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Irrigation Scheduling through Drip/Surface Method: A Review on Growth, Yield, Nutrient Uptake and Water Productivity of Wheat

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ABSTRACT

Water is one of the most essential natural resource, which is often costly and limiting input particularly in arid and Semi-arid. Since water is the life line for accruing desired yield levels, its time of application, method of application and quantity applied levels besides saving water. Further, there is a need for judicious use of water to reap the maximum benefit from this limiting resource. Off late, amongst irrigation methods, drip irrigation plays a vital role in economizing irrigation water, higher water use efficiency and enhancing crop yield in water scarce areas. Many research findings also confirm considerable saving in irrigation water through adoption of precise irrigation method like drip irrigation. The response of wheat to surface check basin and drip irrigation is reviewed.

Key words: Drip irrigation, Growth, Nutrient uptake, Water productivity, Wheat, Yield.

Globally, wheat is the leading cereal crop cultivated in 226.45 million ha with a production of 765.41 million tonnes (CMIE 2019). In India, wheat production is about 106.21 million tonnes from an area of 29.80 million ha (CMIE 2019). Out of total cultivated wheat area in India, 92% area is under irrigation. Presently in changing climatic condition, water scarcity and increasing crop water requirements limit food grain production in India. Off late due to erratic behavior of monsoon and uncontrolled exploitation of ground water (1 m per year over the last 20 years) caused scarcity of water resources (Perveen *et al.* 2012). The scarce water resources in the country necessitate its economic use which will be possible only by efficient water management practices by adopting advanced technology of irrigation like micro-irrigation. Among different irrigation method, drip irrigation is often preferred because of its high (90-95%) water application efficiency (Rajput and Patel, 2006**,** Payero *et al.,* 2008 and Anu and Habeeburrahman, 2015), increased water productivity (Yenesew and Tilahun, 2009) and still regulated deficit irrigation through drip technology can helps in developing practical recommendations for optimizing crop water productivity (WP) under conditions of scarce water supply (Schahbazian *et al*., 2007 and Silungwe *et al*., 2010).

Effect of irrigation (drip/surface) on growth components of wheat

Plant growth depends on cell division and cell expansion for which adequate water supply is essential (Singh and Singh, 1977). Further availability of sufficient amount of moisture optimizes the metabolic process in plant cells and increases the effectiveness of the mineral nutrient. Several report stated that there was a progressive and significant increase in growth parameter with increase in method of irrigation, number of irrigation and quantity of water applied (Mahdi *et al*., 1997, Verma *et al*., 2003, Dilip and Madakini, 1993). Dawood and Kheiralla (1994) recorded higher irrigation treatment had significant effect on plant height, leaf area index and dry matter production. Hence plants were taller and healthier due to increase in irrigation level (Hooda and Agrawal, 1987). Drip irrigation method recorded highest plant height, leaf area index and tillers production of wheat as compared to surface check basin irrigation (Mahdi *et al*., 1997). Further, he reported that growth parameters in spring wheat increased significantly with the increase in water application rate, up to 1.0 ET. Malve *et al* (2017) observed that higher level of pan evaporation replenishment from Drip irrigation @ 0.6 to 1.2 Epan produced significantly higher growth parameters, i.e. plant height, leaf area index, number of tillers m^{-2} and dry matter production over its lower level except that the difference between DI - 1.0 and 1.2 Epan was statistically non-significant in 2012-13 and 2013-14, respectively. Likewise, Abd El-Rahman (2009) in Cario, Egypt conducted experiment under drip irrigation with 4 Lph

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drippers on one line (S1), two lines (S3) and 8 Lph drippers on one line (S2), two lines (S4) and revealed that the magnitude of increase in plant height and leaf area index was in order of S3 > S4 >S1. = S2. These results can be ascribed to the maintenance of higher soil water potential contributing favourable plant water balance as compared to other treatments (Mahdi *et al.* 1997; Vijaykumar 2009).

