

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.

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] (Figure 1). 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 (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 governments promoted 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. 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 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% ET_C) 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 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 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 irrigation reported 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, SPAD, net photosynthetic 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
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<i>Oryza sativa</i> (Rice)	0.41	[52]
<i>Triticum aestivum</i> (Wheat)	2.11	[53]
<i>Zea mays</i> (Maize)	1.67	[16]
<i>Sorghum bicolor</i> (Sorghum)	16.48	[54]
<i>Solanum tuberosum</i> (Potato)	15.4	[55]
<i>Allium sativum</i> (Garlic)	1.10	[56]
<i>Allium cepa</i> (Onion)	2.59	[56]
<i>Solanum lycopersicum</i> (Tomato)	5.17	[56]
<i>Brassica oleracea</i> (Cabbage)	9.16	[56]
<i>Ipomoea batatas</i> (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 a type of micro-irrigation that precisely places water directly 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]. Another field study of drip irrigation on weed dynamics was presented in 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	<i>D.sanguinalis</i>	Maize	1.66	1.44	[63]
	Grass	<i>D.aegyptium</i>		1.32		
Subsurface drip irrigation	Broad leave weed	<i>C.album</i>		1.39		
		<i>O.laciniata</i>		2.40	1.48	
		<i>R. dentatus</i>	1.24			
DI with 100% RDF	All	<i>C.rotundus</i> <i>C.benghalensis</i>	Pegion pea	130.33	136.56	[64]

E.hirta

DI at 0.9 PE				5.90	4.56	
DI at 0.7 PE	All	All	Cauliflower	5.07	4.37	[65]
DI at 0.5 PE				4.47	3.76	
DI at 1.25 Epan				5.26	2.34	
DI at 1.50 Epan	All	All	Rice	5.34	2.40	[66]
DI at 1.75 Epan				5.38	2.42	
DI at 2.0 Epan				5.40	2.44	
Furrow irrigation	Broad leaf weed	Amaranthus sp.		58.6		
	Grass	Cyperus sp.		5.1		
	Broad leaf weed	Portulaca oleracea	Tomato	3.9	254.4	[67]
	Broad leaf weed	Solanum nigrum		77.6		
Sub-surface Drip irrigation	Broad leaf weed	Amaranthus sp.		11.8		
	Grass	Cyperus sp.		0.4		
	Broad leaf weed	Portulaca oleracea	Tomato	0.9	149.2	[67]
	Broad leaf weed	Solanum nigrum		21		

5. 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.

REFERENCES

1. Kumawat PP, Yadav L, Jajoria D, Kumari V, Meena B. Impact assessment of drip irrigation on field crops in India: A Review. *AMA, Agricultural Mechanization in Asia, Africa & Latin America*. 2022;53.
2. Lesk C, Rowhani P, Ramankutty N. Influence of Extreme Weather Disasters on Global Crop Production. *Nature*. 2016;529:84-87. <https://doi.org/10.1038/nature16467>
3. Howell T. Enhancing Water Use Efficiency in Irrigated Agriculture. *Agronomy Journal*. 2001;93(2):281–289.
4. Jayant B, Dahiya K, Rukhiyar A, Ahirwar R, Meena R. A review of drip irrigation system. 2022;1. doi:10.55953/JERA.2022.1103.
5. Narayanamoorthy A. Drip and Sprinkler Irrigation in India: Benefits, Potential and Future Directions. In: *India's Water Future: Scenarios and Issues; Strategic Analyses of National River Linking Project of India*. New Delhi, India: Strategic Analyses of National River Linking Project of India; 2009;Series 2, pp. 253-266.
6. Hoque M. The Way Ahead. In: *Biotechnology for Sustainable Agriculture*. 2018:375–397. doi:10.1016/b978-0-12-812160-3.00013-1.
7. Siyal AA, Bristow KL, Šimunek J. Minimizing nitrogen leaching from furrow irrigation through novel fertilizer placement and soil surface management strategies. *Agric. Water Manag.* 2012;115:242–251.
8. Mačkić K, Bajić I, Pejić B, Vlajić S, Adamović B, Popov O, Simić D. Yield and Water Use Efficiency of Drip Irrigation of Pepper. *Water*. 2023;15(16):2891. <https://doi.org/10.3390/w15162891>
9. Pourgholam-Amiji M, Liaghat A, Khoshravesh M, Azamathulla HM. Improving rice water productivity using alternative irrigation (case study: North of Iran). *Water Supply*. 2020;21:1216–1227.
10. Flores JHN, Faria LC, Neto OR, Diotto AV, Colombo A. Methodology for determining the emitter local head loss in drip irrigation systems. *J. Irrig. Drain. Eng.* 2021;147:06020014..

