Case Study Open Access

Case Study on High-Yield Cultivation Techniques for Fresh-Eating Maize in Different Ecological Regions

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Bioscience Evidence, 2025, Vol.15, No.1 doi: 10.5376/be.2025.15.0002
Received: 28 Nov., 2024
Accepted: 04 Jan., 2025
Published: 12 Jan., 2025

Preferred citation for this article:
Huang L.P., 2025, Case study on high-yield cultivation techniques for fresh-eating maize in different ecological regions, Bioscience Evidence, 15(1): 12-19 (doi: 10.5376/be.2025.15.0002)

Abstract This study analyzes high-yield cultivation techniques for maize across different ecological regions, emphasizing the importance of developing region-specific strategies to maximize productivity. The study evaluates the impact of techniques such as zigzag planting combined with deep nitrogen fertilization, ridge-furrow systems, and high-density planting on maize yield. These methods significantly enhance maize growth by optimizing root and canopy structures, improving water use efficiency, and promoting light interception and photosynthetic productivity. Additionally, selecting maize varieties suited to specific ecological conditions and implementing integrated pest management (IPM) strategies are crucial for maintaining high yields. The study underscores the importance of sustainable practices, such as reducing excessive nitrogen use and improving soil health, to support long-term maize production. Future research should focus on further optimizing these techniques and exploring genetic improvements in maize varieties to adapt to advanced cultivation methods.
Keywords High-yield cultivation; Maize; Ecological regions; Sustainable practices; Integrated pest management

1 Introduction

Maize (*Zea mays* L.) is a staple crop with significant importance in global agriculture, serving as a primary food source for humans and livestock, as well as a key ingredient in industrial products and biofuels (Piscitelli et al., 2021; Mattoo et al., 2023). The demand for maize is increasing due to its versatility and nutritional value, which is driving the need for improved cultivation techniques to meet global food security challenges (Zhang et al., 2019). In regions like China, maize occupies a substantial portion of arable land, highlighting its critical role in national food production (Zheng et al., 2023).

Ecological regions significantly influence maize cultivation, affecting yield and quality due to variations in climate, soil, and water availability. For instance, in semiarid cold regions like Heilongjiang province in China, specific cultivation techniques such as the application of potassium fertilizer have been shown to enhance the yield and quality of fresh-eaten maize varieties (Yang et al., 2021). Similarly, in semi-arid Mediterranean regions, adaptive strategies like deficit irrigation have been explored to optimize maize production under challenging environmental conditions (Piscitelli et al., 2021; Wu et al., 2024). These examples underscore the necessity of tailoring cultivation practices to local ecological conditions to maximize productivity.

This study will analyze the effectiveness of high-yield cultivation techniques for maize across different ecological regions, including evaluating methods such as zigzag planting combined with deep nitrogen fertilization, which significantly enhance maize yield by optimizing root and canopy structures. The study aims to assess the impact of intercropping and high-density planting on yield improvement, as these practices show potential in enhancing light interception and photosynthetic productivity. Through understanding and implementing these techniques, the study will provide valuable insights for sustainable maize production adapted to different environmental conditions.

2 Overview of Different Ecological Regions

2.1 Temperate regions

Temperate regions are characterized by a suitable climate and a long growing season, making them ideal for maize cultivation. The extended growing period allows for the full development of maize plants, leading to higher yields. In these regions, techniques such as optimized fertilization practices have been shown to improve maize yield significantly. For instance, the use of optimized fertilization in temperate areas can enhance the chemical and bacterial properties of rhizosphere soil, which in turn supports better root physiological properties and increases yield (Li et al., 2022). Additionally, mechanized high-yield cultivation techniques, which include the selection of appropriate maize varieties and efficient water and fertilization management, are particularly effective in these regions (Pinyu, 2011).

The temperate climate also supports the use of high-density planting methods, which can further increase yield. Chen et al. (2022)'s study have shown that increasing planting density and nitrogen fertilization under plough tillage can significantly boost maize yield by improving light interception and photosynthetic productivity. This approach is particularly beneficial in temperate regions where solar radiation is adequate to support such intensive cultivation practices (Figure 1).

