



Water-saving irrigation strategies in agronomy: Innovations, challenges, and opportunities

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Abstract

Water scarcity has become one of the most critical constraints to agricultural production worldwide. Increasing competition for freshwater resources, climate change, declining groundwater levels, and inefficient irrigation practices threaten food security and sustainable crop production. Water-saving irrigation strategies have emerged as essential agronomic interventions to enhance water-use efficiency while maintaining or improving crop yields. This review examines major water-saving irrigation technologies, including drip irrigation, sprinkler systems, deficit irrigation, alternate wetting and drying, subsurface irrigation, sensor-based irrigation scheduling, and precision irrigation. The paper discusses recent innovations such as remote sensing, Internet of Things (IoT)-based irrigation management, artificial intelligence-assisted scheduling, and automated irrigation systems. The agronomic, environmental, and economic benefits of these strategies are highlighted, including reduced water consumption, improved nutrient-use efficiency, lower energy requirements, and enhanced resilience to drought stress. The review also identifies key challenges such as high installation costs, technical complexity, maintenance requirements, limited farmer awareness, and policy constraints. Future opportunities lie in the integration of digital agriculture, climate-smart irrigation management, renewable energy-powered systems, and location-specific irrigation scheduling models. The successful adoption of water-saving irrigation strategies will play a pivotal role in achieving sustainable agricultural intensification, climate resilience, and long-term food security.

Keywords: Water-use efficiency, drip irrigation, deficit irrigation, precision irrigation, climate-smart agriculture, irrigation scheduling, sustainable agronomy, water conservation

Introduction

Water is the most critical input for agricultural production and plays a fundamental role in crop growth, nutrient transport, photosynthesis, and physiological development. Globally, agriculture accounts for nearly seventy percent of total freshwater withdrawals, making it the largest consumer of available water resources. However, increasing population growth, rapid urbanization, industrial expansion, and changing climatic conditions have intensified pressure on freshwater supplies [1-4]. Many regions of the world are already experiencing severe water scarcity, declining groundwater tables, irregular rainfall patterns, and prolonged droughts. These challenges pose a significant threat to food security and agricultural sustainability, particularly in arid and semi-arid regions where irrigation is essential for crop production [5-8]. Traditional irrigation practices, especially uncontrolled surface or flood irrigation, often result in substantial water losses through evaporation, runoff, seepage, and deep percolation beyond the crop root zone. Such inefficiencies not only waste valuable water resources but also contribute to soil degradation, salinity buildup, nutrient leaching, and increased energy consumption for water pumping. As freshwater availability continues to decline, the agricultural sector faces the urgent challenge of producing more food with less water while minimizing environmental impacts. Consequently, improving irrigation efficiency has become a central objective of modern agronomic research and policy planning.

Water-saving irrigation strategies have emerged as a key component of sustainable and climate-smart agriculture. These strategies focus on delivering water more precisely to the crop root zone, optimizing irrigation timing and quantity, reducing conveyance losses, and integrating advanced monitoring technologies. Innovations such as drip irrigation, sprinkler systems, deficit irrigation, alternate wetting and drying, subsurface irrigation, and sensor-based irrigation scheduling have demonstrated significant potential for enhancing water-use efficiency while maintaining or improving crop yields. Furthermore, recent advances in digital agriculture, remote sensing, Internet of Things (IoT) technologies, and artificial intelligence have enabled real-time monitoring of soil moisture and crop water status, allowing farmers to make more informed irrigation decisions [9-12]. The importance of water-saving irrigation extends beyond crop productivity. Efficient irrigation management contributes to groundwater conservation, reduces greenhouse gas emissions associated with pumping and energy use, minimizes nutrient losses to water bodies, and enhances resilience to climate variability. In the context of increasing climate uncertainty, water-saving technologies offer a practical pathway for adapting agricultural systems to future water limitations. Therefore, this review aims to examine the major water-saving irrigation strategies used in agronomy, evaluate recent technological innovations, discuss the challenges affecting their adoption, and highlight future opportunities for sustainable and resilient agricultural water management.

