Cotton Genomics and Genetics 2024, Vol.15, No.6, 284-293
http://cropscipublisher.com/index.php/cgg

Review Article Open Access

# A Review of Cotton Cultivation Techniques for High Yield

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Cotton Genomics and Genetics, 2024, Vol.15, No.5 doi: 10.5376/cgg.2024.15.0027
Received: 14 Sep., 2024
Accepted: 21 Oct., 2024
Published: 04 Nov., 2024

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**Preferred citation for this article**:
Li Z., 2024, A review of cotton cultivation techniques for high yield, Cotton Genomics and Genetics, 15(6): 284-293 (doi: 10.5376/cgg.2024.15.0027)

**Abstract** This study summarizes the progress of cultivation techniques to optimize cotton yield and quality, including the application of precision agriculture, improved irrigation strategies, and modern agronomic practices adapted to cotton physiological characteristics. The results show that balanced nutrient management, effective pest control methods, and the application of stress resistance and high-yielding varieties can improve cotton yield. Advances in mechanized and sustainable agricultural practices also show great potential for improving productivity while preserving the environment. This study highlights that combining traditional knowledge with innovative technologies is key to addressing the challenges of climate change and resource constraints, with the aim of achieving sustainable production of cotton and meeting the growing global demand for cotton fiber.

**Keywords** Cotton cultivation; High yield; Precision agriculture; Sustainable practices; Agronomic innovation

## 1 Introduction

Cotton is a crucial crop globally, with significant economic importance. In regions like the northwest inland of China, cotton cultivation has seen remarkable success, with yields reaching 1 900 kg/ha, significantly higher than national and international averages. This success is attributed to advanced cultivation techniques such as earliness-stimulating cultivation, close planting, and drip irrigation under plastic mulching (Feng et al., 2017). However, despite these advancements, challenges such as stagnated yields and increased production costs persist, necessitating further optimization of cultivation strategies.

Achieving high cotton yields consistently is fraught with challenges. Variations in climate, soil conditions, and cultivation practices can significantly impact yield outcomes. For instance, in the Yangtze River area, the application of previously reported agronomic practices has been difficult due to these variations (Liu et al., 2020). Additionally, issues such as poor light transmittance and low exploitation of light resources in regions like Xinjiang impede further yield growth (Hu et al., 2021). High-density planting systems have shown promise in increasing yields, but they also present challenges in terms of nutrient uptake and plant management (Hemalatha et al., 2024).

This study systematically reviewed and analyzed various cotton cultivation techniques to determine the most effective methods for achieving high yields. By examining different methods such as lightweight and simplified cultivation systems, optimal number of result nodes, and high-density planting systems, this study aims to provide comprehensive insights into best practices in cotton cultivation, improve cotton yield and economic efficiency, and address the difficulties and challenges faced by cotton farmers in different regions.

## 2 Agronomic Practices for High Cotton Yield

### 2.1 Optimal planting time strategies

Optimal planting time is crucial for maximizing cotton yield. Early sowing, particularly in marginal cotton-growing regions, extends the growing season, allowing plants to exploit favorable conditions and avoid late-season pests and adverse weather. For instance, a study in the Yangtze River Valley, China, demonstrated that early sowing (May 20) combined with moderate plant density significantly increased seed cotton and lint yield by 29% and 26%, respectively, compared to later sowing dates (Khan et al., 2017). This strategy ensures better utilization of available resources and enhances reproductive organ biomass, leading to higher yields.

### 2.2 Plant density and row spacing management

Plant density and row spacing are critical factors influencing cotton yield. High-density planting systems (HDPS) with narrow row spacing have been shown to improve yield by optimizing light interception and resource use efficiency. For example, in Xinjiang, China, a uniform row-spacing configuration (76 cm) combined with optimal plant densities (13.5~18.0 plants/m²) resulted in higher radiation use efficiency (RUE) and lint yield compared to traditional wide and narrow row-spacing configurations (Figure 1) (Hu et al., 2021). Similarly, high-density planting with narrow spacing (e.g., 90 x 15 cm) has been found to increase seed cotton yield and nutrient uptake, particularly when combined with appropriate fertilization levels (Ajayakumar et al., 2017; Hemalatha et al., 2024).