In case of surface check basin irrigation at IW:CPE ratio of 1.0 recorded growth parameters which was on par with 0.8 and significantly superior than 0.6 in Sriganganagar (Bhaliya *et al*., 1983, Singh *et al*., 2003, Kumar *et al*., 1994). Similarly Singh and Bhan (1998) on clay soil of Jabalpur observed that the significant increase in plant height and dry matter production of wheat during 1990-91 and 1991-92 under IW:CPE ratio of 1.2 as compared to 0.3, 0.6 and 0.9. Contrary to this, IW:CPE ratio of 0.8 recorded maximum growth parameters which was at par with IW:CPE ratio 0.6 in clay loam soil of kota (Yadav and Verma, 1991). Further number of irrigation and quantity of water applied had significant effect on growth parameters of wheat. Higher observation was recorded with more irrigation water levels *i.e*. 4 irrigations applied at CRI, tillering, flowering and dough stage of wheat than that of 3 and 2 irrigations in deep sandy soil of IARI, New Delhi (Kibe and Singh, 2003). Similarly result was noted by Brahma *et al*., (2007), Abd El-Ghany (2012), Mohamed (1999), Hassan (2003) and Kassab and El-Zeiny (2005). On the other hand Saren and Jana (2001) revealed that application of 1FC (6 cm) quantity of irrigation water produced maximum plant height, leaf area index and dry matter production and it was the lowest under ¾ FC levels (4.5 cm). Idnani and Kumar, (2012) found maximum leaf area index and dry matter production was found in irrigation scheduling at CRI + 100 mm than irrigation scheduled at CRI + 150, CRI + 200 mm. Bandyopadhyay and Mallick (2003) pointed higher observations of wheat under IW:CPE 1.2 as compared to 0.9 and 0.6 irrigation regime. Irrigation at 50% ASM increased LAI significantly over 25% ASM at all growth stages. Wide precision planting with 60 mm irrigation at both jointing and heading stages (W2) recorded the highest growth observation followed by same planting method with low irrigation treatment (W1: 60 mm at heading stage) than that of conventional planting with high and low irrigation levels (Dandan *et al*., 2013).

Effect of irrigation (drip/surface) on yield components of wheat

Yield components, *viz*. ear m^{-2}, ear length, number of fertile spikelets ear^{-1}, number of grains ear^{-1} and test weight were significantly higher with drip irrigation at 1.0 Epan over the lower levels but it was statistically on par with higher level of irrigation level (DI - 1.2 Epan) in 2012-13 and 2013-14, respectively (Malve *et al*., 2017). These findings are corroborated with the observations by Mahdi *et al.* (1997) with drip irrigation at 1.0 ET compared to deficit irrigation (0.33 and 0.67 ET). Likewise, Abd El-Rahman (2009) highlighted under drip irrigation with 4 Lph drippers on one line (S1), two lines (S3) and 8 Lph drippers on one line (S2), two lines (S4) and recorded more number of kernels ear^{-1} in 4 Lph drippers on one line followed by two lines. In case of surface check basin irrigation, IW:CPE ratio of 1.0 recorded higher yield components which was on par with 1.2 and significantly higher over 0.6 and 0.8 in clayey soil in Junagadh (Bhaliya *et al*., 1983). This is the tune of Singh *et al*. (2003). On the other hand, IW:CPE ratio of 0.6 produced significantly higher yield components which was at par with IW:CPE ratio of 0.8 but it was significantly superior to 0.4 in clay loam soil of Kota (Yadav and Verma, 1991).

Idnani and Kumar (2012) recorded maximum number of ear m^{-2} and grains ear^{-1} with irrigation scheduled at CRI + 100 mm CPE as compared with CRI + 150mm CPE (40.1), CRI + 200 mm CPE (38.4). Similar kinds of observation was recorded under 1 FC irrigation depth than that of insufficient irrigation water applied at 3/4 and 3/2 FC and over irrigation 2 FC were not conductive for proper crop growth and development (Saren and Jana, 2001). Crop receiving 4 irrigations at CRI, maximum tillering, boot and milk stage produced significantly more fertilizer spikelet ear^{-1}, grains ear^{-1} and test weight than that receiving 2 and 3 irrigations only in sandy loam soil of Ranchi (Verma *et al*., 2003). Similarly, Brahma *et al*. (2007) conceived that significantly higher yield compoenent was recorded in 5 irrigation treatment but it was on par with 3 and 4 irrigation. These results are in accordance with the findings of Mohamed (1999), Sharan *et al*. (2000), Abo-Warda (2002) and Hassan (2003) and Abd El-Ghany *et al*. (2012).