Drip Irrigation

Drip irrigation is widely regarded as one of the most efficient irrigation methods available in modern agriculture because it delivers water directly to the plant root zone through a network of pipes, emitters, and control valves. Unlike conventional surface irrigation systems, drip irrigation applies water slowly and precisely, thereby minimizing losses through evaporation, runoff, and deep percolation. This targeted application ensures that a larger proportion of the supplied water is actually utilized by the crop, resulting in significantly higher irrigation efficiency [13-16]. One of the most important advantages of drip irrigation is its substantial water-saving potential. Numerous studies have reported water savings ranging from 30% to 60% compared with traditional flood irrigation systems. By maintaining optimal soil moisture conditions around the root zone, drip irrigation also promotes better root development, improved nutrient uptake, and enhanced crop growth. The system is particularly suitable for high-value crops such as vegetables, fruit orchards, vineyards, and horticultural crops, where precise water management is essential for achieving superior yield and quality.

Drip irrigation also facilitates fertigation, the practice of applying fertilizers through the irrigation system. Fertigation allows nutrients to be delivered directly to the active root zone in small, controlled doses, improving nutrient-use efficiency and reducing fertilizer losses through leaching or runoff. In addition, because water is applied only near the crop rows, weed growth between rows is significantly reduced, lowering the need for herbicide applications and manual weed control [17]. Despite its advantages, drip irrigation faces several challenges. The initial installation cost is generally higher than that of traditional irrigation systems, and regular maintenance is required to prevent emitter clogging caused by sediments, salts, or biological growth. Farmers also need adequate technical knowledge regarding system design, pressure regulation, filtration, and irrigation scheduling. Nevertheless, the long-term benefits of reduced water use, lower labor requirements, improved fertilizer efficiency, and increased crop productivity often outweigh the initial investment costs. As water scarcity becomes more severe, drip irrigation is expected to play an increasingly important role in sustainable agronomic management.

Table 1: Major Water-Saving Irrigation Strategies and Their Key Characteristics

Irrigation Strategy	Main Principle	Water-Saving Potential
Drip irrigation	Water delivered directly to root zone	30–60%
Sprinkler irrigation	Pressurized water distribution	20–40%
Deficit irrigation	Controlled water stress	10–30%
Alternate wetting and drying	Intermittent flooding in rice	15–30%
Subsurface irrigation	Buried water delivery system	40–70%
Sensor-based scheduling	Water applied based on soil moisture	15–35%
Precision irrigation	Variable-rate and automated application	20–50%

Table 2: Agronomic Benefits of Water-Saving Irrigation

Benefit Category	Observed Advantage
Water productivity	Higher yield per unit of water applied
Nutrient efficiency	Improved fertilizer uptake
Crop performance	Enhanced growth and yield
Drought resilience	Better tolerance to water stress
Soil health	Reduced salinity and waterlogging
Weed management	Lower weed growth in localized systems
Crop quality	Improved fruit size and uniformity

Table 3: Environmental Benefits of Efficient Irrigation Systems

Environmental Aspect	Impact
Groundwater conservation	Reduced extraction rates
Energy consumption	Lower pumping requirements
Greenhouse gas emissions	Reduced fuel and methane emissions
Water pollution	Reduced nutrient leaching
Soil erosion	Lower runoff and sediment loss
Ecosystem protection	Improved water resource sustainability

Table 4: Major Challenges Affecting Adoption

Challenge	Effect on Adoption
High installation cost	Limits smallholder adoption
Technical complexity	Requires specialized training
Maintenance requirements	Increases operational burden
Limited access to credit	Restricts investment capacity
Poor extension support	Reduces effective implementation
Infrastructure constraints	Limits technology deployment
Policy limitations	Insufficient incentives for conservation

Table 5: Future Opportunities in Water-Saving Irrigation

Emerging Technology	Expected Contribution
AI-based scheduling	Optimized irrigation timing
IoT soil sensors	Real-time moisture monitoring
Remote sensing	Crop water stress detection
Drones	Field variability assessment
Solar-powered irrigation	Reduced energy dependence
Variable-rate irrigation	Site-specific water application
Climate forecasting integration	Improved drought preparedness

Sprinkler Irrigation Systems

Sprinkler irrigation is another important water-saving strategy that distributes water under pressure through a system of pipes and nozzles, simulating natural rainfall. This method provides relatively uniform water application across the field and can be used on a wide range of soil types and topographic conditions. Sprinkler systems are particularly advantageous in areas where surface irrigation is difficult due to uneven terrain, sandy soils, or limited water availability.

