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Effect of Drip Irrigation and Fertigation on Growth, Development and Yield of Vegetables and Fruits

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A B S T R A C T

Drip irrigation has the greatest potential for the efficient use of water and fertilizers. The limited area of wetting under trickle irrigation reduces the active root zone and also the foraging area of plants to draw water and nutrients from the soil. For minimizing the cost of irrigation and fertilizers, adoption of drip irrigation with fertigation is essential which will maximize the nutrient uptake, while using minimum amount of water and fertilizer. Fertigation gives advantages such as higher use efficiency of water and fertilizer, minimum losses of N due to leaching, supplying nutrients directly to root zone in available forms, control of nutrient concentration in soil solution and saving in application cost. Thus, fertigation becomes privilege for increasing the yield of most of the crops under drip irrigation. In this paper, the literatures pertaining to the different aspects of fertigation and irrigation are reviewed.

Introduction

Drip irrigation, also known as micro irrigation or trickle irrigation, applies water slowly, directly to the soil around the crop. Drip irrigation generally uses less than half the water of overhead and furrow irrigation. Efficiency with drip irrigation exceeds 90% whereas a sprinkler system is between 50 to 70% efficient. The high efficiency of drip irrigation is due to I) the water soaking into the soil before it can evaporate or run off and ii) application of water only where it is needed (near the crop) rather than over the entire field. iii) Reduces weed growth. iv) Another advantage of drip irrigation is that it reduces water contact with above ground crop growth (leaves, stems, and fruit) thus making conditions less favorable for many diseases.

Drip irrigation is most suitable for row crops (vegetables, soft fruit), tree and vine crops where one or more emitters can be provided for each plant. Generally only high value crops are considered because of the high capital costs of installing a drip system. Drip irrigation is suitable for all soils. On clay soils water must be applied slowly to avoid surface water ponding and runoff. On sandy soils higher emitter discharge rates will be needed to ensure adequate lateral wetting of the soil. Drip irrigation and fertigation favors crop growth and yield of many fruit and vegetable crops.

Fertigation is the application of fertilizer with irrigation water. Fertilizer can be applied

using any irrigation system. In fruit and vegetable production, drip irrigation is the most common system used for fertigation and requires the most knowledge for effective use.

Advantages of drip irrigation

1. Maximum use of available water.
2. No water being available to weeds.
3. Maximum crop yield.
4. High efficiency in the use of fertilizers.
5. Less weed growth and restricts population of potential hosts.
6. Low labour and relatively low operation cost.
7. No soil erosion.
8. Improved infiltration in soil of low intake.
9. Ready adjustment to sophisticated automatic control.
10. No runoff of fertilizers into ground water.
11. Less evaporation losses of water as compared to surface irrigation.
12. Improves seed germination.
13. Decreased to tillage operations.

Disadvantages of drip irrigation

1. Sensitivity to clogging
2. Moisture distribution problem
3. Salinity hazards
4. High cost compared to furrow.
5. High skill is required for design, install and operation.