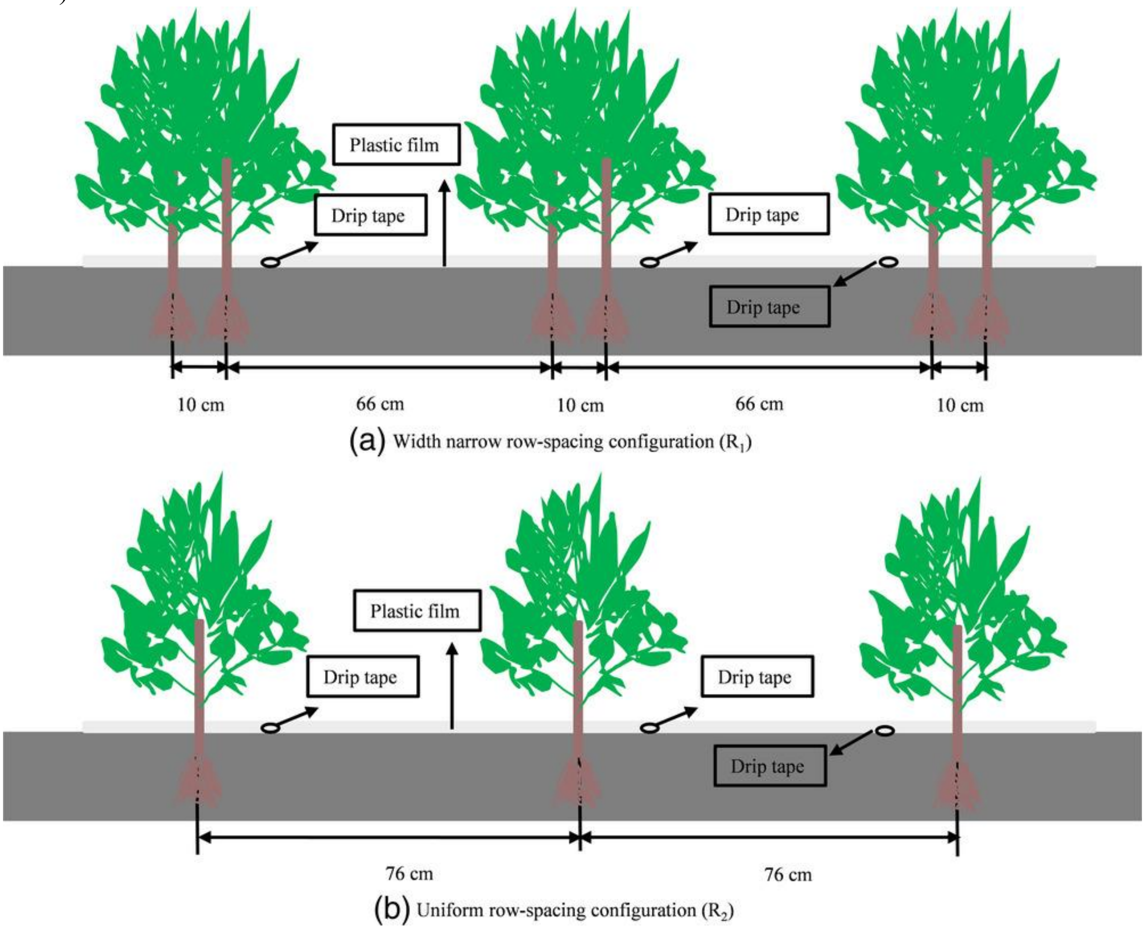


Figure 1 Layout of cotton system with two row-spacing configurations (Adopted from Hu et al., 2021)

### 2.3 Crop rotation and its role in soil health

Crop rotation is a vital agronomic practice for maintaining soil health and enhancing cotton yield. Continuous monoculture can lead to soil degradation, pest buildup, and reduced yields. Integrating crop rotation with legumes, grasses, and brassicas can improve soil fertility, reduce pest and disease incidence, and enhance overall crop productivity (Vitale et al., 2024). For instance, rotating cotton with cover crops like legumes can fix atmospheric nitrogen, improving soil nutrient content and structure, which is essential for sustainable cotton production. Additionally, crop rotation helps in breaking pest and disease cycles, thereby reducing the reliance on chemical inputs and promoting a healthier agroecosystem.

## 3 Irrigation Techniques in Cotton Cultivation

### 3.1 Drip irrigation and water-use efficiency

Drip irrigation has been shown to significantly improve water-use efficiency (WUE) in cotton cultivation. Studies indicate that sub-surface drip fertigation (SSDF) can enhance seed cotton yield (SCY) and water productivity compared to traditional surface flood (SF) methods. For instance, SSDF at 80% crop evapotranspiration (ETc) recorded a 26.6% higher SCY and 18.5% higher nitrogen use efficiency (NUE) compared to SF, demonstrating its potential to save water and increase productivity (Singh et al., 2022). Additionally, mulched drip irrigation has been found to optimize the distribution of fine roots, enhancing the plant's ability to absorb soil water and thereby increasing both yield and WUE (Wang et al., 2020; Wang et al., 2021).

### 3.2 Scheduling and water stress management

Effective irrigation scheduling is crucial for managing water stress and optimizing cotton yield. Research has shown that frequent irrigation during peak fruiting stages can significantly increase yield and WUE. For example, daily drip irrigation has been found to outperform conventional irrigation applied at longer intervals, leading to higher yields and better water-use efficiency. Moreover, irrigation scheduling based on canopy temperature (Tc) has been effective in maximizing cotton yields without excessive water application, highlighting the importance of real-time measurements in irrigation management. Deficit irrigation strategies, where water is applied at reduced levels during certain growth stages, have also been shown to improve WUE without significantly compromising yield, particularly under subsurface drip irrigation (SDI) systems (Shukr et al., 2021).

### 3.3 Challenges of irrigation management in cotton-growing regions

Despite the benefits, several challenges persist in irrigation management for cotton cultivation. One major issue is the variability in water availability and the need for region-specific irrigation strategies. For instance, the FAO-56 crop coefficient values are not suitable for all regions, necessitating the determination of local values for accurate irrigation scheduling (Koudahe et al., 2021). Additionally, the high cost of installing and maintaining drip irrigation systems can be a barrier for many farmers. While daily drip irrigation can increase yield and WUE, it may not be feasible for all due to the expense involved. Furthermore, excessive irrigation, even with efficient systems like mulched drip irrigation, can lead to reduced yields and WUE, emphasizing the need for precise water management (Wang et al., 2020; Wang et al., 2021).