Several types of sprinkler systems are commonly used in agriculture, including center pivot systems, lateral move systems, portable sprinklers, and micro-sprinklers. Center pivot irrigation is widely adopted in large-scale farming operations because it can efficiently irrigate extensive areas with relatively low labor requirements. Micro-sprinklers, on the other hand, are often used in orchards and plantations where localized water application is desirable [18-21]. Compared with conventional flood irrigation, sprinkler systems can significantly reduce water losses and improve irrigation efficiency. Uniform water distribution helps avoid both water stress and waterlogging, thereby promoting better crop growth and yield. Sprinkler irrigation can also be combined with fertigation and chemigation, allowing fertilizers and crop protection chemicals to be applied simultaneously with irrigation water.

However, sprinkler irrigation is not without limitations. Water losses due to wind drift and evaporation can occur, especially under hot and windy conditions. Energy requirements are generally higher because water must be pressurized before application. In some cases, frequent wetting of foliage may increase the risk of certain plant diseases. Proper system design, nozzle selection, and irrigation scheduling are therefore essential to maximize efficiency and minimize potential drawbacks [22]. Advancements in sprinkler technology have led to the development of low-pressure nozzles, variable-rate irrigation systems, and automated control mechanisms that further enhance water-use efficiency. When properly managed, sprinkler irrigation offers a practical balance between water conservation, operational flexibility, and crop productivity, making it a valuable component of modern water-saving agronomic strategies.

Deficit Irrigation

Deficit irrigation is a strategic water management approach in which crops receive less water than their full evapotranspiration requirement during selected growth stages. Unlike traditional irrigation methods that aim to meet the complete water demand of the crop, deficit irrigation intentionally imposes mild water stress during periods when the crop is less sensitive to moisture shortages. The objective is to maximize water productivity

rather than absolute yield per unit area [23-25]. This strategy has gained considerable importance in regions experiencing chronic water scarcity, where limited water supplies must be distributed across larger agricultural areas. By carefully reducing irrigation during non-critical growth stages, farmers can conserve substantial quantities of water while maintaining economically acceptable yields. Crops such as wheat, maize, cotton, grape, olive, and certain fruit trees have shown good responses to moderate deficit irrigation under appropriate management.

The agronomic benefits of deficit irrigation include improved water-use efficiency, reduced pumping and energy costs, and increased crop productivity per unit of water applied. In some cases, controlled water stress can also enhance crop quality attributes, such as sugar concentration in grapes and certain fruits. However, successful implementation requires precise knowledge of crop growth stages, soil water-holding capacity, and climatic conditions. Excessive water reduction can lead to significant yield losses, reduced nutrient uptake, and impaired crop development [26]. Therefore, deficit irrigation must be carefully scheduled using scientific irrigation management tools and local agronomic recommendations.

Alternate Wetting and Drying (AWD)

Alternate wetting and drying is a water-saving irrigation technique primarily used in rice cultivation. Traditionally, rice fields are kept continuously flooded throughout much of the growing season, resulting in high water consumption and significant methane emissions. AWD modifies this practice by allowing the field to dry to a predetermined threshold before re-irrigation is applied. This intermittent flooding approach substantially reduces water use while maintaining favorable conditions for rice growth [27]. One of the major advantages of AWD is its ability to save between 15% and 30% of irrigation water compared with continuous flooding. In addition, periodic soil aeration suppresses methane-producing anaerobic microorganisms, thereby reducing greenhouse gas emissions from rice fields. The technique also lowers irrigation costs by decreasing the frequency and duration of water application [28]. When properly managed, AWD can maintain grain yield comparable to that obtained under conventional flooding systems. However, careful monitoring of field water levels is essential to avoid excessive drying that may stress the crop, particularly during sensitive reproductive stages. The use of simple field water tubes or sensor-based monitoring systems can help farmers determine the appropriate timing for re-irrigation. As concerns over water scarcity and climate change continue to grow, AWD has become an important climate-smart irrigation strategy for sustainable rice production.

