A Monthly e Magazine
ISSN:2583-2212
May 2024 Vol.4(5), 1992-1996

Popular Article

Improved Irrigation and Crop Establishment Techniques for Enhancing Water Use Efficiency in Rice

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https://doi.org/10.5281/zenodo.11429287

Introduction

Rice (Oryza sativa L.) is an essential crop for food security in developing nations. Most of the world's rice is grown in Asian nations using a variety of management practices. A huge amount of water is needed for rice production. However, as rice production accounts for 34–43% of the world's irrigation water demand, the water problem in rice-growing nations is a serious worry. A major problem in nations like China and India is a lack of water. The availability of water in India is decreasing, and by 2030, it is predicted that the demand will be 50% greater than the supply. Waterlogging, increased salinization, decreased agricultural production, and deterioration of the soil can result from the depletion and misuse of water resources. Limited food and water resources pose difficulties for rice growers. In comparison to flooded rice cultivation, innovative irrigation management technologies and improved crop establishment tactics can increase water usage efficiency and conserve more water.

Needs to improve water use efficiency

- Increasing population growth every day
- Decline water storage capacity
- World's demand for food, feed, and fiber
- Deterioration in environmental and water quality
- Production is being pushed into more arid environments
- Decline irrigation water sources
- Competition from other water users

Concept of water use efficiency

The concept of "water use efficiency," first presented by Briggs and Shantz in 1913, depicts the link between plant productivity and water use (kg/ha-mm). The term WUE was introduced by them as a measure of the amount of biomass produced per unit of water used by a plant. Water used by the crop is assessed in terms of water use efficiency (WUE). It is of two types.

1. Crop water use efficiency $= \frac{\text{Crop yield } (Y)}{\text{Evapotranspiration } (ET)}$

2. Field water use efficiency $= \frac{\text{Crop yield } (Y)}{\text{Total amount of water used in the field } (WR)}$

Issues of conventional rice cultivation

1. Low water use efficiency
2. Declining water table
3. Low nutrient and energy efficiency
4. Emission of greenhouse gases
5. Virtual water trade deficit

Techniques for improving the water use efficiency of rice

In the current scenario of the water crisis, to boost the production of rice per drop of water, various improved techniques that can help save water and enhance water use efficiency have been tested and disseminated to farmers for adoption, which include.

1. **Alternate Wetting and Drying (AWD) irrigation**: Rice fields are irrigated with the AWD technique in cycles of saturation (flooding) and drying (unsaturation), which conserves irrigation water, enhances water-use efficiency, lowers greenhouse gas emissions, and uses less labor, fertilizer, and pesticides. Irrigation is applied once the soil reaches a specific lower moisture level. After transplantation, the field is left to dry out for two to three weeks, or until the water table drops to a depth of 10 to 15 cm below the soil's surface. Irrigation water should be administered until the field has three to five centimeters of standing water after the threshold is reached. Up to 37% less water may be used with the AWD irrigation technique without compromising output. Up to 37% less water may be used with the AWD irrigation technique without compromising output. In addition to saving water, AWD systems can lower greenhouse gas emissions by 45–90%, enhance grain quality, maintain or even increase grain yield, and boost water efficiency.

2. The aerobic rice system: It's a creative way to cultivate rice on unsaturated, well-drained soils without ponding water. This approach is strongly advised in locations with growing labor expenses and a shortage of water, as well as in areas with a limited labor supply. By utilizing specialized aerobic rice cultivars that respond well to inputs and optimizing water management techniques; this method yielded an impressive 4 to 6 tons of rice per hectare at a water consumption rate of only 50 to 70%, which is significantly lower than traditional irrigated rice cultivation.

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Published 25.05.2024

3. System of Rice Intensification (SRI): Henri de Laulanie created this integrated crop management technique in Madagascar in 1983. The method has quickly spread to numerous rice-growing nations. By preventing evaporation and severe percolation losses, SRI can save up to 50% of the irrigation water used in traditional methods. The following distinguishing practices define SRI: carefully transplanting single seedlings that are 8–12 days old; plants spaced widely apart in a square shape of 25 cm x 25 cm; management of water on an intermittent basis (irrigation after hair-like crack development); using a rotating hoe to remove weeds, which help to aerate the soil.