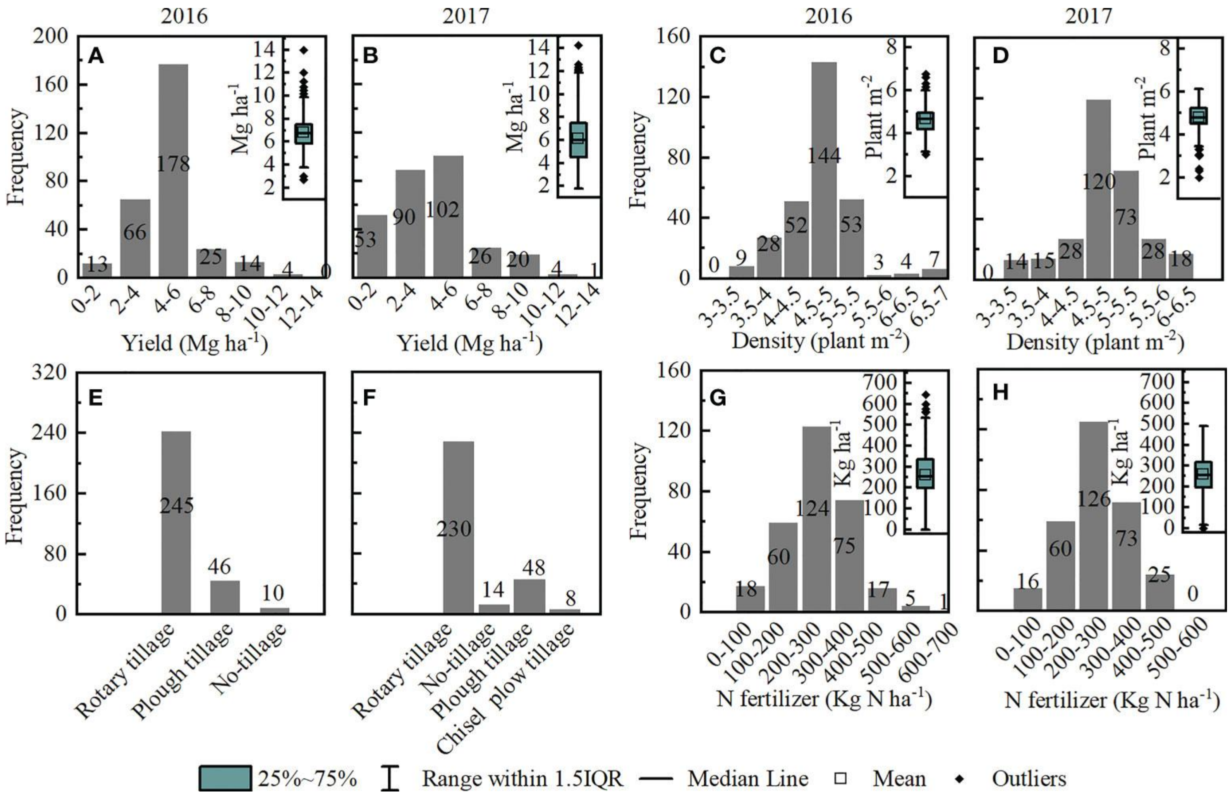

Figure 1 Statistics for yield, planting density, tillage methods, and nitrogen (N) fertilizer survey data of relay intercropping maize from farmers (Adopted from Chen et al., 2022)

Note: (A, B): grain yield in 2016-2017; (C, D): the frequency distribution histogram and boxplot of planting density in 2016 and 2017; (E, F): the frequency distribution histogram of tillage methods in 2016 and 2017; (G, H): the histogram and boxplot of N fertilizer in 2016 and 2017; n=300 (Adopted from Chen et al., 2022)

2.2 Tropical regions

Tropical regions present unique challenges for maize cultivation due to high temperatures and humidity, coupled with a shorter growing season. These conditions can lead to increased evapotranspiration and stress on maize plants. However, innovative cultivation techniques such as ridge-furrow precipitation harvesting with plastic mulching have been shown to improve water use efficiency and grain yield in semi-arid tropical areas (Li et al., 2019). This technique helps in conserving soil moisture and reducing the negative impacts of high temperatures and humidity.