Effect of irrigation (drip/surface) on grain yield of wheat

Many studies have shown that irrigation method (micro-irrigation and surface check basin), irrigation levels (deficient and surplus) and number of irrigation affects the grain yield of wheat (Rao *et al*., 2014, Malve *et al*. 2017, Verma *et al*., 2003). Kamilov *et al*. (2004) stated that drip irrigation increased grain yield of winter wheat by 4.9 to 6.9% in comparison to furrow irrigation. Drip irrigation at 100 ETc recorded highest grain yield of wheat as compared with deficit irrigation levels (60% ETc) but it was at par with 80% ETc (Clinton *et al*., 2005). Similarly, Malve *et al.,* (2017) and Mahdi *et al*. (1997) reported same results with drip irrigation scheduled at 1.0 ET and compared to deficit irrigation levels. Further, laterals spacing and number of laterals in drip irrigated wheat had significant impact on grain yield of wheat. Abd El-Rahman (2009) conducted an experiment on wheat in Cario, Egypt under drip irrigation with 4 Lph drippers on one line (S1), two lines (S3) and 8 Lph drippers on one line (S2), two lines (S4), the results revealed that the magnitude of increase in grain yield, straw yield and biological yield was $S_3 > S_4 = S_2 > S_1$.

Likewise, in case of surface check basin irrigation at IW:CPE ratio of 1.0 recorded higher grain yield of 32.2 q ha^{-1} which was statistically at par IW:CPE ratio of 1.2 but significantly superior over lower ratios of 0.6 and 0.8 in clayey

soil of Junagadh (Bhaliya *et al*., 1983). Significantly higher grain yield of wheat at 1.2 IW:CPE ratio indicated that frequent irrigation was essential for obtaining good yield in sodic soil. These results confirm with those of Gupta *et al*. (1990), Bandyopadhyay and Mallick (2003) and Parihar and Tiwari (2003). In the same line, Kiani and Abbasi (2009) highlighted that 100 and 125% of crop water requirement recorded higher grain yield of wheat (4777 and 4839 kg ha^{-1}) and it was followed by 75 and 50% CWR in surface irrigation method. Singh *et al*. (2003) at Sriganganagar, irrigation applied deficit irrigation at 0.6 or 0.9 IW:CPE ratio gave significantly lower yield than in former irrigation schedules (IW:CPE ratio of 1.0 and 1.2). The results collaborated with the findings of Singh and Bhan (1998) and Kumar *et al*. (1994).

On the other hand in surface check basin irrigation systems, increasing number of irrigations increased the grain yield progressively and significantly over no irrigation. Crop receiving 4 irrigations at CRI, maximum tillering, boot and milk stage gave 13.7 and 29% more grain yield than crop grown with 3 irrigations (CRI, boot and milk) and 2 irrigation (CRI and boot) in sandy loam soils of Ranchi (Verma *et al*., 2003). This finding was in consonance with Pal *et al*. (2001) in sandy loam soil of Ranchi in Jharkhand, in deep sandy soil of IARI, New Delhi (Kibe and Singh, 2003). Similarly, irrigation scheduled at five critical growth stages (I_5) resulted in significantly higher grain yield (2545 kg ha^{-1}) over I_1, I_2 and I_3 irrigation scheduling but was on par with I_4 irrigation scheduling (Brahma *et al*., 2007). These results are in corroboration with those of Mallick *et al*. (1981), Tomar *et al.* (1993) and Abd El-Ghany *et al*. (2012)**.** Pandey *et al*. (2000) demonstrated that when deficit irrigation during the vegetative period was imposed, grain yield was reduced by 7 to 11%. However, 20 to 45% increase in grain yield of spring wheat by reducing irrigation by 30 to 60 mm during the jointing stage (Kang *et al*., 2002). Zhang *et al*. (2006) demonstrated that grain yield, harvest index and water use efficiency greatly improved under regulated deficit as compared to the non-stressed treatment.

