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Effect of irrigation (drip/surface) on sunflower growth, seed and oil yield, nutrient uptake and water use efficiency - A review

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ABSTRACT

Water plays an important role in augmenting the growth and development of crop plants in their different stages of ontogeny. Since water is the life line for accruing desired yield levels, its time of application and method of application plays an important role in increasing the yield levels besides saving water. Further, 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. Off late, among irrigation methods, drip irrigation is receiving better appreciation, acceptance, 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. Optimum irrigation levels with suitable method would help in enhancing the economic yield as well as water use efficiency in many field crops including sunflower crop in line with the high value commercial and horticultural crops.

Key words: Drip Irrigation, Growth, Nutrient uptake, Sunflower, Seed and oil yield, Water use efficiency.

The efforts are now needed to harness the available quantities of water and put them to efficient use to realize higher productivity per drop of available water (Solaimalai *et al.,* 2005). Therefore, greater emphasis needs to be given in improving the irrigation practices to increase the crop production and to sustain the productivity levels (Kalpana and Anita, 2014). Adoption of modern irrigation techniques which are simple, easy to operate and increase the efficiency of water usage. 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 Sunflower: Sunflower (*Helianthus annuus* L.) an excellent source of unsaturated fats, has become second most important crop next to soybean in the world. Sunflower being photo insensitive crop grown throughout year in many parts of the world as rainfed crop but responds positively to irrigation with respect to growth and yield where, precipitation and soil water supply are limited. Sunflower is both tolerant to moderate water stress and capable of bearing high yield in response to applied irrigation (Karam *et al*., 2007) but the amount and timing of irrigation are two important aspects which determine the efficient use of applied water and maximizing crop yields (Sezen *et al*., 2011). Limited supply of water necessitates a shift in the production objectives from attainment of potential yield per unit of land to potential yield per unit of water.

Increase in irrigation levels increased the plant height significantly in sunflower (Taha *et al*., 2001). Tan *et al*. (2000) reported that full and limited irrigation applied at different growth stages significantly influenced the plant height in sunflower. Abdel-Gawad *et al.* (1987) concluded that differences in sunflower plant height persisted throughout the growth season and the crop irrigated at 10 - day interval registered significantly superior plant height than 18 - day interval. Kadasiddappa *et al.* (2015b) recorded significantly highest plant height (228.0 cm) when irrigation was scheduled at 100% Epan and 227.7 cm with drip irrigation scheduled at 80% Epan compared to surface furrow irrigation at 100% IW/CPE (200.0 cm) in sunflower. Likewise, several researchers (Nandagopal *et al*., 1996 and Tomar *et al.,* 1997) reported significant and positive influences on sunflower plant height with adequate water supply at different crop growth stages.

Development of adequate leaf area is necessary for interception and utilization of incident radiation and shown

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to be closely related to final seed yield of sunflower (Unger, 1983). Maintenance of leaf area for maximum photosynthetic capacity during seed filling is essential for maximum yields (Rawson and Turner, 1982). Water stress imposed during vegetative period reduced the number and expansive growth of leaves and caused lower LAI (Hasio, 1973). Velu and Palanisamy (2001) and Kassab *et al.* (2012) reported that induction of moisture stress significantly reduced the growth parameters *viz.,* LAI and dry matter accumulation in sunflower. Several workers (Vivek and Chokar, 1992; Dahiphale and Pawar, 1993 and Tomar *et al.*, 1997) were also reported that maintenance of optimum plant water status through adequate water supply significantly improved the leaf area index. It is well documented in sunflower crop that opportunity to reach greater LAI under well watered conditions than that grown under water limitations (Tyagi *et al.*, 2000 and Soriano *et al.*, 2004). LAI of sunflower crop increased gradually from lower values at an early stage to a maximum of 6.0 at 92 DAS under full irrigation and this was 13% more over deficit irrigation (Karam *et al.,* 2007). On the other hand, Sezen *et al.* (2011) recorded greatest LAI in sunflower with full irrigation (7.6 and 8.4 in the sprinkler and drip irrigation systems, respectively) on 90 DAS and the deficient irrigation reduced the LAI in both the drip and sprinkler systems under Mediterranean climatic conditions. In majority of the studies that took under arid and semi arid conditions, the LAI of sunflower was in the range of 2 to 4 (Soriano *et al.*, 2004) and LAI of 5 to 8 were also observed under assured irrigation (drip irrigation) supply (Cabelguenne *et al.*, 1999 and Kadasiddappa *et al.*, 2015b). Thakuria *et al.* (2004) observed that plant height, leaf number, dry matter accumulation, leaf area index and crop growth rate at various intervals in sunflower were improved under irrigated condition. Aziz and Soomro (2001) revealed that all the growth, yield contributing components (plant height, days to maturity, capitulum diameter, seed yield and oil content) were positively influenced by increased irrigation frequencies in sunflower.

