BIOEDUSCIENCE
ISSN: 2614-1558
http://journal.uhamka.ac.id/index.php/bioeduscience

The Effect of Leaf Defolation and Substitution of NPK Phonska and Guano Fertilizers on Maize (*Zea mays* L.) Production

Vrida Novitasari [1], Djarwatiningsih Poengky Soedjarwo [1*], Hadi Suhardjono [1]

[1] Study Program of Agrotechnology, Faculty of Agriculture, Universitas Pembangunan Nasional "Veteran" East Java, Jl. Raya Rungkut Madya, Gunung Anyar, Surabaya, East Java, Indonesia, 60294
[*] Correspondence: djarwatiningsihps@gmail.com

Abstract

Background: Maize (*Zea mays* L.) is the most essential food commodity after rice and a secondary crop. The demand for Maize in Indonesia is currently relatively high, yet its production has been declining. To increase Maize production, improvements in cultivation techniques are necessary. One such method is optimizing assimilate distribution through leaf defoliation, as well as creating optimal growing conditions through fertilization. Fertilization should be balanced by using both inorganic and organic fertilizers. In this study, NPK Phonska and Guano fertilizers were used. **Methods:** This study employed a factorial randomized complete block design (RCBD) with two factors. The first factor was the level of leaf defoliation below the cob, consisting of three levels: no defoliation (D1), defoliation leaving three leaves (D2), and defoliation leaving two leaves (D3). The second factor was the substitution of NPK Phonska and guano fertilizers with five levels: 100% NPK Phonska (P1), 75% NPK Phonska + 25% Guano (P2), 50% NPK Phonska + 50% Guano (P3), 25% NPK Phonska + 75% Guano (P4), and 100% Guano (P5). **Results:** The study's results showed that defoliation, leaving two leaves below the cob, combined with the application of 7 tons/ha of guano fertilizer without the addition of NPK, increased cob weight, cob length, and dry kernel weight per plant. Additionally, the independent application of 7 tons/ha of guano fertilizer without NPK Phonska significantly increased cob diameter. **Conclusions:** The combination treatment of defoliation, leaving two leaves below the cob, and the application of 7 tons/ha of guano fertilizer without the addition of NPK had the most favorable effect on Maize production.

Keywords: Fertlizer; Guano; Leaf Defolation; Maize; NPK Phonska

Article history
Received: 28 Aug 2024
Accepted: 24 Apr 2025
Published: 31 Jul 2025

Citation:
Novitasari et al. (2025). The Effect of Leaf Defolation and Substitution of NPK Phonska and Guano Fertilizers on Maize (*Zea mays* L.) Production. BIOEDUSCIENCE, 9(2), 164-170. doi: 10.22263/jbes/16135

Introduction

Maize (*Zea mays* L.) is the most essential food commodity after rice and a secondary crop. According to Sidabutar et al. (2014), the demand for Maize in Indonesia is currently relatively high, exceeding 10 million tons of dry-shelled Maize per year. Based on data from Badan Pusat Statistik (2024), Maize production in Indonesia declined from 16.53 million tons in 2022 to 14.77 million tons in 2023 (dry-shelled Maize with 14% moisture content). To improve Maize yields, it is necessary to enhance cultivation techniques, including optimizing assimilate distribution through leaf defoliation and creating optimal growing conditions through proper fertilization.

Defoliation is the removal of unproductive, diseased, or unwanted parts of the plant to increase productivity. Defoliation can be applied to leaves located below the ear to improve the efficiency of photosynthesis, preventing internal competition between older leaves and the cob for assimilates. These older leaves act more as a sink rather than a source and thus become parasitic. Therefore, defoliation is necessary to avoid yield reductions (Valikelari & Asghari, 2014). A study by Sumajow et al. (2016) showed that Maize plants treated with defoliation of lower leaves produced better outcomes in terms of cob circumference, cob length, and cob weight compared to those without defoliation.

