Biological Forum – An International Journal (SI-AAEBSSD-2021) 13(3b): 89-93(2021)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Drip Irrigation in Rice and Wheat Cropping System under Conservation Agriculture: Water Scarcity Solution

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(Received 01 July 2021, Accepted 27 September, 2021)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Water scarcity involving water shortage, water stress and its deficit is a main concern in arid and semi-arid regions around the world. Micro irrigation system such as surface and subsurface drip irrigation systems with excellent uniformity parameter and higher performance are often recommended to solve this problem. Transplanted rice required 40% more water for land preparation and 10% more water for irrigation as compared to wet seeded rice. Study also revealed that under transplanted rice total water consumption was 21% more compared with wet seeded rice. Study showed that drip irrigation increased grain yield of wheat by 4.9 to 6.9%, water use efficiency by 20.89-43.13% and water saving by 36.24-76 % as compared to conventional method of irrigation. For rice crop, drip irrigation system increased grain yield by 5.39 to 30%, water use efficiency by 39.81-69.23% and water saving by 44.5-97 % as compared to conventional method of irrigation. Conservation agriculture coupled with drip irrigation practices saved 46.7 and 44.7% irrigation water under Rice Wheat cropping system as compared to their respective conservation agriculture based systems with flood irrigation as well as CA + Drip in Rice Wheat system recorded 11.2% higher crop productivity and improved irrigation water productivity by 145% and profitability by 29.2% compared to farmers' practice. Subsurface drip irrigated Rice wheat cropping system under conservation agriculture saves 48–53% irrigation water in rice and 42–53% in irrigation water.

Keywords: Drip irrigation, Water scarcity, Water Saving, Water Productivity, Water use efficiency.

INTRODUCTION

Water is the most precious natural resource as well as a basic need of human life. In near future agriculture has to produce more quantities of food and fiber to fulfill the necessity of increasing population with decreasing water availability for irrigation. Per capita land resource has decreased from 0.34 ha in 1961 to 0.12 ha in 2015 (World Bank, 2018). On the other hand, per capita water availability assessed at more than 5300 m^3 in 1951 had decreased to 1588 m^3 in 2010, and is likely to be less than 1500 m^3 by the year 2025 (Gautam, 2016). Availability of fresh irrigation water is getting scanty. Increasing the demand of water for other sectors, the contribution of water for irrigation may likely to reduce from present level of 84 to 69 per cent by 2025 but on the other hand, demand of water for agricultural purposes would increase to produce more food and fiber. Rice wheat cropping system (RWCS) consumes about 11,650 m^3 ha^{-1} water out of which 7650 m^3 ha^{-1} is by rice. Whereas other cropping system in Punjab such as maize, summer moong, groundnut and summer fodder, moong-maize-wheat, maize wheat consumed much less water as compared to RWCS (Sidhu *et al*., 2010). Looking to the future where water availability would become scarcer, nutritional security of nation and surplus food grain production, the switch over to agronomic crops and application of micro-irrigation system (MI system) like surface and subsurface drip irrigation embark a promising proposition (Rao *et al.* 2015, Rao *et al.* 2016a, Rao *et al.* 2016b, Rao *et al*., 2016c, Rao *et al*., 2016d, Gangwar *et al.*, 2017, Bajpai and Kaushal 2020 and Bajpai and Kaushal 2021). Micro-irrigation system mainly subsurface drip irrigation (SDI) works at a minimum or no losses in deep percolation and surface runoff and simultaneously it provides higher application efficiency generally around 80-90 per cent as well as higher crop yield (Bajpai and Saxena *et al.* 2017, Rao *et al.*, 2017a; Rao *et al.*, 2017b; Rao *et al.*, 2017c,).

Water scarcity involving water shortage, water stress and its deficit is a main concern in arid and semi-arid regions around the world. Micro irrigation system such as surface and subsurface drip irrigation systems with excellent uniformity parameter and higher performance are often recommended to solve this problem and to fiercely increase the efficiency of water use as well as fertilizer use over that of conventional surface irrigation systems. Sub surface drip irrigation system is becoming increasingly passable in a form of supplying water soluble fertilizers, irrigation water and chemicals more efficiently as well as uniformly, and have been used on a different range of fruit trees, vegetables and field crops.

