Impact of drip irrigation on crop growth, yield,water productivity,and weed dynamics : A review

ABSTRACT

The global water scenario indicates efficient water management practices are required to sustain agricultural productivity. The scarcity of groundwater resources is a global issue that is caused by increasing global population and climate change in the form of global warming. To alleviate the issue, the major water-consuming area implemented drip irrigation projects. It is recognized for its water-saving potential and gained prominence in crop cultivation. This study aimed to investigate the effect of drip irrigation on the growth, yield, water productivity, and weed dynamics of various crops. Results revealed that wheat under drip irrigation exhibited enhanced growth parameters, including increased plant height, leaf area index, and dry matter accumulation attributed to optimized soil moisture content. Drip irrigation significantly improved yield and yield attributes compared to traditional irrigation methods.Importantly, drip irrigation increased water productivity while reducing water use per unit of production. These findings highlight the potential of drip irrigation to reduce water shortages and increase crop output in the current global water context.

Keywords: Drip irrigation; water productivity;leaf area index;dry matter accumulation; yield, weed suppress.

1. INTRODUCTION

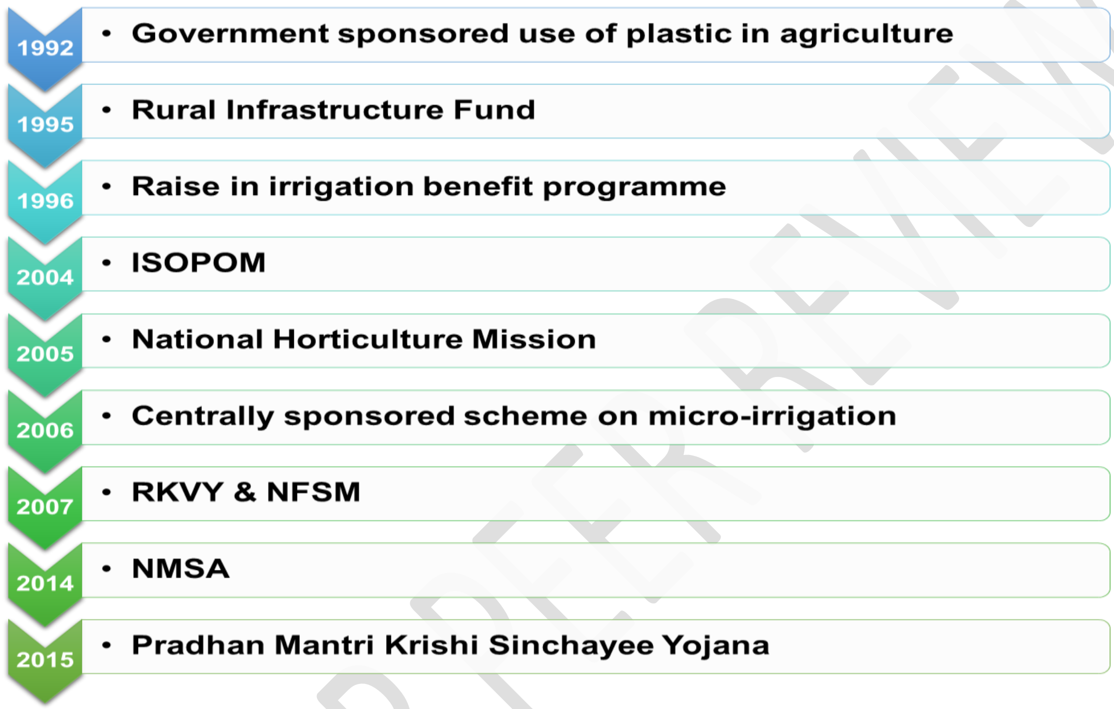
Water is the most important and crucial component in man's life, particularly in agriculture [1].Rapid population growth and extreme climate change are threatening global food security [2]. Due to the rising population and increasing rate of civilization, the most significant constraint on crop production is water availability. There is a need for more agricultural productivity in order to feed the world's constantly expanding population [3]. In traditional surface irrigation, water is distributed to the agricultural land through bunds and channels [4]. In India, the flood technique of irrigation has a water use efficiency (defined as the water consumption percentage compared to total available water) of only approximately 30-45% [5]. Commonly this is a method of wastage of a large quantity of water owing to distribution and evaporation losses [6]. However, conventional irrigation is not only the result of the wastage of water but also pollutes the groundwater through the leaching of chemicals and pesticides [7].This has created an urgent demand for more effective irrigation-saving measures and improved water-use efficiency for sustainable agriculture. This is only attainable with effective water management methods and the use of modern irrigation technologies such as drip irrigation. Drip irrigation (DI) is an efficient method of irrigation that reduces water scarcity problems and benediction for farmers due to high water use efficiency [8] and water productivity [9].In Figure 1, clarifies the importance of drip irrigation on several aspects like reduction the germination of weed, reduces the water loggong conditions, properly weeting the soil surface, no soil erosion etc. A drip irrigation system that is properly planned and operated hasan irrigation efficiency of about 85-90%, in contrast to the surface irrigation method with 40% [5]. In comparison with other irrigation methods, drip irrigation is the most efficient in terms of water use efficiency and reduces the wastage of water through seepage and evaporation [10,11].There is no doubt that drip irrigation has brought about revolutionary advantages [12].

