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Irrigation scheduling through drip and surface methods- A critical review on growth, yield, nutrient uptake and water use studies of *rabi* maize

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ABSTRACT

Water is the prime natural resource, which is often costly and limiting input particularly in arid and semi arid regions, hence needs judicious use to reap the maximum benefit from this limiting resource. Indian farmers are now finding ways to shift from traditional practices to more modern technologies for crop production. Of late, drip irrigation is receiving better appreciation, acceptance, and adaption and plays an important role in saving the water in water scarce areas. It enables the efficient use of limited water with higher water use efficiency. Adaptation of drip irrigation in *rabi* maize which is one of the amenable crop for drip irrigation system is gaining momentum because of its higher productivity coupled with higher price. Irrigation application can be reduced by 50 to 80 per cent with drip irrigation compared to surface irrigation. Further, drip irrigation has the potential for improving two of the most common contributing factors to N leaching – over fertilization and over irrigation. Therefore, optimum irrigation levels with suitable method would help in enhancing the economic yield as well as water use efficiency of maize crop.

Key words: Drip irrigation, Growth, Maize, Nutrient uptake, Water use studies, Yield.

Efficient use of water in any irrigation system is becoming important particularly in arid and semi arid region where water is limited commodity. In surface irrigation methods loss of applied irrigation water is huge through seepage/percolation and evaporation besides leaching of nutrients (Pandey and Sinha, 2006). Under conventional check basin irrigation method the fluctuations in soil matric potentials are relatively large as compared to high frequency (1-2 days interval) drip irrigation. The benefits of drip irrigation may include better crop survival, minimal yield variability and improved crop quality. The drip irrigation was characterized by low rate of water application over a long period of time at frequent intervals into the plant root zone. In drip system, only a fraction of the soil surface is wetted (generally 15-60%) as water is applied precisely and directly in the root zone without wetting the entire surface area (Rao *et al*., 2014). Maximization of crop yield, quality and minimization of leaching loss of nutrients could be achieved by using drip irrigation (Yaghi *et al*., 2013). There was 18-42% saving of irrigation water and 35-103% increase in irrigation water use efficiency (IWUE) with drip irrigation compared to furrow irrigation in maize crop was noticed by Ibragimov *et al*. (2007). Presently, drip irrigation is considered as one of the important component in precision farming. Its usage has been expanded not only to the wide spaced and economically important crops but also to close row crops such as cabbage, potato, wheat, rice etc., in water scarce areas. Paired row planting can be adopted for installing the drip irrigation which enables considerable reduction in the cost of laterals required and also to economize irrigation water without any reduction in recommended plant population (Anonymous, 1995).

Effect of scheduling drip and surface irrigation on growth components of maize: The increase in amount and frequency of irrigation in maize increased the plant height (Kadasiddappa, 2015). Maximum plant height and LAI was recorded when drip irrigation was scheduled at IW/CPE ratio of 1.2 followed by IW/CPE ratios of 1.0 compared to surface irrigation in maize (Sharan, 2012). Further, Bharati *et al*. (2007) reported that the maximum plant height and dry matter of maize were recorded when irrigation was scheduled at IW/CPE ratio of 1.2 compared to 1.0 and 0.8. On the other hand, Shinde *et al*. (2009) showed that irrigation scheduled at 0.8 IW/CPE ratio recorded significantly higher plant height, LAI and dry matter of maize over scheduling of irrigation at critical growth stages. Similarly, Aujla *et al*. (1987) observed that in winter maize irrigation scheduled at 0.9 and 0.6 IW/CPE ratio produced 7 to 9 cm shorter plant length as compared to IW/CPE ratios of 1.0 and 1.2.

Leaf development and expansion of corn has been shown extremely sensitive to water deficits (Mansouri-Far *et al*., 2010) and reduction in leaf expansion was noticed well before leaf photosynthesis reduced (Boyer, 1970).

