A REVIEW

Impact of drip irrigation and fertigation on growth, yield, quality and economic returns in different vegetable crops

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ABSTRACT: The shrinking land, man ratio, water, increasing fertilizer prices, haunting energy crisis, wide spread population and fast degradation of natural resources further emphasise the need for improved water and fertilizer use efficiency. Drip fertigation optimize the use of water and fertilizer enabling to harness high crop yield, simultaneously ensuring a healthy soil and environment. The drip fertigation technology encompasses the application of solid and liquid mineral fertilizers through drip irrigation system thus supplying a nutrient containing irrigation water to crops. A study was conducted with drip irrigation in crop geometry for chilly, bhendi and capsicum crops during Kharif and Rabi season. The pooled data revealed that the highest yield was obtained in treatments with 1.5 m drip lateral spacing with plant spacing of 20 x 72 cm for chilly and 2.5 m drip lateral spacing with a plant spacing of 20 x 72 cm for bhendi which is higher by 55 per cent over control (Anonymous, 1995). Drip irrigation scheduling for brinjal, okra, tomato and cabbage and fertigation for bitter gourd with irrigation scheduled at 100, 80 and 60 per cent ET in main plots and irrigation intervals (daily, 1 and 2 days) in sub-plots showed that the yield of brinjal / okra was maximum at 80 per cent ET (Anonymous, 2004).

KEY WORDS: Drip irrigation, Fertigation, High value vegetables

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degradation of natural resources further emphasise the need
for improved water and fertilizer use efficiency (Dass, 1985).
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Scope of micro irrigation :

The modern technology of drip irrigation is successfully
practiced in many countries for orchards, vegetables,
ornamental crops and as well as high value field crops. It is
gaining momentum and its prospects in the years to come are
expected to be very bright.

Nakayama and Bucks (1991) reported that drip irrigation
method is to provide water most efficiently at the right rate
and practically near the root zone of the crop. In this system,
only a fraction of the soil surface is wetted generally between
15 to 60 per cent. Earlier, drip irrigation was considered an
emerging technology with its application limited to some
special crops. Now a day it is used on a wide variety of crops,
which were initially considered unprofitable for management
under drip irrigation. Bafna et al. (1993) opined that in water
scarcity areas, drip irrigation could be used in row crops such
as sugarcane, cabbage, vegetables, potato, cassava, sugar beet,
onion, mulberry, cotton etc. Considerable saving of irrigation
water could be done by adopting drip method since water is
applied directly in the root zone without wetting the entire
surface area. A study was conducted with drip irrigation in
crop geometry for chilly, bhendi and capsicum crops during
Kharif and Rabi season. The pooled data revealed that the
highest yield was obtained in treatments with 1.5 m drip lateral
spacing with plant spacing of 20 × 72 cm for chilly and 2.5 m
drip lateral spacing with a plant spacing of 20 × 72 cm for
bhendi which is higher by 55 per cent over control
(Anonymous, 1995). Polak et al. (1997) reported that drip
irrigation has high potential in India which can reach an area
of 10.5 M ha within the next decade with major constraint of
high capital investment. Selvaraj et al. (1997) at Bhavanisagar
conducted an experiment where results were encouraging with
drip irrigation for closer spaced crop like turmeric. The fresh
rhizome yield of turmeric was enhanced upto 76.3 per cent
with water saving of 53.1 per cent besides 25 per cent saving
in nitrogen fertilizer when applied through drip system daily
at the rate of 40 per cent of surface irrigation level. It is
estimated that there is a scope to bring 27 M ha of land under
drip irrigation in India (Manjunatha et al., 2001). Tyson and
Harrison (2009) of Georgia University stated that drip
irrigation is gaining popularity for production of some
vegetable crops. It can be used with or without plastic mulch.
One of the major advantages of drip irrigation is its water use
efficiency if properly managed. Studies in Florida have
indicated that 40 per cent less water was required for drip
irrigated vegetables than the sprinkler irrigated vegetables.
Weeds are also less of a problem since only the rows are
watered and the middles remain dry. Also some studies have
indicated that drip irrigation enhances earlier yields and fruit
the effects of irrigation method and water quality on sugar
beet yield, percentage of sugar content and irrigation water
use efficiency (IWUE). The irrigation methods investigated
were subsurface drip, surface drip and furrow irrigation. The
two types of waters used were treated municipal effluent
(EC = 1.52 dS m⁻¹) and fresh water (EC = 0.509 dS m⁻¹). The
highest root yield (79.7 Mg ha⁻¹) and highest IWUE (9 kg
m⁻²) were obtained by using surface drip irrigation.