In tropical regions, the use of in situ rainwater harvesting techniques, such as pot holing and tied ridging, can significantly increase soil moisture content and maize yield. These methods are effective in mitigating the effects of drought stress, which is a common issue in tropical climates with poorly distributed rainfall (Mudatenguha et al., 2014). By enhancing soil moisture retention, these techniques support better maize growth and yield even in challenging tropical environments.

2.3 Cold regions

Cold regions are characterized by large temperature fluctuations and a short growing period, which necessitates specific cultivation strategies for successful maize production. In these areas, the use of ridge-furrow cultivation has been found to increase maize yield and water use efficiency by optimizing soil and climate conditions (Wang et al., 2020). This technique is particularly beneficial in cold regions where the growing season is limited, as it helps in maximizing the use of available resources.

Moreover, the selection of maize varieties that are well-suited to cold climates, along with the implementation of mechanized cultivation techniques, can further enhance yield. These practices include preserving soil moisture and controlling water and fertilization to meet the specific needs of maize in cold regions (Pinyu, 2011). By addressing the unique challenges posed by cold climates, these strategies ensure that maize cultivation remains viable and productive.

3 Maize Variety Selection and Planting Density

3.1 Selecting suitable maize varieties for different ecological regions

Selecting the appropriate maize variety for different ecological regions is crucial for optimizing yield. In Northeast China, compact varieties like Dika159 have shown superior yield and water-use efficiency compared to conventional varieties such as Zhengdan958, especially when combined with increased planting density and optimized irrigation (Shen et al., 2024). Similarly, in the Nigerian Savanna, intermediate maturing maize varieties have demonstrated higher grain yields compared to early and late maturing varieties, indicating the importance of selecting varieties that match the specific environmental conditions (Adnan et al., 2022).

In Southeast China, the sweet maize variety MT6855 has been identified as density-tolerant, showing significant yield improvements with increased planting density, unlike the XMT10 variety. This suggests that selecting varieties with specific traits such as density tolerance can significantly enhance yield and nutrient use efficiency in specific ecological regions (Ye et al., 2023). Additionally, the use of hybrids with traits like erect leaves and smaller leaf angles has been shown to improve light interception and yield in dense planting systems, further emphasizing the need for region-specific variety selection (Zainuddin et al., 2024).

3.2 The impact of maize planting density on yield and how to adjust it

Planting density is a critical factor influencing maize yield. Studies have shown that increasing planting density can significantly enhance yield, as observed in Northeast China where higher densities improved both yield and water-use efficiency (Shen et al., 2024). In China, the optimum planting densities vary across regions, with higher densities yielding better results in areas like Qitai compared to Gongzhuling, highlighting the need to adjust planting density based on local climatic conditions (Xu et al., 2017).The planting density of spring fresh corn in Zhejiang is generally between 45000 and 50000 plants per hectare, as the growth period of spring fresh corn is in a rainy and high humidity season, and the planting density is too low, which affects the yield; Excessive planting density can lead to the occurrence of various diseases, affecting quality and yield (Wang et al., 2023).

Moreover, the development of density-tolerant maize varieties has allowed for higher planting densities without compromising yield. For instance, the MT6855 variety in Southeast China showed increased yield with higher planting densities, while the XMT10 variety did not benefit from such adjustments (Ye et al., 2023). This indicates that while increasing planting density can generally improve yield, it is essential to consider the specific variety's response to density changes to optimize results (Tang et al., 2018).

3.3 Considering the effects of light and ventilation conditions on maize growth in various ecological regions

Light and ventilation conditions significantly affect maize growth and yield. In different ecological regions, factors such as solar radiation and temperature range play a crucial role in determining the optimal planting density and yield outcomes. For example, in China, regions with higher solar radiation and favorable temperature ranges, like Qitai, benefit from higher planting densities, which enhance light interception and yield (Xu et al., 2017).

The structure of the maize canopy, including leaf orientation and angle, also influences light penetration and photosynthesis efficiency. Hybrids with erect leaves and smaller leaf angles have been shown to perform better in dense planting systems by improving light interception and reducing shading, which is crucial for maximizing yield in regions with limited light availability (Tang et al., 2018). Therefore, understanding and optimizing light and ventilation conditions are essential for improving maize growth across different ecological regions.