Effect of irrigation (drip/surface) on Nutrient Uptake of wheat

Irrigation along with nutrient application had profound influence on the concentration and uptake of nutrients both in grain and stover yield of wheat. There was a progressive and significant increase in NPK uptake with increase in irrigation levels (drip and surface check basin). Malve *et al.,* (2017) stated that drip irrigation at 1.0 Epan recorded significantly highest NPK uptake as compared with 0.6, 0.8 Epan and surface check basin irrigation at IW/CPE 1 treatment. These results are in consonance with the finding of Shaymaa *et al. (*2009) opined that more nutrient content and uptake due more dry matter production in higher irrigation level. This was due to better availability of moisture that maintained the soil always at field capacity and availability nutrients throughout the growth stages in drip system leading to better uptake of nutrients. However, Parihar and Tiwari (2003) revealed that N content decreased in grain and straw, while P and K content increased with the increase in number of irrigations from 0.6 to 1.2 IW:CPE ratio. Higher N content under lower moisture regime may be attributed to lower total dry matter (grain and straw). On the other hand, P and K content increased under wetter treatment owing to greater availability of these nutrients than at lower levels of soil moisture. Reddy and Shastry (1983) attributed reduced uptake of phosphorous and potassium under restricted moisture supply to their reduced mobility at low moisture level. Since total biomass was significantly more with higher moisture regime, total nutrient uptake was increased as compared to lower moisture regime. Similarly, 50% of depletion of ASM shows higher N and K concentration and uptake in grain and straw. However, P concentration and uptake was more in grain and less in straw than that of 65% depletion of ASM (Singh and Singh, 1983). Contrary to this, the highest uptake of N, P and K in grain and straw recorded with irrigation up to 1 FC and the lowest observed under ¾ FC irrigation (Saren and Jana, 2001).

Water productivity

Generally water productivity decreases with increases in irrigation as yield gain is less than proportional increase in ET. Drip irrigation recorded highest water productivity over surface check basin irrigation method (Lokhande *et al.,* 2019 and Bhowmik *et al.,* 2018, Malve *et al.,* 2017, Abd El-Rahman, 2009**,** Liao *et al*., 2008 and Sivanappan 2004,). However, water productivity decreases with increases in irrigation as yield gain is less than proportional increase in ET. Malve *et al.,* (2017) noted that application of water through drip at DI - 0.8 Epan registered highest water productivity (1.02 and 1.11 kg/m3) which was superior over 0.6, 1.0 and 1.2 Epan. These findings are in agreement with (Mahdi *et al.* 1997, Clinton *et al.* 2005). Likewise, Arora *et al.* (2007) highlighted water productivity of wheat decreases with increase in irrigation at high initial soil water (75% EW), while at low initial soil water (25% EW), water productivity increase from no irrigation to partial irrigation regime and decrease thereafter with more irrigation. The water productivity curve exhibits a negative correlation and the results indicate that reduced water application increase water productivity. This means that the water productivity indices were influenced by irrigation strategies and deficit irrigation effectively boosted productivity of irrigation water.

Kamilov *et al*. (2004) stated that drip irrigation resulted in saving up to 22% of irrigation water and increased the WP by 10.1 to 35% in comparison with furrow irrigation at irrigation Total water use efficiency (TWUE) and irrigation water efficiency (IWUE) for grain yield under drip irrigation were considerably greater at 0.33 ET than for other rates, whereas TWUE and IWUE for dry matter yield followed the order 0.33 ET > 1.0 ET > 0.67 ET > 1.33 ET > 0 ET (Mahdi *et al*., 1997). Sandhu *et al.* 2019 reported that Drip irrigation with residue retention increased irrigation water productivity by 259% in maize and 66% in wheat compared to furrow irrigation. Mostafa *et al.* (2018) investigated on effect of

lateral arrangement and irrigation intervals on WUE of wheat in clay soil in arid condition of Egypt. He stated that highest value of water use efficiency of grain yield was 7.4 at 8-day followed by 6.62, 5.50 and 1.58 kgm^{-3} for 12-day, 4-day and surface irrigation, respectively performed for double lines a bed with water saving 6.7% and 65% compared to 12-day and surface irrigation respectively. At Sriganganagar the water use efficiency decreased with increase in irrigation levels and the highest WUE was observed in IW:CPE ratio of 0.6 (8.9 and 7.25 kg ha^{-1} mm^{-1}) as compared to 0.8 and 1.0 IW:CPE ratio (Singh *et al*., 2003). Mishra *et al*. (1994) in sandy loam soil of Ambikapur (MP), revealed that the water consumption was the highest under 1.0 IW:CPE ratio followed by 0.75 and 0.50 but water use efficiency was maximum in 0.75 IW:CPE ratio during 1986-1987 and 0.50 IW:CPE ratio during 1987-88. IW:CPE of 0.50, 0.75 and 1.00 caused decreasing pattern in water use efficiency and the WUE acquired from IW:CPE of 0.75 and 0.50 increased about to a tune of 20.6 and 43.6% as compared to that of IW:CPE ratio of 1.0 (Nasseri and Fallahi, 2007). Parihar and Tiwari (2003) found higher water use efficiency under lower IW:CPE ratio (73.10 kg ha^{-1} mm^{-1} at 0.6) followed by 0.9 and 1.2 IW:CPE ratio (63.65 and 59.22 kg ha^{-1} mm^{-1}). Similarly, Singh *et al*. (1981) concluded that water use efficiency decreased from low IW:CPE ratio (126.3 to 142.8 kg ha^{-1} mm^{-1} at 0.6) to high IW:CPE ratio (82.2 to 98.5 kg ha^{-1} mm^{-1} at 1.05). Similar results were reported by Jat and Das (1983) and Agarwal *et al*. (2000).