Figure 1. Importance of drip irrigation

2. DEVELOPMENT OF DRIP IRRIGATION IN INDIA

Research indicates that micro-irrigation has huge potential in India, where it can cover around 80 crops with drip irrigation [13]. Major adopting states of drip irrigation are Maharashtra, Andhra Pradesh, and Tamil Nadu [14]. Initially, the development of drip irrigation was slow but it increased significantly during 1990 by the promotion and launches of various governmental schemes. From 1,500 hectares in 1985 to 70,589 ha in 1991–1992 and 2,46,000 ha in 1997–1998 was the area of adoption of drip irrigation [15]. Thus, by March 2003, the country's total area under drip irrigation may have reached 500,000 hectares

[14]. In almost every Indian state, the area under drip irrigation has grown significantly throughout the 1990s. Therefore, government taking more attention to enhance the adoption of micro-irrigation through several schemes from 1992 (Figure 2).Maharashtra State alone accounted for about 50% of India's total drip-irrigated land throughout all three of the study years. Karnataka, Tamil Nadu, and Andhra Pradesh were the next most popular states [14]. The central and state governmentspromoted the micro-irrigation system by launching Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) in 2015 with a slogan of 'per drop more crop' and 'Har khet ko pani' and up to 90 percent subsidy for drip irrigation accessories [16].



Source- Nitiayog, 2023 [17]

Figure 2. Progression of drip irrigation in India

3. SCHEMATIC LAYOUT OF DRIP IRRIGATION

A drip irrigation system consists of a network of mainlines, sub-mains, and laterals with emitters in different spacing(Figure 3). Water, nutrients, and other necessary growth chemicals are evenly and precisely applied to the plant's root zone through each dripper/emitter and orifice. The emitters release water and nutrients into the soil, which are then drawn by capillary action and gravity into the plant root zone. By doing this, the plant's loss of moisture and nutrients is nearly instantly restored, preventing it from ever experiencing water stress and improving quality, growth potential, and output.

Figure 3. Layout of a complete drip irrigation system

4. LITERATURE REVIEW

4.1 Effect of drip irrigation on growth and development of field crops

Numerous studies on the effects of drip irrigation on crop development have been carried out recently by a large number of researchers. Irrigation treatment at 60,80,100 % ET_C(ET_C - crop Evapotranspiration) significantly influenced wheat growth and yield and yield attributes. Irrigation treatment with 100% ET_C recorded significantly higher plant height (95.64 cm) compared to 60, 80% ET_C. Depressed growth of wheat under deficit irrigation treatment I1 (60% ETc) could be due to alteration of cell turgor and growth via cell division, enlargement, and differentiation [18]. Similarly, drip irrigation scheduled at 1.0 PEF enhanced growth parameters-plant height of wheat at harvest (84.7 cm) [19]. This was related to the findings of Awaad and Deshesh [20] revealed that the application of water at 100% of FC(Field capacity) through drip irrigation recorded the highest plant height (70.43 cm) compared to plant height (67 cm) observed in other irrigation levels. The higher dry matter accumulation in drip irrigation regimes may be due to higher plant height [21]. Similarly, dry matter production (1444 g m^{-2}) increased significantly at each higher levels of drip irrigation DI - 1.2 Epan and on par with DI – 1.0 Epan and significantly superior to DI - 0.6 and 0.8 Epan [22]. When drip irrigation was used instead of surface watering, the highest number of wheat tillers was observed by Mahdi et al. [23]. Similar findings were made by Govindan and Grace [24] and Vijaykumar [25], who discovered that drip irrigation at 150% PE(Pan evaporation)produced more tillers in hybrid rice than irrigation at 100% PE. Reddy et al. [26], on the other hand, reported that in aerobic rice, keeping the soil saturated during the crop growth period produced a notably higher number of tillers than drip irrigation at 100 or 150% PE, and that in Warangal, Andhra Pradesh, the later treatment was superior. The leaf area index was significantly influenced by drip irrigationreported by Chen et al.[27]. Comparing shallow-buried drip irrigation to traditional border irrigation, Zhang et al. [28] discovered that the combination of straw returning and shallow-buried drip irrigation increased the following: photosynthetic rate at milk maturity, intercell CO2 concentration, population photosynthetic potential, canopy photosynthetic capacity, dry matter accumulation, and transfer volume. Surface drip irrigation increased the LAI(Leaf area index), SPAD(Soil plant analysis development), net phytosynthetic rate, stomatal conductance compared to the border irrigation [29, 30]. Furthermore, when comparing surface drip irrigation to other irrigation techniques, such as furrow irrigation, sprinkler irrigation, border irrigation, and rainfed conditions, researchers discovered that surface drip irrigation can enhance the dry matter accumulation, plant height, stem diameter, leaf area, and nutrient absorption of maize [31, 32].

