



# AGRIALLIS

SCIENCE FOR AGRICULTURE AND ALLIED SECTOR

**VOLUME 8 ISSUE 1**

Jan. 2026



A Monthly  
Magazine

## Editorial Board

### *Subject Specialist Editor*

*L. R. Meena*

*Anup Das*

*Goutam Mondal*

*Pampi Paul*

*S. A. Kochevad*

*Babu Lal Meena*

*Ashim K. Dolai*

*Sitesh Chatterjee*

*Saikat Das*

*Siddhartha Dev Mukhopadhyay*

*H. L. Kumaraswamy*

*Anil Kumar*

*M. Vassanda Coumar*

*Mahesh B. Tangli*

### *Content Reviewer*

*Vikas Mangal*

*Santosh Oute*

*Shyam Suraj S R*

*Seema M. Naik*

*Kamalika Bhattacharyya*

*Prasanna Paul*

*Mohamad Magbool Rather*

*Satarupa Ghosh*

*Dipak Dey*

*Rizvankhan S. Ghasura*

### *Senior Content Editor*

*Sanjeev Kumar*

### *Content Editor*

*Subhradip Bhattacharjee*

*Sahaneb Nath*

### *Editor*

*Punam Bhattacharjee*

## Contents

Sl No	Title	Article Id	Page No
1	Application of Agricultural Drainage Systems for Waterlogged and Salt-Affected Soils	AL04491	1
2	Direct-Seeded Rice- A Technology for Reducing Resource Use in Rice production	AL04492	7
3	Epigenome Editing & Stress Memory: A New Frontier in Climate-Resilient Agriculture	AL04493	12
4	Gravity Aeration System in Aquaculture	AL04494	17
5	Impact of Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) On Farmers of North-Eastern India	AL04495	24

Article Id  
AL04491

Email

[subhradip25@gmail.com](mailto:subhradip25@gmail.com)

## APPLICATION OF AGRICULTURAL DRAINAGE SYSTEMS FOR WATERLOGGED AND SALT-AFFECTED SOILS

<sup>2</sup>Basavareddy, <sup>1</sup>Subhradip Bhattacharjee\* and <sup>1</sup>Sujeet Desai

<sup>1</sup>ICAR- Central Coastal Agricultural Research Institute, Ella, Old Goa, Goa-403402, India

<sup>2</sup>College of Agricultural Engineering, University of Agricultural Sciences, Raichur, Karnataka-584104, India

**S**ustainable agricultural production requires maintaining a favourable balance between soil moisture and aeration within the crop root zone. While irrigation ensures adequate water supply, excess water accumulation results in waterlogging, oxygen deficiency, nutrient imbalance, and secondary salinization. In canal command areas, deltaic plains, coastal regions, and heavy clay soils, poor drainage has become a major constraint to productivity. Agricultural drainage refers to the planned removal of excess surface or subsurface water from agricultural lands to maintain an optimal root zone environment. Scientifically designed drainage systems regulate groundwater levels, enhance soil aeration, improve nutrient dynamics, and prevent long-term soil degradation.

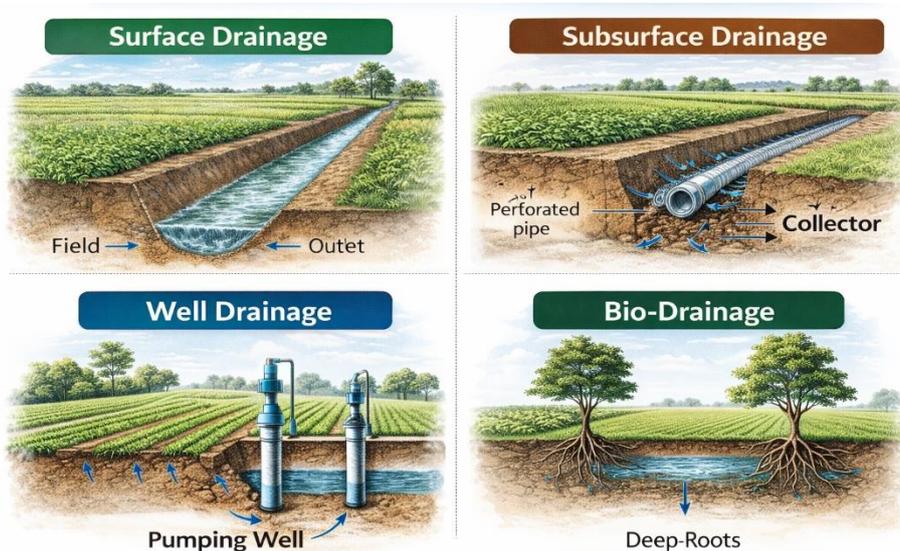
### Causes and Nature of Waterlogging

Waterlogging occurs when the groundwater table rises into or near the effective crop root zone for prolonged periods, typically above a critical depth of 0.6–1.2 m depending on crop type. Saturation of soil macropores restricts oxygen diffusion, creating hypoxic or anaerobic conditions in the rhizosphere. Under such conditions, root respiration declines, nitrification is inhibited, denitrification increases, and reduced compounds such as Fe<sup>2+</sup>, Mn<sup>2+</sup>, and hydrogen sulphide accumulate, adversely affecting plant growth.

The principal causes include seepage from unlined canals, excessive irrigation beyond crop evapotranspiration requirements, flat topography with inadequate natural drainage, presence of low-permeability subsurface layers, and high-intensity rainfall exceeding infiltration capacity. Poor maintenance of drainage networks further aggravates stagnation. In irrigated semi-arid regions, shallow saline groundwater intensifies the problem through capillary rise and salt accumulation in the root zone. Effective drainage planning therefore

requires hydrological assessment, groundwater monitoring, measurement of soil hydraulic conductivity, and estimation of an appropriate drainage coefficient to maintain a favourable root environment.

### Types of Drainage System



**Fig 1.** Types of Drain System

### Surface Drainage Systems

Surface drainage removes excess water from the soil surface before infiltration contributes to groundwater rise. It is particularly effective in high rainfall areas and heavy soils with low infiltration capacity.

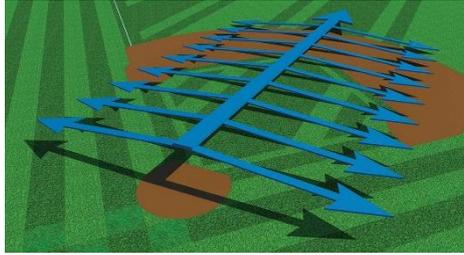
Surface Drainage by Open Channels: Open channel drainage consists of shallow field ditches constructed along natural slopes to intercept and convey runoff. These channels collect excess rainfall or irrigation overflow and discharge it safely to an outlet. Hydraulic design is based on runoff estimation and permissible flow velocity, commonly determined using



**Fig 2.** Surface Drainage by open Channel

Manning's equation. Proper longitudinal slope prevents sediment deposition while avoiding erosion. Although economical and easy to maintain, open channels may reduce cultivable area.

