Chronicle of Bioresource Management 2025, 9(1): 038-044

Chronicle of Bioresource Management
An International E-magazine

March, 2025 Popular Article

Open Access
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Citation: Jangir et al., 2025. Drip Irrigation in Castor: A Potential Boon to Western Rajasthan. Chronicle of Bioresource Management 9(1), 038-044.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

Keywords:

Castor productivity, drip irrigation scheduling, fertigation, fertilizer use efficiency, water saving

Article History

Article ID: CBM6087
Received on 16th January 2025
Received in revised form on 20th February 2025
Accepted in final form on 01st March 2025

Drip Irrigation in Castor: A Potential Boon to Western Rajasthan

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Abstract

Agriculture in western Rajasthan faces severe challenges due to acute water scarcity, erratic rainfall, high evaporation, and over-exploited groundwater. Castor (*Ricinus communis* L.), a drought-tolerant oilseed crop which thrives well in arid conditions, but meeting out the water requirement optimizes yields. Among the methods of irrigation application, drip irrigation is an efficient water supply technology which ensures consistent soil-moisture by delivering water directly to the plant roots, enhancing efficiency by 50% and increasing yield by 20-40%. This article aims to simplify the use, protocols and benefits of the adoption of drip irrigation in castor cultivation for farmers in water-scarce regions like western Rajasthan. It provides practical and accessible guidelines, including detailed layout plans and tips, to help farmers confidently install and manage drip systems. By elucidating the technology, the article empowers farmers to enhance water-use efficiency, improve productivity, and achieve sustainable farming practices.

1. Introduction

Rajasthan is the largest state of India, is known for the diverse climatic and geographic characteristics. Despite having 13.88% of India's cultivable area, 5.67% of population, and about 11% of the country's livestock, the state possesses only 1.16% of India's surface water and 1.70% of groundwater (Tembhurne et al., 2021). This imbalance in water resources has led to severe water scarcity, affecting nearly 70% of the state's agriculture-dependent economy. The unpredictable monsoon further exacerbates the situation, creating irregular employment opportunities and hindering agricultural progress. According to a report by the Times of India, Rajasthan is one of the three states in India that extracts more groundwater than it recharged in 2023, with 74% of its groundwater sources classified as 'over-exploited.' The Central Ground Water Board (CGWB) of the Union Jal Shakti Ministry, revealed that in 2023, Rajasthan extracted 16.74 billion cubic meters (BCM) of groundwater, while

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only 11.54 BCM was recharged. The report highlights that 83% of state's groundwater is used for irrigation, 2% for industrial purposes and 15% for domestic needs. This overexploitation trend has continued for the past decade, causing groundwater levels to decline by an average of 10 meters annually (TOI, 2024). Preference to the water-intensive crops has further worsened the crisis.

Castor (*Ricinus communis* L.) is an indeterminate, non-edible oilseed crop of the Euphorbiaceae family which is native to Eastern Africa, particularly Ethiopia. Due to drought tolerance and suitability for semi-arid regions, it thrives in India's low-rainfall areas. In India, it is mainly cultivated in Gujarat, Rajasthan and Andhra Pradesh, but is also produced to a lesser extent in other states. In Rajasthan and Gujarat, castor is grown under irrigated conditions, which results in higher productivity. Interestingly, both the state together contributed 87% of the country's total castor area under irrigated conditions, while 13% under rain-fed conditions (Kalamkar and Sharma, 2022). After the Gujarat, Rajasthan is the second highest producer of castor (3.66 lakh tonnes) with area 2.09 lakh ha. District wise area, productivity and production of castor seed in Rajasthan area has been given in Figure 1 and 2. Castor is a wider spaced crop and highly responsive to optimal water management. Drip irrigation ensures consistent moisture levels, preventing water stress that could hinder its growth. This promotes uniform plant development, leading to better yields and oil content. Drip irrigation in castor cultivation offers a sustainable solution to these issues, enhancing productivity while conserving resources.