Dry matter accumulation in sunflower is a result of leaf and stem growth during vegetative phase, and a combination of capitulum and seed growth during reproductive phase, and irrigation has profound effect on dry matter accumulation during the reproductive phase (Andhale and Kalbhor, 1978). However, Morizet and Merrien (1990) pointed out that the dry matter accumulation is less affected by water stress in sunflower than in other field crops but irrigation moderates the process of leaf senescence towards the maturity (Chamundeshwari and Rao, 1998). Geetha *et al.* (2012) revealed that water deficit during bud initiation stage caused significant reduction in total dry matter (21%) compared to full irrigation irrespective of the genotype tested. Dry matter accumulation increased throughout the growing season in the fully irrigated (drip) sunflower crop till it reaches to head yellow stage and thereafter, slight decrease in dry matter was observed at physiological maturity due to defoliation (Kadasiddappa *et al.*, 2015b).

Effect of Irrigation (drip/surface) on yield components of Sunflower: Water deficits at any one of the reproductive sub periods i.e. flowering, anthesis and seed filling had significant adverse effect on capitulum diameter, yield plant^{-1} and test weight (Reddy *et al.*, 2004 and Geetha *et al.*, 2012). Chimenti *et al.* (2002) reveled that sunflower is highly sensitive to deficit water stress at flowering and seed maturity stages. Several studies indicated that application of water equivalent to pan evaporation produced maximum capitulum diameter with bold seeds (Singh *et al.,* 1995; Khaliq and Cheema, 2005 and Mehmet Oz *et al.,* 2013). Decreasing the amount of irrigation water applied significantly reduced the capitulum diameter, capitulum weight, seed yield plant^{-1}, test weight, seed yield and straw yield and ultimately biological yield (Alahdadi *et al.*, 2011and Kassab *et al.*, 2012). Similarly, Nezami *et al.* (2008) indicated that plant height, stem diameter, capitulum size, number of seeds capitulum^{-1} and test weight declined under arid and semi arid conditions. Farahvash *et al.* (2011) demonstrated that the different levels of water stress reduced the stem width, head diameter, seed weight, seed number, shoot dry weight, seed yield and harvest index (HI) in sunflower. The decrease in the seed yield under deficit water supply was due to decreased sink size and seed weight as a result of lower photosynthetic efficiency and reduced translocation of organic material from source to sink (Amrutha *et al.*, 2007).

The potential number of seeds capitulum^{-1} is closely related to the water supply after anthesis. Water deficits during seed formation and seed filling period have shown to cause significant reduction in number of seeds (achene) per capitulum (Daulay and Singh, 1983 and Human *et al.,* 1990). Babu *et al.* (1993) reported that, scheduling of irrigation at 60 mm and 80 mm CPE produced significantly more number of filled seeds capitulum^{-1} as compared to irrigations at 100 mm CPE and at critical stages. Nandagopal *et al.* (1996) observed significantly higher filled seeds capitulum^{-1} under moisture stress at seed filling and flowering stages in *kharif* and summer seasons.