Under vegetable crops

Vijayakumar *et al*., (2010) studied that in chili, the maximum yield was observed in drip irrigation along with fertigation of 75% of recommended N and K with maximum shoot length and more number of branches. Swarajyalakshmi *et al*., (2005) reported that the highest green chilli yield (21.56 t ha^{-1}) was recorded through drip method scheduled at 0.8 ET under black polythene mulch. This increase was accounted to 34 per cent over conventional method of irrigation practiced. Waldir *et al*., (2007) proved that in tomato maximum fruit yield was reached when irrigations were performed at SWT thresholds of 35, 12, and 15 kPa during vegetative, fruit development, and maturation growth stages. Ngouajio *et al*., (2007) showed that drip irrigation along with fertigation at flowering and fruit development stage increased tomato yield by 8–15%, fruit number by 12–14% over control treatment. Monte *et al*., (2013) proved that increase in irrigation depth above 80% of Etc, increased crop growth rate (CGR), leaf area index (LAI) and total production of tomato fruits. Harmanto *et al*., (2005) concluded that the drip irrigation at 75% of ETc provided the maximum crop yields and irrigation water productivity in tomato variety Troy 489 under tropical greenhouse conditions. Ughade and Mahadkar (2014) reported that the brinjal crop under Field water use efficiency (FWUE) was maximum under treatment 80% ET with100 % RDF drip fertigation while comparing with 100 and 60% ET with RDF drip fertigation. Patel and Rajput (2007) reported that the potato yield was Maximum when irrigation was applying at the 100% of the crop evapotranspiration (23.6 cm of irrigation water) and by placing the drip tape at 10.0 cm depth followed by 15.0 cm and 20.0 cm depth. Yuan *et al*., (2003) reported that the amount of increasing irrigation water had significant effects on decreasing the canopy temperature and increasing the Total fresh tuber yields and marketable tuber yields (>85 g).Chun-Zhi Zeng *et al*., (2009) showed that fruit quality and quantity of muskmelon yield under 90% of field water capacity is the suitable soil irrigation which can save irrigation water and improve the quality of fruit. Singandupe *et al*., (2007) reported in brinjal that irrigation at 80 per cent ET (6.3 tonnes) has given at par yield with 100 per cent ET (6.45 tonnes). Kaushal *et al*., (2012) reported that the drip irrigation adoption

increased water use efficiency (60-200%), saved water (20-60%), reduced fertilization requirement (20-33%) through fertigation, produced better quality crop and increased yield (7-25%) in capsicum as compared with conventional irrigation. Mahajan and Singh revealed that drip irrigation at 0.5 pan evaporation with fertigation at 100 per cent recommended nitrogen resulted in increased tomato fruit yield by 59.5 per cent compared to conventional method. Imtiyaz *et al*., recorded that the higher marketable cabbage yield of 74.26 t ha-1 was observed in drip irrigation at 11 mm CPE compared to 22 mm CPE (72.39 t ha-1) and 33 mm CPE (45.23 t ha-1). Sharmasarkar *et al*., reported that sugar beet yields and sugar contents under drip irrigation were higher (3-28 per cent) than those with flood irrigation. Hebbar *et al*., revealed that the total dry matter production and leaf area index of tomato were significantly higher in drip irrigation (165.8 g and 3.12 respectively) over furrow irrigation with the higher fruit yield of 19.9 per cent in drip irrigation (71.9 Mg ha−1) over furrow irrigation (59.50 Mg ha−1). Antony and Singandhupe concluded that the drip irrigation at 100 per cent CPE recorded the maximum capsicum yield of 99.97 g plant-1 compared to drip irrigation at 80 and 60 per cent CPE. Muralidhar *et al*., reported that the drip fertigation at 80 per cent of recommended N and K level with water soluble fertilizers registered higher tomato yield (22.3 t ha-1) compared to 100 per cent and 60 per cent of recommended levels in drip irrigation.

Battilani and Solimando (2010) studied that water melon crop under Static and Dynamic fertigation increased commercial yield by 33.7% and 57.7% while comparing with the no irrigation and fertilised treatment. Liu Hucheng *et al.,* (2014) showed that the ginger yield has increased by 17.94% in drip fertigation comparing with 15.78% in conventional irrigation and fertigation. Tanaskovik *et al*., (2011) reported that in tomato drip fertigation treatments 100% and 75% shows greater yield and increases 28% of WUE comparing with conventional fertilizer application and 87% in case of furrow method. Jan Rumpel *et al*., (2007) reported that onion yield were greater with 150 kg/ha N through fertigation (79%) followed by 50 kg/ha N was applied through drip fertigation (41%) over control (Nitrogen without fertigation).Imamsaheb *et al*., (2011) revealed that the application of 100 per cent fertilizers through water soluble fertilizer through drip at 80 per cent evaporation resulted in significantly higher growth attributes viz., plant height (96.70 cm), number of branches (18.25), stem diameter (2.06 cm) and leaf area index (3.49).Neelam and Rajput (2005) reported that in onion that the highest yield was recorded in daily fertigation (29.2t/ha) followed by alternate day fertigation (28t/ha) while the lowest yield was recorded in monthly fertigation (22.4t/ha). Ananta (2006) reported that the highest fruit yield of tomato was noticed when nitrogen was supplied in 80 or 10 split doses with 100 per cent ET through drip irrigation. Singandhupe *et al*., (2007) reported that the pointed gourds (*Trichosanthes dioica*) grown by using fertilizer through drip irrigation system with 100 percent recommended dose at monthly interval gave higher yield of 4.27 tonnes per hectare. Kaniszewski *et al*., (1999) reported that fertigated celeriac plants had greater leaf area, dry matter production, and nitrate-N and total N contents than those given through broadcast N with or without drip irrigation. Kapoor *et al*., (2014) showed that increase in NPK fertigation level from 33.3 to 100% RDF significantly increased number of leaves, relative leaf water content, and marketable yield of cauliflower in comparison to flood and conventional fertilizer application. Veeranna *et al*., (2001) reported that 80%