4 Case Studies

4.1 Temperate regions: successful maize varieties and cultivation techniques

In temperate regions, adjusting maize plant density according to climatic conditions has proven to be an effective strategy for maximizing yield. A study conducted across different ecological regions in China demonstrated that the optimum plant density varied significantly with location, influenced by factors such as solar radiation and temperature range. For instance, the highest yield was achieved with a density of 12 plants per square meter in Qitai, while Yinchuan and Gongzhuling required densities of 10.5 and 7.5 plants per square meter, respectively. These findings highlight the importance of tailoring plant density to local climatic conditions to optimize maize yield (Xu et al., 2017).

Additionally, optimized fertilization practices have been shown to enhance maize yield in temperate regions. A study on fresh waxy maize revealed that a one-time application of a new compound fertilizer at the six-leaf stage significantly increased both the abundance and diversity of rhizosphere soil bacterial communities, as well as the organic matter and total nitrogen content in the soil. This approach not only improved root activity but also resulted in higher yields, demonstrating the effectiveness of synchronizing soil nutrient supply with crop requirements (Li et al., 2022).

4.2 Tropical regions: innovative maize cultivation techniques and water management

In tropical regions, innovative cultivation techniques such as ridge-furrow precipitation harvesting with plastic mulching have been employed to improve water use efficiency and maize yield. This method, tested in semi-arid areas, significantly enhanced grain-filling rates, hormonal changes, and dry matter accumulation in maize. The ridge-furrow technique, combined with appropriate nitrogen management, improved soil water storage and water use efficiency, leading to increased maize yields (Figure 2) (Li et al., 2019).

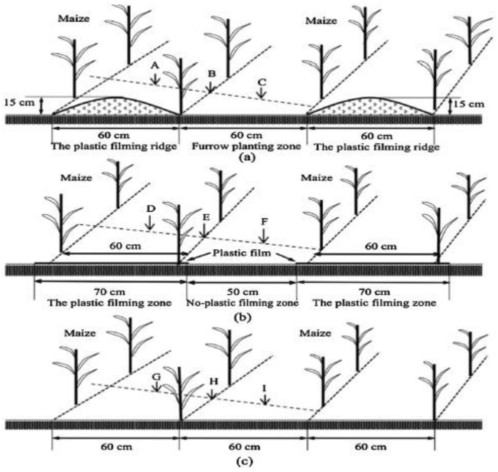

Figure 2 Schematics of the field layouts (Adopted from Li et al., 2019)

Image caption: (a) Ridge and furrow rainfall harvesting (RF) system; (b) flat planting with film plastic mulching (FM); (c) conventional planting without mulching (CP) (Adopted from Li et al., 2019)

Furthermore, intercropping maize with soybeans using high-density planting and high nitrogen fertilization has shown promise in tropical regions. This approach, which involves dense cultivation and plough tillage, resulted in a 28.8% increase in yield compared to traditional farmer practices. The increased leaf area index and improved light interception contributed to higher photosynthetic productivity, thereby enhancing maize yield in these regions (Chen et al., 2022).

4.3 Cold regions: solutions for low temperatures and soil issues in maize cultivation

In cold regions, addressing low temperatures and soil issues is crucial for successful maize cultivation. Ridge-furrow cultivation has been identified as a beneficial technique in these areas, as it increases yield and water use efficiency without significantly affecting total water consumption. This method is particularly effective in regions with medium or fine soil texture and low soil bulk density, where it enhances yield and water use efficiency (Wang et al., 2020).

Additionally, the return of stover and appropriate nitrogen application have been shown to improve soil organic carbon and nitrogen levels, which are critical for maize growth in cold regions. A study found that stover return combined with a nitrogen application rate of 250 kg per hectare significantly increased soil organic carbon, microbial biomass, and maize yield. This approach helps to mitigate the challenges posed by low temperatures and poor soil conditions, thereby supporting higher maize productivity (Liu et al., 2021).