Water requirement

The rate of consumptive water use (mm day^{-1}) increased with crop age and reached its peak during first fortnight of February (boot to flowering) and declined thereafter indicating that the boot to flowering period of wheat growth must match its adequate irrigation supply. Water use rate at different growth stages depends not only on the transpiration but also on the evaporative demand of the atmosphere (Pal *et al*., 1996, 2001). A field experiment was conducted by Abd El-Rahman (2009) on wheat in Cario, Egypt under drip irrigation with 4 Lph discharge rate drippers on one line (S1), two lines (S3) and 8 Lph drippers on one line (S2), two lines (S4), the results revealed that the magnitude of increasing the consumptive use of water (m^3/fed) was $S_4 > S_2 > S_3 > S_1$ treatments. Similar results were obtained by Ehdaie (1995) and Allen *et al*. (1998). Mahdi *et al*. (1997) reported that drip irrigation at 70-70-60% FC consume less amount of water (202 mm) and saved 22% of water than furrow irrigation at 70-80-70% FC (248 mm).

Panda *et al*. (1988) at Chiplima, in sandy loam soil of Uttar Pradesh revealed that the consumptive use of water varied from 25.65 to 33.81 cm within the range of moisture regime from 0.6 to 1.0 IW:CPE ratio. The highest water requirement of 33.18 cm, 37.33 cm and 37.91 cm were recorded from the treatment where irrigation was applied at 1.0 IW:CPE ratio during 1980, 1981 and 1982 respectively. Optimum water requirement was about 35 cm. However, a ratio of 1.0 IW:CPE with 6 cm depth of irrigation was recommended as optimum for scheduling of irrigation to wheat after the first irrigation applied at the CRI stage in the sandy loam soil of Roorkee, UP (Singh *et al*., 2012). In 1998-99, the water use was 30.2, 36.1 and 42.2 cm water and with the soil moisture regime of IW:CPE ratio 0.6, 0.8 and 1.0 respectively and in 1999-2000 it was 33.1, 39.1 and 39.1 cm water in Sriganganagar (Singh *et al*., 2003). Similarly, Singh *et al*. (1981) also opinioned that 18 to 24 cm water consumption with 0.60 IW:CPE ratio and 32 to 40 cm with 1.05 IW:CPE ratio and Parihar and Tiwari (2003) 49.39 cm water use (IW:CPE ratio 1.2) than 29.70 cm (IW:CPE ratio 0.6) and 39.86 cm (IW:CPE ratio 0.9). Likewise, 120% of crop water requirement produced maximum grain yield with seasonal water use of 468 mm followed by 100, 80% of crop water use and the lowest in 60% crop water use with 278 mm of seasonal water use in Pakdaht, Iran (Montazar and Azadegan, 2012). Shao *et al*. (2009) observed that seasonal water use of winter wheat under limited water supply had range of 330-340 mm in 2002-03, 470-520 mm in 2003-04, 340-390 mm in 2004-05, 310-330 mm in 2005-06 mm and 390- 440 mm in 2006-07. Likewise, 323 mm with five irrigation schedule (I_5) was more due to frequent irrigation closely followed by 300 mm (I_4), 256 mm (I_3), 216 mm (I_2) and 158 mm (I_1) irrigation schedule was reported by Pal *et al*. (1996).

CONCLUSION

The efficient use of water by modern irrigation system is becoming increasingly important in Arid and Semi-arid region with limited water resources. To mitigate the water scarce condition in agricultural crop, resorting to the scientific water management is one the best alternative rather indiscriminate use of precious resource. Use of modern technology backed up by scientific knowledge will definitely enhance the crop productivity, water productivity and also leads to to maintain the soil health at optimum conditions. The outcome of this review paper is useful to draft guidelines on irrigation scheduling (drip and surface method) for scientist, farmers, stakeholders and policy makers under different models for profit maximization and resource conservation.

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