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Despite the sensitivity of leaf area expansion to water stress, the final number of leaves produced is unaffected by mild water deficits but leaf appearance may be delayed to some extent (Bennett and Hammond, 1983). Once maximum leaf area has been achieved, stresses occurred during reproductive phase may cause loss of green leaf area through rapid senescence of leaves (Musick and Dusek, 1980). LAI of corn was very low in the first part of the vegetative stage, followed by an intensive increase during tasseling and ear formation and maximum LAI was associated with higher irrigation levels (Cakir, 2004). Oktem (2008) reported maximum LAI (3.85-4.20) and taller plants at full irrigation (100% Epan) whereas the lowest LAI at 30% water deficiency in sweet corn. Similarly, Bozkurt *et al*. (2011) found maximum LAI in plots with irrigation scheduled at 120% Epan (5.4) and minimum in 20% Epan (3.1) at the time of maize harvest. Nandal and Agarwal (1991) revealed that in winter maize significantly higher LAI and dry matter accumulation was attained with scheduling of irrigation at 75 mm CPE as compared to other lower irrigation frequencies i.e. 100 mm and 125 mm CPE. Kadasiddappa, (2015) observed that scheduling of irrigation at 100% Epan in maize resulted in higher mean plant height (227.15 cm), number of leaves plant^{-1} (13.80), LAI (5.80) and dry matter plant^{-1} (279.65 g) over 40% and 60% Epan in sandy clay loam soil of Hyderabad during *rabi* season. Similarly, Balaswamy *et al.* (1986) also observed that the growth characters like plant height, number of functional leaves and shoot dry matter production (228.94 cm, 13.29 and 288.43 g/plant, respectively) was higher in maize due to scheduling of water at 40% ASMD over 60% and 80%in sandy clay loam soil of Hyderabad.Increasing moisture stress resulted in progressively less leaf area, crop growth rate, plant height, shoot dry matter and harvest index (Pandey *et al.*, 2000). Hussaini *et al.* (2001) in Nigeria noticed maximum dry matter, plant height, crop growth rate and relative growth rate (96.3 g/plant, 171.0 cm, 85.1 g/m^2 per week and 610 mg/g per week, respectively) with scheduling of irrigation at 1.0 IW/CPE ratio over 0.6 and 0.8 ratios during *rabi* season in maize crop.

Irrigation has the most profound effect on dry matter production and partitioning into different plant components (Payero *et al.*, 2008). The increase in irrigation frequency and irrigation levels increased significantly the dry matter accumulation and LAI (Sanjeev *et al.*, 2006). Further, the increase in maize dry matter yields with increasing evapotranspiration ranged from 11.5 to 31.8 t/ha (Bozkurt *et al*., 2011) and 33.5 to 48.4 t/ha (Yazar *et al*., 2002). Providing irrigation water at 1.0 IW/CPE ratio produced maximum dry matter of maize followed by 1.2, 0.8 and 0.6 IW/CPE ratios (Kasele *et al*., 1994). The biomass production recorded at 60, 40, 20 and 0 per cent water deficit were 0.684, 0.728, 1.049 and 1.378 kg/m^2, respectively in maize (Silungwe *et al.*, 2010). Water deficit at any time during reproductive phase *viz.*, tasseling, silking, pollination and kernel development can reduce photosynthesis (Boyer, 1970), and the translocation of photosynthates resulting in lower seed dry matter accumulation, even though leaf and stem dry matter accumulation was at acceptable levels during earlier vegetative period (Farre and Faci, 2009).

Effect of scheduling drip and surface irrigation on yield components of maize: Scheduling of irrigation at 0.8 to 1.0 IW/CPE was found to be beneficial for cob length over either lower or higher level of IW/CPE ratios (Tyagi *et al*., 1998). Yield components of maize like cob length, cob girth, number of grains per cob, 100 grain weight were found higher with drip irrigation scheduled at 1.0 Epan compared to surface method (Sharan, 2012 and Kadasiddappa *et al*., 2016). Oktem and Oktem (2009) reported that cob length, number of grains per cob and weight of single fresh cob were highest at 100% Epan whereas, the lowest values were observed at 70% Epan and concluded that deficit irrigation up to 20% (80% Epan) was acceptable for sweet corn production in the South Eastern region of Turkey. Any water deficits imposed at silking have been shown to cause delay in silking and inhibition of pollination resulting in considerable reduction in number of grains per cob (Rajendrakumar *et al*., 1996).Water deficits during grain development period caused increased leaf senescence, reduced photosynthate supply to grains resulting in reduced grain size and weight (Mansouri-Far *et al*., 2010). Grains at the tip of the cob were poorly developed when water deficits coincide with grain development period (Sridhar *et al*., 1991). Alemi (1981) reported that the water stress imposed in maize reduced 1000-grain weight by 8% as compared to non-stress condition.