## 4 Nutrient Management and Fertilization Strategies

### 4.1 Essential macronutrients and micronutrients for cotton growth

Cotton growth and yield are significantly influenced by the availability of essential macronutrients such as nitrogen (N), phosphorus (P), and potassium (K), as well as micronutrients like zinc (Zn), iron (Fe), manganese (Mn), boron (B), molybdenum (Mo), and copper (Cu) (Yogesh et al., 2022). The application of these nutrients through soil and foliar methods has shown to enhance plant height, leaf area index, and dry matter production, which are critical for achieving high yields (Selvakumar et al., 2022; Yogesh et al., 2022). For instance, the foliar application of 2% urea combined with 1% Pink Pigmented Facultative Methylotrophic bacteria (PPFM) significantly improved growth parameters and yield attributes in hybrid cotton (Selvakumar et al., 2022).

### 4.2 Foliar feeding and fertigation techniques

Foliar feeding and fertigation are effective techniques for delivering nutrients directly to the plant, thereby improving nutrient uptake efficiency and crop performance. Foliar application of macro and micronutrients, particularly during critical growth stages such as flowering and boll development, has been shown to enhance growth and yield attributes in cotton (Selvakumar et al., 2022; Yogesh et al., 2022). For example, the foliar application of 2% urea + 1% PPFM at flowering and boll development stages resulted in significant increases in plant height, dry matter production, and seed cotton yield (Selvakumar et al., 2022). Similarly, drip fertigation with liquid multi-nutrient fertilizers has been found to improve growth parameters, yield, and quality of hybrid cotton (Divya et al., 2022).

### 4.3 Integrated nutrient management for sustainable yields

Integrated nutrient management (INM) combines the use of organic and inorganic fertilizers to optimize nutrient availability and improve soil health, leading to sustainable cotton production. Studies have shown that integrating organic fertilizers such as farmyard manure (FYM), vermicompost (VC), and crop residues (CR) with inorganic fertilizers can significantly enhance soil quality and cotton yield (Shi et al., 2022; Lin et al., 2024). For instance, the combination of organic liquid fertilizer with reduced chemical fertilizer (OF0.8) improved soil organic matter content, leaf area, chlorophyll content, and photosynthetic performance, resulting in higher seed cotton yield (Shi et al., 2022; Shi et al., 2023). Additionally, the use of effective microorganisms (EM) in combination with organic and inorganic nutrient sources has been found to increase nutrient efficiency and yield, while reducing the reliance on chemical fertilizers.

## 5 Pest and Disease Management

### 5.1 Common pests affecting cotton yield and their control measures

Cotton crops are susceptible to a variety of pests that can significantly impact yield. Major pests include aphids, jassids, mites, whiteflies, and bollworms. Aphids and jassids primarily affect the vegetative phase, while bollworms are more problematic during the reproductive and maturity phases (Wang and Zhang, 2024). Control measures for these pests often involve the use of chemical pesticides, but there is a growing emphasis on alternative methods due to concerns about pesticide resistance and environmental impact (Deguine et al., 2011). For instance, the use of pheromone traps and biological control agents like predatory beetles and lacewings has shown promise in reducing pest populations.

### 5.2 Disease prevention and management strategies

Disease management in cotton involves both preventive and reactive strategies. Preventive measures include crop rotation, use of disease-resistant varieties, and proper field sanitation to reduce the incidence of soil-borne pathogens. Reactive strategies often involve the application of fungicides and bactericides when disease symptoms are detected. Seed treatment with beneficial microbes like Pseudomonas fluorescence has been effective in reducing disease incidence (Rajashekhar et al., 2020). Additionally, maintaining optimal plant health through balanced fertilization and irrigation can help in mitigating disease impact.

### 5.3 Integrated pest management (IPM) and its benefits

Integrated pest management (IPM) is a holistic approach that combines multiple strategies to manage pest populations below economic thresholds. IPM practices in cotton include regular field monitoring, use of biological control agents, and selective application of chemical pesticides (Mounica and Swaroopa, 2017). The benefits of IPM are manifold: it reduces the reliance on chemical pesticides, thereby lowering production costs and minimizing environmental impact (Llandres et al., 2018; Rajashekhar et al., 2020). For example, IPM practices in Bt cotton have led to a significant reduction in pesticide sprays, resulting in higher net returns and improved yield stability (Mounica and Swaroopa, 2017; Rajashekhar et al., 2020). Moreover, IPM strategies like plant training for induced defense (Figure 2) and the use of cover crops have shown to enhance the natural defense mechanisms of cotton plants, further reducing the need for chemical interventions (Llandres et al., 2018; De Araújo et al., 2024).

