Research Insight Open Access

Insights into Optimizing Cultivation Practices for Enhanced Yield and Quality in Fresh-Eating Maize

Meili Chen
Jinhua Wucheng Chenmeili Family Farm, Jinhua, 321075, Zhejiang, China
Corresponding email: ameilove23@126.com

Bioscience Methods, 2025, Vol.16, No.1 doi: 10.5376/bm.2025.16.0002
Received: 03 Nov., 2024
Accepted: 05 Jan., 2025
Published: 26 Jan., 2025

Preferred citation for this article:
Chen M.L., 2025, Insights into optimizing cultivation practices for enhanced yield and quality in fresh-eating maize, Bioscience Methods, 16(1): 11-22 (doi: 10.5376/bm.2025.16.0002)

Abstract The increasing consumer demand for high-yield and high-quality fresh-eating maize necessitates the adoption of scientific cultivation practices to enhance its yield and quality. This study reviews the latest advancements in optimizing cultivation practices for fresh maize, focusing on key strategies such as planting density, water and fertilizer management, integrated pest and disease control, mechanization, and smart technologies. Findings indicate that precise planting density and water-fertilizer management significantly improve yield and quality, while eco-friendly practices like intercropping and crop rotation enhance soil health and reduce pest risks. Moreover, intelligent monitoring and mechanized operations further boost management efficiency and product quality. Despite the immense potential of optimized cultivation practices in fresh maize production, challenges such as climate change, technical dissemination, and limitations of small-scale farming persist. Future efforts should integrate smart technologies with precision management, develop region-specific cultivation models, and promote sustainable agricultural practices. This study provides theoretical support and practical guidance for fresh maize producers, contributing to the development of efficient and sustainable modern agriculture.

Keywords Fresh-eating maize; Cultivation optimization; Precision management; Ecological agriculture; Smart technologies

1 Introduction

Fresh corn refers to a type of corn that is harvested during the milk ripening period,for fresh-eating ears or processing fresh corn kernels.The cultivation of fresh corn is of significant importance due to its multifaceted value as a food grain, vegetable, and economic crop. Fresh corn is not only a staple in many diets but also a crucial component of agricultural economies, providing substantial income for farmers and contributing to food security (Piao et al., 2016; Li et al., 2022; Zheng et al., 2023). The increasing demand for high yield and quality in the fresh corn market underscores the need for optimized cultivation practices that can meet consumer expectations and market standards (Ren et al., 2020; Capo et al., 2023; El-Syed et al., 2023).

Proper cultivation management plays a pivotal role in enhancing the yield and quality of fresh corn. Techniques such as optimized fertilization, strategic planting patterns, and effective nutrient management have been shown to significantly improve crop performance. For instance, zigzag planting combined with deep nitrogen fertilization has been found to increase maize yield by optimizing root and canopy structures (Zheng et al., 2023). Similarly, the use of organic amendments like biochar and compost, alongside inorganic fertilizers, can enhance nitrogen use efficiency and yield, especially under challenging conditions such as water deficits (Zhou et al., 2022; El-Syed et al., 2023). This study aims to summarize the mechanisms by which optimized cultivation practices impact the yield and quality of fresh-eating maize and propose cultivation strategies suitable for different environments and market demands. By providing insights into effective agronomic practices, this study seeks to support sustainable intensification and enhance the economic viability of fresh-eating maize production in diverse agro-ecological zones.

2 Key Factors Affecting Yield and Quality of Fresh Corn

2.1 Variety characteristics

Fresh corn is mainly divided into sweet corn, waxy corn, and sweet-waxy corn (Wang et al.,2015).The yield and quality of fresh corn are significantly influenced by the type of corn variety. Sweet corn, supersweet corn, and waxy corn each have distinct characteristics that affect their performance (Zhou and Hong, 2024). Sweet corn varieties, such as those studied in Turkey, show significant differences in yield and quality traits like flowering time, plant length, and grain yield. Supersweet corn, known for its high sugar retention post-harvest, demonstrates a high potential for yield and quality, as seen in the Hybrix 39 variety, which achieved the highest wet cob yield (Özata, 2019). Waxy corn, primarily consumed as a fresh vegetable, benefits from specific nitrogen management to enhance its nutritional quality, including anthocyanin and carbohydrate content (Feng et al., 2024). The genetic diversity among these corn types allows for targeted breeding to optimize traits like sweetness, texture, and yield (Dermail et al., 2021).

2.2 Environmental conditions

Environmental factors such as climate, soil type, and water supply play crucial roles in the growth and development of fresh corn. Temperature and photoperiod are strong determinants of flowering and harvest dates, impacting yield in various climates. In Zhejiang, due to the influence of temperature, fresh corn can generally be sown from March to August. However, corn sown during the one month period from mid June to mid July, due to the fact that the heading and flowering period coincides with the local high temperature or even dry season in August, causes pollen breakage, a significant decrease in seed setting rate, and the appearance of missing rows, few grains, and even bald heads in the ear, affecting yield and quality. Soil fertility and water supply also significantly influence sweet corn growth, with effective fertilization improving performance (Sidahmed et al., 2024). A case study on water stress revealed that deficit irrigation can maintain yield and quality by optimizing leaf area index and SPAD values, which are indicators of plant health and productivity (Nemeskéri et al., 2019). In subtropical environments, weather variability, particularly temperature and rainfall, affects biomass accumulation and yield, with spring conditions generally being more favorable than fall (Paranhos et al., 2023).

2.3 The role of cultivation management

Cultivation management practices, including planting density, water and nutrient management, and pest and disease control, have comprehensive effects on the yield and quality of fresh corn. Proper nitrogen application is crucial for enhancing the nutritional quality of waxy corn by regulating nitrogen metabolism and carbohydrate biosynthesis (Feng et al., 2024). Studies have shown that nitrogen fertilization has a significant impact on the accumulation and content of anthocyanins in purple waxy corn kernels. Under high nitrogen levels (N2 and N3), the accumulation and content of anthocyanins were significantly higher compared to low nitrogen levels (N0 and N1) (Figure 1).