System of Rice Intensification

Drip Irrigated DSR

Perforated PVC pipe to examine the below-ground water table in AWD

4. Saturated Soil Culture (SSC): SSC is a shallow irrigation method that maintains soil saturation, reducing hydraulic head, seepage, and percolation flow. It requires less than 3 cm of water depth above the soil, reducing percolation loss and preventing moisture stress. SSC can decrease water input by 40% while slightly reducing yield by 6%. According to Borrell et al. (1993), the weekly intermittent watering reduced water use under SSC by 32%. This technology is more efficient than other technologies that require a 5-cm water depth.

5. Direct-Seeded Rice: DSR is a crop establishment method where rice seeds are sown directly into the field, unlike traditional nursery-grown methods. Seeds can be seeded in dry, well-prepared soil by broadcasting, line-sowing, or using a mechanical seed-cum-fertilizer drill. Light irrigation is applied to encourage germination, followed by 20 days of irrigation for root system growth. Other irrigations are given based on AWD cycles every 7–10 days, depending on soil type, crop growth stage, ET demand, and rain likelihood. Wet DSR involves sowing pre-germinated seeds on puddled wet soil. Dry direct-seeded rice yields 13–18% and reduces total water inputs by 8–12% compared to transplanted rice.

6. Drip-Irrigated Rice: Drip irrigation is a modern approach to water-saving used in direct-seeded rice cultivation. The water productivity of rice is much lower when planted under flood irrigation than

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when rice is irrigated through drip irrigation under direct-seeding rice. Compared to traditional paddy production, it saves 70% of the water and can enhance output by up to 30%. In addition to lowering conveyance losses, deep percolation, and evaporation, it also lowers CH_4 and N_2O emissions by 68.6% and 34.4%, respectively. Drip irrigation promotes healthy crop development by reducing soil evaporation and deep percolation. Drip irrigation systems require specialist installation, upkeep, and labor-intensive tasks, including monitoring soil moisture levels, regulating the water flow rate, and checking for leaks.

7. Smart Irrigation or Intelligent Irrigation System: A smart irrigation system determines the paddy crop's watering requirements based on soil moisture or meteorological data. With its high dependability and low power consumption, the intelligent irrigation system makes use of the agricultural Internet of Things (IoT) to enable real-time remote monitoring of moisture content and accurate irrigation control in paddy fields. In comparison to conventional AWD and basin irrigation techniques, smart irrigation technology, an Internet of Things-based contemporary irrigation system, achieves a water footprint reduction of 40.29% and 29.22% while maintaining plant health and quality (**Laphatphakkhanut *et al.*, 2021**).

Other Management Practices for Maximizing Water Use Efficiency

The WUE will rise with every agronomic management technique that raises grain production. Together with these smart irrigation technologies and upgraded irrigation systems, it is essential to use additional, better agronomic management approaches to achieve higher yield potential. Agronomic management practices such as:

- The optimum time for sowing or planting
- Enough plant population establishment
- Timely control of weeds
- Balance and optimum fertilization
- The proper control of insect pests and diseases
- Water conservation by minimum- or no-tillage
- The use of organic mulch
- Regulated deficit irrigation
- Fertigation
- Crop rotation
- Soil amendments

By applying these techniques to integrated water management schemes, farmers can increase water use efficiency while promoting resilient and sustainable farming systems.

Conclusion

Paddy, a staple food crop, has traditionally relied on flood irrigation, which is highly water-intensive. However, farmers struggle to cultivate paddy profitably to meet global food demands. To address this, rice-growing countries must adopt new practices and technologies that enable the sustainable use of scarce irrigation water. Water-efficient rice production technologies, such as DSR, SRI, aerobic rice, SSC, and drip-irrigated rice, have been introduced to reduce water consumption and

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improve productivity and profitability. Farmers should receive training in new irrigation technology, like smart irrigation that uses sensors and the internet of things, and these technologies should be pushed for widespread use right now.

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Published 25.05.2024