Effect of Urea Application on Corn Productivity: A Meta-Analysis

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Abstract
Purpose: This study provides a meta-analysis of previous research investigating the effect of urea application on corn productivity. The aim is to develop a comprehensive and robust understanding of the relationship between urea use and corn yield, offering evidence-based recommendations for fertilizer management.

Research Methodology: The meta-analysis was conducted through several stages, including determining the reference component of the literature search, collecting and tabulating relevant data, standardizing datasets from multiple studies, and analyzing the results using the OpenMEE software to synthesize findings across different research sources.

Results: The findings indicate that urea application significantly improves corn productivity. The positive impact on yield is even greater when urea is combined with other fertilizers, highlighting the importance of integrated fertilization practices. Furthermore, the timing of urea application is shown to be critical, with pre-planting application producing better results compared to post-planting application, suggesting that nutrient availability during early crop development is essential for optimal growth.

Conclusion: This study concludes that proper urea application, especially when combined with other fertilizers and applied before planting, can substantially enhance corn yield. Optimizing fertilizer use through recommended dosage and timing contributes to improved agricultural productivity.

Limitations: The study is limited to research using combined fertilization approaches, favorable climatic conditions, and controlled agricultural settings such as demonstration plots, which may not fully represent diverse field conditions.

Contribution: The results provide practical guidance for farmers and agricultural practitioners to improve fertilizer management strategies, maximize corn productivity, and support evidence-based agricultural decision-making.

Keywords: *Maize, Meta-analysis, Urea, Productivity.*

1. Introduction

Agriculture plays a critical role in maintaining global food security, and maximizing crop productivity is a major focus of farmers worldwide. Among important agricultural inputs, fertilizer is an important contributor to increasing crop yields. Urea, in particular, has gained widespread recognition as a nitrogen-based fertilizer that is versatile and significantly effective in affecting the productivity of various crops, including in maize cultivation. Maize is a grain food crop that originated in the Americas and has spread to Asia and Africa (Faqih, Dukat, & Trihayana, 2019). Maize is a global food product that serves as a staple food source for human consumption and animal feed, with high economic value and opportunities (Affandi, Hamim, & Nurmauli, 2014). However, the cultivation of this crop often faces challenges, as is the case in Indonesia, where productivity declines annually (BPS 2018). Therefore, efficient fertilization is required to increase the productivity of these crops (Shaila, Tauhid,

& Tustiyani, 2019). With increasing demand, it is necessary to understand the effect of urea on maize productivity to optimize farming practices and meet growing global food demand. As one of the most widely used nitrogen fertilizers worldwide, urea plays a crucial role in increasing crop productivity, especially in the context of the increasing global demand for food. Despite its widespread use, the effect of urea on maize productivity remains a subject of ongoing research, with a considerable degree of uncertainty and variability across different studies (Riesna, Pujianto, Efendi, Nugroho, & Saputra, 2023).

The present study aimed to contribute to this ongoing debate by conducting a meta-analysis of studies that have examined the effect of urea on maize productivity. By synthesizing and analyzing data from multiple studies, this study sought to provide a more comprehensive and robust picture of the relationship between urea use and maize yield (Melvi, Lestari, Ulvan, Aryanto, & Batubara, 2023). The analysis for this study began by collecting and reviewing references related to these studies and conducting an effect size analysis to assess the significance of the effect of urea on maize productivity (Yudhistira, Suprapto, & Sulmartiwi, 2023). Subgroup effects were also included to examine differences in urea effectiveness across locations, seasons, and combinations of urea and other fertilizers. The findings of this study have important implications for fertilizer management strategies and may inform the development of optimal application rates and timing of urea application. Understanding the relationship between urea use and maize productivity will enable stakeholders to develop more targeted approaches to fertilizer management, improve crop resilience, and contribute to global food security (Mardiono, Nanra, & Rican, 2023). In summary, this study is critical for addressing the global challenge of sustainable food production, and the results of this research can serve as recommendations for increasing maize yield productivity, optimizing fertilizer management strategies, and contributing to global food security. These findings may also have broader implications for the sustainable management of agricultural resources and the continued development of effective agriculture-based solutions to address global development challenges (Marhaen, Kusmiadi, & Ropalia, 2023).

2. Methods

The meta-analysis in this study was conducted with several main steps, namely, determining the reference component of the search and reference selection, recording and tabulating the required data, such as the number of samples, mean, and standard deviation, and standardizing the data, before finally running the analysis using OpenMEE. These steps are described in more detail.