water soluble fertilizer (WSF) was effective in producing about 31 and 24.7% higher chilly fruit yield over soil application of normal fertilizers at 100% recommended level in furrow and drip irrigation methods, respectively, with 20% of saving in fertilizers. Roy *et al*., (2011) showed in capsicum that the length and width of fruit and number of fruits per plant increased significantly with increasing nitrogen doses up to 100 kg N/ha. Dingre *et al*., (2012) showed that drip fertigation resulted into 12 to 74% increase in the productivity of onion seed as compared to conventional method. The total irrigation water applied through surface and drip system was 840 mm and 520.45 mm indicating 39% water saving whereas, field water use efficiency of drip fertigation was more by 2.5 times as that of control. Dawelbeit and Ritcher (2004) observed that the drip fertigation system in onion produced higher yields compared to drip irrigation with fertilizer broadcasting.

Under fruit crops

Baskar recorded the highest yield of banana with maximum water use efficiency of 2.18 kg ha-1 cm-1 in drip fertigation at 75 per cent of recommended NPK level compared to drip fertigation at 100 and 50 per cent of recommended NPK levels. Rao and Subramanyam (2007) reported that 50% recommended dose (250 g /plant) of nitrogen through fertigation at fortnight intervals enhanced yield in pomegranate/tree under low rain fall zone. It saved 50 % nitrogen fertilizers and labour cost. Firake&Kumbhar (2002) on pomegranate revealed that the maximum yield obtained (11.88 t ha-1) due to 100% RDF through drip was superior over 100% RDF application through conventional fertilizers and it was at par with 70% RDF through drip with water soluble fertilizers and it saves about 30% RDF under drip irrigation over conventional method. Agarwal *et al*., (2014) reported that the fertigation studies on pomegranate shows the economic yield of 52.5 q ha^{-1} and highest benefit cost ratio of 3.21 were recorded in pomegranate under 80 per cent of fertigation with water soluble fertilizers. Shanmugasundaram and Balakrishnamurthy (2013) investigated in pomegranate cv. mridula showed that 50% RDF in the form of water soluble fertilizers increased flowering and the highest yield from 3rd year on wards. Ramniwas *et al*., (2012) reported that 'Shwetha' cultivar of guava shows 75% RDF and 75% irrigation of IW/CPE through drip resulted in notably greater number of flowers per shoot (32.02), fruit set (45.88%), fruit retention (47.83%) and fruit yield of 29.33 t/ha. LU Yong *et al.*, (2013) showed that while comparing with traditional fertilization treatment, fertigation treatment increased the yield of fuji apple by 13.0% and the fruit hardness increased by 10.6% and the sugar content improved by 7.3%, meanwhile, fruit weight, shape index and the content of chlorophyll in leaves also showed an increasing trend. Wassel *et al*., (2007) showed that the influence of nitrogen fertigation and drip irrigation on fruit setting; number of fruits per tree and fruit weight in litchi Nitrogen was used at 0.4, 0.6, 0.8 and 1.0 k g/ tree annually. Results revealed that initial and final fruit setting were increased by raising the amount of water and nitrogen. Ashokraja (2011) found that fertigation in Muscat Grapes at 125% RDF was superior to 100% RDF and it increases Muscat grape fruit yield (27.5 tons/ha) was possible with WSF at 125% dose. Mursaleen (2014) Studies on guava revealed that 100% water soluble fertilizers gave maximum plant height, canopy fruit weight (182.17 g), yield/plant (6.59 kg) compare other doses of fertilizers. Jeyakumar *et al*., (2010) proved that the papaya has showed positive response to 100% RDF of N and K through drip irrigation resulted in flowering at the shortest height (96.32 cm), stem girth, number of leaves,