5 Maize Soil Management

5.1 Soil improvement techniques

The use of organic fertilizers and pH adjustment are critical techniques for improving soil quality in maize cultivation. Organic fertilizers enhance soil structure, increase microbial activity, and improve nutrient availability, which are essential for healthy maize growth. For instance, optimized fertilization practices have been shown to increase the abundance and diversity of rhizosphere soil bacterial communities, which in turn enhances maize yield (Figure 2)(Li et al., 2022). Additionally, adjusting soil pH to optimal levels can improve nutrient uptake and overall plant health, contributing to higher yields.

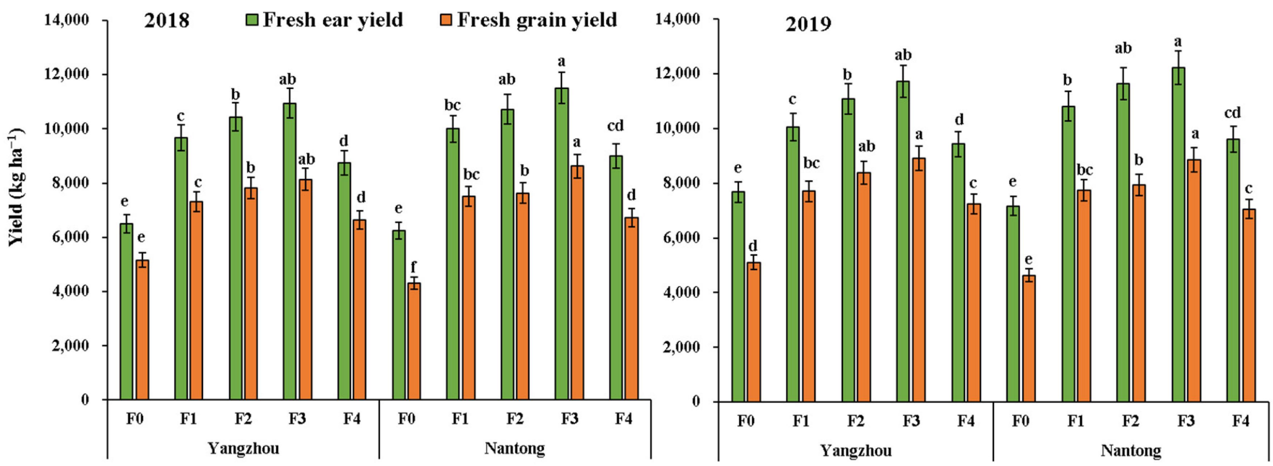

Figure 3 Effects of optimized fertilization practices on ear and grain yield of fresh waxy maize (Adopted from Li et al., 2022)

Image caption: Bars represent means ± standard deviation (n=3). Different letters above the bars represent significant differences at $p<0.05$; F0: no fertilizer; F1, F2, and F3 represent new compound fertilizer applied 225 kg N ha^{-1} at sowing, V3, and V6 stages, respectively; F4: applied 75 kg N ha^{-1} traditional compound fertilizer at sowing stage and 150 kg N ha^{-1} urea at V6 stage (Adopted from Li et al., 2022)

In semi-arid regions, soil improvement techniques such as the application of organic matter can significantly enhance soil water retention and nutrient availability. Studies have demonstrated that organic amendments can increase soil moisture content and reduce the effects of drought stress on maize growth and yield (Mudatenguha et al., 2014). These improvements in soil conditions are crucial for sustaining maize production in challenging environments.

5.2 Suitable tillage methods

Tillage methods play a significant role in maize cultivation, with options like deep tillage and no-till having distinct impacts. Deep tillage can improve soil aeration and root penetration, which are beneficial for maize growth. However, it may also lead to increased soil erosion and moisture loss if not managed properly. In contrast, no-till methods help preserve soil structure and moisture, which are advantageous in dryland farming systems (Wang et al., 2020).

The choice between deep tillage and no-till depends on the specific ecological conditions and management goals. For example, in regions with low soil bulk density, ridge-furrow cultivation, a form of no-till, has been shown to increase maize yield and water use efficiency without significantly affecting total water consumption (Wang et al., 2020). This method is particularly effective in areas with medium or fine soil texture, where it enhances soil moisture retention and reduces erosion.