2.1 Reference Article Search Component

The process of conducting rigorous research often involves a thorough review of the existing literature and published works to ensure that the research is relevant, comprehensive, and current. To locate the most pertinent articles related to a particular area of study, researchers often use various methods to narrow their searches, such as setting specific keywords based on the variables being studied (Putra & Cahyo, 2021). For instance, if one conducts research on the effects of urea fertilizer on corn productivity, keywords such as "urea fertilizer," "productivity," and "corn" corn are likely to return the most relevant results. In this study, relevant databases such as Scopus and Google Scholar were used to collect articles. Subsequently, the suitability of the articles was examined based on the availability of the data and methods used in the studies. Pramono and Pratama (2020) Data were then categorized by various parameters, including country of origin, research location, climate, fertilization method, population value, population mean, standard deviation, and other details, such as year of publication, author, journal title, and article link (Nurhaedah, Irmayani, Ruslang, & Jumrah, 2023). This meticulous cataloging allows researchers to gain a better understanding of the research landscape, identify any significant gaps in the existing literature, and ultimately generate insights that can have meaningful implications for the field. n conclusion, a comprehensive analysis of existing literature is essential for conducting meaningful research. Thoroughly combining relevant databases, selecting suitable articles, and carefully cataloging data are crucial elements in building an informed understanding of a particular area of study. Only then can researchers generate novel insights and advance the field's knowledge base (Melvi, Nurhayati, Batubara, Septama, & Ulvan, 2023).

2.2 Article Search, Review and Selection Process

The data search process was carried out by identifying relevant databases and entering keywords corresponding to the research questions. The first step was to review the titles and abstracts of articles found during the search to evaluate their relevance to the research questions. Articles not relevant to the research topic were excluded. Subsequently, article selection was performed by thoroughly reading the remaining articles after the initial assessment (Melvi, Shevia, et al., 2023). Data were extracted from the selected articles by creating a data template that characterized the study, such as research design, sample size, year of publication, methods used, and reported results. There were 27 articles were found from the use of keywords on the effect of urea fertilizer use on increasing corn productivity. Articles found were then selected based on the availability of relevant data, and only six articles were used in this meta-analysis (Table 1).

Table 1. Articles included in the meta-analysis

No	Author & Year	Article Title and Journal
1	Shaila et al. (2019)	Productivity and efficiency of nitrogen fertilization in maize under different urea and NBPT-treated urea levels *Ciênc Agrotec Lavras*, 35(3): 516-523.
2	Geng et al. (2016)	The controlled release of urea improved the nitrogen use efficiency and yield of wheat and corn. *Agronomy Journal*, 108(4): 1-8.
3	Swify, Avizienyte, Mazeika, and Braziene (2022)	Influence of modified urea compounds on nitrogen use efficiency in a corn growth system. *Sustainability*, 2022(14): 1-18.
4	(Tobing)	Pengaruh dosis pupuk urea dan varietas terhadap pertumbuhan dan produksi jagung (*Zea mays L.*). *Departemen Agronomi dan Holtikultura IPB*.
5	Motasim, Samsuri, Sukor, and Amin (2022)	Effects of liquid urea on the growth and yield of grain corn (*Zea mays L.*). *Communications in Soil and Plant Analysis*, 1-17.
6	Sembiring, Simbolon, and Tarigan (2022)	Respon hasil tanaman jagung (*Zea mays L.*) pada aplikasi dosis pupuk urea dan konsentrasi pupuk organik cair. *Jurnal Agroteknosains*, 6(2):134-143.

Source: Author's Process (2023)

2.3 Data Standardization

In the meta-analysis, standardization was performed to ensure uniformity and comparability of data obtained from different studies (Ramlan, Irmayani, & Nurhaeda, 2023). Data standardization was carried out by identifying the main variables to be standardized in the form of population data, population mean values, and standard deviations of each population. Additionally, it is necessary to ensure consistency in the units of measurement used. If there are differences in the units of measurement, then conversion into consistent units is performed (Suciati, Simamora, Panusunan, & Fauzan, 2023). The data were also reviewed for heterogeneity to ensure that the different studies were fairly compared. The next step was to map the data into a uniform format in the form of Nc = number of control samples, Xc = control mean, SDc = control standard deviation, Ne = number of treatment samples, Xe = treatment mean, and SDe = treatment standard deviation. The following data were collected for meta-analysis (Table 2).

