($p < 0.01$)

* - significant at a level of 5% of probability ($0.01 =< p < 0.05$)

ns - non-significant ($p >= 0.05$)

DAS - Days After Sowing

The results align with findings from Pusparini et al. (2018) and Syafruddin et al. (2012), which highlight that corn hybrids exhibit varied growth responses to fertilizer treatments, with some hybrids showing superior performance under optimal nutrient management. Furthermore, Hasan et al. (2020) and Simanjuntak et al. (2021) demonstrated that NPK fertilizers significantly enhance growth parameters, including stem diameter. This study's observation that nitrogen application influences stem growth but does not interact significantly with hybrid variety supports previous findings emphasizing the independent role of hybrid genetics and nutrient application in corn development.

Physiological Parameters

Relative Chlorophyll Content

Using a chlorophyll meter (SPAD) is a valuable tool for farmers, enabling them to assess crop performance before nitrogen fertilization. This device offers a quick and efficient method for detecting the nutritional status of plants, serving as an effective alternative to traditional methods (Segatto et al., 2017). The relative chlorophyll content of hybrid corn subjected to varying levels of nitrogen shows significant differences among fertilizer applications at 14 DAS and 56 DAS, while no significant effects are observed at 28, 42, and 70 DAS, as shown in Table 4.

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At 14 DAS, data revealed that the control treatment exhibited a significantly lower relative chlorophyll content (35.0) compared to other treatments. In contrast, 60N-90P2O5-60K2O and 180N-90P2O5-60K2O demonstrated higher values of 37.81 and 37.88, respectively. Similarly, at 56 DAS, the control treatment recorded the lowest RCC (40.48), continuing the trend observed at the earlier stage. These findings align with Horváth et al. (2019) and Hurtado et al. (2011), who reported that nitrogen fertilizer enhances chlorophyll levels, particularly during early and mid-growth stages. Moreover, Zhang et al. (2023) documented that hybrid maize treated with higher nitrogen dosages exhibited significantly higher chlorophyll levels than untreated controls, a trend also observed in this study. At 56 DAS, the treatments 120N-90P2O5-60K2O, 60N-90P2O5-60K2O, 180N-90P2O5-60K2O, and 240N-90P2O5-60K2O statistically do not differ from each other, which exhibited high readings of RCC.

Additionally, the data also showed significant differences among hybrid corn varieties at 14, 42, 56, and 70 DAS. At 14 DAS, NK6505 recorded the highest relative chlorophyll content among other varieties. At 42 DAS, the data shifted, with Dekalb8899S measuring 49.51, the highest among the varieties. At 70 DAS, P3530THR significantly obtained the highest relative chlorophyll content, while B118G, with 36.02, similar to Dekalb8899S at 38.18, recorded the lowest relative chlorophyll content.

Table 4. Relative chlorophyll content of agronomic and physiological efficiency of hybrid yellow corn varieties to different fertilization rates

TREATMENTS	RELATIVE CHLOROPHYLL CONTENT				
	14 DAS	28 DAS	42 DAS	56 DAS	70 DAS
Fertilizer Application					
F_1– Control	35.08^{b}	35.91	47.08	40.48^{b}	36.79
F_2– 120N-90P_2O_5-60K_2O	36.76^{ab}	37.79	47.46	46.40^{a}	38.91
F_3– 60N-90P_2O_5-60K_2O	37.81^{a}	37.98	47.18	47.08^{a}	39.18
F_4– 180N-90P_2O_5-60K_2O	37.88^{a}	38.25	47.48	46.45^{a}	38.88
F_5– 240N-90P_2O_5-60K_2O	37.48^{ab}	39.15	47.99	49.08^{a}	40.79
F-test	*	ns	ns	**	ns
Variety					
V_1 - B118G	35.30^{b}	36.46	46.76^{b}	43.51^{b}	36.02^{b}
V_2 - P3530THR	36.38^{b}	38.58	47.02^{b}	47.09^{ab}	42.64^{a}
V_3 - Dekalb8899S	37.33^{ab}	38.75	49.51^{a}	49.31^{a}	38.18^{b}
V_4 - NK6505	38.99^{a}	37.46	46.44^{b}	43.69^{b}	38.80^{ab}
F-test	**	ns	**	**	**
Fertilizer Application x Variety					
F-test	ns	ns	**	ns	**
CV (%)	5.92	9.47	3.81	9.20	10.67

Means in a column with the same letters are not significantly different at 5% level using Tukey's test.