Subsurface Irrigation

Subsurface irrigation involves applying water below the soil surface, either through buried drip lines or by maintaining a controlled water table beneath the crop root zone. Because water is delivered directly within the root environment, evaporation losses from the soil surface are greatly reduced. This makes subsurface irrigation one of the most efficient methods for conserving water in agricultural systems ^[29]. The buried distribution network provides precise moisture control and maintains a relatively stable soil water regime around the roots. Improved moisture availability promotes efficient nutrient uptake and reduces fluctuations in plant water status. In addition, because the soil surface remains comparatively dry, the incidence of foliar diseases and weed growth may be reduced. Subsurface systems are particularly advantageous for high-value crops, greenhouse production, and areas where water conservation is a priority. Despite its high efficiency, subsurface irrigation has several limitations. Installation costs are considerably higher than those of many surface systems, and specialized equipment is often required. Maintenance can also be challenging because buried emitters are difficult to inspect and repair. Problems such as root intrusion, emitter clogging, and uneven water distribution may occur if filtration and system management are inadequate. Nevertheless, where long-term water savings justify the investment, subsurface irrigation offers substantial agronomic and environmental benefits.

Sensor-Based Irrigation Scheduling

Sensor-based irrigation scheduling represents a significant advancement in modern irrigation management. This approach uses soil moisture sensors, tensiometers, weather stations, and evapotranspiration models to determine precisely when and how much water should be applied. Instead of relying on fixed irrigation calendars, water application is based on actual crop and soil conditions ^[30]. Soil moisture sensors provide continuous information about water availability within the root zone, while weather-based systems estimate crop water demand using temperature, humidity, solar radiation, and wind speed data. Decision-support software integrates these data sources to generate optimized irrigation schedules. As a result, irrigation is applied only when necessary, preventing both over-irrigation and water stress.

The benefits of sensor-based scheduling include improved water-use efficiency, reduced energy consumption, lower fertilizer losses, and enhanced crop performance. Automated systems can further increase precision by activating irrigation valves based on predefined moisture thresholds. However, successful adoption depends on proper sensor calibration, reliable data transmission, and farmer training. Initial equipment costs and technical complexity may limit adoption among smallholder farmers, but ongoing reductions in sensor prices and advances in digital agriculture are making these technologies increasingly accessible. Sensor-based irrigation scheduling is expected to become a cornerstone of precision and climate-smart irrigation management in the coming years.

Precision Irrigation Technologies

Precision irrigation represents a major advancement in agricultural water management by integrating information technology, sensing systems, and automated irrigation control to apply water according to the specific needs of

crops and field conditions. Unlike conventional irrigation practices that often apply uniform amounts of water across an entire field, precision irrigation recognizes spatial and temporal variability in soil moisture, crop growth, and environmental conditions. The primary objective is to deliver the right amount of water to the right place at the right time, thereby maximizing water-use efficiency and crop productivity.

Modern precision irrigation systems utilize technologies such as Global Positioning Systems (GPS), remote sensing, drones, wireless sensor networks, and Internet of Things (IoT)-based devices. Soil moisture sensors continuously monitor water availability in different parts of the field, while remote sensing imagery helps identify zones experiencing water stress. Drones equipped with multispectral or thermal cameras can rapidly assess crop health and detect moisture deficiencies that may not be visible from ground observations ^[31]. Artificial intelligence and machine learning algorithms are increasingly being incorporated into precision irrigation platforms. These systems analyze historical weather data, crop growth stages, soil characteristics, and real-time sensor information to generate optimized irrigation schedules. Automated valves and variable-rate irrigation systems can then adjust water application rates according to field variability, reducing unnecessary irrigation and improving overall efficiency.

The adoption of precision irrigation offers several benefits, including reduced water consumption, lower energy costs, improved nutrient-use efficiency, enhanced crop yields, and minimized environmental impacts. However, challenges such as high initial investment costs, technical expertise requirements, data management complexity, and infrastructure limitations may restrict adoption in some farming regions. Despite these constraints, precision irrigation is expected to play a central role in the future of climate-smart and sustainable agriculture.

Agronomic Benefits of Water-Saving Irrigation

Water-saving irrigation strategies provide numerous agronomic advantages that extend beyond simple water conservation. One of the most important benefits is the improvement in water productivity, defined as crop yield produced per unit of water used. By reducing losses through evaporation, runoff, and deep percolation, efficient irrigation systems ensure that a greater proportion of applied water contributes directly to crop growth.