Fertilization in Maize cultivation has commonly involved the continuous and excessive use of inorganic fertilizers. Inorganic fertilizers are considered more practical than organic ones, as they are required in smaller quantities to achieve the same nutrient levels. Consequently, the use of organic fertilizers has declined. NPK Phonska is one of the most frequently used inorganic fertilizers in Maize cultivation. However, Ammurabi et al. (2020) reported that using NPK fertilizers without the addition of organic matter significantly increases Maize yields only during the first 12 years. In the long term, the high-dose use of inorganic fertilizers can lead to environmental pollution, damage to soil structure, loss of biodiversity in soil biota, excessive nutrient leaching, and other adverse effects.

A viable solution to reduce reliance on inorganic fertilizers is the use of organic fertilizers, one of which is guano fertilizer. Guano is derived from bat droppings and contains organic compounds rich in nitrogen (N), phosphorus (P), and potassium (K). It has higher levels of N and P compared to manure, agricultural waste, or municipal solid waste, making it a promising alternative (Azis & Bakar, 2017). Lukman (2022) found that applying Guano at a rate of 7 tons/ha could fulfill Maize nutrient needs for N, P, and K. This was evidenced by the highest values observed in plant height, leaf number, stem diameter, cob diameter, and cob weight compared to other treatments.

To achieve optimal results, both defoliation and fertilization must be applied accurately. Therefore, research on the effects of varying levels of defoliation below the cob and the substitution of NPK Phonska and guano fertilizers on Maize (*Zea mays* L.) production is necessary. This research aims to identify optimal practices for sustainable Maize cultivation.

Methods

This study was conducted from August to December 2023 in Paciran Village, Paciran Subdistrict, Lamongan Regency. The research was a factorial experiment arranged in a Randomized Complete Block Design (RCBD) with two factors and three replications. The first factor was the number of lower leaves removed through defoliation, with three levels: no defoliation (D1), defoliation leaving three leaves (D2), and defoliation leaving two leaves (D3). The second factor was the substitution of NPK Phonska and guano fertilizers with five levels: 100% NPK Phonska (P1), 75% NPK Phonska + 25% Guano (P2), 50% NPK Phonska + 50% Guano (P3), 25% NPK Phonska + 75% Guano (P4), and 100% Guano (P5). The full dose of NPK Phonska fertilizer used was 1.5 tons per hectare, while the full dose of guano fertilizer was 7 tons per hectare. In total, there were 15 treatment combinations, each replicated three times, resulting in 45 experimental units. Each unit consisted of three plant samples, totaling 135 plant samples.

Data Collection

The observed parameters included cob weight (g), cob length (cm), cob diameter (cm), and dry-shelled maize weight per plant (g). Measurements for cob weight, cob length, and cob diameter were taken from ears of Maize that had been husked. Cob weight was measured by weighing the maize cobs using a digital scale. Cob length was measured with a ruler, starting from the bottom to the top of the cob. Cob diameter was measured using a caliper at three points: the top, middle, and bottom of the cob, and the average was calculated. The measurement of dry-shelled maize weight per plant was conducted using kernels with a moisture content of 14%, as determined by a grain moisture meter. The dry kernels were then weighed using a digital scale.

Procedure

The implementation procedure began with land preparation. The experimental field was cleared of debris (such as stones, weeds, etc.) that could hinder plant growth, and the soil was then loosened. Next, experimental plots were prepared, and planting distances were arranged. The plots measured 1 m x 1 m, with a planting distance of 70 cm x 20 cm. The Maize variety used in this study was BISI-18. During planting, basal fertilization was applied using half the designated dose of NPK Phonska and the full dose of guano fertilizer according to each treatment. Follow-up fertilization was carried out when the Maize plants reached 40 days after planting (DAP), using the remaining half of the NPK Phonska dose specified for the treatment. The complete fertilizer dosage is provided in Table 1. Leaf defoliation was performed at 54 DAP (when Maize silks emerged) by cutting the leaves from the leaf stalk base using scissors, following the method described by Aryadi et al. (2013).