** - significant at a level of 1% of probability ($p < 0.01$)

* - significant at a level of 5% of probability ($0.01 =< p < 0.05$)

ns - non-significant ($p >= 0.05$)

DAS - Days After Sowing

Wang et al., (2022) discovered that hybrid maize cultivars had greater chlorophyll content under balanced NPK fertilizer applications, particularly during critical vegetative stages. The study found that hybrids have a larger yield potential and are therefore more responsive to fertilizer control, which aligns with the results observed in this study. The variation in chlorophyll content among the hybrid varieties supports the notion that hybrid maize cultivars can exhibit distinct responses to nutrient availability, with certain varieties, like NK6505 and Dekalb8899S, showing better chlorophyll development under the given treatments. This supports the findings of Wang et al. (2022), as the hybrid varieties demonstrated different chlorophyll responses based on their growth stages and nutrient treatments.

Moreover, among the hybrid corn applied with different nitrogen levels, the data show a highly significant difference during 42 and 70 DAS, as illustrated in Figure 1. At 42 DAS, the interactions between the combinations of 120N-90P2O5-60K2O and 60N-90P2O5-60K2O and all the hybrid varieties statistically exhibited similar values. However, at 70 DAS, it has been statistically noted that combinations 240N-90P2O5-60K2O and P3530THR, 180N-90P2O5-60K2O:NK6505, 120N-90P2O5-60K2O:B118G, and 120N-90P2O5-60K2ODeklab8899S) revealed almost similar RCC readings.

These findings align with Pusparini et al. (2018), who noted that NPK application often enhances chlorophyll content and production in corn. The observed increase in RCC with higher nitrogen rates also corresponds to the findings of Akram (2014), who reported that nitrogen application improves chlorophyll pigments and yield components in maize hybrids. Furthermore, the variability in responses among hybrids supports the conclusions of Linders et al. (2024), which highlighted the role of genotype-by-environment interactions in shaping chlorophyll content and crop performance.