5.3 Methods for improving soil fertility and nutrient management in maize cultivation

Improving soil fertility and nutrient management is essential for high-yield maize cultivation. Optimized fertilization practices, such as the one-time application of new compound fertilizers at specific growth stages, have been shown to enhance soil chemical properties and increase maize yield (Li et al., 2022). These practices synchronize nutrient supply with crop demand, improving nutrient use efficiency and reducing environmental impact.

Incorporating nutrient management strategies, such as balanced fertilization and the use of nitrogen and phosphorus at optimal levels, can significantly improve maize productivity. Studies have shown that applying nitrogen at rates up to 200 kg/ha can enhance soil water storage and improve maize yield components, such as grain-filling rates and hormonal balance (Li et al., 2019). These strategies are particularly effective in semi-arid regions, where efficient water and nutrient use are critical for sustaining maize production.

6 Maize Water Management

6.1 Irrigation methods for maize: drip irrigation, sprinkler irrigation, etc.

Drip irrigation has been shown to significantly enhance maize yield and water use efficiency compared to traditional methods like flood irrigation. In the North China Plain, drip fertigation improved soil water content and nitrogen efficiency, resulting in higher maize yields with reduced water and nitrogen inputs (Guo et al., 2022). Similarly, in semi-arid regions, deficit drip irrigation, which uses 75% of the full irrigation amount, has been effective in maintaining high grain yields while improving water use efficiency by 17.9% compared to full irrigation (Lu et al., 2021). This method also reduces the risk of soil nitrate leaching, making it a sustainable choice for water-scarce areas (Yan et al., 2020).

Sprinkler irrigation, while not as frequently highlighted in the studies, can also be an effective method for maize cultivation, especially in regions where water distribution needs to be more uniform. However, the focus on drip irrigation in the literature suggests it is more efficient in terms of water conservation and yield improvement, particularly in areas with limited water resources (Wu et al., 2019).

6.2 Water management strategies for maize in drought-prone and rainy regions

In drought-prone regions, water management strategies such as in situ rainwater harvesting have proven beneficial. Techniques like mulching, tied ridges, and pot holing significantly increase soil moisture content and maize yield by reducing runoff and enhancing water infiltration (Mudatenguha et al., 2014). These methods are particularly effective in semi-arid areas, where they can increase maize yield by up to 136% compared to traditional flat planting (Mudatenguha et al., 2014).

On the other hand, in regions with abundant rainfall, managing excess water is crucial to prevent waterlogging and nutrient leaching. Strategies such as optimizing irrigation intervals under mulch drip irrigation help maintain soil moisture balance and improve maize yield. A study by Shen et al. (2020) found that a six-day irrigation interval is optimal for maintaining high soil moisture and promoting maize growth, particularly in Northwestern China. This approach ensures that maize plants receive sufficient water without the negative effects of over-irrigation.

6.3 Maintaining soil moisture balance to avoid negative effects on maize growth

Maintaining an optimal soil moisture balance is critical for avoiding negative impacts on maize growth. Drip fertigation systems have been shown to enhance soil moisture retention and improve nutrient uptake, leading to increased biomass accumulation and grain yield (Du et al., 2024). In Northeast China, surface drip fertigation increased maize yield by 41% in sandy soils by optimizing both water and nutrient management (Wu et al., 2019).

In regions with variable precipitation, deficit irrigation strategies can help maintain soil moisture balance by aligning irrigation with crop evapotranspiration and precipitation forecasts. This approach not only improves water use efficiency but also stabilizes maize yield by preventing water stress during critical growth stages (Lu et al., 2021). By carefully managing irrigation levels, farmers can ensure that maize plants receive sufficient water without the risk of waterlogging or nutrient leaching, thereby optimizing growth and yield (Li et al., 2023).

