JUATIKA
JURNAL AGRONOMI TANAMAN TROPIKA
VOL. 8 No. 1 January 2026

DOI :https://doi.org/10.36378/juatika.v8i1.5175
eissn 2656-1727
pissn 2684-785X
pages : 119 – 124

RESEARCH ARTICLE Open Access

Impact of Foliar Fertilizer Application on Three Genotypes Corn (*Zea mays*) Nutrient Efficient in Tidal Lands

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Abstract

Corn is a strategic food commodity with increasing demand, necessitating enhanced production through optimized fertilization, especially in marginal lands such as tidal areas. This study aims to evaluate the effect of foliar fertilizer application on three corn genotypes and its impact on nitrogen fertilizer use efficiency in tidal lands. A split-plot design with three factors was employed: the first factor was corn genotype; the second factor was urea fertilizer dose (0 kg, 255 kg, and 310 kg per hectare); and the third factor was foliar fertilizer treatment, which included no spraying (control), spraying on the 30th day, the 45th day, both the 30th and 45th days, the 60th day, the 75th day, and both the 60th and 75th days. Each treatment was replicated three times. The results indicated that applying 300 kg of urea fertilizer per hectare, combined with foliar fertilizer, positively influenced the growth of the G3 corn genotype and resulted in a high yield in tidal lands. This treatment produced 7.44 tons of corn per hectare, a significant increase compared to other treatments, making it an efficient strategy for enhancing corn productivity in tidal areas. It is recommended that farmers in tidal regions use a combination of 300 kg urea per hectare and foliar fertilizer applications to optimize corn yields.

Keywords: Crop Productivity, Fertilization Optimization, Marginal Land, Nitrogen Fertilization, Superior Varieties

1. Introduction

Corn is a vital commodity that plays a strategic role in meeting food needs, second only to rice. In addition to human consumption, corn is widely used as animal feed, particularly for poultry. Consequently, the demand for corn is substantial. Without increased production, Indonesia will need to import large quantities of corn (Logrieco et al., 2021). In 2016, Indonesia's corn demand totaled 21,417,035 tons, including 404,458 tons for direct human consumption and 16,180,000 tons for animal feed. Therefore, boosting domestic corn production is essential.

Utilizing 20.1 million hectares of tidal land in Indonesia—of which 9.53 million hectares have the potential to be developed as agricultural land—can increase corn production. Approximately 65,000 transmigrant families live and farm on tidal land covering more than 1.3 million hectares in South Sumatra, of which 320,673 hectares (24.7%) have been reclaimed, including 278,000 hectares (32.4%) (Sahuri et al., 2023). Approximately 899,877 hectares of land are used for corn production, comprising 205,705 hectares of intensification land and 159,444 hectares of extensification land.

The primary challenges in tidal flats include excess water, high salinity, and relatively low pH and nutrient levels. One effective solution is the application of ameliorants combined with high fertilizer doses to enhance soil fertility and boost corn production. Ameliorants such as organic fertilizers, manure, and agricultural lime are known to increase soil pH (Haitami et al., 2024). Scientific studies indicate that spikes in fertilizer prices and limited supply can reduce fertilizer usage and negatively affect agricultural production.

However, this approach becomes less effective when fertilizer prices are high or availability is limited when farmers need them. Using hybrid corn cultivars or national corn varieties with high yield potential is one solution. However, farmers sometimes find it difficult to meet the large amounts of chemical fertilizer required by these varieties.

To address these issues, developing nutrient-efficient

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corn genotypes is a strategic alternative. The use of nutrient-efficient corn varieties is a strategic alternative. which still has high yield potential even though it receives only low doses of chemical fertilizer, is the right solution (Panhwar et al., 2019). Fertilizer needs can be reduced by developing corn genotypes that are efficient in nutrient use and adaptable to low-input conditions, making them suitable for small-scale farmers with limited capital. Corn genotypes with high nitrogen and nutrient use efficiency can maintain good yields at lower fertilizer levels than other genotypes, demonstrating the potential to improve nutrient efficiency through plant breeding and appropriate nutrient management practices (Ferrante et al., 2017).