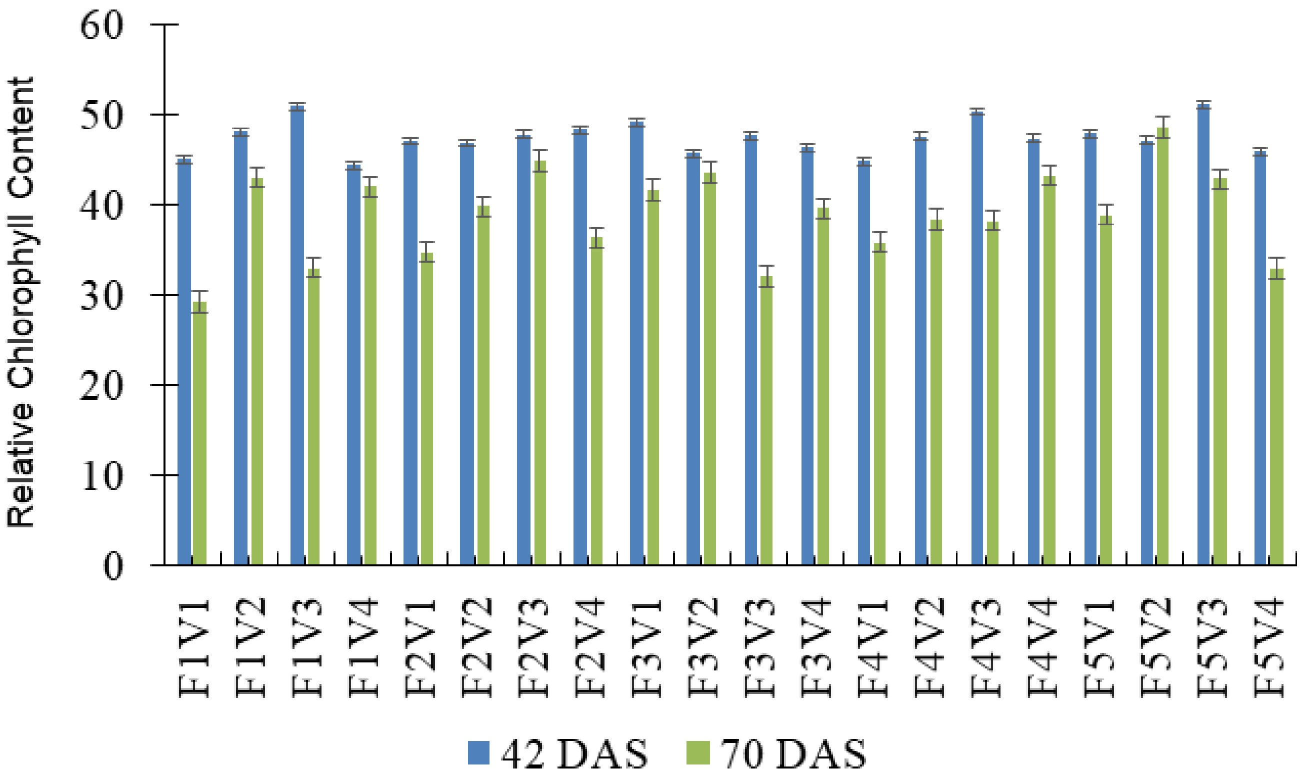

Figure 1. Relative chlorophyll content at 42 and 70 DAS of agronomic and physiological efficiency of hybrid yellow corn varieties to different fertilization rates.

Leaf Area Index

The analysis of variance on the leaf area index (LAI) at different nitrogen application levels revealed no significant differences among treatments at 14, 28, 42, and 56 DAS. However, a highly significant difference was observed at 70 DAS. Among the treatments, hybrid corn applied with 120N-90P2O5-60K2O recorded the highest LAI at 9.17. In contrast, the application of 180N-90P2O5-60K2O resulted in a LAI of 7.33, which was statistically similar to the control treatment (7.66), the lowest recorded value. These results are summarized in Table 5.

Nitrogen application has been widely reported to enhance LAI and yield. A positive relationship between LAI and grain yield has also been documented. This study's findings align with those of Berdjour et al. (2020), who reported that the application of NPK fertilizers had a significant impact on LAI, leaf area, and leaf number in maize grown in the Guinea Savanna. Their research also highlighted a positive correlation between LAI and grain yield, emphasizing the critical role of nitrogen in improving crop productivity.

Moreover, 120N-90P2O5-60K2O acquired higher chlorophyll content at 70 DAS which resulted in greater leaf area. Chlorophyll content and leaf area play a crucial role in regulating water, energy, and carbon exchange during photosynthesis (Mustafa et al., 2024). According to Yang et al. (2022), the chlorophyll content in a plant's leaves can reflect the overall photosynthetic productivity of the population.

Table 5. Leaf area index of agronomic and physiological efficiency of hybrid yellow corn varieties to different fertilization rates

TREATMENTS	LEAF AREA INDEX				
	14 DAS	28 DAS	42 DAS	56 DAS	70 DAS
Fertilization Rates (N-P-K)					
F_1– Control	0.46	1.55	5.63	6.70	7.66^{b}
F_2– 120N-90P_2O_5-60K_2O	0.46	1.68	6.40	7.00	9.17^{a}
F_3– 60N-90P_2O_5-60K_2O	0.47	1.55	5.87	6.95	7.90^{ab}
F_4– 180N-90P_2O_5-60K_2O	0.45	1.62	5.67	7.27	7.33^{b}
F_5– 240N-90P_2O_5-60K_2O	0.51	1.50	6.23	7.14	8.33^{ab}
F-test	ns	ns	ns	ns	**
Variety					
V_1 - B118G	0.53^{a}	1.60	5.34^{b}	7.09	6.80^{b}
V_2 - P3530THR	0.46^{ab}	1.61	5.90^{ab}	7.00	8.02^{a}
V_3 - Dekalb8899S	0.42^{b}	1.61	6.28^{a}	7.20	8.59^{a}
V_4 - NK6505	0.47^{ab}	1.50	6.32^{a}	6.75	8.90^{a}
F-test	**	ns	**	ns	**
Fertilization Rates x Variety					
F-test	ns	ns	*	ns	**
CV (%)	16.03	19.85	13.36	12.31	13.98

Means in a column with the same letters are not significantly different at 5% level using Tukey's test.