**Graded Land Drainage:** Graded drainage involves reshaping land to provide a uniform mild slope, generally between 0.1% and 0.3%, enabling controlled runoff toward an outlet. This system ensures uniform drainage without excessive erosion and is widely adopted in large, mechanized fields. Precision land levelling technologies such as laser levelling have improved its efficiency.



**Fig 3.** Graded Land Drainage

**Bedding System (Raised Bed and Furrow System):** In the bedding system, crops are planted on raised beds separated by furrows that act as drainage channels. The raised micro-relief enhances aeration and prevents root zone saturation. This method is particularly effective for row crops and vegetables grown in heavy soils.



**Fig 4.** Bedding System (Raised Bed and Furrow System)

**Parallel Surface Drains:** Parallel surface drains are constructed at regular intervals across fields with uniform slopes. They intercept surface runoff and convey it to a main drain. The spacing depends on rainfall intensity, soil infiltration capacity, and allowable duration of ponding.

### Subsurface Drainage Systems

Subsurface drainage regulates groundwater levels by removing excess water from beneath the soil surface. It is essential for chronically waterlogged and salt-affected areas.

1. **Tile Drainage (Pipe Drainage System):** Tile drainage consists of perforated pipes installed at depths typically between 1.0 and 1.5 m. Groundwater enters the pipe through perforations and flows by gravity to an outlet. Filter materials prevent soil intrusion and clogging. The system lowers the water table by creating a hydraulic gradient toward the drain line. It is highly effective in controlling salinity and improving soil structure. Though installation costs are higher, the long-term benefits in reclaimed lands are substantial.



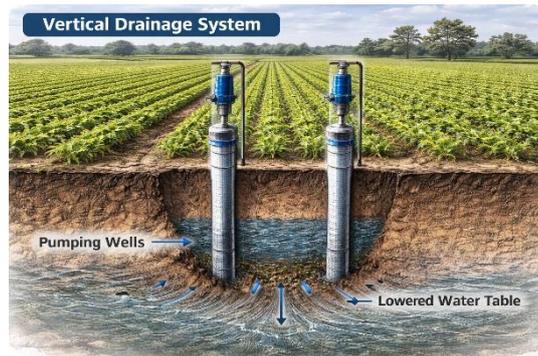
**Fig 5.** Tile Drainage (Pipe Drainage System)

2. **Mole Drainage:** Mole drainage involves forming unlined cylindrical channels in clay soils at depths of 0.4–0.7 m using a mole plough. These temporary channels facilitate lateral movement of water toward collectors. This method is economical and suitable for heavy clay soils but has a limited lifespan, generally three to five years.



**Fig 6.** Mole Drainage

3. **Vertical Drainage System (Drainage by Wells):** Vertical drainage lowers the groundwater table through pumping from wells or tube wells. It is effective in areas with high aquifer transmissivity. Pumped water can be reused for irrigation under conjunctive use strategies. Design considerations include aquifer characteristics, pumping rate, radius of influence, and groundwater quality. Improper management may cause saline upconing or land subsidence.



**Fig 7.** Vertical Drainage

### Bio-Drainage System

Bio-drainage utilizes deep-rooted tree species with high evapotranspiration rates to lower the water table. Species such as Eucalyptus and Casuarina extract groundwater and reduce soil saturation through transpiration. Although environmentally sustainable and low-cost, bio-drainage effectiveness depends on climatic conditions and groundwater salinity. It is best used as a supplementary measure rather than a primary engineered solution.



**Fig 8.** Bio-Drainage

### Layout Systems of Subsurface Drainage

The layout of subsurface drainage systems determines hydraulic performance and economic efficiency. The selection depends on topography, field geometry, and outlet position.

1. **Parallel Layout:** In this arrangement, lateral drains are installed parallel to each other at uniform spacing. It is suitable for fields with uniform slope and soil conditions. This layout ensures systematic water table control across the entire field.

2. Herringbone Layout: The herringbone layout consists of a central main drain with laterals entering at an angle from both sides. It is appropriate for fields with a central depression or natural valley.
3. Gridiron Layout: The gridiron system connects laterals perpendicularly to collectors, forming a grid pattern. It is suitable for flat lands requiring uniform drainage in multiple directions.

### Drain Depth and Spacing

Drain depth and spacing are critical design parameters governed by soil hydraulic conductivity, drainage coefficient, and crop rooting depth. Drain depth usually ranges from 1.0 to 1.5 m. Greater depth permits wider spacing but increases installation cost.

Drain spacing may vary from 20 m in heavy clay soils to 100 m in permeable sandy soils. The spacing is determined using hydraulic equations such as Hooghoudt's equation:

$$L^2 = (8KD(H - h)) / q$$

Where L represents spacing, K is hydraulic conductivity, D is equivalent depth, H is initial water table height, h is desired water table height, and q is drainage coefficient.

### Conclusion

Agricultural drainage systems comprise surface, subsurface, vertical, and bio-drainage approaches that collectively regulate excess water and maintain a favorable root zone environment. The selection of an appropriate system must be guided by a comprehensive evaluation of hydrological regime, soil hydraulic properties, groundwater dynamics, crop tolerance to waterlogging, and economic viability. Scientifically designed drainage not only restores soil aeration and root respiration but also mitigates secondary salinization, stabilizes soil structure, and improves nutrient use efficiency

### References

- Bhattacharya, A.K. and Michael, A.M., 2006. *Land drainage: principles, methods and applications*. Vikas Publishing House.
- Ojah, T.P. and Michael, A.M., 1988. *Principles of agricultural engineering*.
- Murthy, V., & Jha, M. K., 2009. *Land and water management engineering*. Kalyani Publishers.