In addition to genetic approaches, agronomic strategies can also be applied to improve fertilizer efficiency. The use of organic fertilizers can increase soil biological, chemical, and physical activity, thereby positively impacting soil fertility and plant growth (Ye et al., 2020; Singh et al., 2020). Furthermore, foliar fertilizer application has been shown to increase nitrogen use efficiency in corn (Nasar et al., 2022; Niu et al., 2021). Therefore, this study tested reducing the urea fertilizer dose and adding foliar fertilizer as an alternative treatment to increase nutrient use efficiency.

2. Material and Methods

This research was conducted in Mulyasari Village, Tanjung Lago District, Banyuasin Regency, South Sumatra Province. The geographical coordinates of the research location are approximately -2.6599626 degrees (latitude) and 104.7430773 degrees (longitude). The altitude is approximately 10 m above sea level. The research will be conducted from October 2024 to January 2025.

The materials used in this study included corn seeds from three genotypes: A-40, B-35, and C-33. The A-40, B-35, and C-33 lines are inbred corn (*Zea mays* L.) lines developed through a series of inbred crosses from a corn base population selected by a corn breeding institution (e.g., a university or national research institution). All these lines are assumed to have originated from repeated selfing to achieve a high level of genetic uniformity, enabling them to be used as parents in agronomic evaluation and for heterosis potential. The origin of these lines is from the UNSRI laboratory. In addition, insecticides, foliar fertilizers, KCl fertilizers, manure, NPK fertilizers, SP-36 fertilizers, and Urea fertilizers were also used.

This study used a split-plot design with three replications. The main plot consists of three corn genotypes: Lines A-41, B-36, and C-34. In the subplot treatment, there were three levels of second fertilization dose with Urea fertilizer: Control (0 kg/ha), 255 kg/ha, and 310 kg/ha. Meanwhile, the subplot treatment consisted of two levels: without foliar fertilizer and with foliar fertilizer.

The total treatment combinations were 3 (genotype) × 3 (fertilizer dose) × 2 (foliar fertilizer), for a total of 18, each repeated three times, for a total of 54 experimental units.

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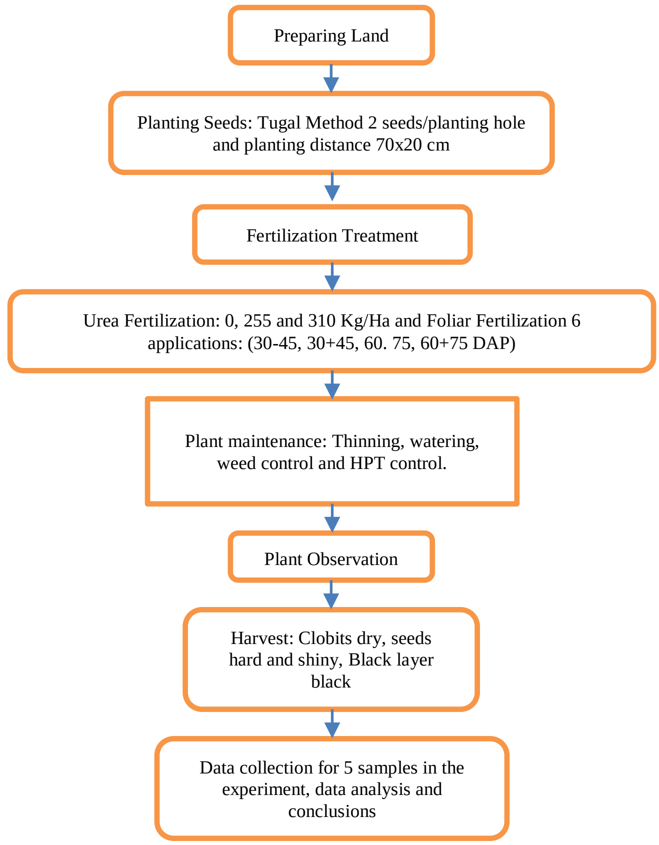

Figure 1. Research Flow Diagram

2.1. Work procedures

Land preparation was carried out mechanically. Seed planting was carried out using a dipstick method, placing two seeds per planting hole with a spacing of 75 cm × 20 cm. Foliar fertilization was applied during the second fertilization by spraying the leaves, carried out six times: on the 30th, 45th, 60th, 75th, and 90th days after planting, and on the 60th + 90th days after planting. Inorganic fertilization was applied with urea at the following rates: 0, 255, and 310 kg/ha. Plant maintenance activities included thinning, watering, weed control, and pest and disease control. Harvesting was carried out when the plants had reached physiological maturity, indicated by the husk starting to dry, hard, shiny seeds, and the presence of a black layer on the seed germ. Data collection was conducted on five samples per treatment.