Test weight of seed is an indicator of seed density and is important with respect to seed yield and quality. Seed filling in sunflower is dependent on the current supply of photosynthate as well as remobilization of previously stored assimilates from leaves and stem (Unger, 1983). Seed size is more influenced by genetic factors than environment except moisture stress. Shortage of water during seed development reduces the seed size resulting in lower yield probably through its effect on the rate of photosynthesis and also by hastening leaf senescence (Reddy and Reddi, 2012).The test weight tended to improve with increase in water supply was also reported by Goksoy *et al*. (2004), Khaliq and Cheema (2005) and Mehmet Oz *et al*. (2013). Harvest indices usually highest when sunflower is adequately irrigated to avoid plant water stress (Karami, 1977 and Connor *et al*., 1985) but excessive irrigation may also promote vegetative growth at the expense of reproductive growth (Unger, 1983). Similar results were also reported by Rammoorthy *et al*. (2009).

Effect of irrigation (drip/surface) on seed yield of sunflower: Many studies have shown that water stress at various growth stages affect the seed yield in sunflower (Tolga and Lokma, 2003 and Kazemeini *et al*., 2009). Velu and Palanisami (2001) stated that water stress could reduce the seed yield up to 29% in sunflower. While, maximum yields were obtained when irrigation was used to provide adequate water during flowering and yield formation periods (Stone *et al*., 1996; Demir *et al*., 2006 and Kazemeini *et al*., 2009). However, adequate water for initial plant growth is important for providing a plant capable of responding to later irrigation (Tolga and Lokma, 2003 and Kazemeini *et al*., 2009). Irrigation levels influenced the growth and yield attributes of sunflower and significant decrease in the seed yield, seed plant^{-1} and oil yield were observed when deficit irrigation levels were applied compared to irrigation at 100% FC (Kazi *et al*., 2002; Tolga and Lokma, 2003 and Kazemeini *et al*., 2009). Irrigated sunflower in semi arid areas has been shown to increase seed yield by 78% in Turkey (Goksoy *et al*., 2004), 33% in Lebanon (Karam *et al*., 2007), 47% in Kansas, USA (Stone *et al*., 1996) compared with non irrigated sunflower crop (Goksoy *et al.,* 2004; Khaliq and Cheema, 2005 and Mehm et Oz *et al.,* 2013). As total irrigation amount through drip increased from 183.2 to 234.7, 234.7 to 286.3 and 286.3 to 337.9 mm, the yield of sunflower was increased by 789.0 kg ha^{-1}, 896.0kg ha^{-1} and 78.0kg ha^{-1}, respectively (Kadasiddappa *et al*., 2015a). Further, Wan *et al*. (2013) cited that the drip irrigation consistently created a favourable soil moisture and low salinity in the root zone when the soil matric potential was maintained higher than -25 kPa and the sunflower seed yield decreased by 3.8% for every unit increase in seasonal average soil salinity in the root zone.