Article Id  
AL04492

## DIRECT-SEEDED RICE- A TECHNOLOGY FOR REDUCING RESOURCE USE IN RICE PRODUCTION

Email

Subham Chakraborty

[subhame2994@gmail.com](mailto:subhame2994@gmail.com)

Department of Agronomy, Institute of Agricultural Science,  
University of Calcutta, 51/2, Hazra Road, Kolkata-700019,  
West Bengal, India

**R**ice also known as “global grain” is the staple food for more than half of the world’s population and 90% of the rice is produced in consumed in Asian countries (Bandumala, 2017). Rice act as calorie source for two-third of the Indian population supplying 43% of calorie requirement (Kaur and Singh, 2017). Rice production plays an important role in maintaining food security of India. According to the estimation on rice production globally, India crossed China followed by Bangladesh and Indonesia. The production of rice is estimated to be 150 MMT in India during the year 2024-2025. The major factor in rice production is water. Rice requires a lot of water than other crop from nursery bed preparation to main field preparation and also during the growth stages until it reaches near about maturity period. In this phase of climate change, to conserve resources but on the other hand to maintain the productivity of rice, direct seeded rice can be very beneficial method of rice production for Indian farmers where use of water is lower than transplanted method and the requirement of nurse bed is avoided. In this method rice seeds pre-germinated are directly sown in the field basically in aerobic or anaerobic situation where the main constraint is weed as the weed readily grows along the rice crop. It was a well-known method until 1950 before the spreading of puddled transplanting method of rice establishment. DSR is a very efficient method in replacing transplanted rice in order to cope up climate change.

### Principles of Establishing Direct-Seeded Rice

There are primarily 3 principles of establishing DSR in field which are as follows:

- i) **Dry-seeded:** Such kind of DSR is done in aerobic condition maintaining a non-puddled condition or sometimes with dibble method or with power tiller operated seeder after minimum tillage or conservation tillage.

**ii) Wet-seeded:** Pre-germinated rice seeds are sown in well-prepared soil mostly aerobic or anaerobic condition. In such case seeds can be broadcasted or line sown as per labour availability. Sometimes drum seeder is also used for sowing in this case and aerobic seeder with furrow opener and closer are also utilized.

**iii) Water-seeding:** In this process, pregerminated seeds are sown in standing water usually broadcasting of seeds are done on standing water (5-10 cm).

(Joshi *et al.*, 2013; Farooq *et al.*, 2011, Singh *et al.*, 2024)

### Advantages of Transplanted Rice Vs Direct Seeded Rice

1. More water is required in TPR whereas less water required in DSR throughout the crop growth period.
2. Labour requirement is higher due to nursery bed management, transplanting, flooding etc. in TPR whereas as nursery management is not required in DSR and transplanting is also not involved.
3. Weed management is possible in TPR but in DSR weeding is the main constraint due to huge weed population. In TPR flooding and manual weeding is much easier but in DSR pre-emergence herbicide is a must.
4. In TPR, water foot print is higher whereas lower water foot print is lower in DSR due to effective usage.
5. In DSR yield is approx. 12% lower than TPR.
6. Rice crop can be harvested slightly faster in DSR than in TPR due to quick maturity as in TPR the transplanting shock received in rice crop delays the maturity.
7. Less strain on ground water in DSR compared to TPR.
8. Higher GHG emission in TPR due to tillage operations and water use and less GHG emission in DSR can be observed.
9. The challenges faced in TPR production is lower than DSR as proper management of soil, crop and other factors are a must in DSR to avoid failure of crop. (Bhatt *et al.*, 2024).

### Why DSR is Important in Modern Day Rice Cultivation

In present days labour shortage, water shortage and GHG load is the main problem. Labour are costly and less due to people shifting towards urban areas and non-agri activities. The depletion of ground water is also leading to water shortage along with carbon and other

harmful gas emission from burning of fuels. It saves labour upto 30-46%. DSR requires zero tillage and aerobic condition sometimes anaerobic conditions are required but water usage is less due to which 10-20% water for irrigation is saved along with energy-saving as tillage operations are limited contributing to less generation of GHG. The methane emission from the field is also reduced by 30-40%. It also cause less soil disturbance due to minimum tillage thus conserving the soil structure and no hard pan in soil is formed below the surface. The aerobic condition produces less or no methane from the rice field. Also, the crop matures faster providing extra time for next crop to be sown in the field. Nutrient management is also easier to non-puddled condition as in puddled soil nitrogen loss is more and requires precise application. Such problem is absent in DSR and crop uptake N, P and K in more amount. Less infestation of disease and pest in DSR also provides upper hand over TPR method. (Singh et al., 2024).

**Table 1:** Suitable varieties for DSR cultivation

Variety Name	Key Features / Suitability for DSR	Purpose
<b>Pusa Basmati 1979</b>	Non-GM herbicide-tolerant Basmati; tolerant to Imazethapyr aiding weed control in DSR conditions.	Released for DSR cultivation in India.
<b>Pusa Basmati 1985</b>	Similar to PB 1979 with herbicide tolerance; suitable for direct seeding with improved weed management.	Developed for DSR and weed control.
<b>Pusa Basmati 1121</b>	Popular basmati cultivar recommended among short/medium-duration varieties for direct-seeding with relatively less water requirement.	Listed as suitable for direct seeding in agronomic recommendations.
<b>Punjab Mehak 1</b>	Medium duration Basmati type indicated in DSR varietal recommendations for basmati direct seeding systems.	Reported among varieties suitable for direct seeding.
<b>CSR 30 (Coarse rice)</b>	Listed as suitable under direct seeding conditions (not basmati).	Reported in ICAR varietal recommendations.
<b>Taraori Basmati</b>	Traditional basmati variety included in varietal recommendations for direct seeding (short/medium duration).	Included in direct seeding recommendations.
<b>CR Dhan 108</b>	Specifically mentioned as suited for DSR systems in newly released rice varieties list.	Recent variety indicated for DSR system adoption.
<b>Sabour Pratap Dhan</b>	New variety noted for DSR system suitability, part of stress tolerant releases.	Reported as DSR-suited variety.

**Swarna  
Purvi  
Dhan-5  
PR 115  
(coarse  
rice)**

Listed as suitable for direct seeding (DSR) in recent varietal evaluation news. Reported among DSR-suited varieties.

Cited among short/medium duration rice types recommended for direct seeding. Mentioned in agronomic package recommendations.

(Kaur and Singh, 2017; IREF, 2026; Agrospectrum India, 2026)

## Conclusion

DSR can be a good alternative for TPR method in future if proper implementation of technology is adopted by farmers as in DSR good management practices are required to attain higher yield through application of nutrients and timely weed management to avoid losses in grain yield. More DSR suitable varieties are required to be introduced which can be grown with less input of water and resistance to pests and diseases. Seed priming can be adopted for getting healthy seedlings. It is technologically sustainable practice and economically well for the farmers to adopt also suitable for climate resilience agriculture practices. Biotechnological approach and agronomical measures are required in combined form for better establishment of DSR in Indian condition.