The sample data criteria measured included plant height during the generative phase, from the ground surface to the highest point of the plant, and were averaged across sample plants in each treatment plot. Leaf chlorophyll content was measured on the third leaf from the top using a chlorophyll meter (SPAD) or the chlorophyll extraction method, with results expressed in mg/g fresh leaf weight. Cob length was measured from the base to the tip of the cob after harvest using a ruler, then averaged across several sample cobs per plot. Cob diameter was measured at the center of the cob using a caliper after harvest, then averaged. The number of rows per cob was calculated manually by counting the rows of seeds arranged in a circle on the sample cob, then averaging across treatments. The number of seeds per cob was calculated by counting all the seeds on the sample cob after shelling, then averaging. The kernel weight per ear is determined by weighing kernels from sample ears on an analytical balance after drying to a moisture content of ±14%, and reporting the results in grams. Yield per hectare is calculated from the dry kernel weight of the plants in the harvest plot and converted to tons per hectare.

2.2. Data analysis

Data analysis was performed using SPSS version 16 to test the effect of treatments on the observed parameters. The obtained data were analyzed using analysis of variance (ANOVA) to determine whether there were significant differences between treatments. If the analysis indicated a significant effect, further testing was performed to compare treatment averages and determine the best treatment.

3. Results and Discussion

3.1. Recapitulation of Diversity Analysis Results

The analysis of variance results presented in Table 1 indicate that the single-factor treatment of urea fertilizer (U) had a highly significant effect (**) on all measured parameters, including plant height, leaf chlorophyll content, cob length, cob diameter, number of rows per cob, number of seeds per cob, shell weight per plant, and yield per hectare. This finding demonstrates that applying urea fertilizer at varying doses significantly influences the vegetative growth and yield components of corn plants. Nitrogen, a key macronutrient found in urea, plays a crucial role in chlorophyll synthesis, cell growth, and grain filling; therefore, its application directly impacts plant productivity (Mustafa et al., 2022).

Meanwhile, the single-factor treatments of genotype (G), foliar fertilizer (P), and the interactions between genotype and foliar fertilizer (GP), urea and foliar fertilizer (UP), or the combination of all three (GUP) showed no significant effects (ns) on any of the observed parameters. The interaction between genotype and urea (GU) had a significant effect (*) only on the number of rows per ear, indicating that the genotypes responded differently to urea application for certain traits. This finding suggests variability in genotypes' ability to utilize nitrogen for the formation of grain rows on the ear. The coefficient of variation (CV) values ranged from 5.55% to 75%, with the highest variation observed in ear length (75% in KKa), indicating substantial data variability for that parameter. Other parameters exhibited lower variability, which was acceptable for field research.

Table 1. Recapitulation of the results of the analysis of the diversity of the influence of genotype, urea fertilizer, and foliar fertilizer on the growth parameters and yield of corn plants.

Parameter	Treatment									
Observation	G	U	P	GU	GP	UP	GUP	Kka (%)	Family Card (%)	KKc (%)
Plant height	tn.	**	tn.	tn.	tn.	tn.	tn.	16	11	9
Corn leaf chlorophyll	tn.	**	tn.	tn.	tn.	tn.	tn.	14	18	24
corn cob length (cm)	tn.	**	tn.	tn.	tn.	tn.	tn.	75	60	28
Cob diameter (cm)	tn.	**	tn.	tn.	tn.	tn.	tn.	12	22	11
Number of rows per cob	tn.	**	tn.	*	tn.	tn.	tn.	34	28	21
Number of seeds	tn.	**	tn.	tn.	tn.	tn.	tn.	5.55	41	34
weight of the seed kernels per crop	tn.	**	tn.	tn.	tn.	tn.	tn.	10	9	11
Production	tn.	**	tn.	tn.	tn.	tn.	tn.	16	28	12