Improved root-zone moisture management enhances nutrient uptake and fertilizer-use efficiency. In systems such as drip irrigation and fertigation, nutrients are delivered directly to the active root zone, reducing nutrient losses and promoting more efficient plant utilization. Better nutrient availability often results in improved vegetative growth, higher biomass production, and increased crop yields ^[32]. Water-saving irrigation also contributes to greater crop resilience under drought and heat stress conditions. Maintaining optimal soil moisture levels during critical growth stages helps stabilize yields and reduce the risk of crop failure. In many crops, precise irrigation management can improve product quality characteristics such as fruit size, sugar content, and uniformity. Furthermore, reduced waterlogging lowers the incidence of root diseases and creates a more favorable soil environment for beneficial microbial activity.

Additional agronomic benefits include improved field accessibility due to reduced surface saturation, lower weed pressure in localized irrigation systems, and greater flexibility in irrigation scheduling. Collectively, these advantages make water-saving irrigation an essential component of sustainable crop management and climate-resilient agronomy.

Environmental Benefits

The environmental benefits of water-saving irrigation strategies are substantial and increasingly important in the context of global climate change and resource conservation. Efficient irrigation systems reduce the volume of water withdrawn from rivers, reservoirs, and groundwater aquifers, thereby helping conserve freshwater resources for future use. Lower extraction rates can slow groundwater depletion and contribute to the long-term sustainability of agricultural water supplies.

Reduced irrigation volumes also decrease energy consumption associated with water pumping and distribution. Lower energy use translates into reduced greenhouse gas emissions, particularly in regions where irrigation pumping depends on fossil-fuel-based electricity or diesel engines. In rice production systems, techniques such as alternate wetting and drying can significantly reduce methane emissions compared with continuously flooded fields [34-37]. Water-saving irrigation helps minimize nutrient leaching and agricultural runoff, reducing the transport of nitrogen, phosphorus, and other contaminants into surface and groundwater bodies. This contributes to improved water quality and lowers the risk of eutrophication in lakes and rivers. Reduced runoff additionally decreases soil erosion and sediment loss, helping preserve fertile topsoil and maintain ecosystem health.

By improving water-use efficiency and reducing environmental degradation, water-saving irrigation supports broader sustainability goals related to climate change mitigation, biodiversity conservation, and integrated water resource management. These environmental benefits reinforce the importance of adopting efficient irrigation technologies as part of comprehensive strategies for sustainable agricultural development.

Challenges and Constraints

Despite the considerable advantages of water-saving irrigation technologies, several challenges continue to limit their widespread adoption across different agricultural systems. One of the most significant constraints is the high initial investment cost associated with technologies such as drip irrigation, subsurface irrigation, automated control systems, sensors, and precision irrigation equipment. Smallholder farmers, particularly in developing countries, often lack the financial resources required for installation and maintenance of these systems.

Another major challenge is the technical complexity involved in operating advanced irrigation technologies. Efficient management of drip systems, sensor networks, automated valves, and digital scheduling platforms requires specialized knowledge and training. Inadequate technical support and limited access to extension services can result in improper system operation, reduced efficiency, and equipment failure.

Maintenance requirements also represent an important limitation. Emitters in drip and subsurface systems may

become clogged due to sediments, salts, or biological growth, while sensors and electronic components require periodic calibration and servicing. Poor maintenance can significantly reduce irrigation performance and increase operational costs.

Institutional and policy-related barriers further affect adoption. In some regions, water pricing policies do not adequately encourage conservation, and subsidy programs for efficient irrigation technologies remain insufficient. Limited access to credit, fragmented landholdings, unreliable electricity supply, and inadequate rural infrastructure can also hinder implementation [38-39]. Additionally, the effectiveness of certain water-saving practices varies depending on local soil characteristics, climate conditions, crop type, and water quality, emphasizing the need for location-specific management strategies.

Economic Considerations

The economic viability of water-saving irrigation systems is a critical factor influencing farmer adoption. Although advanced irrigation technologies generally require higher upfront investment than traditional surface irrigation methods, their long-term economic benefits can be substantial. Reduced water consumption lowers irrigation costs, while improved water-use efficiency often results in higher crop yields and better product quality.