Table 2. Data inputted in OpenMEE

No	Negara	Iklim	Pemupukan	Lokasi	Nc	Xc	SDc	Ne	Xe	SDe
1	Brazil	Tropis	Kombinasi	Tegalan	2	10,805.3	140.6	4	18,083.3	150.0
2	China	Sub tropis	Tunggal	Tegalan	2	8,000.0	53.4	6	7,250.0	45.9
3	Lituania	Sub tropis	Kombinasi	Plot	2	12,840.0	222.0	6	18,255.0	289.0
4	Indonesia	Tropis	Tunggal	Plot	2	6,500.0	35.0	4	8,825.0	52.2

| 5 | Malaysia | Tropis | Kombinasi | Plot | 2 | 6,472.9 | 268.2 | 10 | 12,899.9 | 225.2 |
| 6 | Indonesia | Tropis | Kombinasi | Plot | 4 | 10,281.0 | 189.9 | 12 | 19,126.0 | 380.1 |

Source: Author's Process (2023)

3. Results And Discussion

3.1 Effect of Urea on Maize Productivity

Urea is an efficient nitrogen source that provides essential nutrients for corn growth. Providing additional nitrogen optimizes photosynthesis, shoot formation, and root development, and results in higher productivity, as evidenced by the analysis conducted (Figure 1). Urea use had a strong effect on maize productivity (effect size: 19.882, $p < 0.001$). This means that there was a significant difference between the group that used urea and the group that did not. The implication for the fertilization strategy is that farmers need to use urea efficiently and on time to maximize maize productivity.
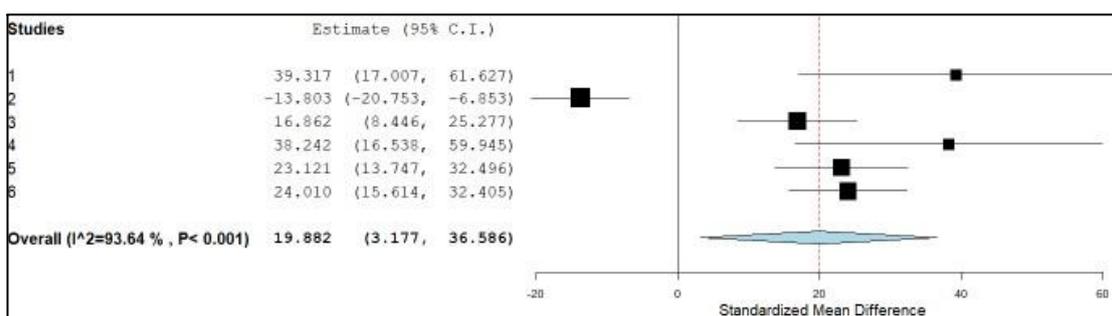

Figure 1. Results of effect size analysis of urea on corn productivity
Source: Author's Report (2023)

3.2 Effect on Fertilizer Combination Subgroup

The use of combination fertilizers and single fertilizers in agriculture can result in different levels of effectiveness. The results of the analysis showed that combination fertilization, such as using urea together with other nutrients such as phosphorus and potassium (NPK), can yield better results than single fertilization using urea alone (Figure 2). Combination fertilizers have higher effectiveness (concentrated range, 16,536 - 28,308) than those using urea alone (spread range, -39.798 - 62.123). Combination fertilization takes advantage of the synergy of different nutrients to maximize plant growth and meet complete nutrient requirements that may not be met by a single fertilizer
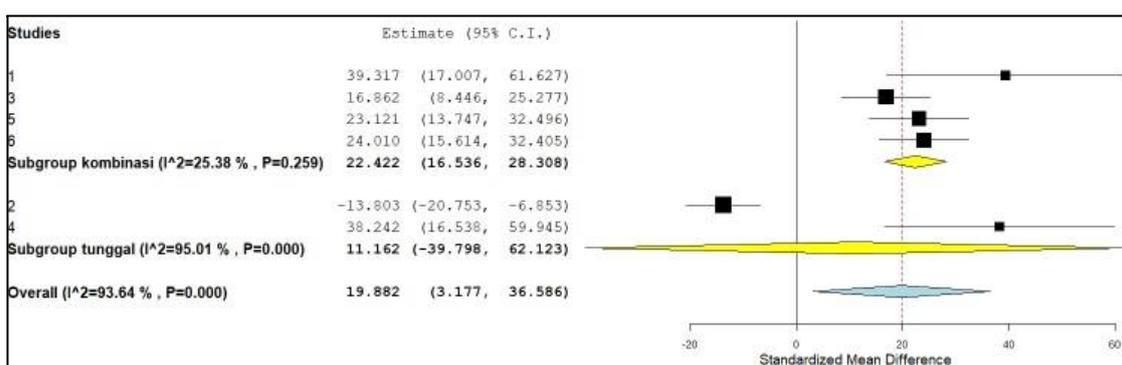