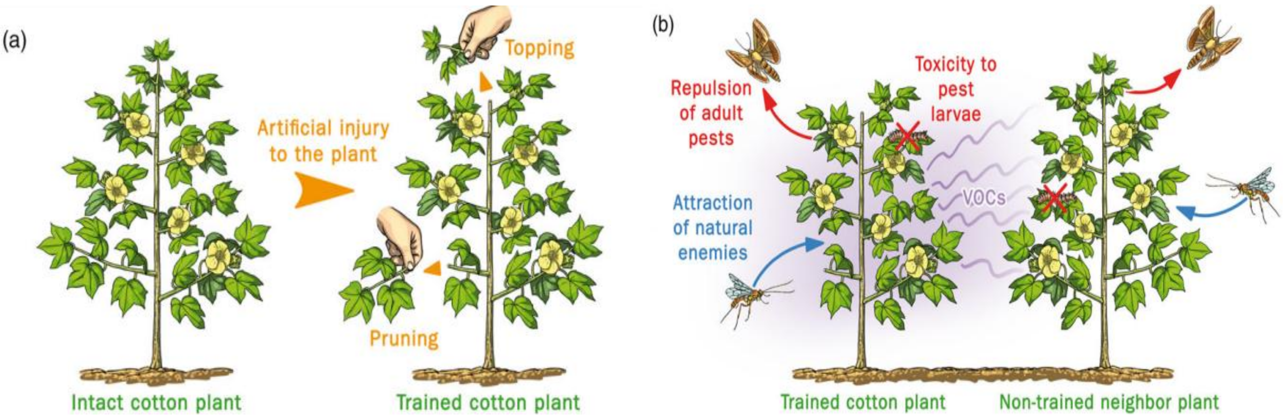


Figure 2 A: Schematic representation of cotton plant training including topping (removal of the terminal bud of the main stem) and pruning (removal of apical points of vegetative and fruiting branches); B: Effects of cotton training on herbivores and natural enemies through the activation of plant resistance strategies in trained and non-trained neighboring plants. VOCs, volatile organic compounds (Adopted from Llandres et al., 2018)

## 6 Use of Growth Regulators and Plant Hormones

### 6.1 Role of growth regulators in enhancing cotton yield

Growth regulators play a crucial role in enhancing cotton yield by influencing various physiological and biochemical processes. For instance, the application of Miantaijin, a plant growth regulator, has been shown to significantly increase cotton yield by optimizing the uptake of essential nutrients such as nitrogen, phosphorus, and potassium (Hu et al., 2023). Similarly, the use of gibberellic acid (GA3) and N6-benzyladenine (6-BA) has been found to increase seed cotton yield by enhancing photosynthesis rates and carbohydrate accumulation in floral buds, which leads to higher boll retention and reduced abscission rates (Fang et al., 2019). Additionally, growth regulators like hydrogen peroxide ($H_2O_2$) can protect cotton plants from heat-induced stress, thereby maintaining physiological processes and improving lint yield (Sarwar et al., 2018).

### 6.2 Application methods and timing for plant hormones

The effectiveness of plant hormones in cotton cultivation is highly dependent on the application methods and timing. For example, Miantaijin is most effective when applied at specific growth stages: seedling, peak squaring, peak flowering, and peak bolling stages (Hu et al., 2023). Foliar spraying and seed soaking are common methods for applying GA3 and 6-BA, with foliar spraying at the squaring stage showing significant improvements in yield components (Fang et al., 2019). Variable-rate application of growth regulators based on zonal analysis can also optimize yield by reducing spatial variability and ensuring appropriate plant height for harvest operations (Vaz et al., 2023). The timing of application is critical, as demonstrated by the use of mepiquat chloride (MC) and Miantaijin during the squaring and flowering periods, which significantly increased lint yield and potassium uptake (Yang et al., 2014).

### 6.3 Case studies of successful growth regulator applications

Several case studies highlight the successful application of growth regulators in cotton cultivation. In the Yangtze River Basin, the application of Miantaijin at a dose of 1 170 $mL \cdot ha^{-1}$ in combination with medium to high planting densities resulted in the highest cotton yields and nutrient uptakes (Hu et al., 2023). Another study demonstrated that foliar application of GA3 and 6-BA increased seed cotton yield by up to 13.3% compared to control treatments, primarily due to enhanced floral bud development and carbohydrate accumulation (Fang et al., 2019). In regions experiencing high temperatures, the application of hydrogen peroxide significantly improved boll weight and fiber quality by mitigating heat stress effects (Sarwar et al., 2018). Additionally, a variable-rate application approach based on plant height measurements and zonal analysis reduced yield spatial variability and increased overall yield in a highly variable cotton field (Vaz et al., 2023).

## 7 Genetic Improvement and Hybrid Varieties

### 7.1 Development of high-yielding cotton varieties

The development of high-yielding cotton varieties has been a focal point of cotton breeding programs. Traditional breeding methods have significantly contributed to the release of high-yielding cultivars with superior fiber quality. For instance, empirical cotton breeding has focused on selecting the best high-yielding progeny from segregating populations, which has led to the development of cultivars resilient to various climatic conditions (Mubarik et al., 2020). Additionally, the integration of conventional breeding, hybrid, and genetically modified organism (GMO) technologies has resulted in hybrid cotton varieties like CCRI63, which account for a substantial portion of cotton production in regions such as the Yangtze River Basin (Li, 2020). These varieties combine high yield, good quality, and biotic stress tolerance, showcasing the effectiveness of integrated breeding approaches.

### 7.2 Role of genetic engineering in improving yield traits

Genetic engineering has played a pivotal role in enhancing yield traits in cotton. Emerging genome engineering technologies, such as the CRISPR/Cas9 system, have the potential to edit genes related to disease susceptibility and yield regulation, thereby improving cotton yield and resilience (Figure 3) (Mubarik et al., 2020). Genetic engineering has also been employed to enhance cottonseed traits, including protein and oil content, through RNA interference and the insertion of additional genes from other sources (Wu et al., 2022). These advancements have not only improved yield but also expanded the industrial applications of cottonseed, making it a valuable source of edible oil and protein.

