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DRIP FERTIGATION IN VEGETABLE CROPS WITH EMPHASIS ON LADY'S FINGER (*Abelmoschus esculentus* (L.) Moench) – A REVIEW

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ABSTRACT

Water and fertilizer are the two important inputs for agricultural production and are interrelated in their effect on plant growth and yield. Since, water and fertilizer are costly inputs, every effort must be made to enhance water and fertilizer use efficiency by reducing their wastage. In recent years fertigation – a technique of application of both water and fertilizers via an irrigation system was shown to be very effective in achieving higher water and fertilizer use efficiency. In this method both water and fertilizer are delivered precisely in the crop root zone as per the crop needs and according to crop developmental phase. Increased growth and yield with drip irrigation has been reported in several crops and the increase in yield ranged between 7-112% depending on the crops / varieties and method of irrigation compared. The water and fertilizer saving through drip fertigation have been reported to be 40-70 and 30-50 per cent respectively.

The pressure for the most efficient use of water for agriculture is escalating with the increased competition for water resources among various sectors with the burgeoning population. The need of the hour is therefore, to maximize the production per unit of water. This calls for adoption of modern irrigation technologies like drip irrigation, which offers efficient and judicious use of irrigation water (Antony and Singadhupe 2004). Drip irrigation through the trickle supply of water drops continuously keeping the soil moist in the rhizosphere has opened new vistas in the agricultural scenario especially for the horticultural crops (Kumar 2000). The results gathered on the efficiency of this system are highly encouraging mainly because of its substantial saving of water, which is a precious commodity of the nature (Batra *et al.,* 2000). Studies in several horticultural crops revealed that there was saving in water ranging from 40 to 70 per cent and an yield advantage of 7 to 112 per cent due to drip irrigation (Sivanappan *et al.,* 1987). The increased yield under drip irrigation has been attributed to better water utilization (Manfrianito, 1974), decreased salt in root zone (Branson *et al.,* 1974), lower chloride levels (Shmueli and Goldberg, 1971), higher oxygen concentration in root zone and increased growth and development (Doss *et al.,* 1977).

Conventional nitrogen (N) fertilization in light soils causes greater loss of N by leaching and volatilization (Amjad *et al.,* 2001). In recent years fertigation – a technique of application of both water and fertilizers via an irrigation system was shown to be very effective in achieving higher water and fertilizer use efficiency (Nakayama and Bucks, 1986). Fertigation, which combines irrigation with fertilizers, is well recognized as the most effective and convenient means of maintaining optimum fertility level and water supply to the specific requirement of crop and soil (Li *et al.,* 2004). Trickle fertigation is an attractive concept as it permits application of nutrients directly at the site of high concentration of active roots as needed by the crop (Abbott and Ah-Koon, 1992). As fertilizer application is based on crop requirements and limited to effective root zone, it redces the loss of nutrients, thereby increasing the use efficiency to as high as 70 to 90 per cent with a saving of 30 to 50 per cent (Hachum *et al.,* 1976).

Bhindi (*Abelmoschus esculentus* L. Moench) is an important warm season vegetable crop cultivated in India. Adaptability

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to a wide range of soil and climatic conditions, suitability for year round cultivation has made bhindi a popular vegetable (Gowda *et al.,* 2002). Non availability of water during summer season is one of the major constraints in attaining potential yield in this crop (Patton *et al.,* 2002). Scheduling irrigation and nitrogen on basis of crop requirement is a sound criteria for efficient management of these resources (Prabhu *et al.,* 2003).

Farmers generally raise lady's finger under surface method of irrigation (Furrow and Check Basin) wherein losses through conveyance, application, evaporation and percolation are common besides having adverse effects of cyclic over irrigation or water stress (Rao, 1994). Drip irrigation is the most effective way to supply water to the bhindi, which not only saves water but also increases yield due to continuous maintenance of moisture content near field capacity (Gowda *et al.,* 2001). Some scattered research information is available in literature about the use of drip fertigation in bhindi. Therefore, in this article an attempt has been made to bring together the available literature on the above aspect under different heads.