Figure 2. Results of effect size analysis based on fertilization type
Source: Author's Process (2023)

3.3 Effect on Planting Location Subgroup

Planting locations can have different effects on agriculture. Planting in demonstration plots or controlled agricultural experiments often results in better effectiveness than planting in larger fields, as evidenced by the analysis conducted (Figure 3). Urea use was more effective on maize grown in demonstration plots (focused range, 16,629 - 28,086) than those grown on the field (spread range, -40,356 - 63,667).

In the demonstration plots, factors such as fertilization, irrigation and soil treatment can be better controlled and optimized to provide more controlled and reliable results.
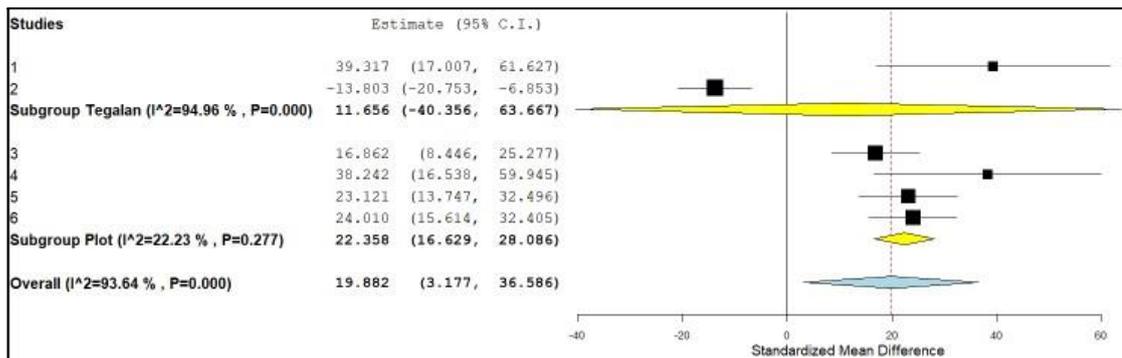

Figure 3. Results of effect size analysis based on the type of planting location
Source: Author's Process (2023)

3.4 Effect on Climate Type Subgroup (Tropical and Subtropical)

The difference in climate between tropical and subtropical regions can affect the effect of urea on maize productivity, as shown by the results of this study (Figure 4). The analysis shows that tropical locations have a higher effectiveness in using urea to increase maize productivity (concentrated range 19,803 - 31,968). This is in contrast to the results shown in subtropical locations where the effectiveness is spread across the zero axis (-28,616 - 31,484). Tropical climatic conditions with sufficient rainfall and warm temperatures throughout the year provide a favorable environment for the growth and development of maize plants. The use of urea can significantly increase maize productivity in the tropics by ensuring optimal nutrient supply.
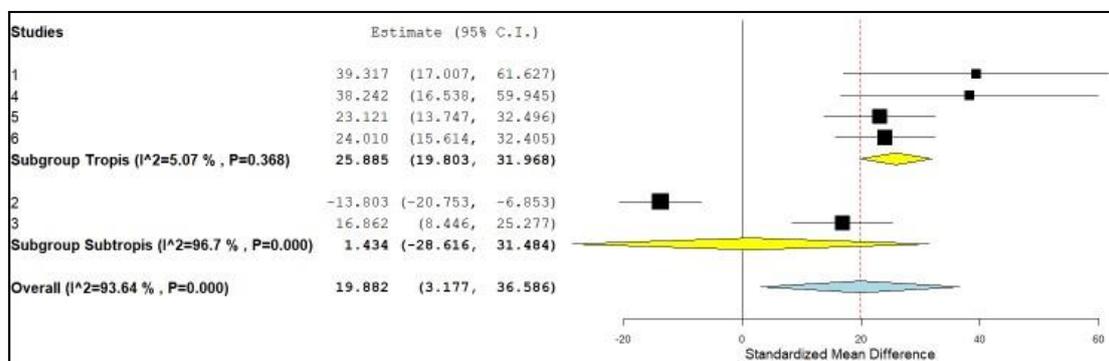