7 Maize Fertilization Techniques

7.1 Proper combination of basal and top dressing fertilizers for maize

The combination of basal and top dressing fertilizers plays a crucial role in optimizing maize yield. Studies have shown that applying a balanced ratio of basal and top dressing fertilizers can significantly enhance maize growth and yield. For instance, a study conducted on maize hybrids demonstrated that a basal fertilization of 120 kg N ha^{-1} followed by top dressing at specific growth stages (V6 and V12) resulted in substantial yield increases compared to basal fertilization alone (Zagyi et al., 2024). Similarly, another study highlighted that a 2:8 basal to top dressing ratio improved dry matter yield and nitrogen recovery efficiency, particularly during normal rainfall years, suggesting this as an optimal strategy for semi-arid regions (Ma et al., 2023; Zhang and Xu, 2024).

Moreover, the timing and method of fertilizer application are critical. Research indicates that split applications of nitrogen, with a portion applied as basal and the remainder as top dressing, can lead to improved nitrogen use efficiency and higher yields. Msarmo (2011)'s study found that applying half of the nitrogen dose as basal and the other half as top dressing increased maize grain yield significantly. This approach not only enhances yield but also reduces the risk of nutrient leaching and environmental pollution.

7.2 Use of efficient fertilizers to improve fertilizer utilization rates

Efficient fertilizers, such as those tailored to specific crop needs, can significantly improve fertilizer utilization rates in maize cultivation. The use of crop-specific blended fertilizers has been shown to enhance growth and yield. In a field experiment, the application of a basal blended fertilizer followed by a top dress of blended fertilizer resulted in the highest plant height, number of leaves, and kernel yield compared to traditional fertilization methods (Arun et al., 2023). This indicates that tailored fertilizers can optimize nutrient availability and uptake.

Additionally, the integration of efficient fertilization techniques, such as fertigation, can further improve utilization rates. A study on drip irrigation and nitrogen fertigation demonstrated a significant increase in maize yield compared to traditional nitrogen application methods. This approach not only stabilized yields over the years but also increased plant yield by approximately 25% on average, highlighting the potential of fertigation in enhancing fertilizer efficiency (Żarski and Kuśmierek-Tomaszewska, 2023). These findings underscore the importance of adopting efficient fertilization strategies to maximize maize productivity.

7.3 Green agriculture principles: reducing chemical fertilizer use and improving soil health to optimize maize growth

Green agriculture principles emphasize reducing chemical fertilizer use while improving soil health to optimize maize growth. One approach is the use of mulching combined with reduced chemical fertilizers, which has been shown to increase soil water content and nitrate-N content, thereby enhancing maize yield. For instance, plastic film mulching with basal and top dressing fertilizers increased maize yield significantly over multiple years, demonstrating the effectiveness of this sustainable practice (Wang et al., 2015; Wang and Xing, 2016).

In addition, the combined use of biological fertilizers and soil amendments can improve soil health and nutrient availability. A study by Padwar et al. (2023) showed that using microbial inoculants (such as Gluconacetobacter diazotrophicus) along with reduced chemical fertilizers can increase nutrient availability in the soil and promote maize growth. This approach not only reduces reliance on chemical fertilizers but also promotes a healthier soil ecosystem, contributing to sustainable maize production. These practices align with green agriculture principles by minimizing environmental impact while maintaining high crop productivity.

8 Maize Pest and Disease Control

8.1 Integrated pest management strategies

Integrated pest management (IPM) for maize involves a combination of physical, biological, and chemical controls to manage pest populations effectively while minimizing environmental impact. Physical controls include practices such as crop rotation and ploughing, which disrupt pest life cycles and reduce their populations (Meissle et al., 2009; Meissle et al., 2011). Biological controls involve the use of natural predators or pathogens to control pest populations. For example, entomopathogenic microorganisms are used to target specific arthropod pests, providing a sustainable alternative to chemical pesticides (Seyi-Amole and Onilude, 2021). Chemical controls, while still used, are increasingly being integrated with other methods to reduce reliance on pesticides and prevent resistance development in pest populations (Wanyi, 2011; Alford and Krupke, 2018).

The integration of these strategies is crucial for maintaining maize yield and quality. In Europe, for instance, IPM practices are being promoted to reduce pesticide use and enhance sustainability in maize production. This includes the use of genetically engineered (GE) maize varieties that express insecticidal compounds, providing a preventive measure against major pests like the European corn borer and the western corn rootworm (Meissle et al., 2011). The combination of these methods allows for a more holistic approach to pest management, addressing both primary and secondary pest issues (Meissle et al., 2009).