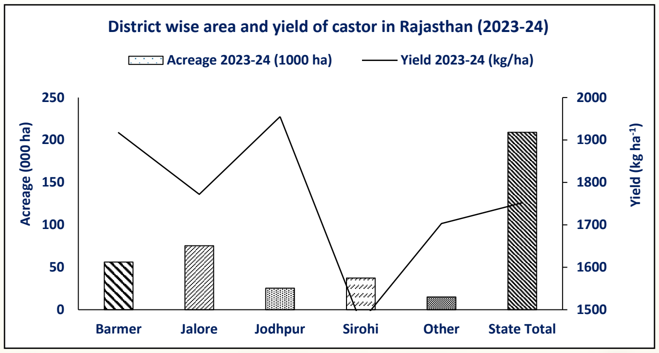

Figure. 1: District wise area and yield of castor seeds in Rajasthan for 2023-24

2. Key Challenges in Western Rajasthan

Western Rajasthan faces critical water scarcity, driven by its low and erratic annual rainfall, often below 250 mm, making it one of India's driest regions. Out of the 18.34 million hectares of net sown area, only 36.3% (approximately 6.66 million hectares) is irrigated. Groundwater is the primary irrigation source for 73% of this land, with wells and tube wells, while about 25% relies on canal systems (Mirdha Hooda, 2013). The region has one of the lowest per capita renewable water resources globally, with just 532 cubic meters per person annually, slightly above the 500 cubic meters threshold for absolute water scarcity (Kumar, 2024). Approximately 58% of the cultivable land is rainfed, creating significant challenges for crop production. The soils are prone to erosion and salinity caused by limited rainfall and high evaporation rates, reducing moisture retention and crop growth. With a projected population increase to 100 million by 2050, the share of water allocated to agriculture is expected to decrease from 83% to 70% (Mirdha Hooda, 2013). These trends highlight the urgent need for effective water resource management and groundwater regulation, particularly for agricultural use. To address these challenges, it is crucial to expand irrigation through improved water-use efficiency in farmer's field. The primary focus should be on western Rajasthan, encouraging farmers to adopt micro-irrigation systems such as drip and sprinkler irrigation, which maximize water efficiency. Additionally, reallocating water resources to less water-intensive crops like castor and optimizing cropping patterns can enhance sustainability.

Drip irrigation offers a solution to these challenges as an efficient method of water use, delivering water directly to the plant roots and minimizing evaporation and runoff. This system is particularly suitable for the arid conditions of Western Rajasthan, as it ensures precise water application, reduces wastage, and helps conserve precious water resources. By conserving groundwater and improving soil health, drip irrigation plays a crucial role in addressing the region's water scarcity while promoting sustainable farming practices.

3. Drip System Installation in Field of Castor Crop

Castor is a drought-hardy crop well-suited to dry and warm regions with annual rainfall of 50-75 cm. However, in areas with heavy rainfall, the crop may develop excessive vegetative growth and turn into a perennial bush. After the rainy season, irrigation should be planned based on the plant's requirements. Typically, irrigation is not needed for 45-60 days after sowing, as the crop can sustain itself on residual soil moisture. At 35-40 DAS, tractor-operated mechanical intercultural operation is performed for weed management and soil aeration, followed by drip irrigation system installation for efficient water management. Care must be taken to avoid uncontrolled irrigation, as it can increase the risk of wilt disease (*Fusarium oxysporum* f. sp. ricini). In famine or drought conditions, irrigation may be required immediately after sowing to ensure proper germination and establishment of the crop. In drip irrigation method, the distance between rows and plants is 120 cm x 90 cm is recommended for castor hybrid seed sowing.

For castor cultivation using the drip irrigation method, ensure the laterals have drippers spaced either 90 cm (one dripper/plant) or 45 cm (two dripper/plant) apart and are connected to the sub-main line with a spacing of 120 cm. Sow castor seeds and maintaining a plant-to-plant distance of 90 cm along the lines. Water should be supplied every three days through the drip system. Adjust the irrigation duration month-wise as per the number of drippers for each plant to match the crop's water requirements as per given in Table 1.