The number of leaves removed varied depending on the treatment. Watering was conducted in the morning before 9:00 AM. Pest and disease control was carried out manually by eliminating pests and infected plant parts. Common pests attacking Maize included insects such as *Oxya* sp., *Peregrinus maidis*, and *Spodoptera frugiperda* (Hasan et al., 2023). Pesticide spraying was applied only when pest damage reached the threshold level. Harvesting was conducted when the plants reached 100 days after planting (DAP). Indicators of harvest maturity included brown husks, dry and blackened silks, and hard kernels (Subekti et al., 2008). Field inspection could be done by pressing a kernel with the thumbnail—if no mark was left, the Maize was ready to harvest. After harvesting, the husks were removed, and measurements of cob weight, length, and diameter were taken. The cobs were then sun-dried for 2–3 days to reduce moisture and ease kernel shelling. The shelled kernels were sun-dried again until they reached a moisture content of 14% (Wartapa et al., 2019). Finally, the dry-shelled Maize was weighed to determine the dry grain weight per plant.

Table 1. Fertilizer Dosage Plant

Fertilization Time	Fertilizer Type	Treatment	Dosage (gr/plant)
At the time of planting	NPK Phonska	P1	10,5
		P2	7,9
		P3	5,2
		P4	2,6
	Guano	P2	24,5
		P3	49,0
		P4	73,5
		P5	98,0
Maize plants aged 40 days after planting	NPK Phonska	P1	10,5
		P2	7,9
		P3	5,2
		P4	2,6

Data Analysis

The data obtained from the experiment were analyzed using an Analysis of Variance (ANOVA) table based on a factorial Randomized Complete Block Design (RCBD). If the ANOVA results showed a significant or highly significant effect, the analysis was followed by a 5% Honest Significant Difference (HSD) test using the formula proposed by Susilawati (2015).

Result

Effect of Treatment on Maize Cob Weight

The writing of research procedures is written in paragraph form. The research procedure is not presented in numbered sections but rather in paragraph form.

Table 2. Average Weight of Maize Cobs (gr)

Leaf Defoliation	Comparison of NPK Phonska and Guano Fertilizer Doses					D Average
	P1	P2	P3	P4	P5	
D1	184,68 ab	221,33 bcd	217,91 bcd	154,43 a	188,30 abc	193,33 a
D2	187,39 abc	190,18 abc	186,06 abc	218,64 bcd	229,93 cd	202,44 a
D3	203,97 bcd	219,63 bcd	218,04 bcd	204,82 bcd	239,69 d	217,23 b
P Average	192,01 a	210,38 ab	207,34 ab	192,63 a	219,31 b	
BNJ DxP = 44,72		BNJ D = 13,35			BNJ P = 20,30	

The analysis of variance (ANOVA) results showed a highly significant interaction between the number of lower leaf defoliation treatments and the dosage ratio of NPK Phonska and Guano fertilizers on the parameter of cob weight without husk. The best treatment combination was D3P5 (defoliation leaving two leaves + 100% Guano), which resulted in a cob weight without a husk of 239.69 grams. Individually, the number of lower leaves removed had a highly significant effect on cob weight without husk. The best single treatment was D3 (defoliation with two leaves remaining), which yielded 217.23 grams. Similarly, the single factor of fertilizer dosage ratio also had a highly significant effect on cob weight without husk. The best treatment was P5 (100% Guano), with a cob weight of 219.31 grams.

Effect of Treatment on Maize Cob Length

Table 3. Average Length of Maize Cob (cm)

Leaf Defoliation	Comparison of NPK Phonska and Guano Fertilizer Doses					D Average
	P1	P2	P3	P4	P5	
D1	18,74 ab	20,62 ab	20,24 ab	18,59 a	18,84 ab	19,41
D2	18,86 ab	18,81 ab	18,73 ab	20,18 ab	19,97 ab	19,31
D3	19,31 ab	19,69 ab	20,08 ab	19,19 ab	20,90 b	19,83
P Average	18,97	19,71	19,69	19,32	19,90	
BNJ DxP = 2,26		BNJ D = tn			BNJ P = tn	

The analysis of variance (ANOVA) showed a highly significant interaction between the number of lower leaf defoliation and the dosage ratio of NPK Phonska and Guano fertilizers on the parameter of cob length without husk. The best treatment combination was D3P5 (defoliation leaving two leaves + 100% Guano), which resulted in a cob length without a husk of 20.90 cm. However, the single factors—the number of lower leaves defoliated and fertilizer dosage ratio—did not have a significant effect on cob length without husk when analyzed independently.