** - significant at a level of 1% of probability ($p < 0.01$)

* - significant at a level of 5% of probability (0.01 =< p < 0.05)

ns - non-significant ($p >= 0.05$)

DAS - Days After Sowing

Additionally, significant effects among hybrid corn varieties were observed at specific growth stages, notably at 14, 42, and 70 DAS. At 14 DAS, B118G exhibited the highest LAI value among the varieties, measuring 0.53, while P3530THR recorded the lowest value at 0.46. Additionally, at 42 and 70 DAS, NK6505 achieved the highest LAI values, reaching 8.90 at 70 DAS. Similarly, nitrogen fertilization further enhances LAI in hybrids, with varying responses observed among different hybrid varieties (Szabó et al., 2022). The relationship between LAI and productivity is well-established; greenery index values at flowering are strongly correlated with grain yield (Castellanos-Reyes et al., 2017).

Moreover, significant interactions between different fertilization rates and hybrid corn varieties were observed at 42 and 70 DAS. Among all combinations, 60N-90P2O5-60K2O and NK6505 achieved the highest LAI value, reaching 10.15 at 70 DAS. However, other combinations revealed statistically similar results to the combination; these combinations can be found in F2, F3, F4, and F5 and selected hybrid varieties, as shown in

Figure 2. Studies on hybrid corn varieties and NPK fertilizer interactions have demonstrated varying effects on growth. Nitrogen levels significantly influenced the leaf area index in hybrid corn, with some varieties responding more effectively to fertilizer treatments (Szabó et al., 2022). Similarly, Musa et al. (2023) reported that the combination of NPK fertilizer at 200:150:100 kg/ha and the Pioneer variety resulted in the highest yield of 11.81 t/ha.