This indicates that appropriate nitrogen application not only enhances crop yield but also improves the nutritional quality of purple waxy corn by regulating the accumulation of secondary metabolites. Adjusting sowing dates can mitigate adverse meteorological impacts, such as temperature and rainfall, on waxy corn yield (Heping et al., 2020). Additionally, the choice of planting density and the timing of sowing are critical, as deviations from optimal conditions can significantly reduce yield (Sidahmed et al., 2024). Effective pest and disease control are also essential to maintain high-quality yields, particularly in environments prone to stress and disease (Olsen et al., 1990).

3 Optimization of Planting Density

3.1 Relationship between planting density and yield

The relationship between planting density and yield in maize cultivation is complex, involving factors such as canopy structure, light utilization efficiency, and kernel number. Increased planting density can enhance the leaf area index (LAI) and intercepted photosynthetically active radiation (IPAR), which are crucial for promoting plant growth and crop productivity. However, excessive density can lead to reduced photosynthetic capacity and yield stability due to decreased stomatal conductance and chlorophyll content (Zhang et al., 2021; Duan et al., 2024). A field study in Southeast China demonstrated that increasing plant density improved the fresh ear yield of certain sweet maize varieties without affecting grain carbohydrate concentration, although it reduced the grain-filling rate and ear length (Ye et al., 2023b). Another study highlighted that higher planting densities increased biomass and radiation use efficiency but also led to a decrease in the light extinction coefficient and harvest index, indicating a trade-off between yield and resource use efficiency (Duan et al., 2024).

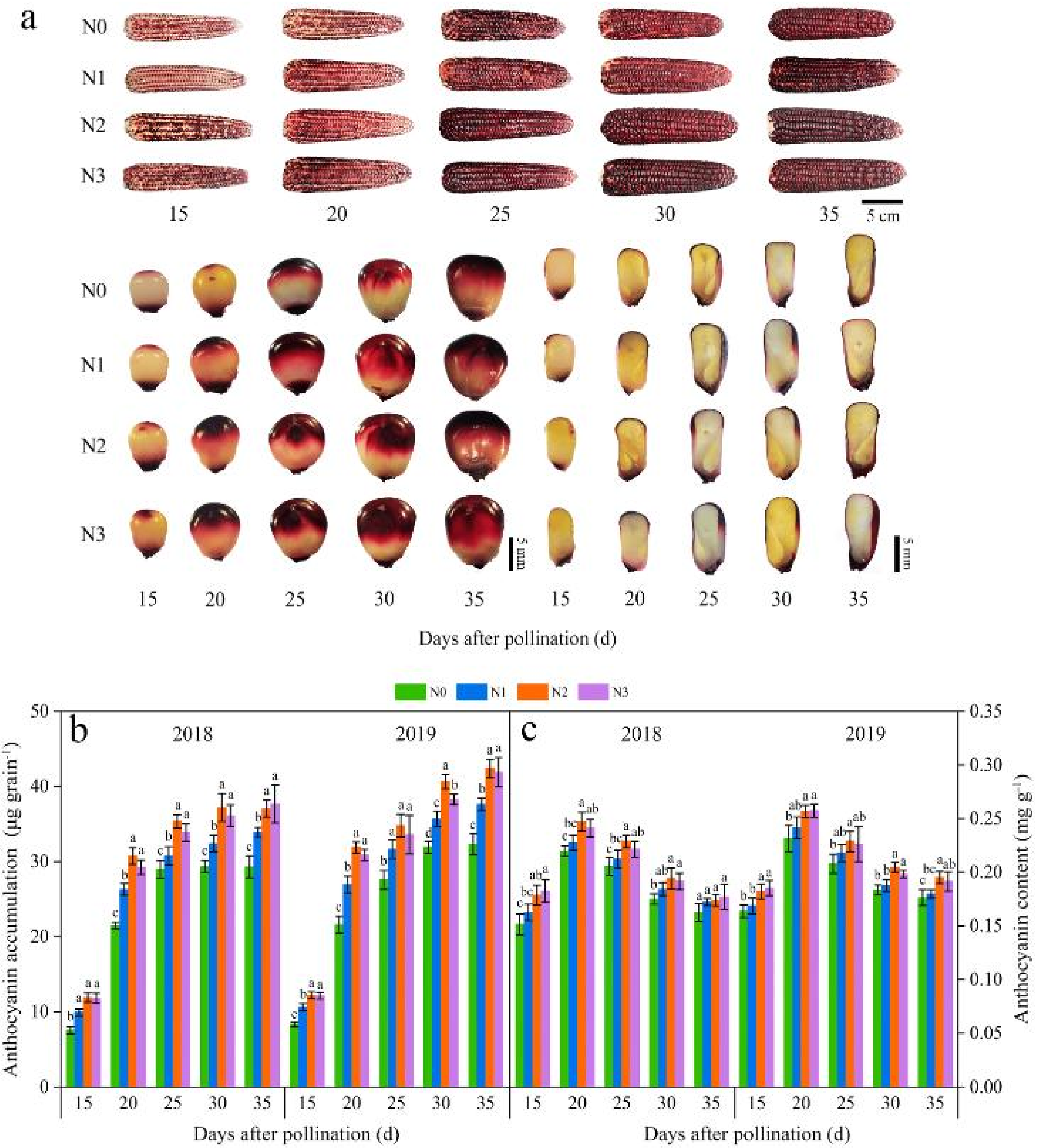

Figure 1 Effects of N application doses on dynamic changes in anthocyanin accumulation amount (AAA) and content in grains of purple waxy maize at different days after pollination (Adopted from Feng et al., 2024)

Image caption: (a) dynamic changes of the phenotypes of Jinnuo20 ears and kernels; (b) anthocyanin accumulation amount (AAA); (c) anthocyanin content (ANC). Different lowercase letters denote significant differences between N rates at the $p < 0.05$ level (Adopted from Feng et al., 2024)

In a field experiment conducted in Southeast China, sweet maize varieties were tested under varying planting densities. The results showed that compact-type varieties like MT6855 and WT2015 benefited from increased density, achieving higher fresh ear yields, while flat-type varieties did not show significant yield changes. This suggests that the response to planting density can vary significantly between different maize varieties (Ye et al., 2023b).