number of fruits, fruit weight, TSS and low fruit cavity index were also found significantly in 100% RDF of N and K through drip while comparing with the soil application of fertilizers. Castellanos *et al.*, (2013) reported that the highest yields were obtained with a dose of about 160 kg ha^{-1} of nitrogen through fertigation and over doses causes negative effects on yield, WUE and loss of nitrate leaching. Liang-zhi *et al.*, recommended that drip fertigation with 4 times/ year effects on increasing fruit yield with 29.4%–36.5% more accumulative yield than the 10 times/year and 16 times/year.

Shirgure (2013) observed that while comparing with plant height and girth the only canopy volume was found significant among the various scheduling irrigation treatments and the highest fruit was observed under irrigation at 80 % ER in stages I-V and 30 % ER in stage VI during the study period. Tank and Patel (2013) proved that the papaya under drip irrigation revealed that 0.8 PEF with 100% recommended dose of N&K shows the maximum yield and greater individual fruit weight and they are at par with treatment drip irrigation @ 0.8 PEF with 80% recommended dose of N&K.Shirgure *et al.,* (2003) studied the effect of irrigation scheduling and fertigation through drip irrigation on 6-8-year-old acid lime which shows that TSS, fruit yield average fruit weight, juice percent and acidity (42.5% and 7.0%) was more in irrigation scheduled at 30 % depletion of available water content with 500:140:70 fertigation. Khan *et al.,* (2013) studied in guava that the controlling Soil moisture potential between -40 kPa to -45 kPa at 0.2 m depth immediately under the drip emitter and fertilizer dose of 80% recommended dose of fertilizer can be used as an indicator for drip irrigation scheduling in semi-arid region of India. Mandal *et al.*, (2007) concluded that the guava plants planted at 5 x 5 m had higher irrigation production efficiency (6.79 kg m-3) than 6 x 6 m (4.70 kg m-3), fruit weight (161.3 g), TSS (11.7^{o}B) and total sugars (10.71%) and vitamin C contents were superior in fruits obtained from drip-irrigated plants as compared to flood-irrigated ones. Kumar *et al.,* (2013) reported that the Safeda under drip irrigation 0.75EpR at 120% RDF and the highest plant canopy (38.86 cm) was recorded in L-49 under drip irrigation 0.75EpR at 120% RDF. Kachwaya and Chandel (2015) reported that the cultivar chandler had shown the significant effect on plant height, leaf area, fruit yield, maximum fruit length, fruit breadth and fruit weight was also recorded in fertigation with full recommended dose of NPK.

Chandel *et al.,* (2013) studied that fertigation with 3/4 of recommended dose of NPK fertilizers had higher fertilizer-use efficiency than the recommended dose of NPK applied both through drip and soil application, that gave higher net returns without affecting the size, yield and quality of fruits.Kumar *et al.,* (2013) reported that the maximum growth of plants was recorded with 1.0 volume of water through drip along with fertigation of 125 per cent RDF. As well as the maximum yield and economics were observed with 0.8 volume of water through drip along with fertigation of 100 per RDF.