Note: G = Genotype; U = Urea Fertilizer; P = Foliar Fertilizer; GU = Interaction of Genotype and Urea; GP = Interaction of Genotype and Foliar Fertilizer; UP = Interaction of Urea and Foliar Fertilizer; GUP = Interaction of Genotype, Urea, and Foliar Fertilizer; ** = Very significant effect at 1% level ($P < 0.01$); * = Significant effect at 5% level ($P < 0.05$); tn = No significant effect ($P > 0.05$); KKa, KKb, KKc = Coefficient of variation in experiments a, b, and c.

3.2. Morphophysiological Appearance of Corn Genotype Treatment

The results of the analysis of the influence of corn genotypes on morphophysiological parameters and plant yield in Table 2 show that the three genotypes (G1, G2, and G3) exhibited relatively uniform responses across most parameters. Plant height ranged from 138.9 to 139.6 cm across the three genotypes, with no significant differences, indicating that plant height characteristics were relatively homogeneous. This finding indicates that the genetic factors controlling plant height in the three genotypes have similar expression under the same environmental conditions. Plant height is an indicator of vegetative growth influenced by the interaction between genotype and the environment, particularly nitrogen availability (Lemaire et al., 2020; Ljubičić et al., 2023).

Leaf chlorophyll levels in the three genotypes also showed no significant differences, ranging from 35.43 to 35.55 *Soil Plant Analysis Development* (SPAD) units. High chlorophyll content is positively correlated with plant photosynthetic capacity and nitrogen utilization efficiency, which ultimately affects plant productivity (Nasar et al., 2021). The uniformity of chlorophyll levels between genotypes indicates that the three genotypes have relatively similar photosynthetic capacity in response to nitrogen availability from fertilizer application.

Yield component parameters such as ear length (12.0-12.9 cm), ear diameter (6.00-6.01 cm), and number of rows per ear (15.0 rows) also showed no significant differences between genotypes. These yield components are traits strongly influenced by genetic factors and by nutrient availability during the flowering and grain-filling phases. However, the number of seeds per ear varied, with G1 (499.7 seeds) significantly different from G2 (485.8 seeds) and G3 (491.3 seeds), as indicated by different letters. This difference may be due to differences in fertilization efficiency and in the genotypes' ability to allocate assimilates to seed formation (Heuermann et al., 2021).

The kernel weight per ear and yield per hectare for the three genotypes showed no significant differences, ranging from 1.61 to 1.62 g and from 7.05 to 7.05 tons/ha, respectively. This indicates that despite slight differences in kernel number per ear, the three genotypes have equivalent yield potential overall. Corn productivity is largely determined by the complex interactions between genotype, cultivation practices, and environmental conditions, particularly water and nutrient availability (Morales et al., 2020). The relatively low LSD of 0.05 for kernel weight per ear (0.14) and yield per hectare (0.14) indicates good observation accuracy and low data variability.

Table 2. Effect of the use of corn genotypes on morphophysiological parameters, yield components, and corn plant production.

Genotype	Plant Height (cm)	Leaf Chlorophyll	Length of the cob (cm)	Diameter Corn (cm)	Number of Rows/Cobs	Number of Seeds/Cobs	Weight of corn kernels/cobs (g)	Production (tons /ha)
G groove A-41	139.6±2.03a	35.55±0.45a	12.0±0.75a	6.00±0.14a	15.0±0.41a	499.7±21.42b	1.62±0.05a	7.05±0.05a
G groove B-36	139.5±2.03a	35.55±0.45a	12.9±0.75a	6.01±0.14a	15.0±0.41a	485.8±21.42a	1.62±0.05a	7.05±0.05a
G groove C-34	138.9±2.03a	35.43±0.45a	12.8±0.75a	6.00±0.17a	15.0±0.41a	491.3±21.42a	1.61±0.05a	7.05±0.05a
BNT 0.05	5.75	1.26	2.11	0.39	1.16	60.55	0.14	0.14

Note: G1, G2, G3 = Corn genotypes 1, 2, and 3; Numbers followed by the same letter in the same column indicate no significant difference based on the Least Significant Difference (LSD) test at the 5% level; ± = Standard error; LSD 0.05 = Least Significant Difference at the 95% confidence level.