3.2 Balancing planting density and quality

While increasing planting density can boost yield, it can also negatively impact maize quality by reducing ventilation and light penetration, leading to poor ear shape and lower sugar content. Excessive density can result in a higher bare plant rate and decreased grain weight, which are detrimental to overall quality (Ye et al., 2023a; Wu et al., 2023b). Optimizing planting density is crucial to maintaining a balance between yield and quality. For instance, a study found that moderate planting densities improved ear shape and sugar content in sweet maize, highlighting the importance of density management in quality enhancement (Ye et al., 2023b).

In a study focusing on sweet maize, it was observed that optimizing planting density improved ear shape and sugar content, particularly in density-tolerant varieties like MT6855. This improvement was attributed to better nutrient accumulation and remobilization, which are essential for maintaining high-quality maize production (Ye et al., 2023a).

3.3 Regional density optimization strategies

Optimal planting density can vary significantly based on regional soil and climatic conditions. In semiarid climates, for example, moderate planting densities are recommended to stabilize yield and enhance resource use efficiency, as excessive densities can lead to reduced photosynthetic capacity and yield stability (Zhang et al., 2021). In contrast, regions with higher solar radiation and favorable climatic conditions may benefit from higher planting densities to maximize yield potential (Wu et al., 2023a). Tailoring planting density to local environmental conditions is essential for optimizing maize production across different ecological regions.

A study conducted in the southern Huang-Huai-Hai region of China found that the agronomic optimal planting density varied between locations, with Taihe benefiting from a higher density due to its greater solar radiation compared to Hefei. This regional adaptation strategy led to significant yield improvements, demonstrating the importance of customizing planting density to local climatic resources (Wu et al., 2023a).

In Zhejiang, the recommended planting density for fresh corn is 45 000 plants per hectare. As the density further increases, the plant height increases, the ear length and diameter decrease, the bald tip becomes longer, the number of rows per ear and the number of grains per row decrease, and the yield actually decreases; When the density is insufficient, the yield reduction is severe due to insufficient number of spikes (Wang et al., 2023).

4 Water and Fertilizer Management Strategies

4.1 Precision water management

Maize requires precise water management to optimize yield and quality, with water demand varying significantly across different growth stages. For instance, the seedling and jointing stages are particularly sensitive to water deficits, necessitating tailored irrigation schedules to accommodate these needs (Xu et al., 2020). Drip irrigation has emerged as a superior method, enhancing soil water content and maintaining optimal soil mineral nitrogen levels, which are crucial for maize growth. This method not only improves water use efficiency but also supports better dry matter accumulation and kernel development.

A study conducted in the North China Plain demonstrated that drip fertigation, with a reduced nitrogen input, significantly increased maize yield by improving pre- and post-silking dry matter accumulation. This approach also enhanced water and nitrogen use efficiencies, leading to higher economic benefits compared to traditional flood irrigation methods (Guo et al., 2022).

4.2 Nutrient management and fertilizer optimization

Nitrogen, phosphorus, and potassium (NPK) are critical in regulating maize yield and quality. Optimized fertilization practices, such as the application of controlled-release fertilizers, have been shown to improve the chemical and bacterial properties of rhizosphere soil, thereby enhancing maize yield (Li et al., 2022; Hou et al., 2024). Additionally, the strategic use of NPK fertilizers, particularly when combined with organic amendments like biochar, can significantly improve nitrogen use efficiency and crop defenses, even under water deficit conditions.

Research indicates that the combination of biochar with inorganic fertilizers enhances nitrogen use efficiency and maize yield, particularly in alkaline soils. This combination not only boosts yield but also improves the sugar content and flavor of maize, making it a viable strategy for enhancing crop quality (El-Syed et al., 2023).

4.3 Comprehensive effects of water-fertilizer coupling

The integration of precision water and fertilizer management strategies can lead to synergistic effects that enhance maize yield and quality. For instance, drip fertigation with optimized nitrogen application rates has been shown to increase both water and nitrogen use efficiencies, resulting in higher yields and economic returns (Guo et al., 2022). Moreover, the use of manure in combination with chemical fertilizers can further improve water and nitrogen use efficiencies, contributing to sustainable agricultural practices (Liu et al., 2024).

The economic benefits of precision water and fertilizer management are significant. Drip fertigation, for example, not only reduces water and nitrogen inputs but also increases net income by improving yield and resource use efficiency (Guo et al., 2022). This approach offers a cost-effective solution for enhancing maize production while minimizing environmental impacts.

5 Cultivation Patterns and Crop Rotation Techniques

5.1 Application of intercropping systems

Intercropping systems, particularly those involving maize and legumes, have been shown to enhance soil health and increase crop yield. By intercropping maize with legumes such as soybeans, cowpeas, and pigeonpeas, farmers can improve nutrient uptake and soil fertility, while also reducing the prevalence of plant pathogens. This is achieved through the interactions between rhizosphere metabolites and soil microbiomes, which are more diverse in intercropped systems compared to monocultures (Liu and Zhao, 2023; Jiang et al., 2024). In Zimbabwe, intercropping maize with legumes like pigeonpea has demonstrated yield stability and increased total system yield, making it a viable option for smallholder farmers (Madembo et al., 2020). Similarly, in Mozambique, maize-legume intercropping has been found to improve food security and economic returns by enhancing soil fertility and reducing climatic risks (Rusinamhodzi et al., 2012). A case study in Kenya using a staggered maize-legume intercropping arrangement showed increased yields and economic benefits, highlighting the potential of intercropping to optimize fresh corn yield and quality (Mucheru-Muna et al., 2010).