Drip irrigation at 0.8 CPE enhanced the growth and
yield parameters of brinjal significantly over the check basin
irrigation during 1989-1991 in Gujarat. It increased the
number (35.5 %) and yield of fruit (41.6 %) over check basin
method of irrigation due to favorable soil moisture status in
root zone throughout the life span of the crop which led to
better growth and distribution of roots (Jadav et al., 1995).

Drip irrigation at 0.8 E_pw with normal planting recorded
higher water use efficiency (WUE) of green cob and fodder
with total water requirement of 330.46 mm for sweet corn
(Viswanathan et al., 2002). Drip irrigation scheduling for
brinjal, okra, tomato and cabbage and fertigation for bitter
gourd with irrigation scheduled at 100, 80 and 60 per cent
ET in main plots and irrigation intervals (daily, 1 and 2 days)
in sub-plots showed that the yield of brinjal / okra was
maximum at 80 per cent ET (Anonymous, 2004).

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). 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.

Evaporation losses :

Saggu and Kaushal (1992) concluded that drip irrigation
with 0.75 ET (30.0 cm of water) provides the highest potato
yield (321q/ha.) which was 26 per cent higher than that of
furrow irrigation. Koumanov et al. (1997) has conducted
studies of different irrigation methods. He has compared drip
irrigation, subsurface irrigation and micro sprinkler irrigation
system. Evaporation under micro sprinkler irrigation
particularly in a young orchard where the tree canopy is not
fully developed, is probably greater compared to the drip and
subsurface drip systems, due to both the large wetted area
and spray losses during irrigation. With the conclusion that
three methods the subsurface irrigation has very minimum
evaporation to compare other systems. Isoda et al. (2007) studied that the effects of three different irrigation methods (drip, porous-tube and furrow irrigations) on yield and water use efficiency in sugar beet were examined. The total amount of water applied by the drip and porous-tube irrigation was both 63 per cent of that of the furrow irrigation. The drip and porous-tube irrigations had more frequency and fewer amount as compared with the furrow irrigation.

**Drip fertigation:**
Fertilizer savings through fertigation can be to the tune of 25–50 per cent (Haynes, 1985). Fertigation reduces the nutrient loss that would normally occur with conventional methods of fertilizer application and thus, permits better availability and uptake of nutrients by the crops, leading to higher yield with high fertilizer use efficiency. Nitrogen use efficiency (NUE) for red chilli fruit production decreased with increasing N upto 240 Kg ha⁻¹ (Payero et al., 1990). Clark et al. (1991) reported that fertigation resulted in reduced water and fertilizer application as compared to those associated with conventional irrigation method.