Quantity, amount and distribution of water have significant impact on seed and oil yield of sunflower (Iqbal *et al*., 2005). Taha *et al.* (2001) and Khot and Patil (2002) found that 100-seed weight was linearly increased with increasing the amount and frequency of irrigation. Mahendar *et al.* (2000) and Toll and Howel (2012) reported that seed yield was enhanced with increase in number of irrigations and quantity of irrigation. Wahab *et al*. (2005) reported that the seed yield increased consistently and significantly as total consumptive water increased throughout the growth period under drip irrigation. The seed yield of sunflower was significantly increased (464 and 537 kg ha^{-1}) with 2259 and 2549 m^3 of water use, respectively compared to 409 kg ha^{-1} obtained with 2045 m^3 of water use. Taha *et al*. (2001) reveled that as the frequency of irrigation increased from 0.6 to 1.0 IW/CPE ratio, yield attributes and seed yield increased significantly from 838 to 1190 kg ha^{-1} in sunflower but, further increase in irrigation levels (1.0 to 1.2 IW/CPE ratio) resulted in reduction in the seed yield by 5.13% (1129 kg ha^{-1}). Similar observations were also made by Singh *et al*. (2007) and Kadasiddappa *et al*. (2015a) in sunflower and Kumawat *et al*. (2016) in sugarcane under drip irrigation. The study carried out by Unlu *et al*. (2011) shows that LAI and dry matter production increased with increase in irrigation levels but deficit irrigation (0.75 Epan) resulted in higher HI values indicating that full irrigation to arid and deficit irrigation to semi arid regions are the viable alternatives under water limited conditions.

Effect of irrigation (drip/surface) on oil content and oil yield: The oil content increased parallel to the increasing amount of irrigation water and ranged from 34.3% to 39.1% in non irrigated conditions and 38.5% to 42.7% in irrigated conditions in different varieties (Tan *et al*., 2000 and Flagella *et al*., 2002). Goksoy *et al*. (2004) revealed that highest oil yield (1841 kg ha^{-1}) was obtained with full irrigation compared to non irrigated treatment (979 kg ha^{-1}) and when compared as percentage, full irrigation produced 88% more oil yield per hectare compared to non irrigated treatment.

Sezen *et al*. (2011) reported that the sunflower oil content was significantly reduced with deficit irrigation (DI) levels, wherein, highest oil content of 46.1% was realized with full irrigation compared to 43.6%, 40.0% and 37.9% obtained with DI 75%, DI 50% and DI 25%, respectively. Similar result was also reported by Kassab *et al*. (2012). The oil contents of 47.0%, 41.9% and 35.6% and the oil yields of 254, 196 and 148 kg ha^{-1} were recorded under drip irrigation with the application of 2549, 2259 and 2045 m^3 of water indicating a significant drop in oil percentage with decreased consumptive use of water in sunflower (Wahab *et al.,* 2005). Babu and Kulkarni (1992) recorded 43.38% of oil in seeds with irrigation at 80 mm CPE which was significantly higher than scheduling irrigations at 100 mm CPE (40.73%) and at critical stages (39.8%). Tomar *et al.* (1996) reported that oil content in sunflower increased with increasing levels of irrigation and maximum oil content (42.57%) was recorded when irrigations were scheduled at 0.8 IW/CPE ratio as compared to 0.6 and 0.4 IW/CPE ratio. Similar observations were also made by El-Kalla *et al.* (1998) and Abu-Ghazala *et al*. (2000). Contrary to the above, there are several reports suggesting that irrigation had no significant influence on sunflower seed oil content (Khanvilkar *et al.,* 1987; Shinde *et al.,* 1990 and Singh *et al.,* 1997). On the other hand, Mehmet Oz *et al.* (2013) reported that oil percent was not affected by the irrigation regimes, but oil yield was affected due to difference in the seed yield.

Effect of irrigation (drip/surface) on nutrient up take of sunflower: Irrigation along with nutrient application had profound influence on the concentration and uptake of nutrients both in seeds and stover of sunflower plants (Puste et al., 2013). There was an increase in N content, while P concentration remains unaffected and potassium content shown a decreasing trend both in seeds and stover with increasing in level of irrigation but total uptake of nitrogen and potassium were higher mainly due to the higher stover as well as seed yield of sunflower obtained at higher moisture levels in comparison with moisture stress conditions (Prasad et al., 1999). Nitrogen, phosphorus, potassium and sulphur uptake increased from 88.64 to 101.17 kg N ha-1, 8.34 to 9.05 kg P ha-1, 60.59 to 65.34 kg K ha-1 and 8.86 to 10.01 kg S ha-1, respectively due to increase in water application rate through irrigation scheduling from 0.8 to 1.0 IW/CPE ratio in sunflower (Meti et al., 2004). Thus, irrigation had a profound effect on uptake as well as concentration of nutrients in the plant system leading to higher economic yield.