Table 1: Month-wise drip irrigation schedule for Castor crop in western Rajasthan

Month	Irrigation time for each session (hours)
August	0.75*
September	2.25
October	0.75 – 2.25
November	0.75 – 2.25
December	0.75 – 2.25
January	0.75 – 2.25
February	2.25 – 3.0
March	2.25 – 3.0

*Decimal hours can be converted into minutes by multiplying by 60; for example, 0.75 hours equals 45 minutes (0.75×60=45)

Drip lines with a 16 mm diameter equipped with dripper at 90 cm space should be operated at a pressure of 1.25 kg cm^{-2}, with each dripper delivering water at a rate of 4 liters per hour.

This approach ensures optimal water distribution and efficient utilization, promoting healthy crop.

4. Spacing of Drip Laterals

(i) Spacing between Drip Lines: Given the row spacing of 120 cm, it is recommended to place the drip laterals at a spacing of 120 cm and along the crop row. This ensures uniform water distribution in the row and provides adequate coverage for the root zone of each plant.

(ii) Spacing between Emitters: Each drip lateral should have emitters spaced every 90 cm (or 45 cm, depending on the emitter flow rate). This spacing is adequate for castor plants since the root zone of each plant should be watered uniformly.

(iii) Emitter Type: Choose drippers with a suitable flow rate for castor's crop. A flow rate of 2-4 liters per hour (lph) per emitter is generally recommended. Pressure-compensating emitters are preferable as they provide consistent water distribution across the field.

5. Ventury System/Fertigation Unit

A Venturi system in drip irrigation is a device used to inject fertilizers, nutrients, or chemicals (fertigation/chemigation) into the irrigation water. It works on the principle of pressure differential created by the flow of water through a narrow, constricted passage, generating a vacuum that sucks the fertilizers into the water stream. The right timing of fertilizer injection in drip irrigation systems is critical for equal distribution of nutrients, minimizing nutrient losses, enhancing nutrient use efficiency and maximizing crop yield. Fertilizer injection should start after the initial irrigation period to wet the soil and should end before the final flush of water to ensure all nutrients reach the root zone. A common practice is to apply fertilizer in the middle time period of the irrigation cycle:

- 25% initial water without fertilizer.
- 50% water with fertilizer injection.
- 25% final water to flush lines.

For an irrigation duration of 30 minutes, the initial 7.5 minutes (25% of the total time) should be used to supply only water to pre-wet the soil and ensure proper system priming. Fertilizer injection should commence after this period and continue until 7.5 minutes before the completion of the irrigation cycle. The final 7.5 minutes should be dedicated to flushing the system with clean water to prevent clogging and ensure uniform nutrient distribution. Fertilizer application interval depends on crop type, growth stage, soil type, and the specific nutrient requirements. In castor, under drip irrigation method, 1/3 of nitrogen is applied before sowing and the remaining 2/3 by dividing nitrogen into four parts, crop stage of 30-70-90 and 110 days in standing crop. Field view of installed drip system with fertigation unit is given in Figure 3.

Figure 3: Field view of installed drip system with fertigation unit

6. Layout Design

For the drip irrigation in castor with a plant geometry of 120 cm×90 cm, field layout is given in Figure. 4, 5 and 6.