In the central plain area of Zhejiang, fresh corn is mainly intercropped with fresh soybeans or sweet potatoes in a strip intercropping-intercropping system, with three harvests per year, significantly improving land use efficiency and increasing grain yield (Wang et al., 2015)

5.2 Role of crop rotation in soil nutrients and disease control

Crop rotation is a critical practice for maintaining soil health and controlling pests and diseases. By rotating crops, farmers can reduce soil nutrient depletion and minimize the incidence of pests and diseases. For instance, rotating maize with legumes like pigeonpea has been shown to significantly increase maize yield by alleviating issues associated with continuous cropping, such as striga infestation (Rusinamhodzi et al., 2012). Practice shows that in intercropping systems (A, D), root length density reaches its maximum in the 10-20 cm soil layer, while in monoculture maize (B, E), root length density is higher in the shallow soil layer, and in monoculture dry-seeded rice (C, F), roots are primarily concentrated below 20 cm (Figure 2). This indicates that intercropping systems can optimize root distribution, which not only increases soil nutrient availability but also improves soil structure and water infiltration, contributing to sustainable agricultural practices (Wu et al., 2024). Crop rotation thus serves as an effective strategy to overcome the challenges of continuous cropping and maintain long-term soil productivity.

5.3 Conservation tillage techniques

Conservation tillage techniques, including crop residue mulching and no-till technologies, play a vital role in sustainable cultivation practices. These techniques help in maintaining soil moisture, reducing erosion, and enhancing soil organic matter content. For example, the integration of reduced tillage with straw retention in wheat-maize intercropping systems has been shown to boost grain yield and water use efficiency while reducing carbon emissions (Yin et al., 2018). Similarly, in highland maize production, intercropping with legumes and retaining crop residues have been found to increase nitrogen accumulation and improve soil biodiversity, leading to sustainable production systems (Punyalue et al., 2018). These conservation tillage practices are essential for optimizing cultivation practices and ensuring environmental sustainability in maize production systems.

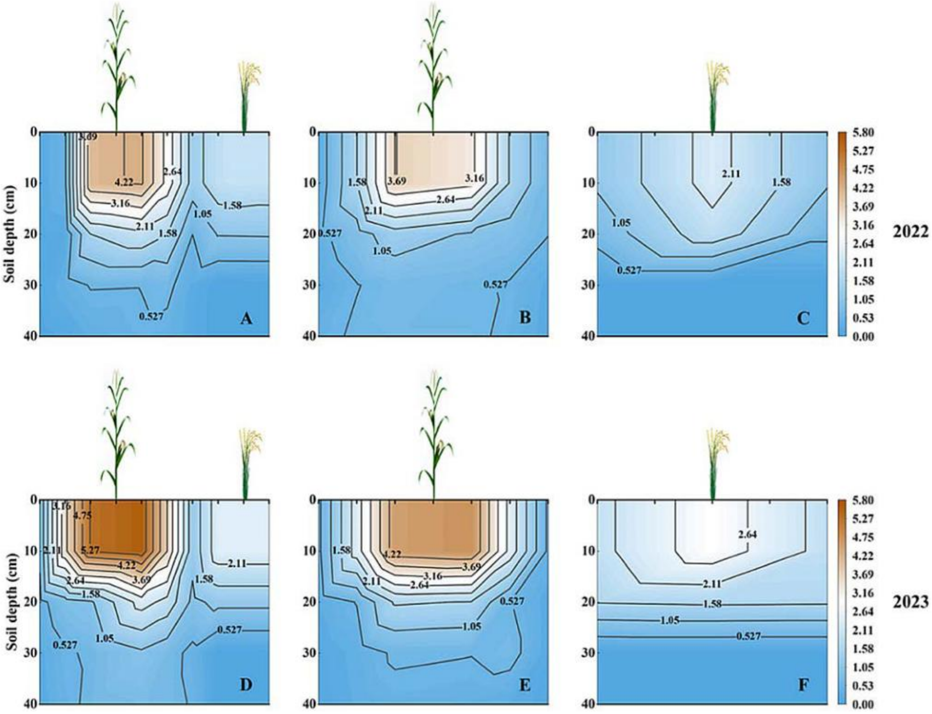

Figure 2 Two-dimensional root length density (cm cm-3) distribution at a 0~40 cm soil depth in the filling growth stages in different planting systems (Adopted from Wu et al., 2024)

Image Caption: (A, D) Rice under dry cultivation–maize intercropping; (B, E) sole maize; (C, F) sole rice under dry cultivation (Adopted from Wu et al., 2024)

6 Integrated Pest and Disease Management (IPM)

6.1 Major pests and diseases and their impacts

In fresh-eating maize cultivation, common pests such as the corn borer and aphids, along with diseases like downy mildew, significantly impact yield and quality. The corn borer can cause extensive damage to maize plants by boring into stalks and ears, leading to reduced plant vigor and yield loss (Busch et al., 2020; Yurina et al., 2023). Aphids, on the other hand, not only weaken plants by sucking sap but also act as vectors for viral diseases, further compromising crop quality and yield (Green et al., 2020). Downy mildew, a fungal disease, affects the leaves and can lead to stunted growth and poor grain development, thereby diminishing both yield and quality (Furlan et al., 2017).

6.2 Biological control and ecological regulation techniques

Biological control and ecological regulation techniques offer sustainable alternatives to chemical pesticides by utilizing natural enemies, microbial agents, and plant-based pesticides. For instance, beneficial microbes like *Trichoderma harzianum* and *Pseudomonas fluorescens* have been shown to suppress disease incidence and enhance plant health, thereby reducing reliance on chemical controls (Khokhar et al., 2024). The use of entomopathogens and other biological agents can effectively manage pest populations such as the fall armyworm, demonstrating economic and environmental benefits (Yurina et al., 2023). A case study on managing corn aphids highlighted the successful application of biological control techniques, which not only reduced aphid populations but also minimized the need for chemical interventions (Pecenka et al., 2021).