**Notations used:** TPR- Transplanted rice, DSR- Direct seeded rice, GHG- Green House Gas

## References

- Bandumula, Nirmala. (2017). Rice Production in Asia: Key to Global Food Security. Proceedings of the National Academy of Sciences, India Section B: Biological Sciences. 88. 10.1007/s40011-017-0867-7.
- Bhatt, R., Chandra, M.S., Dinesh, G.K. (2024). Direct Seeded Rice: A resource conservation technique for reducing water foot prints in rice-wheat cultivation. *The Science World a Monthly e magazine*, 4(6): 2121-2130.
- Farooq MKHM, Siddique KH, Rehman H, Aziz T, Lee DJ, Wahid A. Rice direct Pathak, seeding: Experiences, challenges and opportunities. Soil
- <https://agrospectrumindia.com/2024/05/24/iari-launches-seed-sale-of-robinoweed-basmati-rice-varieties-dsr-cultivation>.
- <https://iref.net/news/31-high-impact-rice-varieties-released-across-india/>

Joshi E, Kumar D, Lal B, Nepalia V, Gautam P, Vyas AK. Management of direct seeded rice for enhanced resource-use efficiency. *Plant Knowledge Journal*. 2013; 2(3):119-134.

Kaur J, Singh A. Direct seeded rice: Prospects, problems/constraints and researchable issues in India. *Current Agriculture Research Journal*. 2017; 5(1):13.

Kaur J. and Singh, A. (2017). Direct Seeded Rice: Prospects, Problems/Constraints and Researchable Issues in India. *Curr. Ag. Res. Journal.*, 5(1). DOI: <http://dx.doi.org/10.12944/CARJ.5.1.03>

Singh, Sumit Kumar, Harsh JainthMonu Kumar, Stuti Maurya, Amit Kumar, Sachin Yadav, and Dinesh Sah. 2024. "Direct-Seeded Rice: Potential Benefits, Constraints and Prospective". *Journal of Scientific Research and Reports*, **30** (7):272- 280. <https://doi.org/10.9734/jsrr/2024/v30i72143>.

Article Id  
AL04493

## EPIGENOME EDITING & STRESS MEMORY: A NEW FRONTIER IN CLIMATE-RESILIENT AGRICULTURE

Email

Sahanob Nath

[nathsahanob@gmail.com](mailto:nathsahanob@gmail.com)

Growing Seed, Dharmanagar, North Tripura- 799251, India

**A**griculture in the 21st century faces unprecedented challenges due to climate change, soil degradation, and increasing biotic and abiotic stresses. Traditional breeding and transgenic technologies have significantly improved crop performance; however, they often require long development cycles and may involve permanent changes to DNA sequences. A promising alternative emerging from molecular biology is epigenome editing, a technology that modifies gene expression without altering the underlying DNA sequence. Closely linked to this is the phenomenon of stress memory, where plants “remember” previous exposure to stress and respond more efficiently upon re-exposure.

Epigenetics refers to heritable changes in gene function that do not involve changes in the DNA sequence. In plants, epigenetic regulation occurs primarily through DNA methylation, histone modifications, and chromatin remodeling. These modifications influence whether a gene is active or silent. Importantly, certain stress-induced epigenetic changes can be stable and sometimes transmitted to subsequent generations, contributing to what is termed transgenerational stress memory.

Epigenome editing combines precision genome-targeting tools with epigenetic modifiers, enabling researchers to activate or repress specific genes associated with stress tolerance. Unlike traditional genome editing, which changes nucleotide sequences, epigenome editing alters regulatory marks such as methyl groups on DNA or acetyl groups on histones. This makes it an attractive strategy for developing climate-resilient crops without introducing foreign DNA.

### Procedure

The process of epigenome editing and investigation of stress memory in plants involves several systematic steps:

## 1 Identification of Target Genes

The first step is identifying stress-responsive genes associated with traits such as drought tolerance, heat resistance, or pathogen defense. Techniques like RNA sequencing (RNA-seq), quantitative PCR, and transcriptome profiling help identify genes that are differentially expressed under stress conditions.

Simultaneously, epigenetic profiling methods such as:

- Bisulfite sequencing (for DNA methylation analysis)
- Chromatin immunoprecipitation sequencing (ChIP-seq)
- ATAC-seq (Assay for Transposase-Accessible Chromatin)

are used to determine epigenetic changes associated with stress responses.

## 2 Design of Epigenome Editing Tools

The most widely used system for epigenome editing is the CRISPR/dCas9 platform. In this system, a catalytically inactive Cas9 (dCas9) protein is fused with epigenetic modifier enzymes such as:

- DNA methyltransferases (for gene silencing)
- DNA demethylases (for gene activation)
- Histone acetyltransferases
- Histone deacetylases

A guide RNA (gRNA) directs the dCas9-effector complex to a specific genomic locus. Unlike conventional CRISPR-Cas9, this system does not cut DNA but instead modifies epigenetic marks at targeted sites.

## 3 Plant Transformation

The designed construct is introduced into plant cells through methods such as:

- Agrobacterium-mediated transformation
- Particle bombardment
- Protoplast transfection

Transformed cells are regenerated into whole plants using tissue culture techniques.

## 4 Validation of Epigenetic Changes

After regeneration, validation is essential to confirm successful editing. This includes:

- Methylation analysis through bisulfite sequencing
- ChIP assays to detect histone modifications
- Gene expression analysis through RT-qPCR
- Phenotypic evaluation under controlled stress conditions follows to assess improvements in tolerance.

## 5 Assessment of Stress Memory

To evaluate stress memory, plants are exposed to a mild stress treatment (priming), allowed to recover, and then re-exposed to stress. Improved performance upon re-exposure indicates memory formation. Researchers also examine whether epigenetic marks persist across developmental stages or generations.

### Principle

The principle of epigenome editing is based on the regulation of gene expression through reversible chemical modifications rather than changes in DNA sequence.

### 1 DNA Methylation

DNA methylation involves the addition of a methyl group to cytosine bases, typically in CG, CHG, or CHH contexts (where H = A, T, or C). Increased methylation in promoter regions usually suppresses gene expression, while demethylation activates genes.

Under stress conditions, plants often undergo dynamic methylation changes. These modifications can remain stable after stress removal, forming the molecular basis of stress memory.

### 2 Histone Modifications

DNA is wrapped around histone proteins to form nucleosomes. Chemical modifications to histone tails—such as acetylation, methylation, phosphorylation, and ubiquitination—alter chromatin structure and gene accessibility.

For example:

1. Histone acetylation generally activates gene expression.
2. Histone deacetylation represses transcription.

Stress exposure may increase activating histone marks at stress-responsive genes, enabling faster transcription during subsequent stress events.