Effect of scheduling drip and surface irrigation on grain yield of maize: Increase in irrigation frequency in *rabi* maize increased the grain yield significantly (7.46 t/ha) with the drip irrigation scheduled at 1.0 Epan coupled with fertigation of 100% RDF with water soluble fertilizers (Ramulu *et al*., 2010). Study carried out by Kadasiddappa *et al.* (2016) revealed that the grain yield increased with increase in water level from 40% Epan to 100% Epan and then declined with an additional water application (up to 120% Epan) through drip. The increase in yield was to the tune of 172% and 39% higher with 100% Epan compared with irrigation scheduled at 40% and 60% Epan, respectively. And it was 37% higher than the surface furrow irrigation method. Vishwanatha *et al.* (2002) revealed that sweet corn yield increased with drip irrigation scheduled at 0.8 Epan and resulted in higher green cob yield (27.97%) over drip irrigation scheduled at 0.4 Epan. Bozkurt *et al.* (2011) indicated that irrigation with 120% pan evaporation replenishment by a drip system resulted in highest cob yield (10.4 t/ha) over 20% of Epan. Mahdi *et al.* (2003) observed maximum grain yield with

scheduling of irrigation at 1.0 ET over 0.6 and 0.8 ET in sandy loam soil at Yuma. Oktem, (2008) obtained the highest fresh maize ears (14.76 and 14.17 t/ha) when irrigation scheduled at 100% Epan and minimum fresh maize ears (9.15 and 8.84 t/ha) at 70% of Epan during 1998 and 1999, respectively. Ramah *et al*. (2009) reported that drip irrigation at 100% and 75% water requirement (WR) coupled with 125% RDF drip fertigation increased the maize yield to the tune of 60.5% and 59.7%, respectively, compared to surface method of irrigation. The mean grain yields of maize increased with increasing water use which resulted in 2.67, 3.62, 3.89, and 4.7 t/ha grain yield at 60, 40, 20 and 0% irrigation water deficits respectively, in drip irrigated maize (Silungwe *et al.*, 2010).

Effect of scheduling drip fertigation on nutrient uptake: In drip fertigation, fertilizer use efficiency was 90% compared to 40-60% observed in surface irrigation with conventional fertilization (Hou *et al.*, 2007). Moreover, fertigation maintained high concentrations of nutrients at top layer of the soil from where plants absorbs maximum water along with nutrients and thus increased nutrient use efficiency (Hebbar *et al*., 2004). Fertigation enabled adequate supplies of water and nutrients with precise timing and uniform distribution to meet the crop nutrient demand (Bar-Yosef *et al*., 1989) and it also enhanced the overall root activity, improved mobility of nutrients and their uptake (Taha, 1999), but, required quantity of fertilizers should be applied before 71 DAS for maize crop, otherwise it reduces the N uptake by the plant (Binder *et al*., 2000). In a study conducted by Kadasiddappa, (2015) wherein the designed fertigation schedule at various ontogeny of the crop (Table 1) through drip irrigation resulted in realizing higher growth and yield parameters of maize crop as compared with the conventional application of fertilizes to soil. The total duration of the crop was divided in to five sub stages and based on the crop growth stages, fertilizers rate was designed. The yield obtained with the designed schedule was 8456 kg/ha^{-} as compared to 6003 kg/ha obtained under conventional application method. Fertigation of N, P and K (100% RDF with water soluble fertilizers) resulted in higher availability of all the three major nutrients in the soil solution which led to higher uptake and better translocation of assimilates from source to sink thus in turn, increased the maize yield (7309 kg/ha) when compared to surface irrigation (4720 kg/ha) with same dose of conventional fertilizers supplied to soil (Anitta and Muthukrishnan, 2011).