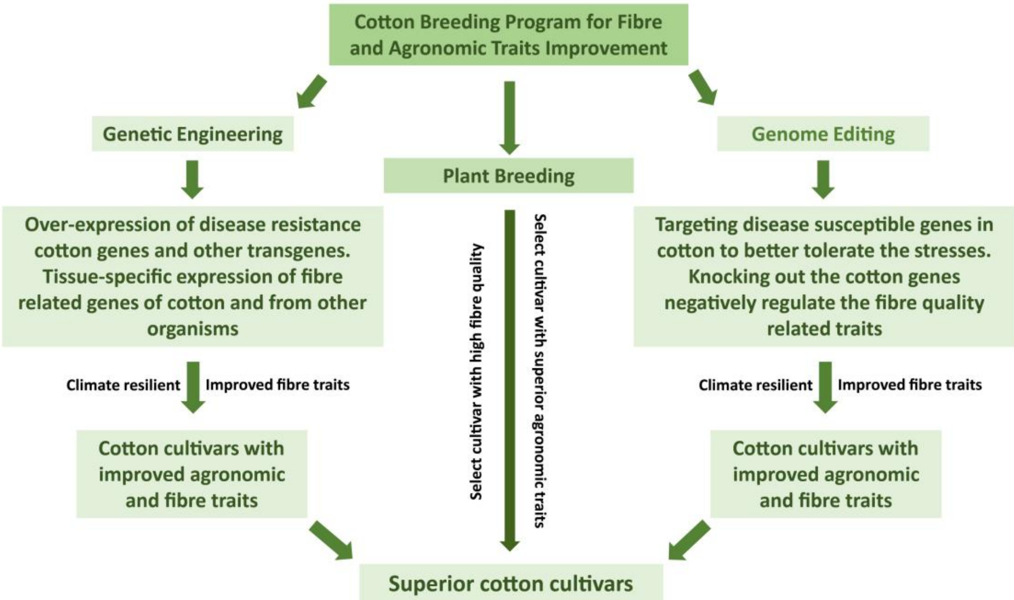


Figure 3 Proposed revamped cotton breeding program (Adopted from Mubarik et al., 2020)

Image caption: Fine-tune the already present traits and add new traits to cultivated cotton varieties through plant breeding, genetic engineering, and genome editing tools. Pyramiding of useful traits by crossing between genetically altered and elite cultivars to develop climate resilient cotton cultivars (Adopted from Mubarik et al., 2020)

### 7.3 Benefits and challenges of hybrid cotton cultivation

Hybrid cotton cultivation offers several benefits, including higher yields and improved fiber quality. Studies have shown that hybrids generally outperform inbred lines in terms of yield and fiber quality traits, demonstrating more stable performance across diverse environments. For example, hybrids like SJ48-1 × Z98-15 and L28-2 × A2-10 have exhibited both superior performance and stability in yield and fiber quality traits (Shahzad et al., 2019b). However, hybrid cotton cultivation also presents challenges. The development of superior hybrids requires a thorough understanding of the genetic control of yield and fiber quality traits, as well as the interaction between genetic and environmental factors (Shahzad et al., 2019a). Additionally, the process of hybridization can be labor-intensive and time-consuming, necessitating the use of advanced breeding techniques and genetic analysis to optimize outcomes (Shahzad et al., 2019a; Zafar et al., 2021).

## 8 Sustainable and Precision Agriculture Techniques

### 8.1 Precision planting and variable-rate technology

Precision planting and variable-rate technology (VRT) are pivotal in optimizing cotton yields while minimizing resource use. Precision planting ensures that seeds are sown at optimal depths and spacing, which enhances germination rates and plant health. VRT allows for the application of water, fertilizers, and pesticides at variable rates tailored to the specific needs of different field zones. This approach has been shown to significantly improve water use efficiency (WUE) and nitrogen efficiency, leading to higher yields and reduced environmental impact. For instance, variable deficit irrigation (VDI) combined with precision agriculture techniques can increase cotton yield by up to 28.664% and water savings by 24.941% (Filintas et al., 2022). Additionally, precision agriculture coupled with crop simulation models and geographic information systems (GIS) can optimize yields while minimizing water and nitrogen inputs.

### 8.2 Sustainable soil and water conservation practices

Sustainable soil and water conservation practices are essential for maintaining soil health and ensuring long-term agricultural productivity. Techniques such as drip irrigation under plastic mulching have been widely adopted to conserve water and improve yields. This method has been particularly effective in the northwest inland cotton-growing region of China, where it has contributed to significantly higher yields compared to national and global averages (Feng et al., 2017). Moreover, integrating organic and inorganic fertilizers can enhance soil quality and boost cotton yield. A study found that combining organic fertilizer with reduced inorganic fertilizer usage significantly improves soil quality and increases agricultural productivity (Lin et al., 2024). Cover crops and crop rotations with legumes and brassicas also play a crucial role in reducing resource depletion and increasing sustainability (Vitale et al., 2024).

### 8.3 Technological innovations for data-driven decision-making

Technological innovations are transforming cotton cultivation by enabling data-driven decision-making. Advanced technologies such as remote sensing, soil moisture sensors, and geostatistical models provide real-time data that can be used to optimize irrigation and fertilization schedules. For example, the use of remote-sensing NDVI (Normalized Difference Vegetation Index) from Sentinel-2 satellite sensors has been shown to accurately compute crop evapotranspiration, which is crucial for effective water management (Filintas et al., 2022). Additionally, the integration of precision agriculture technologies has been instrumental in enhancing efficiency and reducing input costs in U.S. cotton production (Bayramova et al., 2024). These technologies not only improve yield and resource use efficiency but also contribute to the overall sustainability of cotton farming.