Table 2: A complete layout design for castor crop with spacing of 120 cm×90 cm

Feature	Description
Row spacing	120 cm (between plant rows)
Intra-row Spacing	90 cm (between individual plants)
Emitter Spacing	90 cm (or 45 cm) along the drip lateral
Drip lateral spacing	120 cm (same as row spacing)
Mainline	Running parallel to rows at the edge of the field
Sub mainlines	Connecting the mainline to the drip laterals
Emitter type	Pressure-compensating emitters (4 lph or 2 lph)
Fertigation unit	Connecting to sub main line to equally distribute fertilizers through drippers

7. Water supply, Flow Rate and Watering Frequency

For a 120 cm x 90 cm plant geometry, water requirement per plant can be determine based on the crop's evapotranspiration (ET) needs, soil moisture retention, and regional climate. A typical emitter flow rate for castor is around 2-4 liters per hour. Adjust the number of emitters based on water requirements. The irrigation schedule for castor under a drip irrigation system can typically be set at three-day intervals during the growing season, depending on local weather conditions and soil moisture status. Alternatively, scheduling irrigation based on an IW/CPE (Irrigation Water/cumulative Pan Evaporation) ratio of 0.8 has been found to be more effective for castor cultivation, particularly in arid and semi-arid regions.

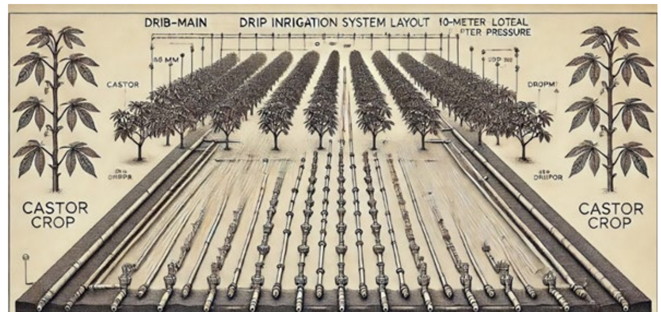

Figure 4: A simplified layout with field view of 120 cm×90 cm spacing

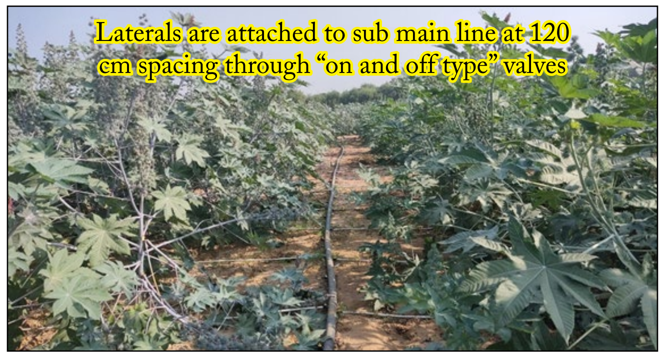

Figure 5: A simplified layout with field view of 120 cm×90 cm spacing

Figure 6: A simplified layout with field view of 120 cm×90 cm spacing

8. Maintenance Considerations

Proper maintenance is crucial for the efficient operation of a drip irrigation system. Regular flushing of the system is necessary to prevent the clogging of emitters, ensuring smooth water flow. Additionally, emitters should be checked periodically to verify that water is being distributed uniformly across the irrigation area. This helps maintain optimal performance and prevents water wastage or uneven irrigation.

9. Benefits of Drip Irrigation in Castor Cultivation

• Drip irrigation is highly beneficial for castor cultivation, especially in water-scarce regions, as it ensures precise water delivery to the root zone, maintaining optimal moisture levels (Rao, 2018). This system reduces evaporation losses, minimizes nutrient leaching, and efficiently meets the crop's water needs at different growth stages, enhancing irrigation management while minimizing wastage.

• Drip irrigation significantly lowers seasonal water demand in castor compared to traditional surface irrigation. While the normal seasonal water requirement for castor is around 500 mm, drip irrigation reduces it to approximately 350 mm (Singh et al., 2012). Studies have shown substantial water savings, with reductions of 22.13%, 33.22%, and 39.78% recorded at Rajendranagar, Palem, and Narkhoda, respectively, averaging 31.71% compared to surface irrigation. Additionally, trickle irrigation scheduling saved 30% more water than the check basin method (Rao et al., 2021). This efficiency is attributed to minimizing non-beneficial water losses, including conveyance and seepage losses, reduced soil evaporation, elimination of in-field runoff, and negligible deep percolation losses during the growing season (Kumar et al., 2013).