Effect of Treatment on Maize Cob Diameter

Table 4. Average Maize Cob Diameter (cm)

Leaf Defoliation	Comparison of NPK Phonska and Guano Fertilizer Doses					D Average
	P1	P2	P3	P4	P5	
D1	3,10	3,20	3,24	2,90	3,14	3,12
D2	3,08	3,15	3,06	3,13	3,33	3,15
D3	3,14	3,23	3,19	3,12	3,31	3,20
P Average	3,11 ab	3,19 ab	3,16 ab	3,05 a	3,26 b	
BNJ DxP = tn		BNJ D = tn			BNJ P = 0,17	

The analysis of variance (ANOVA) showed that there was no significant interaction between the number of lower leaf defoliation and the dosage ratio of NPK Phonska and Guano fertilizers on the parameter of cob diameter without husk. The number of lower leaves defoliated, as an individual factor, also did not have a significant effect on cob diameter without husk. However, the single factor of fertilizer dosage ratio had a substantial impact on cob diameter without husk. The best treatment was P5 (100% Guano), which resulted in a cob diameter of 3.26 cm.

Effect of Treatment on Dry Maize Kernel Weight per Plant

Table 5. Average Weight of Dry Maize Kernels per Plant (gr)

Leaf Defoliation	Comparison of NPK Phonska and Guano Fertilizer Doses					D Average
	P1	P2	P3	P4	P5	
D1	124,27 bcd	130,02 bcd	128,70 bcd	96,98 a	129,90 bcd	121,97 a
D2	117,60 abc	120,98 abcd	114,31 ab	136,21 bcd	140,00 cd	125,82 ab
D3	116,84 abc	136,99 bcd	137,11 bcd	125,79 bcd	142,38 d	131,82 b
P Average	119,57 a	129,33 ab	126,71 ab	119,66 a	137,43 b	
BNJ DxP = 24,31		BNJ D = 7,26			BNJ P = 11,04	

The analysis of variance (ANOVA) showed a highly significant interaction between the number of lower leaf defoliation and the dosage ratio of NPK Phonska and Guano fertilizers on the parameter of dry-shelled maize weight per plant. The best treatment combination was D3P5 (defoliation leaving two leaves + 100% Guano), which produced a dry-shelled maize weight per plant of 142.38 grams. The number of lower leaves defoliated, as an individual factor, had a highly significant effect on dry-shelled maize weight per plant, with the best result observed in treatment D3 (defoliation leaving two leaves), yielding 131.82 grams. Similarly, the fertilizer dosage ratio, considered as a single factor, also had a highly significant effect, with the best result obtained from P5 (100% Guano), which produced 137.43 grams of dry-shelled Maize per plant.

Discussion

The results of the study showed that the combination of defoliation, leaving two leaves below the cob, and the application of guano fertilizer at a dose of 7 tons/ha without the addition of NPK Phonska produced the best outcomes in terms of cob weight without husk, cob length without husk, and dry shelled maize weight per plant. The single factor of lower leaf defoliation also demonstrated that leaving two leaves below the cob resulted in the best outcomes for cob weight without husk and dry-shelled maize weight per plant. Likewise, the single factor of fertilizer dosage ratio indicated that applying 7 tons/ha of Guano without NPK Phonska provided the best results for cob weight without husk, cob diameter, and dry-shelled maize weight per plant.

Defoliation leaving two leaves below the cob produced higher yields compared to no defoliation. This finding is consistent with the research by Pamungkas et al. (2017), which demonstrated that defoliation of leaves below the cob can enhance cob and kernel weight compared to plants without defoliation, with the most effective treatment being the complete removal of leaves below the cob. This suggests that the removal of lower leaves results in more assimilates being redirected to the cob, leading to better cob and kernel weight. Surtinah (2005) also explained that in non-defoliated plants, assimilates are not only used for kernel development but also distributed to vegetative organs, leading to internal competition within the plant.

Wang et al. (2014) further noted that the lower the position of the leaves, the less sunlight they receive, which in turn decreases the rate of photosynthesis. To survive, these lower leaves require support from the upper leaves. As a result, the lower leaves no longer serve as producers of assimilates but rather as consumers of assimilates. This creates competition between the lower leaves and the cob for the assimilation of nutrients. Therefore, removing unproductive lower leaves through defoliation can optimize the distribution of assimilates to essential parts of the plant, such as flowers and fruit.