Energy savings constitute another important economic advantage. Efficient irrigation systems require less pumping time and reduce fuel or electricity consumption, thereby lowering operational expenses. In drip irrigation systems, the integration of fertigation can improve fertilizer-use efficiency and reduce fertilizer costs, further enhancing profitability.

Several economic analyses have demonstrated that the payback period for water-saving irrigation investments can be relatively short for high-value crops such as vegetables, fruits, vineyards, and greenhouse crops. However, for low-value staple crops, profitability may depend on factors such as water prices, energy costs, yield response, and availability of government incentives [40-44]. Financial support mechanisms play a crucial role in promoting adoption. Subsidies, low-interest loans, microcredit programs, and public-private partnerships can significantly reduce the financial burden on farmers. In addition, collective investment models and community-based irrigation schemes may improve access to efficient irrigation technologies for smallholder producers who cannot individually afford large investments.

Future Opportunities

Future opportunities in water-saving irrigation are closely linked to advances in digital agriculture, climate-smart farming, and renewable energy technologies. The integration of artificial intelligence (AI), machine learning, and big data analytics is expected to transform irrigation management by enabling highly accurate prediction of crop water requirements based on weather forecasts, soil conditions, and crop growth stages.

Satellite-based remote sensing and drone technologies will increasingly provide real-time information on crop water stress, allowing irrigation decisions to be made with greater precision. Low-cost IoT sensors and wireless communication networks are becoming more accessible,

making automated irrigation management feasible even for medium- and small-scale farms ^[45–46]. Another promising opportunity is the adoption of solar-powered irrigation systems, which can reduce dependence on fossil fuels and lower operating costs in remote areas. The combination of solar energy with smart irrigation controllers offers significant potential for sustainable water and energy management. Research is also focusing on variable-rate irrigation, where water application is adjusted according to field variability, and on the integration of irrigation scheduling with climate forecasting models. Community-scale smart irrigation networks, cloud-based decision support systems, and mobile phone applications can further improve farmer access to irrigation information and management tools. Overall, the future of water-saving irrigation lies in the development of affordable, data-driven, and climate-resilient systems that can optimize water productivity while supporting sustainable agricultural intensification. Continued investment in research, infrastructure, farmer training, and supportive policies will be essential for realizing these opportunities and ensuring efficient water management in agriculture.

Conclusion

Water-saving irrigation strategies have become indispensable for sustainable agronomy in an era of increasing water scarcity and climate uncertainty. Technologies such as drip irrigation, sprinkler systems, deficit irrigation, alternate wetting and drying, subsurface irrigation, and precision irrigation offer substantial improvements in water-use efficiency while supporting crop productivity and environmental conservation. The integration of sensors, remote sensing, automation, and artificial intelligence is transforming irrigation management from a fixed-schedule approach to a data-driven, real-time decision-making system.

Despite challenges related to cost, technical expertise, maintenance, and institutional support, the long-term agronomic and economic benefits of water-saving irrigation are significant. Future progress will depend on the development of affordable technologies, farmer training programs, supportive policies, and region-specific irrigation management strategies. Widespread adoption of innovative water-saving irrigation systems can play a crucial role in enhancing climate resilience, conserving freshwater resources, reducing environmental impacts, and ensuring sustainable food production for a growing global population.