### **3 Chromatin Remodeling**

Chromatin remodeling complexes reposition nucleosomes, making DNA more or less accessible to transcription machinery. This structural change is critical in regulating stress-induced gene expression.

### **4 Stress Memory Mechanism**

Stress memory can be categorized into:

- Somatic memory – persists within the same plant generation.
- Transgenerational memory – inherited by offspring.

When plants experience stress, epigenetic marks are established at specific genomic loci. If these marks are maintained after stress removal, they facilitate rapid gene reactivation during future stress exposure. This enhances survival and productivity under recurring stress conditions.

The principle underlying epigenome editing is to artificially induce or stabilize these beneficial epigenetic marks at targeted genes, thereby mimicking natural stress memory mechanisms.

### **Conclusion**

Epigenome editing and stress memory represent transformative advances in agricultural biotechnology. By modifying gene expression without altering DNA sequences, epigenome editing provides a precise, potentially reversible, and socially acceptable alternative to conventional genetic modification. It allows breeders and molecular biologists to enhance crop resilience against drought, heat, salinity, and pathogens.

Understanding stress memory mechanisms opens new avenues for sustainable crop improvement. Instead of relying solely on structural gene changes, scientists can harness

plants' inherent adaptive capacity. This is particularly relevant in the era of climate change, where repeated stress exposure is becoming common.

However, challenges remain. The stability of induced epigenetic modifications, potential off-target effects, and regulatory considerations need careful evaluation. Long-term field studies are essential to confirm the durability and heritability of engineered epigenetic traits.

## References

- Konecny, T., Asatryan, A., & Binder, H. (2025). Responding to stress: diversity and resilience of grapevine in a changing climate under the perspective of omics research. *International Journal of Molecular Sciences*, 26(16), 7877.
- Abro, A. A., Qasim, M., Abbas, M., Muhammad, N., Ali, I., Khalid, S., ... & Liu, F. (2025). Integrating physiological and molecular insights in cotton under cold stress conditions. *Genetic Resources and Crop Evolution*, 72(3), 2561-2591.
- Qadir, M., Kaur, N., Rahman, F. U., Nabi, F., Ahmed, Z. F., & Wu, J. (2026). Epigenetic modifications in plant abiotic stress adaptation: towards climate-resilient and sustainable crop improvement. *Frontiers in Plant Science*, 17, 1738299.
- Syeda, A. (2025). Harnessing multi-omics and genome-editing technologies for climate-resilient agriculture: bridging AI-driven insights with sustainable crop improvement. *Plant Molecular Biology*, 115(6), 1-24.
- Jin, Q., Chachar, M., Ali, A., Chachar, Z., Zhang, P., Riaz, A., ... & Chachar, S. (2024). Epigenetic regulation for heat stress adaptation in plants: new horizons for crop improvement under climate change. *Agronomy*, 14(9), 2105.

Article Id  
AL04494

Email

[mohanfishco1@gmail.com](mailto:mohanfishco1@gmail.com)

## GRAVITY AERATION SYSTEM IN AQUACULTURE

<sup>1</sup>Maloth Mohan\*, <sup>1</sup>Dalip Kumar Bishnoi, <sup>2</sup>Sanjeev Sharma and  
<sup>3</sup>Nitish Bansal

<sup>1</sup>Department of Fish Engineering, College of Fisheries Science,  
CCS Haryana Agricultural University, Hisar-125004, Haryana  
India

<sup>2</sup>Department of Fish Processing Technology, College of  
Fisheries Science, CCS Haryana Agricultural University, Hisar-  
125004, Haryana India

<sup>3</sup>Department of Fisheries Resource Management, College of  
Fisheries Science, CCS Haryana Agricultural University, Hisar-  
125004, Haryana India

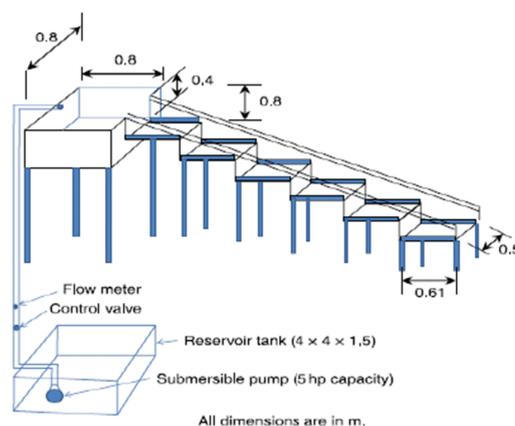
The oxygen in the air is absorbed and circulated in the form of bubbles over the water body is known as aeration. The aeration process increases the dissolved oxygen (DO) concentration after-treatment of the sewage discharge, agricultural run-off, aquaculture water body, etc., simultaneously remove dissolved gases such as CO<sup>2</sup>, H<sub>2</sub>S, volatile organic chemicals (VOCs), and dissolved metals. Aeration can be accomplished through the infusion of air into the water column. Natural aeration and artificial aeration are the two main types of aeration practices used to increase DO levels in water bodies. The two processes involved in improving the DO level naturally in natural aeration are atmospheric diffusion and plant photosynthesis. However, in order to increase productivity, fish farmers have been intensifying the culture in recent years, resulting in an increasing trend of DO requirements. Simultaneously, in the case of natural aeration, DO concentrations decrease during the night, posing a problem for culture species respiration. To avoid all these negative issues, it has been observed that artificial aerators are widely applicable in aquaculture operations. Basically, an artificial aeration system increases the contact area between air water interfaces so that more amount of oxygen from the air can mix in water by agitating it. Generally, the artificial aeration could be achieved by three methods: (1) surface aeration by the paddle wheel aerators, spiral aerators, pump-sprayers, and vertical pumps; (2) diffused aeration by the propeller-aspirators and submersible aerators; and (3) gravity aeration by the cascade aerators. The cascade aerators provide better aeration due to the high turbulent mixing, long exposure time, and substantial

air bubble entrainment. The cascade aerators improve the water quality by displacing the water from bottom to top and removing volatile organic contents present in the pond bottom. It has no moving parts; hence, less maintenance is required. Cascade aerator, a type of gravity aerator, is very popularly used in water treatment plant to remove iron and manganese or various dissolved gases or volatile organic compounds. One of the best advantages of cascade aerators is that the energy consumption is very less compared to other type of aerators. In this article, the classification and detailed discussions have been made for different gravity aeration systems.