Water use and water use efficiency of sunflower: Toll and Howel (2012) found that the increase in irrigation level from 25% ET to the 100% ET by 315 mm, increased yield by 87% and seed mass by 54% in first year of study and same increase in irrigation treatment in second year by 390 mm, increased yield by 130% and seed mass by 38%. On the other hand, Demir *et al.* (2006) reported maximum irrigated seed yield of 395 g m^{-2} with 652 mm of ET (0.61 kg m^{-3}) from Turkey and 559 g m^{-2} with 629 mm of ET (0.89 kg m^{-3}) from Lebanon (Karam *et al*., 2007).

Abdou *et al.* (2011) found that the highest ETc values of 532 mm, 527 mm from the of June sown sunflower crop with irrigation scheduled at 1.2 CPE at ARC, Giza, Egypt under clay loam soil conditions. On the other hand, Soriano *et al.* (2004) revealed that delaying sunflower sowing dates led to reduce the seasonal consumptive use and water use efficiency.

Stone *et al.* (1996) inferred that, as the total irrigation amount increased from 100 to 200, 200 to 300 and 300 to 400 mm, sunflower yield increased by 0.53 Mg ha^{-1}, 0.43 Mg ha^{-1} and 0.37 Mg ha^{-1}, respectively. Abdou *et al.* (2011) found highest WUE (0.47 kg m^{-3}) under June sown sunflower crop with 1.2 CPE irrigation level in clay loam soil. The water use efficiency in sunflower is influenced primarily by irrigation method (Rana *et al.,* 2006), irrigation level (frequency or amount) (Kadasiddappa *et al.,* 2015a) and irrigation timing (relative to growth stage). Reported values ranged from 0.09 to 1.37 kg of seed m^{-3} of water use (Unger, 1983). In general, WUE increased as irrigation levels decreased in sunflower (Chamundeshwari, 1993 and Venkanna *et al.,* 1994).

Water use efficiency also depends on the discharge rate of the drip system wherein, lowest WUE (102 kg m^{-3}) was observed with the highest discharge rate (8.0 LPH) as against the WUE of 111 and 121 kg m^{-3} observed at the discharge rates of 4.0 and 2.0 LPH, respectively (Badr and Taalab, 2007). Chandrasekhar (2014) indicated that with the lower the rate of discharge greater will be the WUE in sunflower. Kadasiddappa e*t al*. (2015b) found that in hybrid sunflower irrigating at 80% and 100% Epan ratios gave consistently better performance for yield parameters, yield and WUE during *rabi* seasons due to adequate water supply in these treatments than 40%, 60% and further increase in irrigation water application up to120% Epan decreased the water use efficiency. Similar observations were also made by Abu-Ghazala *et al*. (2000) and Wahab *et al*. (2005).Karam *et al*. (2007) found that WUE increased at deficit irrigation (0.83 kg m^{-3}) than full irrigation treatment (0.74 kg m^{-3}). Toll and Howel (2012) were also noticed significantly highest water productivity with decreased amount of irrigation water. Singh *et al*. (2009) inferred that an increase in irrigation frequency increased the seasonal water use but decreased the water use efficiency. On the other hand, Sezen *et al*. (2011) found water productivity values ranging from 0.39 kg m^{-3} in rainfed to 0.97 kg m^{-3} in the PRD-50 in 2006 and from 0.56 kg m^{-3} in DI-50 to 0.85 kg m^{-3} in the PRD-50 in 2007 and indicated that PRD resulted in greatest water productivity in both the years of study. Thus, the greatest water use efficiency was obtained with suboptimal or deficit irrigation than full irrigation treatment in sunflower.

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