## 9 Case Study: Successful Implementation of High-Yield Techniques in Cotton

### 9.1 Background and objectives of the case study

The northwest inland region of China has emerged as a leading cotton-growing area, with a significant increase in cotton yield due to the adoption of advanced cultivation techniques. This case study aims to explore the methods and techniques employed in this region to achieve high cotton yields, analyze the results, and discuss the challenges and implications for broader application. The primary objective is to understand how these techniques can be optimized and applied in other regions to enhance cotton production.

### 9.2 Methods and techniques employed for achieving high yield

Several innovative techniques have been implemented in the northwest inland region to boost cotton yield. Earliness-stimulating cultivation maximizes the use of accumulated heat, allowing for earlier planting and harvesting, which leads to higher yields. Close planting and short plant Height ensure adequate use of light energy, promoting better growth and higher productivity. Drip irrigation under plastic mulching improves yield by ensuring efficient water use and reducing evaporation (Feng et al., 2017). Mechanization and precision seeding reduce labor inputs and enhance planting accuracy, leading to better crop establishment and higher yields (Dai et al., 2017; Feng et al., 2017). Implementing high-density planting systems has shown to increase yields significantly by optimizing plant spacing and nutrient uptake (Hemalatha et al., 2024). Combining irrigation with fertilization ensures that nutrients are delivered efficiently to the plants, promoting better growth and higher yields (Dai et al., 2017; Feng et al., 2017).

### 9.3 Results, challenges, and implications for wider application

The implementation of these techniques in the northwest inland region has led to remarkable results. The region has achieved a unit yield of 1 900 kg/ha, which is significantly higher than the national and global averages (Feng et al., 2017). The integration of agronomic techniques with mechanization has not only enhanced yields but also reduced production costs, making cotton farming more profitable (Dai et al., 2017; Feng et al., 2017). Techniques like single-seed precision sowing and high-density planting have optimized plant growth and resource use, leading to higher productivity (Dai et al., 2017; Hemalatha et al., 2024). However, several challenges need to be addressed for wider application. The use of plastic mulching has led to significant pollution issues, which need to be managed through better waste disposal and recycling practices. Continuous use of certain techniques has resulted in a decline in fiber quality, necessitating the development of new methods to maintain high standards. The increasing costs of cotton production require continuous optimization of cultivation strategies to ensure economic sustainability (Feng et al., 2017).

## 10 Conclusion

This systematic review of cotton cultivation techniques for high yield has highlighted several key strategies and insights. The northwest inland region of China has achieved remarkable cotton yields through techniques such as earliness-stimulating cultivation, close planting, short plant height, and drip irrigation under plastic mulching. Light and simplified cultivation (LSC) methods, which integrate modern agricultural equipment and technology, have also proven effective in reducing labor intensity and improving yield. The construction of an optimum number of fruiting nodes (FNN) has been identified as a critical factor for high yield, promoting photosynthetic capacity and dry matter accumulation in reproductive organs. Additionally, uniform row-spacing with optimal plant density has been shown to enhance radiation use efficiency (RUE) and lint yield in Xinjiang. High-density planting systems, appropriate plant spacings, and tailored fertilizer levels further contribute to increased productivity and profitability.

Future research should focus on optimizing cotton cultivation strategies to address current challenges such as stagnated yields, plastic film pollution, and fiber quality degradation. Investigating the ecophysiology of LSC and developing new materials and equipment will be crucial for further reforming and optimizing planting systems. Additionally, exploring the potential of heat and water resources, as well as integrating agronomic techniques with mechanization, can enhance yields and economic benefits. Research on the effects of different plant spacings and fertilizer levels in high-density planting systems should continue to refine these practices for maximum yield and efficiency. Finally, comprehensive steps to improve the cultivation system at all stages of production are necessary to enhance cotton fiber quality.

Achieving sustainable high yield in cotton cultivation requires a multifaceted approach that integrates advanced agronomic techniques, modern agricultural equipment, and tailored cultivation practices. The success of regions like the northwest inland of China demonstrates the potential of combining earliness-stimulating cultivation, close planting, and efficient irrigation methods. Light and simplified cultivation systems offer a sustainable model that reduces labor intensity and enhances yield. By focusing on optimizing plant density, row-spacing, and nutrient management, cotton growers can achieve higher productivity and profitability. Continued innovation and research are essential to address ongoing challenges and ensure the long-term sustainability of high-yield cotton cultivation.

**Acknowledgments**
The author appreciates the comments from two anonymous peer reviewers on the manuscript of 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**

Ajayakumar M., Umesh M., Shivaleela S., and Nidagundi J., 2017, Light interception and yield response of cotton varieties to high density planting and fertilizers in sub-tropical India, Journal of Applied and Natural Science, 9: 1835-1839.
https://doi.org/10.31018/JANS.V9I3.1448

Bayramova J., Pires S., Barnes E., Morgan G., Kurtz R., and Daystar J., 2024, Sustainable cotton farming trends: leveraging natural resource survey insights for U.S. cotton production, BioResources, 19(4): 7279-7319.
https://doi.org/10.15376/biores.19.4.7279-7319

Dai J., Kong X., Zhang D., Li W., and Dong H., 2017, Technologies and theoretical basis of light and simplified cotton cultivation in China, Field Crops Research, 214: 142-148.
https://doi.org/10.1016/J.FCR.2017.09.005