### Types of Gravity Aeration System

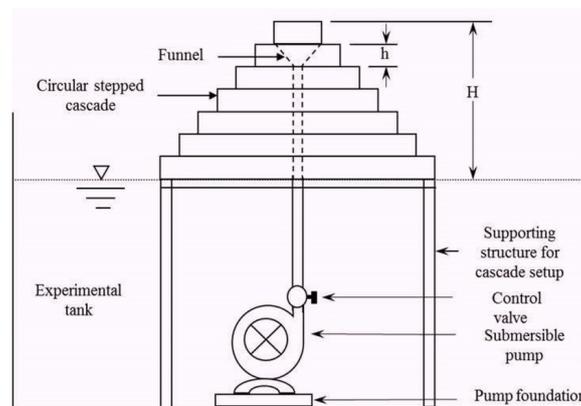
**Cascade Aeration System:** Aeration by cascading is a suitable and attractive way of adding and mixing atmospheric oxygen into the water body. Cascade creates the turbulent condition in the steps, which extends the residence time and significant air bubble entrainment results in the higher amount of dissolved oxygen absorption.

**Stepped Cascade Aerator:** Stepped cascades have been utilized for the scattering of high speed of stream and air circulation execution. Basically, it is used for pre or post aeration purposes. There are number of steps through which water flows. Because of the water fall on the steps, the disturbance made on the water surface breaks the air water interface and transfers oxygen and evacuate unpredictable natural substances, viz., methane, chlorine, disintegrated iron, manganese, carbon dioxide, and hydrogen sulfide. Stepped cascade aerators are only successful to remove 60–70% of carbon dioxide, but quite effective in raising the DO content of water. The stepped cascade aerators are not popularly used in aquaculture ponds. This may be due to the fact that the efficiency of the cascade aerator is significantly lower than that of other existing aerators. Therefore, stepped cascade can be used in conjunction with another system to get the desired result.



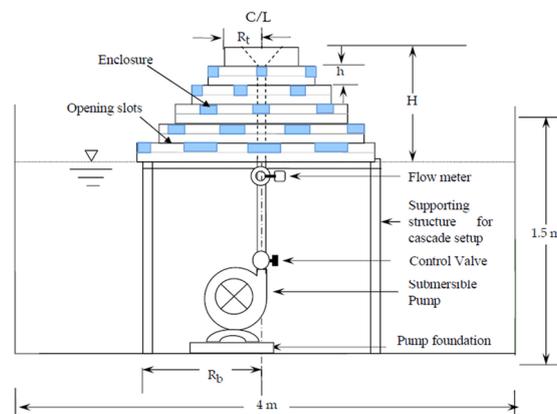
**Source:** Stepped cascade aerator (Moulick *et al.* 2010)

**Circular Stepped Cascade:** A circular stepped cascade in combination with a pump is the key of the main aeration unit. Basically, this type of aeration system is used in wastewater treatment plant or in aquaculture pond. Being a simple device with only static components, such a system will reduce the cost of maintenance as well as energy consumption when compared to other existing aeration systems. Circular stepped cascade consists of circular steps in which water allows falling from the upper step to subsequent next and finally to bottom step in a uniformly distributed manner. The submersible pump attached to the control valve is placed below the circular stepped cascade and regulates the water flow. Circular stepped cascade is used for fish hatcheries, and intensive aquaculture operations.



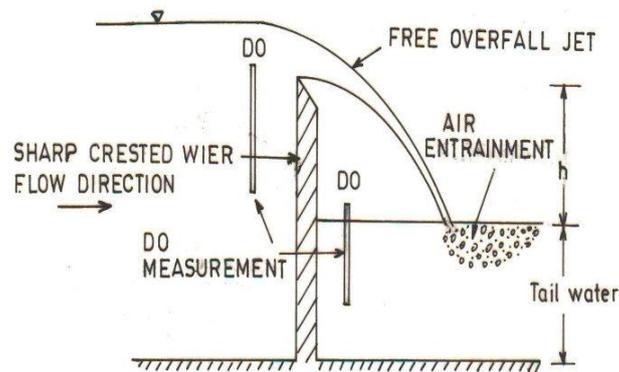
**Source:** Circular stepped cascades (Singh 2010)

**Pooled Circular Stepped Cascade:** Pooled circular stepped cascade (PCSC) is the modified version of the circular stepped cascade. The PCSC aerator had the barriers in each step of the cascade, and the distance between the barriers was optimized. The water flow over PCSC aerator in a zigzag manner increased the dissolved oxygen content into the water body. Hence, it was expected to increase the oxygen transfer rate as well as the higher efficiency of the aeration system.



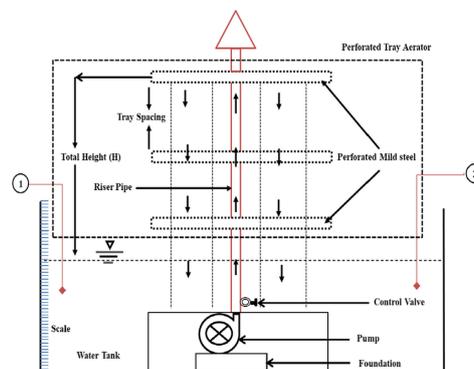
**Source:** Pooled circular stepped aerator (Kumar et al. 2013b)

**Weir Aeration System:** Weir aeration process was first introduced by Gameson (1957). It is one of the popular gravity aeration systems for water treatment purpose or aquaculture operation. It has different cross-sectional geometry like triangular and rectangular labyrinth. Aeration occurs over a weir with a splashboard that breaks the water droplets by gravity and then flows over the various screens. The free over fall water in the form of the jet from the weir plunging into downstream water causes entrainment of air bubbles, hence, accelerates the aeration process. Weir aeration is economically inexpensive compared to other aeration systems such as surface aeration, even when energy costs for pumping the water are included.



**Source:** Weir aeration system (Arun Goel, 2013)

**Tray Aeration System:** Tray aerator is useful in wastewater or aquaculture water treatment. It resembles a section wherein water is pumped via submersible pump through a riser pipe to the highest point of the segment, and water streams falling down due to gravitational force over a progression of tray found one underneath the other. The water is uniformly circulated all over the perforation of each and every tray until it reaches the level of the water body. This process confirms a large contact surface between the air and the water. Perforated tray aerator was particularly developed to solve the problem of low dissolved oxygen in aquaculture ponds and to minimize the energy consumption of the aeration system. For the removal of iron and manganese, multiple tray aerators were widely used.