11. Fukai S, Mitchell J. Factors determining water use efficiency in aerobic rice. *Crop. Environ.* 2022;1:24–40.
12. Bansal G, Mahajan A, Verma A, Singh DB. A review on materialistic approach to drip irrigation system. *Mater. Today: Proc.* 2021;46:10712–10717.
13. INCID. Drip Irrigation in India. Indian National Committee on Irrigation and Drainage, New Delhi; 1994.
14. GOI. Report of Task Force on Micro-irrigation. (Chairman: N. Chandrababu Naidu), Ministry of Agriculture, Government of India, January 2004.
15. AFC. Evaluation of Drip Irrigation System. Agricultural Finance Corporation (AFC) Limited, Mumbai; October 1998.
16. Sujatha HT, Angadi SS, Yenagi BS, Meena RP. Effect of drip irrigation regimes on growth, yield and economics of maize (*Zea mays*) genotypes. *The Indian Journal of Agricultural Sciences.* 2023;93(2):163-8. DOI: <https://dx.doi.org/10.56093/ijas.v93i2.132048>
17. NITI Aayog. Efficiency of Micro-Irrigation in economizing water use in India: Learning from potential and under-explored states. 2023. Available at: <https://www.niti.gov.in/sites/default/files/2023-03/Efficiency%20of%20Micro-Irrigation%20in%20economizing%20water%20use%20in%20India%20Learning%20from%20potential%20and%20under%20explored%20states.pdf>.
18. Yadav T, Yadav G, Kumar A, Kumar D, Yadav R. Salicylic acid and thiourea mitigate salinity and drought stress in wheat (*Triticum aestivum*). *The Indian Journal of Agricultural Sciences.* 2022;92(12):1431–1436.
19. Damor NN, Solanki RM, Hadiyal JG, Dharaiya BK. Effect of drip irrigation schedules and fertigation levels on growth parameters and yields of wheat (*Triticum aestivum* L.). *Journal of Pharmacognosy and Phytochemistry.* 2021;10(2):1546-1550.
20. . Awaad MA, Deshesh THMA. Wheat growth and nitrogen use efficiency under drip irrigation on semi-arid region. *Eurasian Journal of Soil Science.* 2019;8(3):229-236.
21. Dar EA, Brar AS, Ahmad M, Bhat MA, Poonia T. Growth, yield and economics of drip-irrigated wheat (*Triticum aestivum* L.) as influenced by timing and depth of irrigation water application. *Indian Journal of Agronomy.* 2019;64(3):360-367.
22. Malve S, Velchala P, Dhake A. Impact of drip irrigation and N-fertigation scheduling on wheat (*Triticum aestivum*) under semi-arid tropical environment. *Indian Journal of Agricultural Sciences.* 2017;87:580-588. DOI: 10.56093/ijas.v87i5.70091.
23. Al-Kasi MM, Berrada A, Stack M. Evaluation of irrigation scheduling programme and spring wheat yield response in southwestern Colorado. *Agricultural Water Management.* 1997;34:137–148.
24. Govindan R, Grace TM. Influence of drip fertigation on growth and yield of rice varieties (*Oryza sativa* L.). *Madras Agricultural Journal.* 2012;99(4-6):244-247.