8.2 Pest and disease control strategies specific to common maize pests in different regions

Different regions face unique challenges with maize pests and diseases, necessitating tailored control strategies. In the United States, corn rootworm is a significant pest, managed through a combination of Bt corn hybrids, soil insecticides, and neonicotinoid seed treatments (NSTs) (Alford and Krupke, 2018). These treatments are often used in rotation to prevent resistance and reduce costs, while maintaining high levels of pest control efficiency (Alford and Krupke, 2018).

In subtropical areas of North America, pests such as Helicoverpa zea and Spodoptera frugiperda cause significant ear injury, leading to aflatoxin accumulation. Management strategies in these regions focus on maximizing genetic resistance to pests and diseases, using biological controls like non-aflatoxigenic strains of Aspergillus flavus, and employing cultural practices such as early planting to avoid peak pest periods (Pruter et al., 2020). These strategies are designed to reduce aflatoxin risk while maintaining yield and quality.

8.3 Application of precision spraying and pest/disease monitoring techniques for maize

Precision spraying and monitoring techniques are becoming increasingly important in maize pest and disease management. These technologies allow for targeted application of pesticides, reducing the amount of chemicals used and minimizing environmental impact. Precision spraying systems can apply pesticides only where needed, based on real-time data from pest and disease monitoring systems (Meissle et al., 2009). This approach not only improves the efficiency of pest control but also helps in reducing the development of resistance in pest populations.

Monitoring techniques, such as pest and disease surveillance programs, provide critical data that inform decision-making in IPM. These programs help identify pest outbreaks early, allowing for timely interventions that prevent significant crop damage (Meissle et al., 2009). In Europe, for example, multicriteria assessments and decision support systems are being developed to create region-specific strategies that harmonize pest control measures within a broader EU framework (Meissle et al., 2009). These advancements in precision agriculture are essential for sustainable maize production in diverse ecological regions.

9 Conclusion and Recommendations

High-yield cultivation techniques for maize vary significantly across different ecological regions, reflecting the diverse environmental conditions and resource availability. In China, zigzag planting combined with deep nitrogen fertilization has been shown to significantly enhance maize yield by optimizing root and canopy structures, thereby improving resource utilization. In semi-arid regions, ridge furrow rainfall harvesting systems have been effective in increasing soil water storage and water use efficiency, which are critical for maize growth under water-limited conditions. High-density planting and optimized nutrient management, including balanced fertilization and gradual potassium application, have also been identified as effective strategies to increase yield and improve maize quality in various regions.

To support maize farming, it is recommended that agricultural policies focus on promoting the adoption of high-yield cultivation techniques tailored to specific ecological conditions. This includes providing training and resources for farmers to implement zigzag planting and deep fertilization methods in suitable regions. Additionally, policies should encourage the use of ridge furrow systems in semi-arid areas to enhance water conservation. Technical support should also be provided to facilitate the transition to high-density planting and optimized nutrient management practices, which have been shown to increase yield and efficiency. Furthermore, promoting sustainable practices that balance yield with environmental impact, such as reducing excessive nitrogen use, is crucial for long-term agricultural sustainability.

Future research should focus on further refining and adapting high-yield cultivation techniques to local conditions, considering both biotic and abiotic factors that affect maize production. Studies should explore the long-term impacts of these techniques on soil health and environmental sustainability. Additionally, research into the genetic improvement of maize varieties to enhance their compatibility with advanced cultivation methods could provide significant yield benefits. Investigating the interactions between different cultivation techniques and their cumulative effects on yield and resource efficiency will also be valuable. Developing precision agriculture technologies to optimize input use and monitor crop health in real-time could further enhance maize productivity across diverse ecological regions.

Acknowledgments

The author expresses deep gratitude to Professor R. Cai from the Zhejiang Agronomist College for his thorough review of the manuscript and constructive suggestions. The author also extends thanks to the two anonymous peer reviewers for their valuable revision recommendations.

Conflict of Interest Disclosure

The authors affirm that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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