The increase in yield and its quality together with the improved water and fertilizer efficiency, make fertigation an attractive technology in modern irrigated agriculture (Papadopoulos, 1992). Drip fertigation provides an efficient method of fertilizer delivery and if properly managed, reduce overall fertilizer application rate and minimize the adverse environmental impact (Hartz and Hochmuth, 1996). Unlike surface irrigation and conventional fertilizer application, fertigation makes uniform distribution of nutrient solution in the root zone and thereby increases the fertilizer use efficiency, since the uptake of nutrients by the plant roots depends on their availability to the root system (Rao, 1996). Satisha (1997) found that the efficiency of phosphorus fertilizer could be increased upto 45 per cent by trickle irrigation compared to only 10-20 per cent achievable by conventional method of application. Fertigation enhanced the overall root activity, improved the mobility of nutritive elements and their uptake, as well as reducing the contamination of surface and ground water. The fertigation technique is used mainly with N and K fertilizers (Taha, 1999). Drip irrigation has gained wide spread popularity as an efficient method for fertigation because both water and nutrients are delivered at a rate, duration and frequency, so as to maximize crop water and nutrient uptake, while minimizing leaching of nutrients and chemicals from the root zone of agricultural fields (Gardenas et al., 2005).

**Effect of different levels fertigation on growth parameters:**
Tumbare et al. (1999) revealed that 100 per cent recommended liquid fertilizer has given highest plant height of 106.3cm. Tumbare and Bhoite (2002) reported in chilli that 100 per cent recommended dose gives higher plant height of 62.2 cm and number of branches of 8.4. Shinde et al. (2002) in brinjal drip irrigation with 125 per cent recommended dose of solid soluble fertilizer recorded highest plant height of 84.5cm and plant spread of 52.08cm as compared to check basin with normal fertilization. All the growth attributes of chilli, viz., plant height (79.40cm), number of branches per plant (21.13) and dry matter accumulation (g) per plant(185.66), were significantly higher owing to fertigation of recommended dose of fertilizer at every irrigation (2 day intervals) up to 105 days (Tumbare and Nikam, 2004). Yadav et al. (2004) found in brinjal that maximum plant height of 61.7 cm, number of branches per plant of 11.1 and biological yield of 405.7g with 80mm CPE irrigation treatment and 100 kg of nitrogen, 50 kg phosphorus and 25 kg potassium per hectare. Gonfa et al. (2008) revealed that the plant height at 30 and 60 DAT was increased by 61 and 72 per cent in treatments (100% level of water requirement, three cycles per day and split fertigation). The application of 100 per cent fertilizers through water soluble fertilizer through fertigation was the best system for growth, yield, quality and economically viable for onion seed production with saving of water and fertilizer (Bhakare and Fatkal, 2008). Imamsahab 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).

**Effect of different levels fertigation on yield parameters:**
Growth and fruit yields were greater with liquid fertilization than solid fertilization, the difference being is 13.5 per cent more yield. This could be attributed to higher efficiency of liquid fertilizer (Soliman and Doss, 1992). Papadopoulos (1992) reported in potato that fresh yield of tuber increased (26.4 to 48.7 t/ha) with increase in P concentration in the irrigation 0 to 60 mg/lit. Bracy et al. (1995) registered significant increase in bell pepper yield in response to fertigation of N and K through drip irrigation significantly higher tomato fruit yield (107.3 t ha⁻¹) was obtained by fertigation which was 42.3 per cent higher than band placement. The capsicum plants that received fertigation had higher leaf NO₂ concentration and yielded more than three times those plants that received fertilizer prior to
planting (Obreza and Vavrina, 1995). Deek et al. (1997) reported that N fertilization through drip irrigation with ten equal splits and equal time of intervals resulted in high tomato yield of 47.1 t ha\(^{-1}\) as compared to fertigation with three equal splits and equal time intervals (35.8 t ha\(^{-1}\)). Selvaraj et al. (1997) revealed that drip irrigation to tapioca at 50 per cent of surface level once in 2 days has registered higher tuber yield of 51.6 t/ha which was comparable with that of surface irrigation together with water saving up to 50 per cent and nitrogen saving up to 33 per cent. Tumbare et al. (1999) reported that the highest yield of 19.49 tonnes was recorded in treatment fertigated with 125 per cent recommended dose of liquid fertilizer.

Muralidhar (1999) stated that higher WUE (2.34 kg m\(^{-2}\)) was recorded at an application of 100 per cent recommended dose of water soluble fertilizer through drip irrigation in capsicum, which was at par with 75 per cent recommended dose. The yield was nearly 22-27 per cent higher when tomato was fertigated 100 per cent N: P: K as compared to yield obtained by normal fertilization (Prabhakar and Hebbar, 1999).