EFFECT OF DRIP IRRIGATION ON

Soil moisture characteristics

Trickle irrigation operates on the basis of a constantly maintained wetted zone around plant roots, moisture distribution in the soil and wetted area under a point source (driper) which are greatly affected by the application rate and duration of irrigation. With lower application rate of 5 l hr^{-1} for longer time (2 hrs / day), the depth of wetting was more when compared to higher application rate of 30 l hr^{-1} for shorter time (20 min./day) (Sivanappan and Padmakumari, 1979). Hachum *et al.,* (1976) reported that under an isolate dripper, the vertical component of wetted zone becomes larger and the horizontal component becomes smaller with decrease in discharge rate, the extent of wetted zone is determined by the emitter spacing (Keller and Karmeli, 1975).

Increase in volume of water application resulted in increased wetted soil volume and discharge rate, reduced vertical movement of wetting zone and increased horizontal movement (Ahluwalia, 1993). Shanke *et al.,* (2003) revealed that with lower discharge rates, the leading edge of wetting profiles were found to have a narrow shape (carrot shape) and become rounded (onion shape) with higher discharge rate (4 -6 l hr^{-1}). The depths attained by the wetting profiles were shallow with wider bulb formation in clay soil and elongated bulb formation in clay loam (Satpute *et al.,* 1992). It is observed that the wetting pattern was more uniform with drip irrigation at low discharge with longer time as compared to high discharge with shorter time (Mane *et al.,* 1986).

Soil moisture content

Hendrick and Wierenga (1990) pointed out that variability in soil water tension was related to the method of irrigation, slow and frequent watering eliminated wide fluctuations in soil moisture under drip irrigation (Sivanappan, 1998). Bucks *et al.,* (1984) reported that the soil water content in a portion of plant root zone remained fairly constant because irrigation water was applied slowly and frequently at a predetermined rate. Black (1976) reported that water content in drip irrigation was always nearer to field capacity in root zone but unsaturated, hence gravitational force was minimum. Water retention curve drawn by Bar-Yosef and Sheikhoslami (1976) showed constant water retention in soil under drip irrigation. Goldberg *et al.,* (1971) observed a reduction in the upper most and lowest layers, the most marked decrease occurred in the region between the nozzles. At other depths in the width and length of the bed, the moisture content was fairly uniform. The uniform moisture content in these layers was probably due to the high moisture content in the middle three layers (above field capacity) and also due to the high hydraulic conductivity of the soil.

Bar-Yosef (1977) studied the effect of different discharge rates of trickle irrigation on moisture distribution in tomato and revealed that before irrigation the moisture content was 3.3 per cent at surface and 6.5 per cent at 46 cm depth. One hour after irrigation the gravimetric water content was 6.9 and 7.6 per cent in surface and 46 cm depth respectively. Bharadwaj *et al*. (1995) reported that the soil water distribution in both 0 to 0.15 m and 0.15 to 0.30 m depths was uniform under drip irrigation and decreased as the soil depth and horizontal distance from the dripper increased. Experiments on drip irrigation in tomato, cabbage, capsicum and watermelon revealed that the soil moisture level in the root zone was near field capacity throughout the crop growth period (Gowda and Gowda, 1990). Shrivastava *et al*. (1994) reported that the available soil moisture in drip and furrow methods of irrigation at 1.0, 0.8 and 0.6 Epan was 92, 75 & 60 and 50, 40 & 25 per cent respectively.