6.3 Precision pest and disease monitoring and control

Precision agriculture technologies, including drones and sensors, are revolutionizing pest and disease monitoring and control in maize cultivation. These technologies enable early detection and targeted interventions, reducing the need for blanket pesticide applications and minimizing environmental impact. By integrating precision tools with IPM strategies, farmers can achieve more efficient resource use and enhance crop protection, ultimately leading to improved yields and reduced costs. The use of drones for aerial surveillance and sensors for real-time data collection allows for precise application of control measures, ensuring that interventions are timely and effective (Kebe et al., 2023).

7 Application of Mechanization and Smart Technologies

7.1 Mechanized cultivation and management

The promotion and application of mechanized technologies in maize cultivation, such as sowing, irrigation, and harvesting, are crucial for enhancing efficiency and reducing labor costs. Mechanized sowing techniques, like drill sowing, have been shown to improve maize yield by optimizing plant population and ensuring uniform seed distribution (Imran et al., 2021). Mechanized irrigation systems can also enhance water use efficiency, which is vital for maintaining crop health and yield (Ren et al., 2020).

Controlling quality loss in fresh corn during mechanical harvesting mechanical harvesting can lead to quality loss if not properly managed. However, advancements in harvesting technology have minimized these losses by improving the precision and gentleness of the harvest process. For instance, the use of automated systems that adjust to the crop's condition can significantly reduce damage to the corn, thereby maintaining its quality for fresh consumption (Figure 3) (Jaidka et al., 2019).

Figure 3 Damage of maize crop by maize stem borer (Adopted from Jaidka et al., 2019)

7.2 Intelligent monitoring and precision management

The integration of IoT and remote sensing technologies in field management allows for real-time monitoring and precision management of maize crops. These technologies enable farmers to make informed decisions regarding irrigation, fertilization, and pest control, thereby optimizing resource use and enhancing yield (Patel et al., 2024). Water and fertilizer smart decision-making systems based on sensor data smart decision-making systems that utilize sensor data for water and fertilizer management have been developed to improve maize yield and resource efficiency. These systems can adjust irrigation and fertilization schedules based on real-time soil moisture and nutrient levels, leading to more efficient use of resources and improved crop performance (Xin and Tao, 2019).

7.3 Automated harvesting and quality grading

Automated harvesting and quality grading systems are pivotal in improving the market competitiveness of fresh-eating maize. These systems not only increase the speed and efficiency of the harvest but also ensure that only the highest quality produce reaches the market. Automated grading systems use advanced imaging and sensor technologies to assess the quality of maize, ensuring consistency and reducing human error (Jaidka et al., 2019).

8 Case Studies of Successful Practices

8.1 Demonstration of high-yield, high-sugar sweet corn cultivation techniques

The integration of drip irrigation with precision fertilization has been shown to significantly enhance the yield and quality of sweet corn. This approach optimizes water and nutrient delivery directly to the root zone, improving water use efficiency and nutrient uptake. For instance, optimized fertilization practices, such as the one-time application of new compound fertilizers at specific growth stages, have been demonstrated to increase maize yield by synchronizing soil nutrient supply with crop requirements (Li et al., 2022). Additionally, the use of biochar with inorganic fertilizers has been found to improve nitrogen use efficiency and yield, especially under water deficit conditions, by enhancing the plant's defense system and nutrient uptake (El-Syed et al., 2023). These practices collectively contribute to higher yields and better quality in sweet corn cultivation.

8.2 Region-specific adaptation cultivation models

In the South Asian subtropical region, managing fresh corn cultivation under high-temperature conditions requires adaptive strategies that consider local climatic challenges. The use of genotype-environment-management (G×E×M) interactions has been effective in optimizing maize productivity and eco-efficiency. For example, delaying sowing dates and adjusting planting densities have been shown to mitigate the negative effects of high temperatures, thereby enhancing maize yields (Xin and Tao, 2019; Zhang et al., 2020). These adaptive management practices are crucial for maintaining yield stability and quality in regions facing climatic extremes.

8.3 Green and ecological cultivation models

Sustainable cultivation models that incorporate organic fertilizers and biological control methods have proven effective in enhancing soil health and crop yield. The incorporation of organic fertilizers, such as compost, alongside inorganic fertilizers, has been shown to significantly improve soil quality and crop yield by increasing soil organic carbon and nitrogen content (Zhou et al., 2022). Additionally, the use of biochar with organic amendments has been found to improve maize yield and quality by enhancing soil microbial activity and nutrient availability (El-Syed et al., 2023). These green cultivation practices not only boost yield but also promote ecological sustainability by reducing reliance on chemical inputs and enhancing soil biodiversity.

8.4 Facility promoted early cultivation mode

In Zhejiang, by raising the temperature in greenhouses and using plug trays or nutrient bowls for seedling cultivation, the seedling cultivation of fresh corn is advanced to early February, transplanted in late February, and fresh ears are harvested in mid May (Figure 4). The sales unit price of fresh ears is over 15 yuan/kilogram, and the output value reaches 150 000 yuan/hm^2, achieving a "1 000 kg grain yield and 10 000 yuan income of per acre (6 667 m^2)". It is listed as the main technology promoted by the Department of Agriculture and Rural Affairs of Zhejiang Province (Zhao et al.,2020).

Figure 4 Greenhouse promotes early cultivation of fresh corn in Zhejiang

Image caption: a: Plug seedling cultivation in greenhouse; b: Greenhouse cultivation

9 Current Challenges and Future Directions

9.1 Challenges posed by environmental changes

Environmental changes, such as climate change and soil degradation, present significant challenges to maize cultivation. Climate change impacts, including increased temperatures and altered precipitation patterns, affect maize yield and quality. For instance, in the North China Plain, maize yield has been observed to decrease due to increased minimum temperatures and decreased solar radiation (Zhang et al., 2020). Soil degradation, characterized by declining soil quality, further complicates cultivation management. The incorporation of organic fertilizers has been shown to improve soil quality and crop yield, but the challenge remains in balancing these practices with sustainable soil management (Zhou et al., 2022). Additionally, water scarcity exacerbated by climate change necessitates efficient water management strategies to maintain maize productivity (El-Syed et al., 2023).