Conservation agriculture (CA) technologies are an approach associated with the little soil mechanical disturbance, permanent organic soil cover through residues of crops, diversification of crop for managing the agro-ecosystem, achieving higher productivity with increased profit and food security. By keeping all the above aspects in the mind the present review has been planned on "Drip Irrigation in Rice and Wheat Cropping System under Conservation Agriculture: Water Scarcity Solution"

Water Requirement of Conventional Flood Irrigated Rice-Wheat Crops

Bhuiyan *et al.,* (1995) reported that transplanted rice required 40% more water for land preparation and 10% more water for irrigation as compared to wet seeded rice. Study also revealed that under transplanted rice total water consumption was 21% more compared with wet seeded rice. Castaneda *et al.,* (2002) found that water use in irrigated rice is high because the crop is grown under low land condition. The soil is puddled and the field is kept flooded with 3 to 5 cm depth of water after transplanting until 10 days before harvest. Because of continuous presence of ponded water, there is a huge loss of water by evaporation seepage and percolation out of root zone.

Irrigation management effects on yield and water productivity of rice was studied by Cabangon *et al.,* (2005). Research consisted of three crop establishment methods i.e. Dry seeded rice (DSR), wet seeded rice (WSR) and transplanting rice (TPR) and three irrigation techniques like continue flooding, alternate wetting and drying and flush irrigation. Lowest yield and water productivity (5 t/ha, 1.5 kg/m^3) was observed under continues flooding method. Study also revealed that DSR had significantly less irrigation water and higher water productivity than WSR and TPR as no need for maintaining standing water for about 20 days after transplanting.

Growth and yield of rice cultivars under various methods were studied by Gill *et al.,* (2006). Lowest water productivity was observed under transplanted rice 0.29 and 0.39 kg m^{-3} whereas water productivity ranged between 0.4 and 0.46 kg grain m^{-3} under direct seeded rice.

Shao *et al.* (2009) observed that water use of wheat under limited water supply had range of 330-340 mm, 470-520 mm, 340-390 mm, 310-330 mm, 390- 440 mm in year of 2002-03, 2003-04, 2004-05, 2005-06 and 2006-07 respectively. Karrou *et al.,* (2012) reported that 6330 m^3/ha water applied under famers practice (conventional irrigation) irrigated wheat.

The rice–wheat crop rotation (RWCS) has led to a manifold increase in irrigation water demand. RWCS consumes about 11,650 m^3 ha^{-1} water out of which 7650 m^3 ha^{-1} is by rice. Whereas other cropping system in Punjab such as maize, summer moong, groundnut and summer fodder, moong-maize-wheat, maize wheat consumed much less water as compared to RWCS (Sidhu *et al.* 2010). Due to the large amount of water required in Punjab for rice wheat cropping system under surface method of irrigation, excessive groundwater pumpage has occurred, and has led to a long-term groundwater decline of 41.6 cm/yr (Jalota *et al.*, 2018).Sharma *et al.* (2018) reported total irrigation water applied (cm) in border irrigated wheat was 45 cm. Study also revealed that grain yield and water productivity under border irrigation were 16.22% and 30.76% lower than pressurized sprinkler method.

Rice Wheat Cropping System under Conservation Agriculture

Singh *et al.,* (2009) conducted a research on nitrogen and residue management effects on agronomic productivity and nitrogen use efficiency in rice–wheat system in Indian Punjab. The three years study revealed that in sandy loam, 7% higher wheat yield was obtained with straw mulch zero- till as compared to residues burnt zero- till which was at par with straw burnt conventional till. For silt loam, 4.4% higher wheat yield was obtained with straw mulch- zero- till as compared to straw incorporated-conventional till, which was at par with straw burnt- conventional till. It was concluded that soil organic carbon was increased by recycling of crop residue (incorporation and surface mulch) compared with straw burning.