Plant water relations

The transpiration rate of plant is highly correlated with plant water uptake and it also depends on leaf area and stomatal conductivity and has positive and significant correlation with soil moisture content (Vera, 1995). Rao and Bhatta (1988) reported that photosynthetic and transpiration rates decreased when water stress was imposed at vegetative, flowering and fruit formation stages in capsicum. Srinivas and Hegde (1992) reported that the transpiration rate was higher at 100 per cent evaporation replenishment both at vegetative (49.8 mg H_2O cm^{-2} sec^{-1}) and fruiting stages (41.3 mg H_2O cm^{-2} sec^{-1}) in bhendi. In brinjal, higher transpiration rate (14.24 mg H_2O cm^{-2} sec^{-1}) was recorded under drip irrigation was comparable with 100 per cent of Epan followed by 75 per cent of the Epan. In surface irrigation, transpiration rate decreased with increase in the days between irrigations (Bobade *et al*. 2002). Sharnappa et al., (2001) observed higher transpiration rate of 10.38 and 9.11 mg H_2O cm^{-2} sec^{-1}, respectively under drip irrigation equivalent to 150 and 125 per cent of water requirement through furrow irrigation in capsicum. Singadhupe *et al*. (2000) recorded higher transpiration rate (1.3 m mol m^{-2} sec^{-1}) with drip irrigation at 100 per cent pan evaporation as over to surface irrigation at 1.0 IW/CPE ratio (1.27 m mol m^{-2} sec^{-1}) in bitter gourd. In carrot higher leaf water potential of -0.26 MPa was observed at higher available soil moisture (1.2 IW/CPE) Batra and Kalloo (1999). Chartzoulakis and Drosos (1995) in brinjal observed higher leaf water potential (LWP) and stomatal conductance with drip irrigation at 1.00.

Stomatal diffusive resistance (SDR) is an important physiological that responds sharply to any little change in the soil moisture status. It is inversely related to soil moisture content (Hegde, 1989). Horton *et al*. (1982) recorded lower stomatal diffusive resistance (SDR) under higher quantity of water through drip irrigation than in conventionally irrigated plot, in capsicum. According to Gowda et al. (2002) stomatal diffusive resistance was relatively high with increasing water stress in chilli under surface irrigation method. In capsicum, development of water deficit in leaves caused an increase in stomatal diffusive resistance and SDR increased as the stress period prolonged and it ranged between 12-16 sec cm^{-1} upto 8 days as compared to 0.9 to 5 sec cm^{-1} in unstressed plot. (Salvadore et al., 1996). In brinjal, higher SDR value (8.49 sec cm^{-1}) was recorded upto 50 per cent of surface irrigation through drip and less SDR was observed under

75 and 100 per cent of surface irrigation through drip (Narayanaswamy *et al.*, 1996). The fluctuation in SDR was lower in drip irrigation compared to surface irrigation. Lower SDR (3.02 sec. cm^{-1}) was observed under drip irrigation equivalent to 150 per cent of water requirement through furrow irrigation and higher SDR (4.57 to 4.60 sec cm^{-1}) was observed under surface irrigation at 2 to 6 days after irrigation (Patel et al., 1995).

Growth parameters

Drip irrigation at 80 per cent Epan resulted in taller plants, more number of branches, higher leaf area index and dry matter production of bhendi compared to surface irrigation at 35, 60 and 85 mm CPE (Abrol and Dixit, 1972). According to Tiwari *et al.* (1998) drip irrigation to bhendi at 0.6, 0.8 and 1.0 VD (volume of irrigation requirement through drip irrigation) resulted in maximum plant height, Leaf area index, Crop growth rate, Relative growth rate, net assimilation rate and dry matter production over furrow irrigated crop. Punamhoro *et al.* (2003 a) revealed that bhendi irrigated through drum kit and bucket kit system of drip irrigation recorded tallest plants, maximum leaf area, number of branches and dry matter production over rest of the irrigation methods (micro sprinkler, over head sprinkler irrigation, flood, check basin, furrow irrigation).