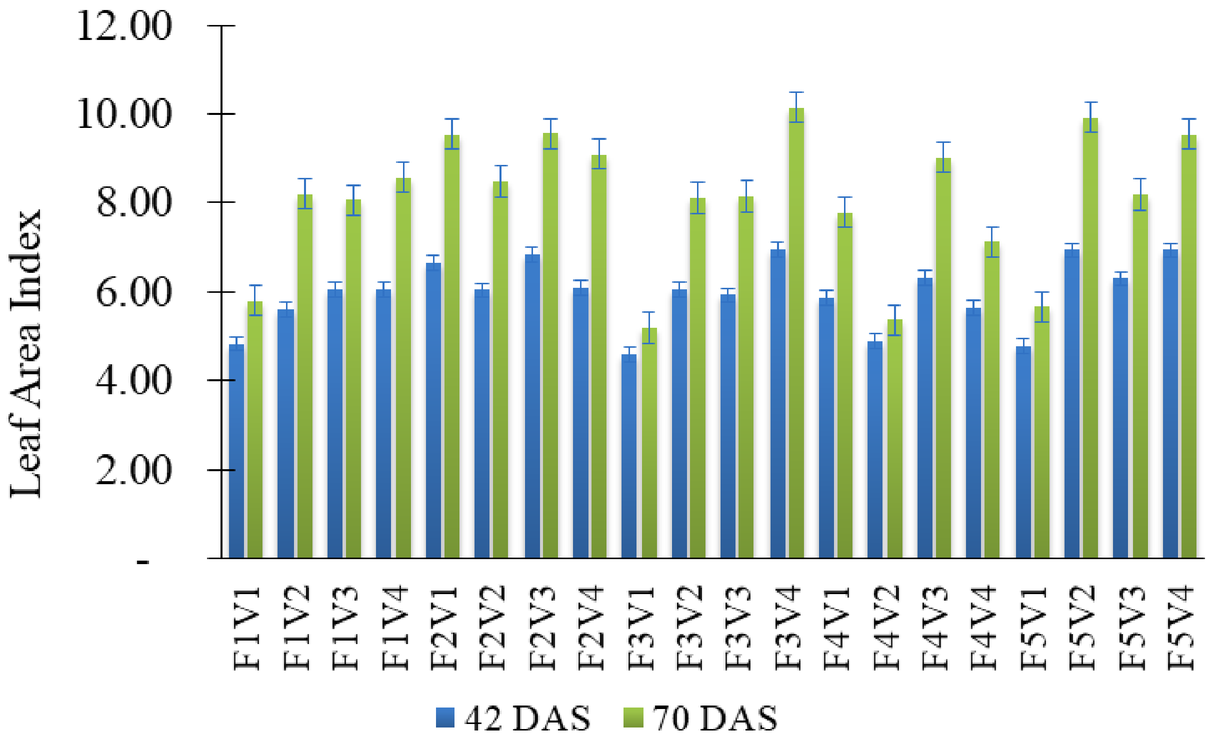

Figure 2. Leaf area index at 42 and 70 DAS of agronomic and physiological efficiency of hybrid yellow corn varieties to different fertilization rates.

Yield and Yield Components

Cob Length (cm)

Statistical analysis revealed significant differences in cob length among hybrid corn varieties and fertilizer applications, as shown in Table 6. Fertilizer treatments 240N-90P2O5-60K2O, 60N-90P2O5-60K2O, 180N-90P2O5-60K2O, and 120N-90P2O5-60K2O resulted in statistically similar values, which demonstrated the longest cobs. Among the hybrid corn varieties, NK6505 exhibited superior cob length (18.36 cm), while P3530THR recorded the shortest cob length (16.25 cm). Furthermore, the interaction of 240N-90P2O5-60K2O combined with NK6505 achieved the highest cob length (19.45 cm), whereas control: P3530THR recorded the lowest cob length (14.86 cm). Statistically, several treatment combinations revealed similar results.

These results align with findings from Law-Ogbomo and Law-Ogbomo (2009) and Zapałowska and Jarecki (2024), which reported that NPK fertilization significantly enhances cob length, grain yield, and other yield components in maize. Zapałowska and Jarecki (2024) highlighted that mineral NPK fertilization outperforms organic fertilizers in improving cob length, grains per cob, and thousand-grain weight. Additionally, Thakur et al. (2009) demonstrated that NPK application considerably increases cob length, diameter, and grain production, consistent with the positive impact of NPK fertilizer in this study.

In terms of hybrid variety performance, the findings partially align with Azam et al. (2007), who reported that Pioneer hybrids produced the longest cobs and highest grain output. However, in this study, NK6505 outperformed P3530THR in cob length, contrasting with Azam et al.'s observations of superior performance by specific Pioneer hybrids. Additionally, the study confirms Zarei et al.'s (2012) findings that cob length and yield components, such as grain weight and kernel number, significantly influence grain yield.

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Table 6. Cob length (cm), cob weight (g), dry weight (1000 grains) and grain yield of agronomic and physiological efficiency of hybrid yellow corn varieties to different fertilization rates