9.2 Technical dissemination and limitations of small-scale farming

Small-scale farmers face bottlenecks in adopting new cultivation measures due to limited access to technology and resources. The dissemination of optimized fertilization and planting practices is crucial for improving yield, yet small-scale farmers often lack the infrastructure and knowledge to implement these strategies effectively (Piao et al., 2016; Li et al., 2022). The adoption of advanced techniques, such as zigzag planting and deep nitrogen fertilization, which have been shown to significantly increase maize yield, is hindered by the lack of technical support and financial resources (Zheng et al., 2023). Moreover, the complexity of integrating new technologies into existing farming systems poses additional challenges for small-scale farmers (Capo et al., 2023).

9.3 Future development directions

To address these challenges, future development should focus on integrating smart technologies and precision management into maize cultivation systems. The use of models like CERES-Maize can help optimize genotype-environment-management interactions, enhancing yield and eco-efficiency (Zhang et al., 2020). Developing high-yield, high-quality cultivation models tailored to different regions is essential. For example, optimizing planting density and fertilization rates can significantly improve yield and resource use efficiency (Xin and Tao, 2019). Promoting sustainable development and green agriculture practices, such as the use of biochar and organic amendments, can enhance soil health and crop resilience to environmental stresses (El-Syed et al., 2023). These strategies will be crucial in ensuring the sustainability and productivity of maize cultivation in the face of ongoing environmental changes.

Acknowledgments

I am deeply grateful to Professor R.X. Cai for his multiple reviews of this paper and for his constructive revision suggestions. Thank you to the peer reviewers for their suggestions on revisions and improvements to this study.

Conflict of Interest Disclosure

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

References

Busch A., Douglas M., Malcolm G., Karsten H., and Tooker J., 2020, A high-diversity/IPM cropping system fosters beneficial arthropod populations, limits invertebrate pests, and produces competitive maize yields, Agriculture, Ecosystems & Environment, 292: 106812.
https://doi.org/10.1016/j.agee.2019.106812

Capo L., Sopegno A., Reyneri A., Ujvári G., Agnolucci M., and Blandino M., 2023, Agronomic strategies to enhance the early vigor and yield of maize part II: the role of seed applied biostimulant, hybrid, and starter fertilization on crop performance, Frontiers in Plant Science, 14: 1240313.
https://doi.org/10.3389/fpls.2023.1240313

Dermail A., Fuengtee A., Lertrat K., Suwarno W., Lübberstedt T., and Suriharn K., 2021, Simultaneous selection of sweet-waxy corn ideotypes appealing to hybrid seed producers, growers, and consumers in Thailand, Agronomy, 12(1): 87.
https://doi.org/10.3390/agronomy12010087

Duan M., Zhang X., Wei Z., Chen X., and Zhang B., 2024, Effect of maize canopy structure on light interception and radiation use efficiency at different canopy layers, Agronomy, 14(7): 1511.
https://doi.org/10.3390/agronomy14071511

El-Syed N., Helmy A., Fouda S., Nabil M., Abdullah T., Alhag S., Al-Shuraym L., Syaad K., Ayyoub A., Mahmood M., and Elrys A., 2023, Biochar with organic and inorganic fertilizers improves defenses, nitrogen use efficiency, and yield of maize plants subjected to water deficit in an alkaline soil, Sustainability, 15(16): 12223.
https://doi.org/10.3390/su151612223

Feng W., Xue W., Zhao Z., Wang H., Shi Z., Wang W., Chen B., Qiu P., Xue J., and Sun M., 2024, Nitrogen level impacts the dynamic changes in nitrogen metabolism, and carbohydrate and anthocyanin biosynthesis improves the kernel nutritional quality of purple waxy maize, Plants, 13(20): 2882.
https://doi.org/10.3390/plants13202882

Furlan L., Vasileiadis V., Chiarini F., Huiting H., Leskovšek R., Razinger J., Holb I., Sartori E., Urek G., Verschwele A., Benvegnù I., and Sattin M., 2017, Risk assessment of soil-pest damage to grain maize in Europe within the framework of integrated pest management, Crop Protection, 97: 52-59.
https://doi.org/10.1016/J.CROPRO.2016.11.029

Green K., Stenberg J., and Lankinen Å., 2020, Making sense of integrated pest management (IPM) in the light of evolution, Evolutionary Applications, 13(8): 1791-1805.
https://doi.org/10.1111/eva.13067

Guo D., Chen C., Zhou B., Ma D., Batchelor W., Han X., Ding Z., Du M., Zhao M., Li M., and Ma W., 2022, Drip fertigation with relatively low water and N input achieved higher grain yield of maize by improving pre-and post-silking dry matter accumulation, Sustainability, 14(13): 7850.
https://doi.org/10.3390/su14137850

Hou J., Zhang J., Bao F., Zhang P., Han H., Tan H., Chen B., and Zhao F., 2024, The contribution of exotic varieties to maize genetic improvement, Molecular Plant Breeding, 15(4): 198-208.
https://doi.org/10.5376/mpb.2024.15.0020

Imran A., Khan A., Mahmood T., Tawaha A., and Khanum S., 2021, Adequate fertilization, application method and sowing techniques improve maize yield and related traits, Communications in Soil Science and Plant Analysis, 52(19): 2318-2330.
https://doi.org/10.1080/00103624.2021.1925688

Jaidka M., Bathla S., and Kaur R., 2019, Improved technologies for higher maize production, Maize-Production and Use, 2019: 81-100.
https://doi.org/10.5772/intechopen.88997