Yield attributes and yield

Sivanappan *et al.* (1976) reported that drip irrigated bhendi recorded higher early yields (initial harvest) than furrow-irrigated crop. However, the total yield was comparable with each other. Gorantiwar *et al.* (1991) reported that the number of pods $plant^{-1}$, pod length, pod weight and pod yield of bhendi were significantly higher in drip irrigation (water applied at 40, 60, 80 and 100 % wetted area) over furrow irrigation and the increase in yield was 35 to 45 per cent. Drip irrigation at 0.6, 0.8 and 1.0 VD levels resulted in higher yield attributes (pod length and pod weight) and yield in bhendi over furrow irrigated crop and the increase in yield was to a tune of 55 per cent (Mateos *et al.*, 1991). This result indicates that even by 40 per cent deficit water supply through drip irrigation resulted in 45 per cent higher yield over furrow irrigation. Jayakumaran and Nandini (2001) observed no significant difference in yields of bhendi irrigated either through drip system at 20, 50 and 75 per cent evapotranspiration or furrow irrigation at 100 per cent evpotranspiration (40 mm CPE) in heavy black soils.

Water use efficiency (WUE)

Kadam *et al.* (1995) recorded higher water use efficiency (374 kg ha^{-1} cm^{-1}) with drip irrigation over furrow irrigation (214 kg ha^{-1} cm^{-1}). Gorantiwar *et al.* (1994) compared drip irrigation with varying levels of water application (equivalent to 40, 60, 80 and 100 % wetted area) and furrow irrigation with IW/CPE ratio of 0.8, the results of the study revealed that WUE was more in drip irrigation over furrow irrigation. Punamhoro *et al.* (2003 b) studied the performance of bhendi under different irrigation methods viz., drip irrigation with bucket kit and drum kit, microsprinkler, overhead sprinkler irrigation, flood irrigation, check basin irrigation and furrow irrigation. The results of the study revealed that highest WUE of 2.52 q ha^{-1} cm^{-1} was recorded in drip irrigation with bucket kit, while the lowest WUE of 1.06 q ha^{-1} cm^{-1} was noticed with flood irrigation.

EFFECT OF FERTIGATION ON

Growth parameters

Jadav *et al.* (1995) observed tallest plants, more leaves per plant, higher leaf area and dry matter production with the crop fertigated through subsurface biwall drip with 75 % recommended dose of nitrogen (RDN) over band placement of 100 % RDN with furrow irrigation. Drip irrigation with 75 per cent nitrogen resulted in maximum plant height, leaf area, number of branches and dry matter production over band placement of 100 per cent nitrogen through furrow irrigation (Tumbare *et al.*, 1999). Narda and Lubana (1999) conducted trickle fertigation studies with three levels of nitrogen viz., 33.3, 50 and 100 kg N ha^{-1} in 3, 5 & 7 splits respectively and furrow irrigation with band placement of 100 kg N ha^{-1} in 2 splits. The results revealed that the crops with trickle fertigation performed better in terms of growth dynamics viz., plant height, leaf area index, crop growth rate, relative growth rate, leaf area duration, biomass duration, net assimilation rate and dry matter production over furrow irrigated crop.

Yield attributes and yield

Rajput and Patel (2002) at Water Technology Centre, New Delhi conducted a fertigation trial in bhendi with 40, 60, 80 and 100 per cent RDN through drip and 100 percent RDN by broadcasting with furrow irrigation, the results of the study revealed that drip fertigation was superior over broadcasting in terms of enhancing yield attributes and yield. Application of 60 % RDN through drip fertigation recorded comparable pod yield with that of 80 and100 percent RDN, which indicates a saving of nitrogen to the tune of 40 per cent. Satputeet al., (1992) reported that drip fertigation with 100 per cent nitrogen recorded maximum number of pods per plant (21), pod yield per plant (129.3 g) and yield (17.3 t ha^{-1}) over furrow irrigation + band placement of 100 per cent N. Similarly, fertigation of 75 per cent RDN through subsurface biwall drip system recorded higher pods per plant, pod weight and pod yield over 100 per cent RDN applied by band placement + furrow irrigation, indicates a saving 25 per cent nitrogen (Chaudhari et al.,1995).