Mali *et al.,* (2015) studied that in litchi highest fruit weight at 60 % ETc with irrigation starting from flowering stage and the prolonged moisture stress between two irrigations under basin system resulted in lowest fruit length, fruit diameter and highest fruit cracking percentage (10.2%) and maximum irrigation water use efficiency (57.1 g/m3) was observed in case of drip irrigation having irrigation at 20 % of Sadarunnisa *et al.*,(2010) reported that in papaya the maximum yield, no. of fruits/plant, fruit weight was obtained under 75% drip

with fertigation which was on par with the yield of plants supplied with 100% RDF through drip compared to the treatments in which soil application of fertilizers was done.

Tiwari *et al.,* (2013) reported that the water requirement of Sapota crop varies between 2.14 mm (10.71 L) per day per plant in winter season and 6.89 mm (34.44 L) per day per plant in summer season for 100% water requirement treatment at peak growth stage and maximum yield of sapota was obtained under 100% drip with plastic mulch was found to increase by 21.05% in comparison to ring basin irrigation. Sujatha *et al.*,(2006) studied that the Drip irrigation in mango cv. Kesar at 0.75 Ep registered higher fruit weight during first year and number of fruits in second year than control (without irrigation). Application of organic and inorganic forms of nutrients individually or in combination increased the fruit number and weight significantly over control. Prakash *et al.,* (2015) studies revealed that the irrigation treatments 13 – 24 L day^{-1} $plant^{-1}$ recorded the highest percentage of fruit set, fruit weight, number of fruits per tree, fruit yield per tree and quality characters like, TSS, ascorbic acid, sugar, carotenoids were also the highest in the same treatment. In case of sub plots percentage of fruit set, fruit weight, number of fruits per tree, fruit yield per tree were recorded by the application of 100% RDF through fertigation. Kumari *et al.,* (2014) reported that the irrigation was applied at 75% ETC and percentage water saving for drip fertigation treatment was 33.94% over the conventional irrigation. Pramanik *et al.,* (2014) proved that the guava fruits yield increased significantly with increase in application of irrigation water and nitrogen fertilizer. However, maximum fruit yield, higher water use efficiency, net return and B:C ratio was registered from drip irrigation at 1.00 Mathura *et al.,* (2002) suggested that in litchi application of potassium @ 249 g K/tree/year resulted in the maximum yield (27.62 kg/plant), tree height (3.52 m), spread (5.50 m) and tree volume (56.98 m3) over control and similarly application of N significantly influenced tree height, volume, trunk girth, spread, fruit length, fruit volume, TSS and ascorbic acid content.Sharma *et al.*, (2013) Evaluated that highest fruit yield of guava of 18.7 t/ha was obtained with drip irrigation at 100% ETc& 100% of recommended dose of N whereas the lowest yield of 11.0 t/ha was recorded under drip irrigation at 60% Kachwaya *et al.,* (2016) revealed that drip irrigation at 120 % gave significantly higher fruit yield compared with drip irrigation at 80 and 60 % ETc over furrow irrigation. Similarly, the photosynthetic rate, transpiration rate, number of stomata and size of stomata were higher in drip irrigation at 120 % ETc, followed by drip irrigation at 100 % ETc. Although the physiological performance was slightly better under 120 % ETc in comparison to 100 % ETc drip irrigation, but there was 16–30 % increase in yield in case of 100 % Etc irrigation treatment over furrow irrigations treatment. Singh *et al.,* (2009) reported that drip irrigation at 80% evapo-transpiration (ET) crop based on pan evaporation applied gave significantly higher fruit yield (45.57 tonnes/ha) compared with the surface irrigation (29.43 tonnes/ha. Ramniwas *et al.*, investigation indicated that the effect of irrigation and fertigation levels showed that 100% irrigation of cumulative pan evaporation + 100% water soluble fertilizers gave maximum yield/plant (6.59 kg).

However, maximum benefit: cost ratio of (2.91) was obtained at 75% irrigation of cumulative pan evaporation + 75% water soluble fertilizers. Patil and Das concluded that the nutrient status determined in terms of available N,P,K in kg/ha was significantly influenced by different drip irrigation and fertilizer management significantly highest

fruit yield (87.20 q/ha) was recorded in drip irrigation at 100 EPR along application of 75 % RDF of N through drip irrigation over other treatments.