3.3. Morphophysiological Appearance of Urea Fertilizer Dose Treatment

The analysis of the effect of urea fertilizer dosage on morphophysiological parameters and corn yield in Table 3 shows that increasing the urea fertilizer dosage significantly affected all observed parameters. Plant height showed a positive response to increasing urea dosage, increasing from 105.2 cm in the control (without urea), to 133.2 cm at a dose of 255 kg/ha, and reaching 179.4 cm at a dose of 310 kg/ha. This increase in plant height indicates that nitrogen supplied by urea fertilizer plays a significant role in promoting vegetative growth by stimulating cell division and elongation (Sharma et al., 2021).

Leaf chlorophyll content increased significantly from 22.01 SPAD units in the control to 42.17 SPAD units at a dose of 255 kg/ha and 42.38 SPAD units at a dose of 310 kg/ha, although the two fertilizer doses were not significantly different. This increase in chlorophyll content indicates that nitrogen application stimulates chlorophyll synthesis, which is involved in photosynthesis. High chlorophyll content is positively correlated with photosynthetic capacity and plant productivity, because chlorophyll is the main pigment that captures light energy to convert CO_2 and H_2O into carbohydrates (Gu et al., 2017). This increase in photosynthetic efficiency will ultimately increase biomass accumulation and plant yield.

Yield component parameters showed a consistent response to increasing urea doses. Ear length increased from 11.79 cm in the control to 13.14 cm at 255 kg/ha and 13.95 cm at 310 kg/ha, with significant differences between treatments. Ear diameter also increased gradually from 5.70 cm in the control to 6.12 cm and 6.23 cm at doses of 255 kg/ha and 310 kg/ha, respectively. This increase in ear dimensions reflects adequate nitrogen availability during the reproductive phase, which allows plants to allocate more assimilates to generative organs (Chen et al., 2016). The number of rows per ear also increased significantly from 14.0 rows in the control to 14.8 rows and 16.6 rows at doses of 255 kg/ha and 310 kg/ha, respectively, indicating that nitrogen affects flower primordia differentiation and ear structure formation.

The number of seeds per ear increased significantly, from 429.3 in the control to 490.8 at 255 kg/ha and 556.8 at 310 kg/ha. This increase in seed number resulted from a combination of increasing the number of rows per ear and the number of seeds per row, both of which are strongly influenced by nitrogen availability during the flowering and fruiting phases. Adequate nitrogen during this critical period ensures optimal fertilization levels and reduces seed abortion, thus increasing the number of seeds formed (Monzon et al., 2021).

The weight of kernels per ear and production per hectare also increased significantly with increasing urea doses. The weight of kernels per ear increased from 1.44 g in the control to 1.67 g at a dose of 255 kg/ha and 1.75 g at a dose of 310 kg/ha, while production per hectare increased from 6.43 tons/ha in the control to 7.28 tons/ha and 7.46 tons/ha at doses of 255 kg/ha and 310 kg/ha, respectively. This increase in production is the cumulative result of improvements in all yield components, from the number of rows per ear and the number of kernels per ear to the weight of individual kernels (Hidayatullah et al., 2025). However, the difference in yield between doses of 255 kg/ha and 310 kg/ha was relatively small, indicating an optimal fertilizer rate at which further increases do not yield a proportional response. This finding aligns with the law of diminishing returns in fertilization, where nitrogen use efficiency decreases at very high doses due to losses from volatilization, leaching, or denitrification (Martínez-Dalmau et al., 2021).

Overall, the results of this study indicate that urea fertilizer at 255-310 kg/ha significantly increased corn growth, yield components, and productivity compared with the control. However, from an agronomic and economic efficiency perspective, 255 kg/ha is recommended as the optimal dose because it provides relatively high yields with lower inputs, in line with sustainable agriculture principles that emphasize efficient use of inputs.