Figure 4. Results of effect size analysis based on climate type
Source: Author's Process (2023)

4. Conclusion

The implementation of good agricultural practices and appropriate application of urea fertilizers are crucial for optimal maize growth and yield. Poor application of urea can lead to fertilizer loss through leaching, volatilization, or denitrification, resulting in reduced nutrient uptake by the crop. The sustainable utilization of urea can also significantly reduce environmental pollution and increase soil fertility. In addition, the effective management of urea application can help reduce costs and improve profits for farmers. With the world's population projected to hit 9.7 billion by 2050, it is necessary to adopt sustainable technologies that can boost agricultural productivity, ensure food security, and improve livelihoods. The use of urea as a fertilizer has been proven beneficial for maize productivity, but its efficient and proper utilization is imperative for achieving optimal results. Through a combination of good agricultural practices and proper use of urea, farmers can significantly increase their maize yields, thereby contributing to global food security and sustainable agriculture (Riani, Handayani, & Ritonga, 2023).

Expanding on the limitations of this study, it is essential to highlight the necessity for a holistic assessment of agricultural practices that use urea. Undoubtedly, it has numerous advantages, including low cost, high availability, and quick action, making it a popular choice for farmers worldwide. However, the long-term implications of its use cannot be ignored. Extensive application of urea can cause environmental degradation, including increased soil acidity and contamination of groundwater resources. Additionally, the impact of climate change, such as water scarcity and erratic weather patterns, can exacerbate the effects of urea use. Therefore, it is crucial to explore sustainable alternatives to urea-based farming that prioritizes environmental protection and food security in the long run (Melvi, Ulvan, Aditama, & Batubara, 2023).

The findings of this study highlight the critical role of urea as a crucial input for smallholder farmers seeking to improve their yield and income from maize production. The use of good agricultural practices combined with the judicious use of urea can help smallholder farmers maximize the benefits of their farming activities while maintaining low production costs. Policymakers can play a crucial role in promoting the widespread adoption of such practices among farmers while ensuring that fertilizers are easily accessible, locally available, and cost-effective (Nurhaedah et al., 2023). Policymakers must focus on improving the agricultural value chain by providing farmers with cooperative extension services and technical support. This can help build smallholder farmers' capacity to adopt and implement best practices, explore newer technologies, and enhance their productivity. Moreover, policymakers must focus on promoting sustainable agriculture by promoting organic farming and crop rotation practices, which foster better soil health and reduce dependence on chemical fertilizers. In conclusion, the study's findings offer insightful recommendations that could help transform the agricultural landscape and improve the livelihoods of smallholder farmers in the long run. Policymakers play a crucial role in ensuring the effective implementation of these recommendations, which can ultimately lead to a more sustainable and prosperous agricultural sector (Torong, Mardiono, Apriyanto, & Friadi, 2023).

he findings have significant implications for smallholder farmers and policymakers. Smallholder farmers can significantly increase their maize production by adopting good agricultural practices and the proper use of urea, which is cost-effective and readily available. Policymakers can develop policies that promote the sustainable use of fertilizers, encourage the adoption of good agricultural practices, and ensure that farmers have access to high-quality fertilizers at affordable prices. Future studies should focus on investigating the effects of urea on other crops and their yields under different climatic conditions (Anwar & Ferdilla, 2024). Additionally, research should be conducted on the potential impact of urea on soil quality, the environment, and the potential to reduce its negative effects. Another area of future study is the development of alternative fertilizers that promote sustainable agriculture and are cost-effective. Future studies could also explore the socioeconomic factors that affect the adoption of good agricultural practices and use of urea fertilizers (Ramlan et al., 2023). It is important to understand barriers to adoption, such as lack of knowledge and access to resources, and to develop interventions aimed at addressing these barriers. Another area of future research could be the use of precision agriculture technologies to optimize urea application. Precision agriculture technologies, such as satellite and drone imagery and soil sensors, can provide real-time data on soil nutrient levels, allowing for the targeted and precise application of urea fertilizers. This approach could further increase crop yields while reducing negative impacts on the environment (Mardiono et al., 2023). Overall, this study's findings have important implications for sustainable agriculture and food security. By adopting good agricultural practices and the proper use of fertilizers, farmers can improve their productivity and income while contributing to global food security. However, care must be taken to ensure that these practices are sustainable and do not negatively affect the environment. Future studies can help refine our understanding of the best practices and promote sustainable and environmentally friendly agricultural practices (Yando, Panusunan, & Fauzan, 2023).

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