Under plantation crops

Pramanik *et al.,* reported that the banana was considerable improvement in plant height, pseudo stem girth, leaf area, leaf area index and leaf number with drip irrigation at 70% of CPE compared to conventional surface irrigation and Maximum fruit yield and water use efficiency (WUE) in main and ratoon crop was obtained with drip irrigation at 60% CPE with 80% of recommended NPK fertilizers.

The maximum yield attributes viz., spathe length, number of inflorescence, number of bunches/palm/year and number of nuts/bunch of 127.76 cm, 13, 13 and 31, respectively were recorded in 100% of recommended dose of drip fertigation with 100 µm polythene mulching. The lowest spathe length, number of inflorescence, number of bunches/palm/year and number of nuts/bunch of 92.16 cm, 8, 8 and 12, respectively were recorded in control treatment without mulch.

Krishnamoorthy and Raja Mani (2013) reported that maximum vegetative parameters like trunk girth increment, Canopy spread, leaf fresh weight and yield of Cocoa were obtained under fertigation with 125% Krishnamoorthy *et al.,* (2013) concluded that in cocoa fertigation with 125% RDF as Water Soluble Fertilizers through drip irrigation increased all vegetative growth parameters compared with conventional method of fertilizer application. Husameldin *et al.,* (2013) concluded that 80% RDF performed well in respect of growth parameters and shortened the total crop duration in banana crop. Dinesh and Ahmed (2014) experimented on almond, results indicated that the maximum tree height (3.56 m), nut weight (2.73 g), nut yield (5.98 kg/tree; 6.64 t/ha), and leaf nutrient content (2.38% N; 0.17% P; 1.41% K) were recorded in 75% RDF through fertigation. Sujatha and Ravi *et al.,* (2013) showed that productivity per unit area (kg ha^{-1}) under drip along with fertigation was significant and higher by 12 % in areca nut–cocoa system (3,450) than sole areca nut (3,090) and fertigation at 75 % RDF improved the yield of cocoa by 52 % over control alone.

Under plastic mulching

Paul *et al.,*(2013) studied that the capsicum yield (28.7 t/ha) was recorded maximum under 100% net irrigation volume with drip irrigation (VD) and plastic mulching and net seasonal income by 57 % and 54 % respectively as compared to conventional surface irrigation without mulch.

Reddy *et al.,* (2015) reported that in tomato highest water use efficiency (1.44) was observed in drip + polythene mulch + trellising followed by drip + polythene mulch (1.26).Singh *et al.,* (2007) reported that guava yields 164% more yield under drip irrigation when compared with ring basin irrigation and drip with plastic mulching treatment (VDM). Joshi *et al.,* (2012) concluded that treatments in combination with Mulch + drip irrigation at 100% WR + 125% RDF at each level of fertilizer doses were more effective in improving plant parameters in the first year but in the subsequent years Mulch + drip irrigation at 100% WR +75% RDF gave the highest fruit yield. Singh *et al.,* (2009) reported that use of black polyethylene mulch plus drip irrigation further raised the fruit yield to 57.87 tonnes/ha compared to surface irrigation alone or with mulch. Reddy *et al.,* (2015) reported that in tomato Drip + polythene mulch+ trellising given maximum values compared to drip + polythene mulch and drip alone. Seyfi and Rashidi (2007)

reported that the highest fruit weight and fruit thickness was obtained for the DI + PM treatment and lowest for the CI treatment. The crop yield was highest (27.07 t ha-1) for the DI + PM treatment was found to be more effective irrigation method in improving WUE and increasing cantaloupe yield.

In conclusion, drip irrigation and fertigation technology is beneficial to the farmers for higher production and quality of fruit and vegetable production. Achieving maximum fertigation efficiency requires knowledge of crop nutrient requirements, soil nutrient supply, fertilizer injection technology, irrigation scheduling, crop and soil monitoring techniques.

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