TREATMENTS	COB LENGTH (cm)	COB WEIGHT (g)	DRY WEIGHT 1000 GRAINS (g)	GRAIN YIELD (t ha^{-1})
Fertilizer Application				
F_1– Control	16.00^{b}	168.91^{c}	225.33	6.95^{b}
F_2– $120N-90P_2O_5-60K_2O$	17.31^{a}	201.16^{bc}	235.91	9.72^{a}
F_3– $60N-90P_2O_5-60K_2O$	17.55^{a}	205.58^{bc}	236.58	9.71^{a}
F_4– $180N-90P_2O_5-60K_2O$	17.35^{a}	234.16^{ab}	253.41	9.78^{a}
F_5– $240N-90P_2O_5-60K_2O$	18.09^{a}	246.25^{a}	237.25	9.97^{a}
F-test	**	**	ns	**
Variety				
V_1 - B118G	17.24^{b}	177.06^{b}	238.00	8.12^{b}
V_2 - P3530THR	16.25^{c}	199.40^{b}	230.26	9.41^{a}
V_3 - Dekalb8899S	17.18^{bc}	190.20^{b}	234.40	9.52^{a}
V_4 - NK6505	18.36^{a}	278.20^{a}	248.13	9.85^{a}
F-test	**	**	ns	**
Fertilizer Application x Variety				
F_1V_1	16.21^{aAB}	154.00^{aA}	227.66	6.61^{bA}
F_1V_2	14.86^{aB}	151.00^{bA}	217.33	6.90^{cA}
F_1V_3	15.73^{bAB}	148.66^{aA}	220.00	7.07^{bA}
F_1V_4	17.21^{aA}	222.00^{bA}	236.33	7.19^{bA}
F_2V_1	17.00^{aA}	149.00^{aB}	241.33	8.19^{aC}
F_2V_2	16.61^{aA}	200.00^{abAB}	226.66	9.66^{bB}
F_2V_3	17.08^{abA}	207.00^{aAB}	237.66	9.99^{aAB}
F_2V_4	18.47^{aA}	248.66^{bA}	238.00	11.04^{aA}
F_3V_1	18.04^{aA}	216.33^{aA}	253.33	9.13^{aA}
F_3V_2	16.61^{aA}	185.00^{bA}	214.66	9.77^{bA}
F_3V_3	17.08^{abA}	209.33^{aA}	223.66	9.91^{aA}
F_3V_4	18.47^{aA}	211.66^{bA}	254.66	10.00^{aA}
F_4V_1	17.26^{aAB}	182.00^{aB}	244.66	8.23^{aC}
F_4V_2	16.24^{aB}	186.33^{bB}	244.00	9.64^{bB}
F_4V_3	17.53^{abAB}	217.00^{aB}	258.33	10.16^{aAB}
F_4V_4	18.39^{aA}	351.33^{aA}	266.66	11.09^{aA}
F_5V_1	17.68^{aAB}	184.00^{aC}	223.00	8.43^{aC}
F_5V_2	17.10^{aB}	247.66^{aB}	248.66	11.10^{aA}
F_5V_3	18.13^{aAB}	169.00^{aC}	232.33	10.47^{aAb}
F_5V_4	19.45^{aA}	357.33^{aA}	245.00	9.91^{aB}
F-test	*	**	ns	**
CV (%)	5.60	16.42	11.52	5.52

Means in a column with the same letters are not significantly different at 5% level using Tukey's test.

** - significant at a level of 1% of probability ($p < 0.01$)

* - significant at a level of 5% of probability ($0.01 =< p < 0.05$)

ns - non-significant ($p >= 0.05$)

DAS - Days After Sowing

Cob Weight (g)

The cob weight of different hybrid corn varieties applied with varying levels of nitrogen showed highly significant differences among fertilizer treatments, hybrid varieties, and their interactions, as presented in

Table 6. The data revealed a trend similar to that observed in cob length. Control treatment recorded the lowest cob weight at 168.91 g, while the application of 240N-90P_2O5-60K_2O resulted in the highest cob weight at 246.25 g.

Among the hybrid varieties, NK6505 exhibited the highest cob weight, measuring 278.20 g, outperforming other varieties. Furthermore, the interaction of 240N-90P2O5-60K2O:NK6505 achieved a significantly higher cob weight of 357.33 g, indicating the combined effect of optimal fertilizer application and superior hybrid variety selection, but statistically, there are other combinations demonstrated similar values to 240N-90P2O5-60K2O: NK6505, as shown in Table 6.

Dry Weight of 1000 Grains (g)

The dry weight of 1000 grains of hybrid corn applied with varying nitrogen levels showed no significant effect between fertilizer treatments or their interactions, as presented in Table 6.