Jiang P., Wang Y., Zhang Y., Fei J., Rong X., Peng J., Yin L., and Luo G., 2024, Intercropping enhances maize growth and nutrient uptake by driving the link between rhizosphere metabolites and microbiomes, New Phytologist, 243(4): 1506-1521.
https://doi.org/10.1111/nph.19906

Kebe A., Hameed S., Farooq M., Sufyan A., Malook M., Awais S., Riaz M., Waseem M., Amjad U., and Abbas N., 2023, Enhancing crop protection and yield through precision agriculture and integrated pest management: a comprehensive review, Asian Journal of Research in Crop Science, 8(4): 443-453.
https://doi.org/10.9734/ajrcs/2023/v8i4225

Khokhar M., Kumar R., Kumar A., Sehgal M., Singh S., Meena P., Singh N., Acharya L., Birah A., Singh K., Bana R., Gurjar M., Chander S., and Choudhary M., 2024, Impact of IPM practices on microbial population and disease development in transplanted and direct-seeded rice, Frontiers in Microbiology, 15: 1388754.
https://doi.org/10.3389/fmicb.2024.1388754

Li G., Li W., Zhang S., Lu W., and Lu D., 2022, Optimized Fertilization practices improved rhizosphere soil chemical and bacterial properties and fresh waxy maize yield, Metabolites, 12(10): 935.
https://doi.org/10.3390/metabo12100935

Liu M., and Zhao H., 2023, Maize-soybean intercropping improved maize growth traits by increasing soil nutrients and reducing plant pathogen abundance, Frontiers in Microbiology, 14: 1290825.
https://doi.org/10.3389/fmicb.2023.1290825

Liu Y., Bai M., Shen F., Wu Z., Yang J., Li N., Liu H., Dai J., and Han X., 2024, Enhancing soybean and maize yields through improved nitrogen and soil water use efficiencies: a 40-year study on the impact of farmyard manure amendment in Northeast China, Plants, 13(4): 500.
https://doi.org/10.3390/plants13040500

Madembo C., Mhlanga B., and Thierfelder C., 2020, Productivity or stability? Exploring maize-legume intercropping strategies for smallholder conservation agriculture farmers in Zimbabwe, Agricultural Systems, 185: 102921.
https://doi.org/10.1016/j.agsy.2020.102921

Mucheru-Muna P., Pypers P., Mugendi D., Kung'u J., Mugwe J., Merckx R., and Vanlauwe B., 2010, A staggered maize-legume intercrop arrangement robustly increases crop yields and economic returns in the highlands of Central Kenya, Field Crops Research, 115(2): 132-139.
https://doi.org/10.1016/J.FCR.2009.10.013

Nemeskéri E., Molnár K., Rácz C., Dobos A., and Helyes L., 2019, Effect of water supply on spectral traits and their relationship with the productivity of sweet corns, Agronomy, 9(2): 63.
https://doi.org/10.3390/AGRONOMY9020063

Olsen J., Blight G., and Gillespie D., 1990, Comparison of yield, cob characteristics and sensory quality of six supersweet (sh2) corn cultivars grown in a subtropical environment, Australian Journal of Experimental Agriculture, 30(3): 387-393.
https://doi.org/10.1071/EA9900387

Özata E., 2019, Evaluation of fresh ear yield and quality performance in super sweet corn, International Journal of Life Sciences and Biotechnology, 2(2): 80-94.
https://doi.org/10.38001/IJLSB.566890

Paranhos J., Foshee W., Coolong T., Heyes B., Salazar-Gutiérrez M., Kesheimer K., and Da Silva A., 2023, Characterization of sweet corn production in subtropical environmental conditions, Agriculture, 13(6): 1156.
https://doi.org/10.3390/agriculture13061156

Patel P., Choudhury S., Gupta S., Das A., Pathak S., Kumar D., and Panda C., 2024, Optimizing input management practices for sustainable maize production, Journal of Scientific Research and Reports, 30(8): 305-312.
https://doi.org/10.9734/jsrr/2024/v30i82252

Pecenka J., Ingwell L., Foster R., Krupke C., and Kaplan I., 2021, IPM reduces insecticide applications by 95% while maintaining or enhancing crop yields through wild pollinator conservation, Proceedings of the National Academy of Sciences of the United States of America, 118(44): e2108429118.
https://doi.org/10.1073/pnas.2108429118

Piao L., Qi H., Li C., and Zhao M., 2016, Optimized tillage practices and row spacing to improve grain yield and matter transport efficiency in intensive spring maize, Field Crops Research, 198: 258-268.
https://doi.org/10.1016/J.FCR.2016.08.012

Punyalue A., Jamjod S., and Rerkasem B., 2018, Intercropping maize with legumes for sustainable highland maize production, Mountain Research and Development, 38(1): 35-44.
https://doi.org/10.1659/MRD-JOURNAL-D-17-00048.1

Ren H., Cheng Y., Li R., Yang Q., Liu P., Dong S., Zhang J., and Zhao B., 2020, Integrating density and fertilizer management to optimize the accumulation, remobilization, and distribution of biomass and nutrients in summer maize, Scientific Reports, 10(1): 11777.
https://doi.org/10.1038/s41598-020-68730-8

Ren H., Li Z., Cheng Y., Zhang J., Liu P., Li R., Yang Q., Dong S., Zhang J., and Zhao B., 2020, Narrowing yield gaps and enhancing nitrogen utilization for summer maize (*Zea mays* L) by combining the effects of varying nitrogen fertilizer input and planting density in DSSAT simulations, Frontiers in Plant Science, 11: 560466.
https://doi.org/10.3389/fpls.2020.560466

Rusinamhodzi L., Corbeels M., Nyamangara J., and Giller K., 2012, Maize-grain legume intercropping is an attractive option for ecological intensification that reduces climatic risk for smallholder farmers in central Mozambique, Field Crops Research, 136: 12-22.
https://doi.org/10.1016/J.FCR.2012.07.014