References

- Food and Agriculture Organization. Irrigation and water management for sustainable agriculture. Food and Agriculture Organization, 2023.
- Kumar A, Sinha SK, Singh SK, Rana L, Singh AK, Sunita K, *et al.* Influence of intercropping and planting techniques on sugarcane yield and nutrient absorption in the North West Alluvial Plains of Bihar. *AATCC Review*, 2025;13(1):144–153.
- Intergovernmental Panel on Climate Change. Climate Change 2023: Synthesis Report. Intergovernmental Panel on Climate Change, 2023.
- Fereres E, Soriano MA. Deficit irrigation for reducing agricultural water use. *Agricultural Water Management*, 2022;268:107637.
- Babu TM, Lakshmi T, Prasad SV, Sumathi V, Murthy BR. Constraints of Farmer Producer Organizations (FPOs) members in Rayalaseema region of Andhra Pradesh. *AATCC Review*, 2022;14:105–110.
- Madhu DM, Sinha DK, Singh KM, Kumari T, Singh RP, Kumari S, *et al.* Achieving sustainable development goal by empowering women through mulberry silk production in Karnataka, India. *Agriculture Association of Textile Chemical and Critical Reviews Journal*, 2023;10:1–6.
- Kumar A, Bairwa M, Meena SK, Singh SK, Sinha SK, Rana L, *et al.* Comparative analysis of macronutrient, soil sulphur availability and micronutrient dynamics across diverse land use types of Indo-Gangetic plains of India. *AATCC Review*, 2025;13(1):467–472.
- Pereira LS, *et al.* Improved irrigation scheduling under water scarcity. *Agricultural Water Management*, 2021;243:106438.
- Shah F, *et al.* Alternate wetting and drying in rice production. *Field Crops Research*, 2022;282:108491.
- Smith R, *et al.* Precision irrigation technologies and climate resilience. *Computers and Electronics in Agriculture*, 2023;210:107913.
- Zhang X, *et al.* IoT-based irrigation management systems. *Sensors*, 2023;23(9):4356.
- Harisudan C, Natarajan K, Vincent S, Allwin L, Baskaran R, Bharathi Kumar K. Seed encapsulation and supplemental nutrition for enhancing the productivity of summer sesame (*Sesamum indicum* L.). *AATCC Review*, 2023;11(3):6–9.
- Zou X, *et al.* Water-saving irrigation and crop productivity. *Agricultural Water Management*, 2022;263:107451.
- Lavanya N, Laxminarayana P, Devi KS, Jayasree G, Prayaga L. Nutrient uptake, fibre quality and productivity of high-density cotton as influenced by drip irrigation and crop growth stage-based fertigation levels. *Agriculture Association of Textile Chemical and Critical Reviews Journal*, 2022.
- Devi MG, Lakshmi VV. A review on occupational health problems in carpet weaving. *Agriculture Association of Textile Chemical and Critical Review Journal*, 2022.
- Allwin L, Jayasheelan M, Elanchezian K, Harisudan C, Balasubramanian P, Srividhya S, *et al.* Bionomics and morphometrics of different developmental stages of Orchid blossom midge, *Contarinia maculipennis* Felt in Perunchilambu, Tamil Nadu, India. *AATCC Review*, 2023, 341–345.
- Shrivastava AK, Prajapati B, Sarvade S. Impact of chemical weed control on green fodder yield of berseem (*Trifolium alexandrinum* L.) and soil environment—a review. *AATCC Review*, 2022;10(2):96–104.
- Muzaffar SS. Meeting the demand: Achieving zero hunger through balanced food supply and demand. *Agriculture Archives: An International Journal*, 2022.
- Abebe D, Tesfaye Y. Study on the prevalence and farmers management practices of termites on maize (*Zea mays* L.) in Eastern Wollega. *Agriculture Archives: An International Journal*, 2023.
- Kaman PK, Das A, Verma R, Narzary PR, Saikia B, Kaman N. The importance of nanotechnology on sericulture as a promising field. *Agriculture Association*