4.2 Effect of drip irrigation on yield and yield attributes

Drip irrigation may reduce pollution hazards and drastically boost agricultural yields, crop quality, and the efficiency with which water and fertilizer are used when compared to conventional irrigation system [33]. Studies have shown that compared to border irrigation, furrow irrigation, flooding irrigation, and rain-fed watermelon, cotton, wheat, maize, sunflower, potato, onion, and areca nut yields were significantly increased [34-40]. Furthermore, earlier findings showed that surface flood irrigation, micro-spray irrigation, and furrow irrigation all produced lower potato yields in the root zone than did alternate subsurface drip irrigation[41, 42]. Guo et al.[43]present that wheat yield and productivity increased by drip irrigation compared to conventional irrigation. A similar result was obtained under drip irrigation by Ma et al.[44]. Furthermore, drip irrigation has been shown to be superior to alternative irrigation techniques in situations when there is a water constraint while maintaining crop yields [45].

4.3 Effect of drip irrigation on water productivity

A study showed that drip irrigation increased water productivity in comparison to flood irrigation, border irrigation, furrow irrigation, and sprinkler irrigation, regardless of whether the volume of drip irrigation was more (100–120%) or smaller (<100%) than these other techniques [45]. Another study also revealed that furrow irrigation and flood irrigation method has lowest water productivity compared to drip irrigation [46-48].When comparing drip irrigation to border irrigation, Tian et al. [49] discovered that the former greatly increased winter wheat water productivity by an average of 57.58%. In an investigation by Fan et al. [50], the water productivity of pepper cultivation grown with drip irrigation achieved its maximum and outperformed those grown with micro-sprinkler irrigation by a substantial margin. The same result obtained by Arafa et al.[51], who conducted a field experiment on two irrigation methods were sprinkler irrigation method: solid-set sprinkler irrigation system and drip irrigation method: surface and subsurface drip irrigation systems. The observation revealed that water use efficiency and water saving had been enhancement with about 43.13 and 76%, respectively, when using drip irrigation systems. Similar findings was presented in Table 1.

Table 1. Effect of drip Irrigation regimes on water productivity

Crops	Water productivity (kg m^{-3})	Reference

Oryza sativa (Rice)	0.41	[52]
Triticum aestivum (Wheat)	2.11	[53]
Zea mays (Maize)	1.67	[16]
Sorghum bicolor (Sorghum)	16.48	[54]
Solanum tuberosum (Potato)	15.4	[55]
Allium sativum (Garlic)	1.10	[56]
Allium cepa (Onion)	2.59	[56]
Solanum lycopersicum (Tomato)	5.17	[56]
Brassica oleracea(Cabbage)	9.16	[56]
Ipomoea batatas (Sweet potato)	1.48	[56]

4.4 Effect of drip irrigation on weed dynamics

Drip irrigation is beneficial for controlling weeds because it can direct water where it will most benefit crops and reduce the area available for weed development. Surface drip irrigation is atype of micro-irrigation that precisely place water direct to the root zone of the crop and away from weed seeds[57]. According to Hussein et al. [58], one of the major and indirect barriers to increasing agricultural output was the 40–50% water loss that weeds create. Common annual weeds cultivated alongside crops have been seen to transpire around four times as much water as a crop and to require three times as much water to produce a unit quantity of dry matter as other crops. Weeds alone caused a 50% reduction in crop output under conditions of water stress by competing for soil moisture. Surface drip irrigation has been shown to lower weed pressure in a number of crops, including cotton, maize and tomatoes [59-61].A study found that, in comparison to the flood technique of irrigation, micro-irrigation has significant advantages in terms of water savings and productivity improvements [62]. Under different levels of irrigation regimes the dry weight and population of weeds differed significantly in soyaben [68]. Similarly the same result was obtained by Bahadur et al. [69], reported that surface irrigation are more suspectible for weed growth dynamics compared to drip irrigation.Another field study of drip irrigation on weed dynamics was presented in the Table 2.