De Araújo W., Fernandes M., Degrande P., Salustino A., Neto D., and Malaquias J., 2024, Exploring the impact of cover crops in integrated pest management: pest and natural enemies population dynamics in no-tillage cotton production, Bulletin of Entomological Research, 114(4): 581-590.
https://doi.org/10.1017/S0007485324000452

Deguine J., Ferron P., and Russell D., 2011, Sustainable pest management for cotton production, a review, Agronomy for Sustainable Development, 28: 113-137.
https://doi.org/10.1051/agro:2007042

Divya K., Kaleeswari R., Jeyanthi D., Amirtham D., and Sankaranarayanan K., 2022, Evolution of liquid multinutrient fertilizer for hybrid cotton, International Journal of Plant & Soil Science, 34(20): 666-671.
https://doi.org/10.9734/ijpss/2022/v34i2031202

Fang S., Gao K., Hu W., Wang S., Chen B., and Zhou Z., 2019, Foliar and seed application of plant growth regulators affects cotton yield by altering leaf physiology and floral bud carbohydrate accumulation, Field Crops Research, 231: 105-114.
https://doi.org/10.1016/J.FCR.2018.11.012

Feng L., Dai J., Tian L., Zhang H., Li W., and Dong H., 2017, Review of the technology for high-yielding and efficient cotton cultivation in the northwest inland cotton-growing region of China, Field Crops Research, 208: 18-26.
https://doi.org/10.1016/J.FCR.2017.03.008

Filintas A., Nteskou A., Kourgialas N., Gougoulias N., and Hatzichristou E., 2022, A comparison between variable deficit irrigation and farmers' irrigation practices under three fertilization levels in cotton yield (*Gossypium hirsutum* L.) using precision agriculture, remote sensing, soil analyses, and crop growth modeling, Water, 14(17): 2654.
https://doi.org/10.3390/w14172654

Hemalatha G., Nagabhushanam U., Veeranna G., and Ramulu C., 2024, Performance of cotton under different spacings and fertilizer levels on growth, yield, nutrient uptake and economics in high density planting system, International Journal of Research in Agronomy, 7(9S): 860-866.
https://doi.org/10.33545/2618060x.2024.v7.i9sl.1622

Hu L., Pan X., Wang X., Hu Q., Wang X., Zhang H., Xue Q., and Song M., 2021, Cotton photosynthetic productivity enhancement through uniform row - spacing with optimal plant density in Xinjiang, China, Crop Science, 61: 2745-2758.
https://doi.org/10.1002/csc2.20535

Hu T., Liu Z., Jin D., Chen Y., Zhang X., and Chen D., 2023, Effects of growth regulator and planting density on cotton yield and N, P, and K accumulation in direct-seeded cotton, Agronomy, 13(2): 501.
https://doi.org/10.3390/agronomy13020501

Khan A., Wang L., Ali S., Tung S., Hafeez A., and Yang G., 2017, Optimal planting density and sowing date can improve cotton yield by maintaining reproductive organ biomass and enhancing potassium uptake, Field Crops Research, 214: 164-174.
https://doi.org/10.1016/J.FCR.2017.09.016

Koudahe K., Sheshukov A., Aguilar J., and Djaman K., 2021, Irrigation-water management and productivity of cotton: a review, Sustainability, 13(18): 10070.
https://doi.org/10.3390/su131810070

Li C., 2020, Breeding crops by design for future agriculture, Journal of Zhejiang University-SCIENCE B, 21: 423-425.
https://doi.org/10.1631/jzus.B2010001

Lin S., Wang Q., Wei K., Zhao X., Tao W., Sun Y., Su L., and Deng M., 2024, Comprehensive assessment of combined inorganic and organic fertilization strategies on cotton cultivation: implications for sustainable agriculture, Journal of the Science of Food and Agriculture, 104(14): 8456-8468.
https://doi.org/10.1002/jsfa.13673

Liu Z., Chen Y., Li Y., Chen C., Ma Y.X., Chen D., Zhang X., and Zhou M., 2020, Construction of optimum number of fruiting nodes benefit high yield in cotton population, Industrial Crops and Products, 158: 113020.
https://doi.org/10.1016/j.indcrop.2020.113020

Llandres A., Almohamad R., Brévault T., Renou A., Téréta I., Jean J., and Goebel F., 2018, Plant training for induced defense against insect pests: a promising tool for integrated pest management in cotton, Pest Management Science, 74(9): 2004-2012.
https://doi.org/10.1002/ps.5039

Mounica D., and Swaroopa V., 2017, Innovative frontline demonstrations in tribal areas to enhance *Bt* cotton yield and income through integrated pest management, International Journal of Farm Sciences, 6: 177-182.

Mubarik M., Ma C., Majeed S., Du X., and Azhar M., 2020, Revamping of cotton breeding programs for efficient use of genetic resources under changing climate, Agronomy, 10(8): 1190.
https://doi.org/10.3390/agronomy10081190

Rajashekhar M., Rajashekar B., Reddy T., Ramakrishna K., Shankar A., Jahan A., and Reddy M., 2020, IPM: an ecofriendly and low cost technology in arresting pest complex for higher net returns in cotton, Journal of Entomology and Zoology Studies, 8: 1726-1728.