Table 3. Effect of urea fertilizer dose on morphophysiological parameters, yield components, and corn plant production.

Urea Fertilizer	Plant Height (cm)	Leaf Chlorophyll	Length of the cob (cm)	Diameter Corn (cm)	Number of Rows	Number of Seeds	Shell weight (g)	Production (tons /ha)
Control	105.2±9.89a	22.01±0.42a	11.79±0.49a	5.70±0.08a	14.0±0.27a	429.3±12.39a	1.44±0.03a	6.43±0.08a
255 kg/ha	133.2±9.89b	42.17±0.42b	13.14±0.49b	6.12±0.08b	14.8±0.27b	490.8±12.39b	1.67±0.03b	7.28±0.08b
310 kg/ha	179.4±9.89c	42.38±0.42b	13.95±0.49c	6.23±0.08c	16.6±0.27c	556.8±12.39c	1.75±0.03c	7.46±0.08c
BNT 0.05	28.0	1.19	1.38	0.22	0.77	35.04	0.09	0.24

Note: Numbers followed by the same letter in the same column indicate no significant difference based on the Least Significant Difference (LSD) test at the 5% level; ± = Standard error; LSD 0.05 = Least Significant Difference at the 95% confidence level; Kg/Ha = Kilograms per hectare.

3.4. Correlation Analysis

The results of the correlation analysis in Table 4 indicate that the number of rows per ear is closely related to most of the observed parameters. A very significant and very strong positive correlation was found in the number of seeds per ear (r = 0.968**) and ear length (r = 0.899**), indicating that increasing the number of rows per ear directly increases the number of seeds and requires more ear space. A very significant positive correlation was also found for production per hectare (r = 0.828**) and plant height (r = 0.765**), indicating that the number of rows per ear is an important yield component that contributes to plant productivity and is associated with vegetative growth vigor.

Other parameters, such as ear diameter (r = 0.344**) and leaf chlorophyll content (r = 0.319**), showed a highly significant positive correlation but with lower values, indicating a weaker relationship. Interestingly, the number of rows per ear was not significantly correlated with kernel weight per plant (r = 0.192tn), indicating a compensatory mechanism between kernel number and individual kernel weight (a trade-off), where increasing the number of rows is not always followed by a proportional increase in kernel weight (Tillett et al., 2022). Overall, the number of rows per ear can be used as a selection criterion in breeding programs to increase corn yields, particularly by increasing kernel number per ear and production per hectare.

Table 4. Correlation analysis between the number of rows per ear and morphophysiological parameters, yield components, and corn plant production.

Observation Parameters	Correlation coefficient (r)
Plant height	0.765**
Corn leaf chlorophyll	0.319**
corn cob length (cm)	0.899**
Cob diameter (cm)	0.344**
Number of seeds	0.968**
weight of the seed kernels per crop	0.192tn
Production	0.828**

Note: r = Pearson correlation coefficient; ** = Highly significantly correlated at the 1% level (P < 0.01); * = Significantly correlated at the 5% level (P < 0.05); tn = Not significantly correlated (P > 0.05).

4. Conclusion

Based on the study results, it can be concluded that urea fertilizer treatment, as a single factor, has a highly significant effect on all parameters of corn growth and yield. In contrast, genotype and foliar fertilizer factors did not exhibit a significant effect. The interaction between genotype and urea significantly affected only the number of rows per ear. Increasing the urea fertilizer dose from the control to 255 kg/ha and 310 kg/ha significantly enhanced plant height, leaf chlorophyll content, ear dimensions (length and diameter), number of rows per ear, number of seeds per ear, weight of shells per plant, and production per hectare. The three genotypes tested showed relatively uniform performance across most parameters, with a significant difference observed only in the number of seeds per ear. Correlation analysis revealed that the number of rows per ear was strongly associated with the number of seeds per ear, ear length, and production per hectare, but was not significantly correlated with the weight of shells per plant. From an agronomic efficiency perspective, applying urea at 255 kg/ha is recommended as the optimal rate, as it provides a significant yield increase with better input efficiency compared to 310 kg/ha.

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