Gathala *et al.,* (2011) reported zero tillage rice on flat bed yielded 15% lower than conventional practice of puddling and transplanting but yielded 48% higher than direct seeded on raised bed. Whereas wheat yielded 18% higher with zero tillage compared to conventional-tillage. Water productivity of rice was highest (0.36 kg grain m^{-3}) in puddling and transplanting with mid-season alternate wetting and drying and lowest (0.17 kg grain m^{-3}) in direct-seeding on permanent raised beds. The effect of rice straw mulch on soil evaporation of irrigated wheat in Punjab was studied by Singh *et al.* (2011). Evaporation was lowered by 35 and 40 mm under mulched condition over the crop growth season in high and low rainfall years, respectively.

Crop establishment, tillage and water management technologies on crop and water productivity of rice cultivars were studied by Kumar *et al.* (2012). Study revealed that grain yield in conventional puddled transplanting was higher as compared to, unpuddled transplanting, reduced-till transplanting, and direct-seeding systems. The dry-direct seeding of rice crop had a savings in labor and machine use. It was also observed that zero-tillage transplanted and reduced till dry-direct-seeded rice had a higher net return than the conventional and unpuddled system.

Effects of tillage and crop establishment methods, crop residues, and nitrogen levels on wheat productivity for rice-wheat cropping system were studied by Sah *et al.* (2014). Study revealed that zero tillage wheat produced significantly higher grain yield (2616.5 kg ha^{-1}), saved 10.4 % energy input, enhancing 25.2 % energy use efficiency and increased 12.4 % energy output as compared to conventional tillage. Study also revealed that residue retention increased 4 % grain yield over residue removal. Research suggested that zero-till wheat with 40-cm residue retention and 100 kg N ha^{-1} application was best for Tarai region of Nepal.

Performance of crop residue management in crop productivity of rice-wheat cropping system was studied by Nandan *et al.* (2018). Study revealed that continuous residues retention significantly improves the grain yield of rice and wheat crops. For rice 9.4-9.7 per cent while for wheat 4.6- 9.3 per cent higher grain yield were grasped with retention of crop residue.

Drip Irrigation in Rice and Wheat Cropping System: Water Scarcity Solution

Water use efficiency of winter wheat under drip irrigation system was studied by Kamilov *et al.,* (2004). Study showed that drip irrigation increased grain yield of winter wheat by 4.9 to 6.9% as compared to furrow irrigation which was scheduled at 70-80-70% of field capacity. Higher water use efficiency was observed under drip irrigated wheat (1.62 kg m^{-3}) as compared to the furrow irrigation (1.34 kg m^{-3}) with same irrigation schedule. Liao *et al.,* (2008) reported 36.24 % of water saving in drip irrigation as compared to conventional irrigation.

Influence of drip fertigation on growth and yield of rice was studied by Govindan and Grace (2012). Study reported that 5.51–5.68 and 4.95–5.08 t ha^{-1} grain yield with 822–1027 and 591–757 mm of water were observed under drip irrigation system at 150% and 100% PE (Potential evaporation) respectively and water use efficiency 6.93–8.25 kg ha^{-1} mm^{-1} was observed under drip irrigation at 100 % PE and 100% fertigation.

Water use efficiency (WUE) and performance of rice under drip irrigation was studied by Haibing *et al.,* (2013). Highest WUE was found in drip irrigation treatment, which was 1.52–2.12 times higher than conventional flood irrigation treatment. Wang *et al.* (2013) studied effect of irrigation water application in drip irrigated wheat on its yield. Highest wheat yield of 6388 Kg ha^{-1} and water use efficiency of 15.21 kg mm ha^{-1} was observed under 375 mm of irrigation water application. Mahapatra (2015) reported that drip irrigated rice under mulched condition with dripline spacing of 50 cm and emitter spacing of 30 cm with emitter discharge rate of 1.3 lph at 10% soil moisture depletion level increased yield by 42% and saved 41% irrigation water as compared with conventional flood irrigation system.