**Source:** Tray aerator (Roy *et al.* 2020a)

## Requirement of Aeration in Aquaculture Operation

The falling of dissolved oxygen (DO) concentration below 5.0 mg/L shows that the survivability of aquatic species is affected adversely. The fish mortality could be high if dissolved oxygen concentration remains below 1–2 mg/L for a few hours. Hence, the continuous supply of oxygen for maintaining the adequate DO concentration to the aquaculture ponds becomes a prerequisite for the healthy growth and survival of aquatic species. Due to this oxygen, depletion occurs at the bottom strata, causing threat to lake and pond aquaculture. Aeration also helps to control accumulation of metals in storage reservoirs and increased the DO.

Aerators are not needed in ponds with extensive culture and a low stocking density of less than 10 per m<sup>2</sup> of water spread area. However, partial water exchange at an advanced level to the tune of 10 to 20% is likely to produce good. Aerators may not be essential in ponds with a higher stocking density of 10 to 12 per m<sup>2</sup> and a targeted production level of 2 to 2.5 tons/ha in each culture with two cultures per year. However, sufficient water exchange, which may vary from 5% at the beginning to 50% towards harvest, may be necessary.

Aerators are required if the stocking density is high, on the order of 15 per m<sup>2</sup> and higher. In such cases, four paddle wheel aerators of 1 kW each are required for a pond with a common size of 4000 to 5000 m<sup>2</sup>. Water exchange is also needed, which may vary between 20 and 30% per day. If the stocking density is very high, say 100/m<sup>2</sup>, a large number of aerators is required. Pond sizes for such intensive culture are typically small, ranging from 500 to 1000 m<sup>2</sup>. Such ponds need two to four aerators depending upon the feeding rate, pond size, and stocking density. The water exchange requirement in such ponds is very high, ranging from 50 to 100% depending on the stage of growth.

## Location of Aerators in Aquaculture Ponds

Aerators not only increase the DO in the pond but also help in proper mixing and circulation of water body. This helps to create the air–water interaction into the water which finally enhances the oxygen transfer in the water body. Therefore, appropriate location of aerators plays a very important role in pond. Aquaculture ponds are normally in rectangular shape. In a rectangular pond, the aerator can be placed in the middle of one of the long sides. Placement of aerator needs to be such that water moves parallel to the shorter side. On the other hand, a poor placement could be in one corner, causing water to flow diagonally to the other

corner and preventing effective mixing. However, in order to effectively distribute the aerated water across the pond and produce water circulation, wise judgment should be employed in aerator placement.

### **Advantages of Gravity Aerators Over Other Existing Aeration Practices in Economic Point of View**

The economical aerator is one that can meet the oxygen demand of a pond with the minimum cost. This cost includes both fixed and operating costs. An aerator with a high SAE value may result in lower operating costs but not necessarily in total minimum cost. When an aerator with a low SOTR value gives a high value of SAE, more numbers of such aerators are needed, which results in higher fixed costs. Therefore, coordination is required between SOTR and SAE for different pond sizes to achieve the optimum economic situation. Thus, an appropriate economic analysis must be performed before selecting the aerator for an aquaculture pond.

### **Conclusions**

Dissolved oxygen is the most important factor in an aquaculture operation due to the vital need of all organisms living and having in water. Currently, the artificial aerators are widely used all over world due to their advantage for increasing dissolved oxygen concentration. In surface aeration system (paddle wheel aerator, spiral aerator) is subjected to high maintenance cost, wear and tear; therefore, as far as possible, it is better to use gravity type aerator as it involves gravity as the only means of adding oxygen to water. Typically, intensive aquaculture ponds with high stocking density of cultured aquatic species have pond volume from 1000 to 4000 m<sup>3</sup>. From management point of view, it is a practice to use small ponds for performing intensive culture. The use of gravity aerators offers a more practical option for places where land availability is a constraint, and cost of construction is low. From the energy consumption perspective, it is recommended that gravity aerators operate at an optimum efficiency range that corresponds to good aeration performance

### **References**

- Boyd CE, Tucker CS (2014) Handbook for aquaculture water quality. Craftmaster Printers Inc, Auburn, Alabama
- Chanson H, Toombes L (2002) Energy dissipation and air entrainment in stepped storm waterway: experimental study. J Irrig Drain Eng 128(5):305–315

- 
- Chesness JL, Stephens JL (1971) A model study of gravity flow aerators for catfish raceway systems. *Transactions of the ASAE* 14(6):1167–1169
- Cheng X, Xie Y, Zhu D, Xie J (2019) Modeling re-oxygenation performance of fine-bubble–diffusing aeration system in aquaculture ponds. *Aquacult Int* 27(5):1353–1368
- Doley H, Kumar A (2015) Development of inclined cascade aerator. *Journal of Basic and Applied Engineering Research* 2:947–950
- Du Y, Chen F, Zhou L, Qiu T, Sun J (2020) Effects of different layouts of fine-pore aeration tubes on sewage collection and aeration in rectangular water tanks. *Aquacult Eng* 89:1-9

Article Id  
AL04495

## IMPACT OF PRADHAN MANTRI KRISHI SINCHAYEE YOJANA (PMKSY) ON FARMERS OF NORTH-EASTERN INDIA

Email

Jagathjhuti Datta

[jagathiyoti@gmail.com](mailto:jagathiyoti@gmail.com)

Growing Seed, Kumarghat, Unakoti, Tripura- 799288, India

**A**griculture remains the backbone of rural livelihoods in India, particularly in the North-Eastern Region (NER), where a large proportion of the population depends on farming for income and food security. However, agriculture in the region faces several constraints including irregular rainfall distribution, limited irrigation infrastructure, hilly terrain, fragmented land holdings, and shifting cultivation practices. These challenges often lead to low productivity and high vulnerability to climate variability.

To address the critical issue of irrigation and water management in agriculture, the Government of India launched the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) on 1 July 2015 with the vision of ensuring water access to every farm (“Har Khet Ko Pani”) and promoting efficient water use through the concept of “More Crop Per Drop.”

The scheme has been instrumental in strengthening irrigation infrastructure, promoting micro-irrigation technologies, and improving water conservation practices across the country. In the North-Eastern states, where agriculture largely depends on monsoon rainfall, PMKSY has played a particularly transformative role in improving crop productivity, cropping intensity, and farmers’ livelihoods.

### Overview of the PMKSY Scheme

The Pradhan Mantri Krishi Sinchayee Yojana is an umbrella programme designed to integrate multiple irrigation initiatives under a single framework. The scheme focuses on improving water use efficiency and expanding irrigation coverage across agricultural lands.

The major components of PMKSY include:

### 1. Accelerated Irrigation Benefit Programme (AIBP)

- Supports the completion of long-pending irrigation projects to increase irrigation potential.