While some studies have reported significant effects of fertilizer treatments on growth indices and yield components (Khan, 2022; Pusparini et al., 2018; Kandil, 2013; Awdalla et al., 2018), the findings on 1000-grain weight have been inconsistent. For example, Khan (2022) found that while tillage methods and fertilizer levels did not significantly interact for most growth indices, they did influence 1000-grain weight. This contrasts with the current study, which found no significant effect. Similarly, Kandil (2013) observed that increased nitrogen levels produced the highest 1000-grain weight, aligning partially with Pusparini et al. (2018), who reported that 300 kg/ha of NPK fertilizer optimized hybrid corn growth and production.

In contrast, Awdalla et al. (2018) found that NPK levels and hybrid cultivars did not affect 100-grain weight, a result that aligns with the findings of this study, suggesting that the impact of NPK fertilization on grain weight may vary based on hybrid type, soil conditions, and agronomic practices. Additionally, Pusparini et al. (2018) noted that different hybrid varieties respond variably to fertilizer application, with some hybrids outperforming others in yield, supporting the idea that hybrid-specific responses may explain the lack of uniform effects on 1000-grain weight.

Grain Yield (t ha-^{1})

The grain yield of hybrid corn applied with varying levels of nitrogen fertilization showed highly significant differences, as presented in Table 6. The data revealed that all fertilizer treatments, regardless of nitrogen levels, produced statistically similar grain yields, except for the control treatment, which had the lowest yield at 6.95 t ha^{-1}.

Among the hybrid corn varieties, NK6505 recorded the highest grain yield at 9.85 t ha^{-1}, followed closely by Dekalb 8899S with 9.52 t ha^1 and P3530THR with 9.41 t ha^{-1}. In contrast, B118G produced the lowest yield among the varieties, at 8.12 t ha^{-1}. The interaction between fertilizer application and hybrid corn varieties also showed highly significant differences. Statistically, the combinations of 120N-90P2O5-60K2O x NK6505, 60N-90P2O5-60K2O x B118G, 60N-90P2O5-60K2O x Dekalb8899S, 60N-90P2O5-60K2O x NK6505, 180N-90P2O5-60K2O x NK6505, and 240N-90P2O5-60K2O x P3530THR demonstrated similar results, thus, these combinations achieved higher grain yields compared to other combinations. The control x B118G recorded the lowest grain yield, at 6.61 t ha^{-1}.

These findings are supported by Tamang et al. (2024), who reported that increasing nitrogen levels can enhance grain yield up to a certain threshold, beyond which yields may plateau or even decline. Additionally, Adhikary and Adhikary (2013) found that higher nitrogen doses in acidic soils can result in maximum grain yields, underscoring the importance of soil conditions in determining nitrogen response.

Similarly, Miao et al. (2007) highlighted that variable-rate nitrogen application can improve yields for certain hybrids compared to uniform-rate application, though hybrid selection plays a critical role in optimizing both yield and grain quality. This aligns with Adhikary and Adhikary's (2013) findings that optimal nitrogen rates depend on soil conditions, emphasizing the need for tailored fertilizer management strategies to maximize hybrid corn yield.

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Cost and Return Analysis

Return on Investment (%)

Return on investment is a crucial economic metric that compares the financial advantages to the related costs to assess how profitable agricultural techniques are. To evaluate the financial effectiveness of various treatments, ROI was examined in this study, presented in Table 7. The findings showed a highly substantial impact, highlighting how important cost-effective measures are to optimizing profitability. These results offer important new information about how to best allocate resources for agricultural output that is both sustainable and profitable.

The cost of production was computed based on the prevailing price of hybrid corn seeds, labor costs from land preparation, planting, maintenance, and harvesting, per unit area. The data shows that the treatment combination of 240N-90P_2O_5-60K_2O and Dekalb8899S incurred the highest total production costs at approximately Php90, 215 per hectare, while control and P3530THR recorded the lowest expenses at approximately Php50,933.30.