Table 2. Effect of drip irrigation regimes on weed dynamics

Drip Irrigation Regimes	**Class of weed**	**Species**	**Crops**	**Weed density (no. m^{-2})**	**Weed Dry weight (g m^{-2})**	**Reference**
Surface drip irrigation	Grass	D.sanguinalis	Maize	1.66	1.44	[63]
	Grass	D.aegyptium		1.32		
Subsurface drip irrigation	Broad leave	C.album		1.39	1.48	
		O.laciniata		2.40		

	weed	R. dentatus		1.24		
DI with 100% RDF	All	C.rotundus C.benghalensis E.hirta	Pegion pea	130.33	136.56	[64]
DI at 0.9 PE	All	All	Cauliflower	5.90	4.56	[65]
DI at 0.7 PE				5.07	4.37	
DI at 0.5 PE				4.47	3.76	
DI at 1.25 Epan	All	All	Rice	5.26	2.34	[66]
DI at 1.50 Epan				5.34	2.40	
DI at 1.75 Epan				5.38	2.42	
DI at 2.0 Epan				5.40	2.44	
Furrow irrigation	Broad leave weed	Amaranthus sp.	Tomato	58.6	254.4	[67]
	Grass	Cyperus sp.		5.1		
	Broad leave weed	Portulaca oleracea		3.9		
	Broad leave weed	Solanum nigrum		77.6		
Sub-surface Drip irrigation	Broad leave weed	Amaranthus sp.	Tomato	11.8	149.2	[67]
	Grass	Cyperus sp.		0.4		
	Broad leave weed	Portulaca oleracea		0.9		

	Broad leave weed	Solanum nigrum	21

5. Limitations of Drip irrigation

In geographical context, drip irrigation can be effective in a wide range of climates and regions, its adoption may be limited by factors such as topography, soil type, and water availability. In arid and semi-arid regions, where water scarcity is a significant concern, drip irrigation systems are often favored. However, in areas with abundant rainfall or high humidity, other irrigation methods such as overhead sprinklers or flood irrigation may be more commonly used. In cropping context, Primary and secondary tillage operations may be limited by dripline placement [70]. Drip irrigation systems are susceptible to clogging due to sediment, algae, or microbial growth, which can impair water flow and reduce system efficiency.Continuous maintenance is necessary to keep the system operating well and prevent clogging. This maintenance includes filtering water sources, cleaning emitters, and flushing lines.

6. CONCLUSION

First off, the current study offers factual proof of drip irrigation technology that affects the growth, and yield of crops. Drip irrigation may greatly increase a crop's growth productivity. Due to high water use efficiency, drip irrigation is mostly used for crops cultivated in greenhouses, high-value crops, intensive farming, and locations with limited water supply, such as dry and semi-arid regions. Furthermore, it can preserve water resources while improving crop growth and yield, as well as water productivity. Similarly, it reduced weed density and their drymatter accumulation, which reduces loss of water through transpiration. Hence, the drip irrigation has the potential to increase agricultural yield and water productivity and sustainability overall.

7. Future research direction

Drip irrigation is becoming more popular when combined with precision agriculture methods like remote sensing, IoT (Internet of Things), and AI (Artificial Intelligence) to allow for real-time scheduling and monitoring of irrigation based on crop requirements, soil moisture content, and meteorological conditions. In order to guarantee even water distribution and reduce water waste, research might concentrate on improving the configuration and design of drip irrigation systems. To get the optimum effectiveness, this may necessitate researching variables like emitter spacing, flow rates, and pressure fluctuations.It is necessary to create drip irrigation systems that are resistant to these difficulties since changing climatic patterns are causing droughts and other extreme weather events to occur more frequently. This might entail researching how crops react to water stress, refining crop types resistant to drought, and creating drip irrigation management plans that are adaptable to changing weather patterns. In agricultural environments, drip irrigation can have an impact on ecosystem services, biodiversity, and water usage patterns. To evaluate its ecological implications, including effects on wildlife habitats, downstream consumers' access to water, and the resilience of the ecosystem as a whole, more research is required. In order to determine if drip systems are cost-effective in various agricultural contexts and to devise ways to lower their cost and increase accessibility for small-scale farmers, additional study is required.

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