Response of rainfed rice supplemented with drip and surface irrigation was studied by Panigrahi *et al.* (2015). Grain yield of 4.27, 4.39 and 3.92 t/ha was observed with 100%, 125% and 75% of ETc (Crop Evapotranspiration) in drip irrigation treatments respectively, whereas it was 4.48 t/ha with puddled transplanted rice, but maximum irrigation water use efficiency was obtained at 100% ETc. (0.604 kg m^{-3}) under drip irrigation as compared to conventional method (0.432 kg m^{-3}). The grain yield of drip-irrigated rice was 26% higher than rain-fed rice.

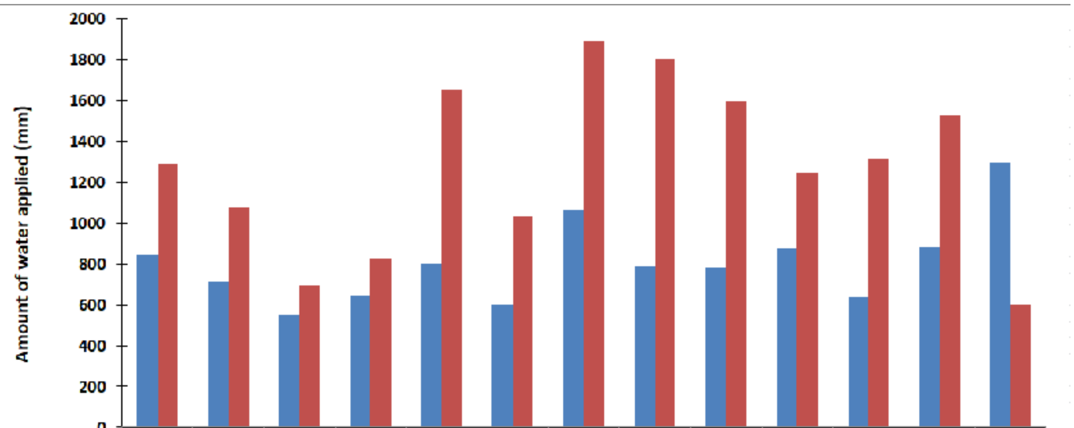
Sonit *et al.* (2015) reported 62 % of water saving under drip irrigated rice as compared with conventional flood irrigation system with dripline spacing of 45 cm and emitter spacing of 50 cm with emitter discharge rate of 4.0 lph. Paired row planting for paddy cultivation under drip irrigation system was studied by Tajane *et al.,* (2016). Results of the study revealed that paired row plating with inline drip irrigation system with lateral spacing of 90 cm, emitter spacing of 40 cm and 2 lph emitter discharge rate produced 30 % more grain yield and 97% water saving over surface irrigation method.

Performance of drip-irrigated dry-seeded rice (var. 'PR-115') in South Asia was studied by Sharda *et al.,* 2017. Study consisted of four irrigation regimes and three nitrogen levels. Higher grain yield and water use efficiency (7.34–8.01 t ha^{-1} with 860 mm of water applied, 0.81–0.88 kg m^{-3}) was observed under drip irrigation at 1.5 × Epan as compared to flood irrigation (6.63–7.60 tonne ha^{-1} with 1455 mm water applied, 0.42–0.52 kg m^{-3}). Water saving of 40–42% was reported under drip irrigation over flood irrigation.

Bansal *et al.,* (2018) conducted a research on drip irrigation in rice (PR 126) for higher productivity and profitability in Haryana. Experiment consisted of three different irrigation methods viz. drip, sprinkler and flood irrigation. Highest grain yield and water use efficiency (6950 kg ha^{-1}, 17.1 kg ha mm^{-1}) were observed under drip irrigation method compared to flood irrigation (6225 kg ha^{-1}, 11.5 kg ha mm^{-1}).

Sarkar *et al.,* (2018) studied the effect of drip irrigation on yield and water saving of summer rice cultivation. Grain yield of 3.10 t/ha was observed under drip irrigation with 57 % water saving over conventional irrigation system whose yield was only 2.29 t/ha. Umair *et al.,* (2019) conducted a research on water-saving potential of subsurface drip irrigation for wheat. Study reported that subsurface drip irrigation reduced ET by 26% compared to conventional flood irrigation system, and 15% compared to surface drip irrigation.