Table 7. Return on investment of 1-ha production of agronomic and physiological efficiency of hybrid yellow corn varieties to different fertilization rates

	TOTAL PRODUCTION COST (PhP)	GROSS SALES @PhP 25.00 kg^{-1}	NET INCOME (PhP)	ROI (%)
Fertilizer x Variety				
F_1V_1	51,066.66	165,430.72	114,364.06	223.95^{aA}
F_1V_2	50,933.30	172,747.85	121,814.55	239.16^{abA}
F_1V_3	52,850.00	176,989.66	124,139.66	234.89^{abA}
F_1V_4	52,700.00	179,958.93	127,258.93	241.48^{aA}
F_2V_1	76,187.66	212,832.98	136,645.32	179.35^{bC}
F_2V_2	76,054.30	249,630.71	173,576.41	228.23^{abB}
F_2V_3	77,971.00	257,796.21	179,825.21	230.63^{abAB}
F_2V_4	77,821.00	284,201.49	206,380.49	265.20^{aA}
F_3V_1	71,276.66	236,375.05	165,098.39	231.63^{aA}
F_3V_2	71,143.30	252,281.85	181,138.55	254.61^{aA}
F_3V_3	73,060.00	255,887.39	182,827.39	250.24^{aA}
F_3V_4	72,910.00	258,750.61	185,840.61	254.89^{aA}
F_4V_1	78,632.16	213,787.39	135,155.23	171.88^{bC}
F_4V_2	78,498.80	248,994.44	170,495.64	217.20^{bB}
F_4V_3	80,415.50	262,038.02	181,622.52	225.86^{abAB}
F_4V_4	80,265.50	285,367.99	205,102.49	255.53^{aA}
F_5V_1	88,431.66	218,771.52	130,339.86	147.39^{bC}
F_5V_2	88,298.30	285,474.04	197,175.74	223.31^{abA}
F_5V_3	90,215.00	269,779.33	179,564.33	199.04^{bAB}
F_5V_4	90,065.00	255,781.34	165,716.34	184.00^{bB}
F-test				**
CV (%)				7.17

Means in a column with the same letters are not significantly different at 5% level using Tukey's test.

** - significant at a level of 1% of probability ($p < 0.01$)

* - significant at a level of 5% of probability (0.01 =< p < 0.05)

ns - non-significant ($p >= 0.05$)

DAS - Days After Sowing

Moreover, $240N-90P_2O_5-60K_2O$ and P3530THR combination produced the highest gross sales at 285,474.04. In contrast, the highest net return was gained by the combination $120N-90P_2O_5-60K_2O$:NK6505, which also yielded the highest ROI of 265.20%. Lower ROIs indicate less profitability relative to investment, stressing the importance of strategic decision-making in agricultural management. It has been noted that $240N-90P_2O_5-60K_2O$: P3530THR and $120N-90P_2O_5-60K_2O$:NK6505 varied in the total production cost. The combination of $120N-90P_2O_5-60K_2O$:NK6505 acquired a lower production cost compared to $240N-90P_2O_5-60K_2O$:P3530THR, which resulted in $120N-90P_2O_5-60K_2O$:NK6505 acquiring the highest ROI.

These findings give useful insights for farmers and stakeholders, assisting them in improving production techniques to increase profitability and achieve long-term economic returns in maize cultivation. Farmers can dramatically enhance their ROI and overall financial outcomes by selecting the best fertilizer application and hybrid variety combinations.

CONCLUSION

This study aimed to evaluate the agronomic and physiological efficiency of four distinct hybrid corn varieties under varying nitrogen fertilization rates. This research study was conducted at Claveria, Misamis Oriental. Data revealed that the application of varying nitrogen levels significantly influenced the agronomic traits of hybrid corn, including plant height, number of leaves, and stem diameter. Physiological responses, particularly Relative Chlorophyll Content (RCC) and Leaf Area Index (LAI), also varied significantly among hybrids and nitrogen treatments. The combination of $120N-90P_2O_5-60K_2O$ and NK6505 showed superior performance, achieving the highest RCC, LAI, cob length, cob weight, and grain yield. This combination also resulted in the highest return on investment at 265.20%. Based on these findings, the $120N-90P_2O_5-60K_2O$: NK6505 combination is recommended to optimize grain yield and profitability, making it a suitable option for improving economic outcomes and production efficiency in hybrid corn cultivation.

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