Maize is a high resource user in terms of both water and nutrients and the integrated management of these two resources through drip method could result in substantial increase in yield besides saving of both the resources. Drip irrigation coupled with nitrogen fertigation was reported to result in better nutrient uptake, nutrient use efficiency and nutrient content over broadcast and side dressing (Kumar and Pandian, 2010). Increased frequency of irrigation did not influence the N and P content in the grain and stover of maize but had a significant influence on the nutrient uptake of the crop (Banga *et al*., 1998). Frequent irrigation coupled with increasing levels of nitrogen, phosphorus application resulted in increased concentration and nutrient uptake in maize crop (Hussaini *et al.*, 2008). Kumar *et al*. (1999) observed that irrigating the maize at 0.75 IW/CPE ratio was found to be beneficial in nutrient release, thereby greater uptake of nutrients which ultimately resulted in increased grain yield and also higher water use efficiency. In corn Lamm *et al*. (2004) stated that irrigation should be scheduled at 75% of crop evapotranspiration (ETc) in order to realize higher yield (13.4 Mg/ha), apparent N use efficiency and WUE through subsurface drip irrigation. Multiple split application of N in a cropping season at different growth stages resulted in realizing higher seed N uptake and concentration in corn compared to early concentrated application (Tarkalson and Payero, 2008).

Effect of scheduling drip and surface irrigation on water requirement and et of maize crop: Optimization of water applied to the crops by drip irrigation is very essential as yields of the crops are adversely affected either with excess or deficit water supply. Crop water use varies substantially during the growing period due to variation in crop canopy and climatic conditions. The prediction of ETa and crop coefficients (Kc) as a function of growth period is very much important for determining crop water use and scheduling irrigation at regional level (Allen *et al.*, 1998). Maximum yield in maize depends upon the availability of adequate quantity of water, especially in areas where production suffers due to scarcity and/or irregular distribution of rainfall.

The irrigation water requirement of maize generally varies according to evaporative demand and rainfall of that

Table 1: Designed fertigation schedule for maize crop.

Crop stage	Duration (Days)	N (kg/ha)	%	P_2O_5kg/ha	%	K_2O kg/ha	%
Germination & emergence	0-10	8	5	20	20	-	-
Early vegetative development	11-30	32	20	30	40	15	25
Grand growth	31-55	56	35	30	40	15	25
Tasseling &silking	56-75	48	30	-	-	15	25
Grain development	76-90	16	10	-	-	15	25
Total	0-90	160	100	80	100	60	100

(Kadasiddappa *et al*., 2013)

region (Bowman *et al.,* 1991). Javaid *et al.* (2009) reported that the total ET_c for maize crop calculated for the whole growing season by pan evaporation method was 450 mm and daily crop evapotranspiration from date of sowing to harvest indicated that it was initially low, increased gradually up to the mid stage and decreased towards maturity. Kadasiddappa *et al.* (2013) reported that ET_c for maize crop calculated for the entire growing season by pan evaporation method was 351.65 mm and maximum yield (8456 kg/ha) was obtained when irrigation was scheduled at 100% Epan replenishment through drip irrigation at Hyderabad. At Karnal the average daily ET_c of maize varied from 2.8 mm/day in the early growing period to 4 mm/day at development and reproductive stages and 7.7 mm/day at silking stage and the measured seasonal ET_c was 354 mm (Narendra *et al.*, 2003). The water requirement of maize crop ranged between 436 to 441 mm when water was scheduled at 0.4 IW/CPE ratio during *rabi* season (Jadhav *et al.,* 1994). Similarly, maximum maize yield was realized when irrigation scheduled at 0.75 IW/CPE ratio with total seasonal water use of 304 mm during summer season in silty clay loam soil of Kashmir valley (Khan *et al.,* 1996). Vishwanatha *et al.* (2000) noticed that higher yield (200.7 q/ha) of sweet corn at 0.8 Epan with total water use of 517 mm over 0.4 Epan and 0.6 Epan (330 and 424 mm, respectively) during summer in red sandy loam soil at Bangalore. Tekin and Cigdem (2008) stated that the average seasonal water use values in drip irrigation ranged from 257 to 285 mm and the maximum and minimum values were associated at 50% and at 30% ASW treatments, respectively in corn. Oktem *et al.* (2003) indicated that drip irrigation scheduled at 2 days interval with 100% ET replenishment which consumed 1008 mm of seasonal water found optimal for sweet corn grown in semi-arid region of Turkey. The seasonal water requirement of maize was found to vary (200 to 600 mm) depending on the location, soil type, season, variety, irrigation schedules, crop growth stage and amount of rainfall (Mahdi *et al.,* 2003). Payero *et al.* (2008) revealed that when drip irrigation treatments scheduled between 53 to 356 mm and 22 to 226 mm resulted in seasonal crop ET of 580-663 mm and 466-656 mm, respectively in two consecutive *rabi* seasons and yields between treatments differed by as much as 22% to 55%.