Graphical representation of irrigation water applied for rice crop under drip and flood irrigation system in different soil texture is shown in Fig. 1.



	Sandy clay loam (Komball 2017)	Sandy clay loam (Rekha et. al. 2015)	Clay loam (Parthasa rathi et. al. 2017)	Clay (Parthasa rathi et. al. 2013)	Sandy clay loam (Ramulu et. al. 2016)	Sandy loam (Sharma et. al. 2018)	Loam (Adekoya et. al. 2014)	Loam (Beser et. al. 2015)	Clay (Tajane et. al. 2016)	Sandy loam (Mahapat ra 2015)	Silty clay loam (Bhardwaj et. al. 2018)	Sandy loam (Sharda et. al. 2017)	silt loam soil (Sidhu et.al. 2019)
Drip Irrigation system	844	714	547	642	801	600	1065	789	780	879	639	882	1296
Flood Irrigation system	1288	1073	697	825	1654	1035	1890	1806	1595	1247	1319	1527	600

Soil texture and Author Name

Fig. 1. Irrigation water applied for rice crop under drip and flood irrigation system for different soil texture Drip Irrigation System under Conservation Agriculture.

Effect of conservation tillage on growth, productivity of drip irrigated rice was studied by Kumar *et al.,* (2016). Study consisted of four methods of irrigation i.e. Sprinkler, drip, chaplin drip and flood irrigation under reduced and zero tillage practices. Study reported that maximum consumption of water under flood irrigation i.e. 470 mm/ha which was significantly higher than other micro irrigation system (drip irrigation 211 mm/ha). Impacts of conservation agriculture with a drip irrigation system on water management were studied by Assefa *et al.,* (2018). Study revealed that evapotranspiration and surface runoff were found to decrease significantly under conservation agriculture (CA) by up to 49% and 62%, respectively as compared to conventional tillage (CT). Study also revealed that requirement of irrigation water reduced under CA by about 14–35% for various crops. CA coupled with drip irrigation was found to be a promising approach as efficient water saving technology and has substantial potential to sustain and intensify crop production in the region.

Sub-surface drip fertigation with conservation agriculture (CA) in a rice-wheat system was studied by Sidhu *et al.,* (2019). Experiment consisted of two drip laterals spacing i.e. 33.75 cm or 67.5 cm with installation depths of 0, 15 or 20 cm and compared with conventional and zero tillage (ZT) based flood-irrigated rice wheat (RW) systems. Study revealed that grain yield and irrigation water input in rice and wheat were similar under different sub surface drip fertigation treatments (SSDF). Irrigation water savings observed 48–53% in rice and 42–53% in wheat under combination of SSDF and CA compared to flood irrigation system. Conservation agriculture coupled with drip irrigation (CA + Drip) practices saved 46.7 and 44.7% irrigation water under Rice Wheat and Maize Wheat cropping systems compared to their respective CA-based systems with flood irrigation as well as CA + Drip in Rice Wheat system recorded 11.2% higher crop productivity and improved irrigation water productivity by 145% and profitability by 29.2% compared to farmers' practice (Jat *et al.,* 2019).

CONCLUSIONS

Looking to the future where water availability would become scarcer, nutritional security of nation and surplus food grain production, switch over to agronomic crops like wheat and rice and adaptation of micro-irrigation system like surface and subsurface drip irrigation under conservation agriculture embark a promising proposition.Puddled transplanted rice required 35 to 40% more irrigation water than no-tillage direct seeded rice. As well as direct seeded rice had significantly higher water productivity than wet seeded rice and puddled transplanted rice as no need for maintaining standing water for about 20 days after transplanting. Subsurface drip irrigated Rice wheat cropping system under conservation agriculture saves 48–53% irrigation water in rice and 42–53% in irrigation water.

Acknowledgement: Authors fully acknowledge Punjab Agricultural University (PAU), Ludhiana and Borlaug Institute for South Asia (BISA), Ludhiana, Punjab for providing the necessary support to carried out this research study.
Conflicts of Interest. None.

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