25. Vijaykumar P. Optimization of water and nutrient requirement for yield maximization in hybrid rice under drip fertigation system rice (*Oryza sativa* L.). M.Sc. (Agri.) Thesis, Tamil Nadu Agricultural University, Coimbatore. 2009.
26. Reddy M, Padmaja B, Reddy VV. Production Potential and Economics of Different Crops in Rice Fallows under No Till Condition in Telangana Region of Andhra Pradesh. *The Andhra Agricultural Journal*. 2013;60(1):24-27.
27. Chen R, Xiong XP, Cheng WH. Root characteristics of spring wheat under drip irrigation and their relationship with aboveground biomass and yield. *Scientific reports*. 2021;11(1):4913. DOI: 10.1038/s41598-021-84208-7
28. Zhang M. Effects of Straw Returning and Irrigation Methods on Water and Nitrogen Use Efficiency and Soil Quality in Root Soil Layer of Spring Maize. Master's Thesis, Inner Mongolia University for Nationalities, Tongliao, China. 2021.
29. Tian D, Hou C, Ren J, Hao L, Li Z. Effects of different irrigation methods and fertilizer amount on wheat yield and utilization of water, fertilizer and medicine. *Water Sav. Irrig*. 2022;10:100–104.
30. Zhao J, Xu X, Qu W, Liu S, Xu Y, Meng F, Jia J, Zhao C. Protective enzyme activity of flag leaf and yield of drip-irrigated winter wheat. *J. Irrig. Drain*. 2022;41:43–51.
31. Jia B, Fu J. Critical nitrogen dilution curve of drip-irrigated maize at vegetative growth stage based on leaf area index. *Trans. Chin. Soc. Agric. Eng*. 2020;36:66–73.
32. Li M. Effects of different irrigation modes on physiological growth, yield and water use efficiency of maize. *Shaanxi Water Resour*. 2022;38:38–41.
33. Fernández-Gálvez J, Simmonds LP. Monitoring and modelling the three-dimensional flow of water under drip irrigation. *Agric. Water Manag*. 2006;83:197–208.
34. Xu J, Li CF, Meng QF, Ge JZ, Wang P, Zhao M. Effects of different drip-irrigation modes at the seedling stage on yield and water-use efficiency of spring maize in Northeast China. *Acta Agron. Sin*. 2015;41:1279–1286.
35. Yang H, Li X, Wang B, Zhong H, Zhang B, Wang Z. Effect of drip irrigation under plastic film mulching on soil water-heat utilization and high yield on oil sunflower. *Trans. Chin. Soc. Agric. Eng*. 2016;32:82–88.
36. Zhao Y, Shi S, He Z, Lou C. Effects of new slow-release fertilizer on potato yield and soil nutrient transport under different irrigation modes. *Jiangsu Agric. Sci*. 2016;44:130–132.
37. Liu Y, Cao B, Xu K. Effects of irrigation modes and nitrogen, phosphorus and potassium ratios on yield and water and fertilizer productivity of welsh onion. *China Veget*. 2020;2:52–56. Available online: <https://www.cnveg.org/CN/Y2020/V1/I2/52> (accessed on 17 January 2023).
38. Jiang J, Zhang H, Li H, Luo T, Xin X, Yang F. Effects of different irrigation methods on growth, fruit quality and yield of arecanut. *Tianjin Agric. Sci*. 2021;41:1–4.

39. Bai C, Zhou C, Wang X, Luo D, Zhu L, Yao L. Soil pH and salinity as affected by fertilizer ratio of potassium and nitrogen in drip fertigation and fertilization method in litchi. *Chin. J. Soil Sci.* 2021;52:1104–11136.
40. . Liu Z, Ye Y, Wang L, Zhang Y, Qi Y, Mu J, Zhang L. Effects of drip irrigation and spray irrigation fertilization on spatial differentiation of soil nutrients and root growth of tea seedlings. *J. Soil Water Conserv.* 2022;36:330–339.
41. Huang H, Li W, Xie L, Xiang L, Meng X, Xie A, Wei L, Chen Q, Nong T. Effects of drip irrigation on agronomic characters and yield of sugarcane. *Modern Agric. Sci. Technol.* 2010;19:107–108. (In Chinese)
42. Zhang Z, Liang B, Li J, He H, Jin S. Effects of different fertigation methods on yield and nutrient uptake of potato. *Chin. Agric. Sci. Bull.* 2013;29:268–272.
43. Guo X, Zhao Q, Li J, Wang Z, Zhang Y, Xue X. Daily drip irrigation based on real-time weather improves winter wheat grain yield and water use efficiency. *Irrigation and Drainage.* 2022;71:589-603.
44. Ma ST, Wang T, Ma SC. Effects of drip irrigation on root activity pattern, root-sourced signal characteristics and yield stability of winter wheat. *Agricultural Water Management.* 2022;271:107783. DOI: 10.1016/j.agwat.2022.107783
45. Yang P, Wu L, Cheng M, Fan J, Li S, Wang H, Qian L. Review on Drip Irrigation: Impact on Crop Yield, Quality, and Water Productivity in China. *Water.* 2023;15:1733. <https://doi.org/10.3390/w15091733>
46. Zhou S, Zhang F, Wang X, Mi G, Mao D. Comparative study on nitrogen absorption and utilization characteristics of different winter wheat varieties under high yield conditions. *Soil Fert.* 2000;4:20–24.
47. Ran Y, Wu W, Liu H, Wang S, Tang X. Response of mountain maize yield to ecological factors under the condition of nitrogen, phosphorus and potassium deficiency. *Guangdong Agric. Sci.* 2018;45:7–13.
48. Huang Z, Shi Y, Song S, Zhao Y, Bao Z, Liu L, Ma B. Effects of nitrogen, phosphorus and potassium deficiency on water and fertilizer utilization efficiency of winter wheat under different irrigation methods. *Water Sav. Irrig.* 2022;11:79–85.
49. Tian D, Hou C, Ren J, Hao L, Li Z. Effects of different irrigation methods and fertilizer amount on wheat yield and utilization of water, fertilizer and medicine. *Water Sav. Irrig.* 2022;10:100–104.
50. Fan J. Effects of different irrigation methods on pepper growth. *Hydro Sci. Cold Zone Eng.* 2022;5:41–45. (In Chinese)
51. Arafa YE, Essam AW, Hazem EM. Maximizing water use efficiency in wheat yields based on drip irrigation systems. *Australian Journal of Basic and Applied Sciences.* 2009;3(2):790–6.
52. Akbar G, Islam Z, Umar M, Salam S. Water productivity of furrow, drip and flood irrigated rice under loam soil. *Sarhad Journal of Agriculture.* 2022;38(5):95-103. DOI: <https://dx.doi.org/10.17582/JOURNAL.SJA/2022/38.5.95.103>