Fertilizer use efficiency (FUE)

Fertigation permits application of various nutrients and fertilizer formulations directly at the site of active roots in desired concentration and thus improves the nutrient use efficiency (Asokaraja, 1998). The improved fertilizer application efficiency in drip fertigation was as a result of small and controlled amount of fertilizers applied as per the crop requirement in contrast to large amount of fertilizer placed on the bed at the beginning of the season (Dangler and Locascio, 1990). Unlike surface irrigation and conventional fertilizer application, fertigation makes uniform distribution of nutrient solution in the root zone and thereby increase the fertilizer use efficiency, since the uptake of nutrients by the plant roots depend on their availability to the root system (Rao, 1996). Mohan and Arumugam (1994) stated that application of 50 per cent recommended dose of N through biwall subsurface irrigation system recorded the highest nitrogen use efficiency (147.5 kg / kg N) in bhendi. FUE was higher by 33 per cent under drip fertigation compared to conventional application (Khan *et al.*, 1996). Patel and Rajput (2003) observed that drip fertigation in bhendi has resulted in higher nitrogen use efficiency (70 kg / kg N) over broadcasting of nitrogen (48.7 kg / kg N).

ECONOMICS

Sivanappan (1978) stated that income/year was Rs. 10,000 by introducing drip irrigation on a small farm where the available water was not sufficient to irrigate through surface method. Padmakumari and Sivanappan (1978) worked out the economics of drip irrigation taking into account the depreciation and interest on capital and reported that the net increase in income with different cropping patterns was about Rs. 1,421/ha/ year. As the water quantity is limited by this method, the area of irrigation is increased by three times thus increasing the income and employment opportunity in the villages. Tiwari *et al.* (2003) obtained a net seasonal income of 1159 \$ and 714 \$ with drip and furrow irrigated bhendi respectively. Narayan *et al.*

(1994) indicated that the gross returns from sweet pepper were higher with drip irrigation (Rs. 36,480 ha^{-1}) over with furrow irrigation (Rs. 34,650 ha^{-1}). Drip fertigation recorded the highest net income of Rs. 109 ha^{-1} in cabbage and Rs. 88 ha^{-1} in okra per mm of water used over rest of the iirigation methods (Khan *et al.*, 1996). Studies on relative effectiveness of drip irrigation and surface irrigation on tomato revealed that the percent increase in net income was 37, 46 and 57 with drip at 0.4, 0.6 and 0.8 PE respectively over surface irrigation (Shrivastava *et al.*, 1994). Tiwari *et al.* (2003) recorded higher net profit per mm of water used in drip irrigation (16.51 $) over surface irrigation (6.58 $) in cabbage. Khan *et al.* (1999) found that drip fertigation with 100 per cent water soluble fertilizers in potato had recorded a net profit of Rs. 38,742 ha^{-1} as against Rs. 33,604 ha^{-1} in drip fertigation +100 per cent conventional fertilizer and Rs. 32,583 ha^{-1} in furrow irrigation with 100 per cent normal fertilizer. Amarananjundeswara (1995) recorded higher net income (Rs. 38,642 ha^{-1}) with 100 per cent water soluble fertilizer (WSF) through fertigation, followed by 80 per cent WSF (Rs. 38,256 ha^{-1}). Shinde and Firake (1998) stated that amongst micro-irrigation systems adapted to chilli, the cane wall drip tape was most economical with the benefit: cost (B:C) ratio of 2.84 : 1 and net extra income of Rs. 42,164 ha^{-1} over surface irrigation.

CONCLUSION

From the foregoing review, it can be concluded that drip irrigation increases the yield by 15 to 60 per cent over surface irrigation in various vegetable crops. The variation in physiological characters like transpiration rate, Stomatal diffusive resistance, leaf water potential are less under drip irrigation as compared to surface irrigation due to controlled and frequent application of water. Apart from water saving, higher yield, higher water use efficiency and fertilizer use efficiency, higher benefit cost ratio is also obtained in drip irrigation as compared to surface irrigation. Drip irrigation cum fertigation increases the yield due to higher nutrient uptake and thereby improves water and fertilizer use efficiency. In turn fertilizer could be saved to the tune of 25 to 50 per cent through fertigation.

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