• Water use efficiency (WUE) encompasses various efficiency parameters that measure how effectively water is utilized in agricultural systems. These include conveyance efficiency, application efficiency, and distribution efficiency across irrigation methods like drip, sprinkler, and surface systems. The water-use efficiency (WUE) is significantly higher with drip irrigation, ranging from 30-40% more efficient than flood irrigation systems. Additionally, drip irrigation reduces evapotranspiration by 13% and decreases transpiration by 11-14%, resulting in an increase in ecosystem and canopy water use efficiency (WUE) by 9-14% and 11%, respectively, compared to traditional irrigation practices (Wang et al., 2020). Thus, drip irrigation is an effective strategy for conserving irrigation water and enhancing crop WUE in arid regions. Table 3 presents a comparison of water use efficiencies across various irrigation methods, clearly demonstrating that the drip irrigation system is more efficient than both conventional and sprinkler systems.

Table 3: Water use efficiency metrics of micro irrigation systems and traditional surface methods

Efficiency type	Drip irrigation	Sprinkler irrigation	Surface irrigation	References
Conveyance	90–95%	90–95%	60–80%	Keller and Bliesner (1990)
Application	85–95%	70–85%	50–70%	Burt et al. (1997)
Distribution	90–95%	80–90%	60–80%	Allen and Willardson (1997)
Surface water moisture evaporation	20-25	30-40	30-40	Kumar et al. (2013)
Overall efficiency	80-90	50-60	30-35	Bonanomi et al., 2011

• Drip irrigation enhances water use efficiency, leading to higher crop productivity and resource conservation. Scheduling of irrigation through trickle method with N application @ 120 kg ha^{-1} through fertigation resulted in significantly higher seed yield (Ramanjaneyulu et al., 2018). Studies show castor yield can increase by 20-40% under drip irrigation. At Mandor, Rajasthan, drip irrigation achieved higher yields while conserving 31-54% water (Singh et al., 2012). In Anand, Gujarat, frequent irrigation at 0.8 PET improved growth, nutrient availability, and yield (Patel et al., 2010). Across Telangana, surface drip irrigation increased castor yields by an average of 69.41% compared to conventional methods (Rao et al., 2021)

• Furthermore, by enabling fertigation, it allows for the controlled application of fertilizers, ensuring that nutrients are delivered directly to the plants, improving nutrient uptake and reducing fertilizer wastage. It enhances the efficient and economic use of fertilizers

(Camp et al., 2001). Under certain conditions, drip irrigation can achieve comparable or higher yields while significantly reducing nitrogen usage by up to 50% (Patel et al., 2017).

• As a result, the overall production cost is reduced while fertilizer usage decreases, and yield improves. In comparison, the check basin system which is less precise, often leads to uneven water distribution, higher water wastage, and increased labour and operational costs, all of which contribute to lower economic yields and profitability of castor cultivation then drip irrigation. Raising castor using drip irrigation at 1.0V of water provided maximum net returns per hectare, which was 9.56% higher than the returns from the check basin system (Singh et al., 2012).

• Drip irrigation technology has proven highly effective in increasing castor bean yields and expanding irrigated acreage, particularly in water-scarce regions, thereby enhancing farm profitability. It not only conserves water but also improves castor productivity, offering a more sustainable and profitable solution for farmers. Drip irrigation has already demonstrated its potential in regions like Jodhpur and Barmer, where castor farmers have reported a 30-50% increase in yields. Government schemes, such as PMKSY (Per Drop More Crop), have played a pivotal role in promoting micro-irrigation in Rajasthan.

10. Conclusion

Drip irrigation transforms castor cultivation into a profitable and sustainable enterprise in Western Rajasthan. Castor, a drought-tolerant crop, holds significant potential in this region when supported by efficient water management systems. It optimizes water use, enhances productivity, and aligns with the region's need for climate-resilient farming practices. By adopting this technology, farmers can not only improve their livelihoods but also contribute to the sustainable development of the region.

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