- of Textile Chemical and Critical Reviews Journal, 2023, 40–46.
21. Singh S, Pratap B, Vishwakarma G, Rao A, Singh AK. Evaluation of economic feasibility for aonla production with the aid of integrated nutrient management. Agriculture Association of Textile Chemical and Critical Reviews Journal, 2022, 39–44.
 22. Sapkal AD, Kamdi SR, Jadhav RA, Meshram MP. Genetic analysis of yield and its components in F1 and F2 population of Indian mustard [*Brassica juncea* (L.) Czern. and Coss.]. AATCC Review, 2023;1:28–39.
 23. Vardhan H, Sharma Y, Sharma A, Paras M, Agrahari R, Sharma K. Exploring heterosis utilization in cucurbitaceous vegetable crops. Agriculture Archives, 2022, 1.
 24. Yesmin N. A critical assessment on essential unity of religions with special reference to Bhagwan Das and Ananda K. Coomaraswamy. Journal of Diversity Studies, 2023;2(1):6–8.
 25. Swathi R, Sushama PR, Vijjulatha M. Investigation of the antimicrobial properties of *Tamarindus indica* L. (Red Tamarind) fruit pulp. Microbiology Archives: An International Journal, 2024.
 26. Lamani HD, VijayKumar R, Devi HL, Parveen S. Climate crisis chronicles: Understanding global warming's impact and solutions. Journal of Diversity Studies, 2024.
 27. Prabhavathi SJ, Subrahmaniyan K, Kumar MS, Gayathry G, Malathi G. Exploring the antibacterial, anti-biofilm, and anti-quorum sensing properties of honey: A comprehensive review. Agriculture Archives, 2023.
 28. Sapna, Kumar V, Sachan K, Singh A. IoT innovations revolutionizing agricultural practices for sustainability. Journal of Diversity Studies, 2024.
 29. Ranjithkumar G, Reddy AJ, Madhana Keerthana S, Bisen R. Unearthing plant breeding: Tracing principles, evolution, genetics, and agricultural origins. Agriculture Archives: An International Journal, 2022.
 30. Sachan K, Saxena A, Kumar S, Mishra A, Verma A, Tiwari DD, *et al.* Urban soil health check and strategies for monitoring and improvement. Journal of Diversity Studies, 2024.
 31. Alamari FFA, Ashokri HAA. Leachate treatment evaluation of landfill leachate treatment plant of Taman Beringin Solid Waste Transfer Station, Kuala Lumpur, Malaysia. Journal of Diversity Studies, 2023;2(1):9–12.
 32. Sultana N, Saini PK, Kiran SR, Kanaka S. Exploring the antioxidant potential of medicinal plant species: A comprehensive review. Journal of Plant Biota, 2023;2(2):9–18.
 33. Asma J, Subrahmanyam D, Krishnaveni D. Deciphering host plant resistance mechanisms against tungro virus in rice: A comprehensive exploration. Agriculture Archives, 2022, 1.
 34. Singh BP, Krishnamoorthi A, Kumar V, Kalaiselvi P. Revolutionizing agriculture farming through artificial intelligence. Journal of Diversity Studies, 2024.
 35. Alemu TT. Effect of storage time and room temperature on physicochemical and geometric properties of banana (*Musa* spp.) fruit. Journal of Plant Biota, 2023, 30–40.
 36. Dash SK, Hansdah B, Baral JRRB, Sahoo SL. *Christella parasitica* (L.) Lev.: A potent pharmacological and pesticidal pteridophyte. Journal of Plant Biota, 2024.
 37. Naik DB, Rao BB, Kumar CU, Bhavani NL. Phytochemical analysis of different varieties of sorghum biocolor in Telangana State, India. Agriculture Archives: An International Journal, 2022;1:16–20.
 38. Babu S, Darjee S, Alekhyia G. Enhancing farmer prosperity: Implementing integrated farming systems for increased income. Agriculture Archives: An International Journal, 2022.
 39. Alemu TT. Effect of storage time and room temperature on physicochemical and geometric properties of banana (*Musa* spp.) fruit. Journal of Plant Biota, 2023, 30–40.
 40. Azra BH, Vidhya C, Abhinandana K, Rout S, Kalaimani PS. Essential antinutrients in plant-based proteins and exploring their nutritional implications. Journal of Plant Biota, 2023;2(2):5–8.
 41. Singh P, Singh R. Bacteriophage therapy as a next generation solution for treating drug resistant bacterial infections. Microbiology Archives: An International Journal, 2023;5(2):21–24.
 42. Keerthi MM. Microbial frontiers innovations and challenges shaping the future of microbiology. Microbiology Archives: An International Journal, 2024.
 43. Anushi BPS, Siddiqua A, Khayum A. The art and science of flavour: A journey through aromas in horticultural crops. Journal of Plant Biota, 2024.
 44. Joshi C, Shukla K, Odedra KN, Jadeja BA. *Lawsonia inermis* L. (Henna): A comprehensive review of its phytochemistry, pharmacological potential, traditional uses, and commercial applications. Journal of Plant Biota, 2025;4(1):99–110.
 45. Myster RW. Tree families and physical structure across an elevational gradient in a Southern Andean Cloud forest in Ecuador. Journal of Plant Biota, 2024.