Sarwar M., Saleem M., Ullah N., Rizwan M., Ali S., Shahid M., Alamri S., Alyemeni M., and Ahmad P., 2018, Exogenously applied growth regulators protect the cotton crop from heat-induced injury by modulating plant defense mechanism, Scientific Reports, 8: 17086.
https://doi.org/10.1038/s41598-018-35420-5

Selvakumar S., Thiruppathi M., Immanuel R., Sivaraman A., and Chakravarthy G., 2022, Impact of foliar fertilization of nutrients and biofertilizer on the growth and yield of hybrid cotton (*Gossypium hirsutum* L.), Crop Research, 57: 275-280.
https://doi.org/10.31830/2454-1761.2022.cr-821

Shahzad K., Li X., Qi T., Guo L., Tang H., Zhang X., Wang H., Zhang M., Zhang B., Qiao X., Xing C., and Wu J., 2019a, Genetic analysis of yield and fiber quality traits in upland cotton (*Gossypium hirsutum* L.) cultivated in different ecological regions of China, Journal of Cotton Research, 2: 14.
https://doi.org/10.1186/s42397-019-0031-4

Shahzad K., Qi T., Guo L., Tang H., Zhang X., Wang H., Qiao X., Zhang M., Zhang B., Feng J., Iqbal M., Wu J., and Xing C., 2019b, Adaptability and stability comparisons of inbred and hybrid cotton in yield and fiber quality traits, Agronomy, 9(9): 516.
https://doi.org/10.3390/agronomy9090516

Shi X., Hao X., Khan A., Li N., Li J., Shi F., Tian Y., Nepal J., Wang J., and Luo H., 2023, Increase in cotton yield through improved leaf physiological functioning under the soil condition of reduced chemical fertilization compensated by the enhanced organic liquid fertilization, Frontiers in Plant Science, 14: 1225939.
https://doi.org/10.3389/fpls.2023.1225939

Shi X., Hao X., Li N., Li J., Shi F., Han H., Tian Y., Chen Y., Wang J., and Luo H., 2022, Organic liquid fertilizer coupled with single application of chemical fertilization improves growth, biomass, and yield components of cotton under mulch drip irrigation, Frontiers in Plant Science, 12: 763525.
https://doi.org/10.3389/fpls.2021.763525

Shukr H., Pembleton K., Zull A., and Cockfield G., 2021, Impacts of effects of deficit irrigation strategy on water use efficiency and yield in cotton under different irrigation systems, Agronomy, 11(2): 231.
https://doi.org/10.3390/AGRONOMY11020231

Singh K., Singh P., Singh M., Mishra S., Iqbal R., Al-Ashkar I., Habib-Ur-Rahman M., and Sabagh E., 2022, Sub-surface drip fertigation improves seed cotton yield and monetary returns, Frontiers in Plant Science, 13: 1038163.
https://doi.org/10.3389/fpls.2022.1038163

Vaz C., Franchini J., Speranza E., Inamasu R., De C. Jorge L., Rabello L., De O.N. Lopes I., Chagas S., De Souza J., De Souza M., Pires A., and Schepers J., 2023, Zonal application of plant growth regulator in cotton to reduce variability and increase yield in a highly variable field, Journal of Cotton Science, 27(2): 60-73.
https://doi.org/10.56454/miuc6583

Vitale G., Scavo A., Zingale S., Tuttolomondo T., Santonoceto C., Pandino G., Lombardo S., Anastasi U., and Guarnaccia P., 2024, Agronomic strategies for sustainable cotton production: a systematic literature review, Agriculture, 14(9): 1597.
https://doi.org/10.3390/agriculture14091597

Wang J., Du G., Tian J., Jiang C., Zhang Y., and Zhang W., 2021, Mulched drip irrigation increases cotton yield and water use efficiency via improving fine root plasticity, Agricultural Water Management, 255: 106992.
https://doi.org/10.1016/J.AGWAT.2021.106992

Wang J., Du G., Tian J., Zhang Y., Jiang C., and Zhang W., 2020, Effect of irrigation methods on root growth, root-shoot ratio and yield components of cotton by regulating the growth redundancy of root and shoot, Agricultural Water Management, 234: 106120.
https://doi.org/10.1016/j.agwat.2020.106120

Wang J.M., and Zhang J., 2024, Assessing the impact of various cotton diseases on fiber quality and production, Field Crop, 7(4): 212-221. (doi: 10.5376/fc.2024.07.0021)

Wu M., Pei W., Wedegaertner T., Zhang J., and Yu J., 2022, Genetics, breeding and genetic engineering to improve cottonseed oil and protein: a review, Frontiers in Plant Science, 13: 864850.
https://doi.org/10.3389/fpls.2022.864850

Yang F., Du M., Tian X., Eneji A., Duan L., and Li Z., 2014, Plant growth regulation enhanced potassium uptake and use efficiency in cotton, Field Crops Research, 163: 109-118.
https://doi.org/10.1016/J.FCR.2014.03.016

Yogesh G.S., and Prakash S.S., and Thimmegowda M.N., 2022, Effect of micronutrients application under different fertilizer prescription methods on growth and yield of *Bt* cotton, International Journal of Plant & Soil Science, 34(20): 558-564.

Zafar M., Manan A., Razzaq A., Zulfqar M., Saeed A., Kashif M., Khan A., Sarfraz Z., Mo H., Iqbal M., Shakeel A., and Ren M., 2021, Exploiting agronomic and biochemical traits to develop heat resilient cotton cultivars under climate change scenarios, Agronomy, 11(9): 1885.
https://doi.org/10.3390/agronomy11091885

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