53. Lu J, Geng C, Cui X, Li M, Chen S, Hu T. Response of drip fertigated wheat-maize rotation system on grain yield, water productivity and economic benefits using different water and nitrogen amounts. *Agricultural Water Management*. 2021;258:107220. DOI: <https://dx.doi.org/10.1016/j.agwat.2021.107220>
54. Ibrahim WM, Ati AS, Majeed SS. Response Water Productivity and Sorghum Yield to Deficit Irrigation Under Surface Drip Irrigation System. *IOP Conference Series: Earth and Environmental Science*. 2023;1259(1):012029. DOI: <https://dx.doi.org/10.1088/1755-1315/1259/1/012029>
55. Kaur A, Singh KB, Gupta RK, Alataway A, Dewidar AZ, Mattar MA. Interactive effects of nitrogen application and irrigation on water use, growth and tuber yield of potato under subsurface drip irrigation. *Agronomy*. 2022;13(1):11. DOI: <https://dx.doi.org/10.3390/agronomy13010011>
56. Assefa T, Jha M, Reyes M, Tilahun S, Worqlul AW. Experimental evaluation of conservation agriculture with drip irrigation for water productivity in sub-Saharan Africa. *Water*. 2019;11(3):530. DOI: <https://doi.org/10.3390/w11030530>
57. Coolong T. Using Irrigation to Manage Weeds: A Focus on Drip Irrigation [Internet]. *Weed and Pest Control - Conventional and New Challenges*. InTech; 2013. Available from: <http://dx.doi.org/10.5772/54153>
58. Hussein FA, El-Saeid HM, El-Said-Amin ABA. Water loss by weeds: a review. *Int. J. Chem. Tech. Res*. 2015;7(1):323-336.
59. Grattan SR, Schwankl LJ, Lanini WT. Weed control by subsurface drip irrigation. *California Agriculture*. 1988;42(3):22-24.
60. Dastorani MT, Heshmati M, Sadeghzadeh MA. Evaluation of the efficiency of surface and subsurface irrigation in dryland environments. *Irrigation and Drainage*. 2010;59(2):129-137.
61. Sutton KF, Lanini WT, Mitchell JP, Miyao EM, Shrestha A. Weed control, yield, and quality of processing tomato production under different irrigation, tillage, and herbicide systems. *Weed Technology*. 2006;20(4):831-838.
62. Narayanamoorthy A. Impact assessment of drip irrigation in India: the case of sugarcane. *Devel. Pol. Rev*. 2004;22(4):443-462.
63. Mohanpuria R, Kaur S, Kaur T, Singh KB, Brar AS, Deol JS. Integration effect of drip irrigation and mulching on weeds and spring maize productivity.
64. Kakade SU, Mohurle LA, Bhale VM, Deshmukh JP. Effect of Drip Fertigation on Growth, Weed Dynamics, Yield and Economics of Pigeon pea. *Journal of Agriculture Research and Technology*. 2019 Jan;44(1):51.
65. Baghla S, Gangmei TP, Kumar A, Rana SS. Effect of irrigation and weed management practices on weed studies, water use efficiency and yield of cauliflower (*Brassica oleracea* var. botrytis L.). *IJCS*. 2020;8(5):2703-6.

66. Goud BR, Reddy GP, Chandrika V, Naidu MVS, Sudhakar P, Reddy KM, Nayaka GV, Suresh G, Adilakshmi G, Sagar GK. Effect of irrigation regimes and nitrogen levels on weed dynamics in aerobic rice under drip irrigation in Southern-Agroclimatic Zone of Andhra Pradesh. 2021
67. Shrestha A, Mitchell JP, Lanini WT. Subsurface Drip Irrigation as a Weed Management Tool for Conventional and Conservation Tillage Tomato (*Lycopersicon esculentum*Mill.) Production in Semi-Arid Agroecosystems. Journal of Sustainable Agriculture. 2007;31(2):91–112. doi:10.1300/j064v31n02_07

UNDER PEER REVIEW