Effect of scheduling drip and surface irrigation on water productivity/water use efficiency: The efficient use of water by modern irrigation system is becoming increasingly important in arid and semi arid regions with limited water resources (El- Hendaway *et al.*, 2008). Highest WUE will frequently occur at relatively dry or deficit irrigation treatments having less than the highest economic yields. In a survey conducted in west Asian region during 1995 to 2000 revealed that 30 to 50% of irrigation water can be saved under drip irrigation compared with conventional irrigation practices without sacrificing crop yield or quality in annual crops (FAO/IAEA, 2002). Reduction in water consumption due to drip method of irrigation over the surface method of irrigation varied between 30 to 70% and productivity gain in the range of 20 to 90% for different crops (Anitta and Muthukrishnan, 2011). Highest WUE was obtained with the suboptimal irrigation levels through drip than full irrigation levels throughout the crop growth period in maize (Couto *et al.,* 2013). Vishwanatha *et al.* (2000) reported that drip irrigation levels significantly influenced sweet corn yield and recorded 40.04 kg/ha-mm of WUE with drip irrigation at 0.4 Epan over weekly surface irrigation at 0.8 Epan with a water saving of 187.36 mm.

Kadasiddappa *et al.* (2013) reported that mean water use efficiency increased with concurrent increase in water application from 40% Epan (234.2 mm) to 80% Epan (382.4 mm) and further increase in water application to 120% Eapn (530.6 mm) decreased the water use efficiency. The highest water use efficiency recorded was 22.4 kg/ha-mm at 80% Epan and lowest was 11.7 kg /ha-mm at surface irrigation scheduled at 1.0 IW/CPE ratio in maize. However, Payero *et al.* (2006) found no increase in WUE in the semi-arid environment of the US Great Plains with deficit irrigation. On the other hand, Liu *et al.* (2002) opined that reducing the soil evaporation could increase the WUE of summer maize, since the soil evaporation comprises about 30% of total evapotranspiration. Anitta and Muthukrishnan (2011) observed higher WUE (23.8 kg/ha-mm) and water saving up to 32 to 43% in drip fertigated maize with 150% RDF compared to surface method of irrigation that had lower values of WUE (9.7 kg/ha-mm). It would be possible to grow sweet corn with deficit irrigation of 10% level and IWUE ranged between 1.36-1.62 kg/m^3 and water saving rate ranged from 10.9 to 31.1% (Oktem, 2008). Irrigation scheduling at 0.8 Epan accompanied by 140 to 250 kg N/ha and plant population of 57000 to 69000 plants/ha is the best management system for optimum WUE (181.9 to 189.3 kg/ha-cm) in corn (Mahdi *et al.,* 2003). Kumar *et al.* (2013b) showed that drip irrigation consumed less water than the conventional surface method of irrigation in maize and WUE increases as water consumption decreases through drip irrigation system which in turn saved water to the tune of 71 to 126 mm and recorded significantly higher WUE in the range of 18.3 to 21.7 kg/ha-mm.

Therefore, to mitigate the water scarce condition in agriculture crop production, resorting to the scientific water management is one of the best alternative rather indiscriminate uses of precious resource. Use of modern technology backed up by scientific knowledge will definitely enhances the crop productivity, water productivity and also leads to maintain the soil health at optimum conditions.

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