Sidahmed H., Illés Á., ALmahi A., and Nagy J., 2024, Performance of agricultural factors on yield of sweet corn (*Zea mays* L. *Saccharata*)-a review, Acta Agraria Debreceniensis, 1: 143-156.
https://doi.org/10.34101/actaagrar/1/12830

Tan H., Zhao F., Han H., Bao F., Chen B., Hou J., Lou X., and Wang G., 2020, Effects of meteorological factors on yield characters of waxy corn at different sowing dates, Journal of Plant Sciences, 8(6): 214-220.
https://doi.org/10.11648/J.JPS.20200806.14

Wang G., Zhao F., Tan H., Bao F., Han H., and Su T., 2015,The current situation and main planting modes of fresh corn industry in Zhejiang province, Journal of Zhejiang Agricultural Sciences, 56(10): 1553-1556, 1628.
https://doi.org/10.16178/j.issn.0528-9017.20151007

Wang N., Shao T., Huang H., and Wu M., 2023, The effect of planting density on the yield and main characteristics of fresh eating corn colored sweet glutinous 168, Horticulture & Seed, 43(12): 91-92.
https://doi.org/10.16530/j.cnki.cn21-1574/s.2023.12.031

Wu W., Zhang L., Chu Z., Yue W., Xu Y., Peng C., Chen X., Jing L., Ma W., and Wang S., 2023b, Improvement of climate resource utilization efficiency to enhance maize yield through adjusting planting density, Agronomy, 13(3): 846.
https://doi.org/10.3390/agronomy13030846

Wu X., Tong L., Kang S., Du T., Ding R., Li S., and Chen Y., 2023a, Combination of suitable planting density and nitrogen rate for high yield maize and their source-sink relationship in Northwest China, Journal of the Science of Food and Agriculture, 103(11): 5300-5311.
https://doi.org/10.1002/jsfa.12602

Wu Z., Xue B., Wang S., Xing X., Nuo M., Meng X., Wu M., Jiang H., Ma H., Yang M., Wei X., Zhao G., and Tian P., 2024, Rice under dry cultivation-maize intercropping improves soil environment and increases total yield by regulating belowground root growth, Plants, 13(21): 2957.
https://doi.org/10.3390/plants13212957

Xin Y., and Tao F., 2019, Optimizing genotype-environment-management interactions to enhance productivity and eco-efficiency for wheat-maize rotation in the North China Plain, Science of the Total Environment, 654(1): 480-492.
https://doi.org/10.1016/j.scitotenv.2018.11.126

Xu J., Cai H., Wang X., Ma C., Lu Y., Ding Y., Wang X., Chen H., Wang Y., and Saddique Q., 2020, Exploring optimal irrigation and nitrogen fertilization in a winter wheat-summer maize rotation system for improving crop yield and reducing water and nitrogen leaching, Agricultural Water Management, 228: 105904.
https://doi.org/10.1016/j.agwat.2019.105904

Ye D., Chen J., Wang X., Sun Y., Yu Z., Zhang R., Saddique M., Su D., and Muneer M., 2023a, Coupling effects of optimized planting density and variety selection in improving the yield, nutrient accumulation, and remobilization of sweet maize in Southeast China, Agronomy, 13(11): 2672.
https://doi.org/10.3390/agronomy13112672

Ye D., Chen J., Yu Z., Sun Y., Gao W., Wang X., Zhang R., Nisa Z., Su D., and Muneer M., 2023b, Optimal plant density improves sweet maize fresh ear yield without compromising grain carbohydrate concentration, Agronomy, 13(11): 2830.
https://doi.org/10.3390/agronomy13112830

Yin W., Guo Y., Hu F., Fan Z., Feng F., Zhao C., Yu A., and Chai Q., 2018, Wheat-maize intercropping with reduced tillage and straw retention: a step towards enhancing economic and environmental benefits in arid areas, Frontiers in Plant Science, 9: 1328.
https://doi.org/10.3389/fpls.2018.01328

Yurina N., Syahrawati M., Arneti A., and Busniah M., 2023, The environmentally IPM package for controlling fall armyworm (*Spodoptera frugiperda*) in maize field, Jurnal Proteksi Tanaman, 7(1): 55-64.
https://doi.org/10.25077/jpt.7.1.55-64.2023

Zhang L., Zhang Z., Luo Y., Cao J., and Li Z., 2020, Optimizing genotype-environment-management interactions for maize farmers to adapt to climate change in different agro-ecological zones across China, Science of the Total Environment, 728: 138614.
https://doi.org/10.1016/j.scitotenv.2020.138614

Zhang Y., Xu Z., Li J., and Wang R., 2021, Optimum planting density improves resource use efficiency and yield stability of rainfed maize in semiarid climate, Frontiers in Plant Science, 12: 752606.
https://doi.org/10.3389/fpls.2021.752606

Zhao F., Cai R., Zhou Z.,Tan H., Han H., Bao F., Wang G., 2020, Innovative farming system in Zhejiang: high-value cultivation of rotation between sweet corn and late rice, Molecular Plant Breeding, 18(23): 7953-7958.
https://doi.org/10.13271/j.mpb.018.007953

Zheng Y., Yue Y., Li C., Wang Y., Zhang H., Ren H., Gong X., Jiang Y., and Qi H., 2023, Revolutionizing maize crop productivity: the winning combination of zigzag planting and deep nitrogen fertilization for maximum yield through root-shoot ratio management, Agronomy, 13(5): 1307.
https://doi.org/10.3390/agronomy13051307

Zhou J., and Hong W.Y., 2024, Genome-wide association study of maize kernel quality related traits and their molecular mechanisms, Maize Genomics and Genetics, 15(1): 1-8.
https://doi.org/10.5376/mgg.2024.15.0001

Zhou Z., Zhang S., Jiang N., Xiu W., Zhao J., and Yang D., 2022, Effects of organic fertilizer incorporation practices on crops yield, soil quality, and soil fauna feeding activity in the wheat-maize rotation system, Frontiers in Environmental Science, 10: 1058071.
https://doi.org/10.3389/fenvs.2022.1058071