### 2. Har Khet Ko Pani (HKKP)

- Ensures water availability to all agricultural fields through infrastructure development such as canals, groundwater development, and water body restoration.

### 3. Command Area Development and Water Management (CADWM)

- Promotes efficient distribution and management of irrigation water at the field level.

### 4. Per Drop More Crop (PDMC)

- Encourages micro-irrigation technologies such as drip and sprinkler irrigation to enhance water use efficiency.

The primary objectives of PMKSY include expanding cultivable land under assured irrigation, improving on-farm water management, enhancing water use efficiency, and promoting sustainable water conservation practices.

### Importance of PMKSY for the North-Eastern Region

The North-Eastern Region comprises eight states—Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, and Sikkim. Despite abundant rainfall, irrigation coverage in many parts of the region remains low due to topographical constraints and lack of infrastructure.

Key agricultural challenges in the region include:

- Dependence on rain-fed farming
- Limited irrigation facilities
- Soil erosion and water runoff in hilly terrain
- Fragmented land holdings
- Low adoption of modern irrigation technologies

PMKSY addresses these issues through watershed development, water harvesting structures, and micro-irrigation systems that are particularly suitable for the region's agro-ecological conditions.

For example, in Arunachal Pradesh alone, micro-irrigation initiatives have benefited thousands of small and marginal tribal farmers while expanding irrigation coverage across several thousand hectares of farmland.

### Key Impacts of PMKSY in North-Eastern India

**1. Expansion of Irrigation Coverage:** One of the most significant achievements of PMKSY in the North-Eastern states has been the expansion of irrigation facilities in previously rain-fed areas. The construction of minor irrigation structures, check dams, and water harvesting systems has improved water availability for farmers.

In many villages, small irrigation channels and lift irrigation systems have enabled farmers to cultivate crops beyond the monsoon season, increasing cropping intensity.

**2. Promotion of Micro-Irrigation Technologies:** The Per Drop More Crop component promotes efficient irrigation technologies such as drip and sprinkler systems. These technologies help farmers:

- Reduce water wastage
- Improve crop yield
- Increase fertilizer efficiency through fertigation
- Save labour and energy

Micro-irrigation is particularly useful for horticultural crops such as pineapple, orange, turmeric, ginger, and vegetables, which are widely grown in the North-Eastern region.

**3. Improved Crop Productivity:** Improved irrigation facilities have significantly enhanced agricultural productivity in the region. Farmers are now able to cultivate multiple crops throughout the year instead of relying solely on monsoon cultivation.

In irrigated areas, farmers have reported increased yields in crops such as:

- Paddy
- Maize
- Vegetables

- Spices
- Horticultural crops

Reliable irrigation also reduces the risk of crop failure during dry spells.

**4. Crop Diversification:** PMKSY has encouraged farmers to diversify their cropping systems. Earlier, most farmers depended on traditional paddy cultivation during the monsoon season. With improved irrigation, farmers are now shifting towards high-value crops such as:

- Baby corn
- Vegetables
- Floriculture crops
- Spices like turmeric and ginger
- Fruit crops such as pineapple and banana

Crop diversification increases farmers' income and improves nutritional security.

#### **5. Water Conservation and Sustainable Farming**

The scheme also emphasizes water conservation through:

- Rainwater harvesting
- Watershed development
- Restoration of traditional water bodies
- Soil moisture conservation techniques

These practices help maintain groundwater levels and ensure sustainable agricultural development.

In several areas, watershed-based interventions have improved soil moisture and groundwater recharge, which in turn enhances crop growth and farm productivity.

**6. Income Enhancement for Farmers:** Improved irrigation access allows farmers to grow multiple crops annually, thereby increasing farm income. With better water management and adoption of improved technologies, farmers can produce higher yields and cultivate commercial crops.

The combined effect of irrigation expansion, crop diversification, and improved productivity has contributed to enhanced livelihoods in rural communities across the North-Eastern region.

### Challenges in Implementation

Despite its significant achievements, PMKSY faces certain challenges in the North-Eastern region:

1. Difficult terrain and infrastructure limitations
2. Limited awareness among farmers about modern irrigation technologies
3. High installation cost of micro-irrigation systems
4. Maintenance issues of irrigation structures
5. Fragmented landholdings and scattered farms

Addressing these challenges requires stronger institutional support, capacity building, and community participation.

### Conclusion

The Pradhan Mantri Krishi Sinchayee Yojana has emerged as a transformative initiative for Indian agriculture by addressing one of the most critical constraints—water availability. In the North-Eastern region, where agriculture is highly dependent on rainfall, the scheme has played a crucial role in expanding irrigation infrastructure, promoting efficient water management, and improving farmers' livelihoods.

Through micro-irrigation, watershed development, and water conservation practices, PMKSY has contributed to sustainable agricultural development in the region. With continued policy support, community participation, and technological innovation, the scheme has the potential to further enhance agricultural productivity, resilience, and income generation for farmers in the North-Eastern states.

### References

Government of India. (2015). *Pradhan Mantri Krishi Sinchayee Yojana: Operational guidelines*. Ministry of Jal Shakti, Department of Water Resources, River Development & Ganga Rejuvenation. <https://pmksy.gov.in>

- Ministry of Agriculture & Farmers Welfare. (2022). *Per Drop More Crop (Micro-Irrigation) scheme guidelines*. Government of India. <https://agricoop.nic.in>
- Ministry of Agriculture & Farmers Welfare. (2023). *Agricultural statistics at a glance 2023*. Government of India. <https://agricoop.nic.in>
- Press Information Bureau. (2023). *Achievements of Pradhan Mantri Krishi Sinchayee Yojana*. Government of India. <https://pib.gov.in>
- Food and Agriculture Organization. (2020). *Irrigation in Southern and Eastern Asia in figures: AQUASTAT survey*. FAO. <https://www.fao.org>
- NITI Aayog. (2021). *Water management in agriculture in India: Policy perspectives*. Government of India. <https://www.niti.gov.in>
- Indian Council of Agricultural Research. (2022). *Annual report 2021–22*. ICAR, New Delhi. <https://icar.org.in>
- Department of Land Resources. (2022). *Watershed development component of PMKSY: Programme report*. Ministry of Rural Development, Government of India. <https://dolr.gov.in>
- Government of India. (2020). *Micro-irrigation in India: Status and prospects*. Ministry of Agriculture & Farmers Welfare.
- Tripathi, A., Mishra, A. K., & Dubey, S. (2020). Impact of micro-irrigation technologies on agricultural productivity in India. *Indian Journal of Agricultural Economics*, 75(2), 236–248.