The application of Guano at 7 tons/ha resulted in better maize production compared to NPK Phonska at 1.5 tons/ha. This aligns with the findings of Jamilah (2010), who studied the substitution of synthetic fertilizers with Kronobio compost on nutrient uptake and maize yield. Kronobio compost, made from a mixture of Guano, *Chromolaena odorata*, and compounds, was able to replace 75% of the recommended synthetic fertilizer dosage (150 kg/ha N, 100 kg/ha P_2O_5, and 75 kg/ha K_2O) when applied at 6.24 tons/ha. Both NPK Phonska and Guano are necessary fertilizers for Maize because they contain essential macronutrients—nitrogen (N), phosphorus (P), and potassium (K)—which are critical for plant growth. However, NPK Phonska and Guano differ in composition and characteristics. Guano, being an organic fertilizer, not only contains N, P, and K but also includes micronutrients such as calcium, magnesium, and various trace elements. This complete nutrient profile provides a more balanced nutrition for maize plants (Szpak et al., 2012). In contrast, NPK Phonska, as an inorganic fertilizer, typically contains only a limited range of nutrients.

Guano is also rich in organic matter, which plays a key role in improving soil fertility. According to Hartatik et al. (2015), organic matter enhances the physical, chemical, and biological properties of soil. Physically, it improves soil structure, water-holding capacity, and aeration. Chemically, it serves as a source of macro and micronutrients, stabilizes soil pH, increases cation exchange capacity (CEC), and prevents toxicity from metal ions such as Al, Fe, and Mn by forming stable complexes. Biologically, organic matter supports the activity of soil microbes. With the presence of organic matter in Guano, the soil condition is better compared to treatments using only NPK Phonska, which lacks organic content. Based on the findings of this study, it can be concluded that guano fertilizer at 7 tons/ha is capable of fully substituting NPK Phonska fertilizer at 1.5 tons/ha.

Conclusions

Defoliation leaving two leaves below the cob produced the best results for both cob weight and dry-shelled maize weight per plant. The application of Guano at 7 tons/ha was able to fully substitute NPK Phonska at 1.5 tons/ha, as reflected in the parameters of cob weight, cob diameter, and dry-shelled maize weight per plant. There was a significant interaction between the two treatment factors, where the combination of defoliation, leaving two leaves below the cob, and the application of 7 tons/ha of Guano without the addition of NPK Phonska yielded the most favorable outcomes for cob weight cob length and dry shelled maize weight per plant. It is recommended that further research be conducted on the optimal dosage of Guano for maize cultivation, allowing for its full potential to be utilized in environmentally friendly and sustainable agricultural practices.

Acknowledgments

Acknowledgments are extended to all parties, especially to the Agrotechnology lecturers of UPN “Veteran” East Java, the lecturers of the Faculty of Agriculture at UPN “Veteran” East Java, as well as to all friends who have provided assistance, suggestions, and guidance throughout the preparation of this research.

Declaration statement

The authors reported no potential conflict of interest.

References

Ammurabi, S. D., Anas, I., & Nugroho, B. (2020). Substitusi Sebagian Pupuk Kimia dengan Pupuk Organik Hayati pada Jagung (*Zea mays*). *Jurnal Ilmu Tanah Dan Lingkungan*, *22*(1), 10–15. https://doi.org/10.29244/jitl.22.1.10-15

Aryadi, D. P., Nurmauli, N., & Hamim, H. (2013). Defoliasi dan Pemberian Pupuk Urea dalam Meningkatkan Hasil Jagung (*Zea mays* L.) Varietas Pioneer 27. *Jurnal Agrotek Tropika*, *1*(2), 128–133. https://doi.org/10.23960/jat.v1i2.1979

Azis, A., & Bakar, B. A. (2017). Kajian Efisiensi Pemupukan Fosfat (Guano) pada Tanaman Kedelai di Lahan Sawah Provinsi Aceh. *Prosiding Seminar Nasional Hasil Penelitian Tanaman Aneka Kacang Dan Umbi*, 110–120.

Badan Pusat Statistik. (2024). Luas Panen dan Produksi Jagung di Indonesia 2023 (Angka Tetap). *Berita Resmi Statistik No. 21/03/Th. XXVII, 1 Maret 2024*, 20 hal.

Hartatik, W., Husnain, & Widowati, L. R. (2015). Peranan Pupuk Organik dalam Peningkatan Produktivitas Tanah dan Tanaman. *Jurnal Sumberdaya Lahan*, *9*(2), 107–120.

Hasan, P. A., Hidayah, N., & Fadillah, N. (2023). Insect Pest Diversity of Maize Plants (*Zea mays*) in Baringeng Village, Soppeng Regency, South Sulawesi Province. *BIOEDUSCIENCE*, *7*(1), 33–40. https://doi.org/10.22263/j.bes/7111419

Jamilah. (2010). Serapan Hara dan Hasil Jagung yang Diaplikasi Pupuk Buatan dan Kompos Kronobio. *Jurnal Agrivigor*, *10*(1), 10–17.

Lukman. (2022). Pemanfaatan Pupuk Guano dalam Sistem Pertanian Berkelanjutan dan Dampaknya pada Pertumbuhan dan Hasil Tanaman Jagung Manis (*Zea mays* saccharata L). *Jurnal Ilmu Pertanian Indonesia*, *27*(4), 590–595. https://doi.org/10.18343/jipi.27.4.590

Pamungkas, P. P., Maizar, & Sulhaswardi. (2017). Pengaruh Pemberian Pupuk NPK Grower dan Defoliasi terhadap Perkembangan Biji dan Produksi Tanaman Jagung (*Zea mays* L.). *Dinamika Pertanian*, *XXXIII*(3), 303–316.

Sidabutar, P., Yusmini, & Yusri, J. (2014). Analisis Usahatani Jagung (*Zea mays*) di Desa Dosroha Kecamatan Simanindo Kabupaten Samosir Provinsi Sumatera Utara. *Jurnal Online Mahasiswa Fakultas Pertanian Universitas Riau*, 1–14.

Subekti, N. A., Syafruddin, Efendi, R., & Sunarti, S. (2008). Morfologi Tanaman dan Fase Pertumbuhan Jagung. In *Jagung: Teknik Produksi dan Pengembangan* (pp. 16–28). Maros: Balai Penelitian Tanaman Serealia.

Sumajow, A. Y. M., Rogi, J. E. X., & Tumbelaka, S. (2016). Pengaruh Pemangkasan Daun Bagian Bawah terhadap Produksi Jagung Manis (*Zea mays* var. saccharata Sturt). *ASE*, *12*(1A), 65–72.

Surtinah. (2005). Hubungan Pemangkasan Organ Bagian Atas Tanaman Jagung (*Zea mays* L.) dan Dosis Urea terhadap Pengisian Biji. *Jurnal Ilmiah Pertanian*, *1*(2), 27–35.

Susilawati, M. (2015). *Perancangan Percobaan*. Denpasar: Universitas Udayana.

Szpak, P., Millaire, J., White, C. D., & Longstaffe, F. J. (2012). Influence of Seabird Guano and Camelid Dung Fertilization on the Nitrogen Isotopic Composition of Field-Grown Maize (*Zea mays*). *Journal of Archaeological Science*, *39*, 3721–3740. https://doi.org/10.1016/j.jas.2012.06.035

Valikelari, F., & Asghari, R. (2014). Maize Yield and Yield Components Affected by Defoliation Rate and Applying Nitrogen and Vermicompost. *Indian Journal of Foundamental and Applied Life Sciences*, *4*(4), 396–403.

Wang, L., Yang, X., Ren, Z., & Wang, X. (2014). Regulation of Photoassimilate Distribution between Source and Sink Organs of Crops through Light Environment Control in Greenhouses. *Agricultural Science*, *5*, 250–256.

Wartapa, A., Slamet, M., Ariwibowo, K., & Hartati, S. (2019). Teknik Budidaya Jagung (Zea Mayz L) Untuk Meningkatkan Hasil. *Jurnal Ilmu-Ilmu Pertanian*, *26*(2), 1–13. https://doi.org/10.55259/jiip.v26i2.193