Natrajan et al. (2002) revealed that in tomato fertigation with 250:250:250 kg per hectare water soluble fertilizer has recorded highest yield of 102 tonnes per hectare. Application of 100 per cent recommended dose of solid soluble fertilizer through fertigation recorded significantly higher yield of green chilli (Capsicum annuum L.). However, it was at par with application of 70 per cent N and 80 per cent P and K through fertigation indicating saving of N to the extent of 30 per cent, while P and K to extent of 20 per cent (Tumbare and Bhoite, 2002). In experiment conducted in brinjal by using irrigation and different levels of fertigation (50, 75, 100 and 125% recommended dose of solid soluble fertilizer) was found that micro jet irrigation with 100 per cent recommended dose of solid soluble fertilizer recorded highest number of fruits per plant (433.13), weight of fruit (44.18g) and fruit yield (41.51 tonnes per hectare) (Shinde et al., 2002). The maximum tomato fruit yield of 27.4 and 35.2 t/ha in two years was recorded at 120 kg N/ ha. Total nitrogen update in drip irrigation was 8 to 11 per cent higher than that of furrow irrigation. At the highest level of applied nitrogen 120 kg N/ ha, total average N uptake of applied of two years were found to be 64.5 kg/ha and 104.7 kg/ha (Singandhupe et al., 2002). Ajmal Khan (2000) stated that fertigation of recommended dose of nitrogen as urea and K\(_2\)O as muriate of potash applied in 15 equal splits at eight days interval starting from 8 DAP to 120 DAP through drip system recorded higher tomato yield as compared to surface irrigation with conventional method of fertilizer application on sandy loam soil at Madurai (TNAU) in Tamil Nadu. Ramas et al. (2003) in a greenhouse experiment found that the highest yield (1.687kg plant\(^{-1}\)) and higher relative nitrogen recovery were obtained with 160 kg N ha\(^{-1}\) in tomato.

All the growth attributes of chilli, viz., number of fruit per plant (716), weight of fruit per plant (2.33kg) and yield of green chili (9.18t/ha) were significantly higher owing to fertigation of recommended dose of fertilizer at every irrigation (2 days interval) up to 105 days (Tumbare and Nikam, 2004). Patel and Rajput (2005) reported in tomato that fertilizer application at 100 per cent recommended dose through fertigation recorded an increase in yield of 25.21per cent. Banu (2005) conducted an experiment to investigate the effect of various levels of irrigation (0.5, 0.75 and 1.0 Epan) and nitrogen levels (60, 90 and 120 kg per hectare) on pod yield of bhendi. The result indicated that crop irrigated through drip at 1.0 Epan and fertigated with 120 kg nitrogen per hectare produced significantly higher yield as compared to other levels.

Neelam and Rajput (2005) reported 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.

The pointed gourds (Trichosanthes dioica) grown by using fertilizer through drip irrigation system with 100 per cent recommended dose at monthly interval gave higher yield of 4.27 tonnes per hectare (Singandhupe et al., 2007). Kavitha et al. (2007) elucidated the effect of shade and fertigation on growth, yield and quality of tomato hybrid “Ruchi”. The main plot treatments were open and shade, and sub plot treatments were three levels (100, 75 and 50% of recommended dose) of water soluble and straight fertilizers. Application of water soluble fertilizer to the crop grown under shade gave significantly higher yield (99.8, 109.5 and 106.7 t/ha) as compared to open condition. Manish (2007) conducted an experiment to evaluate the agro techniques viz., growing media, irrigation regime, fertigation and mulching on productivity of tomato. He reported that growing media of soil: compost: sand (2: 1:1), irrigation regime of 20 kPa, 50 kg per hectare as basal dose with straight fertilizers and fertigation at the rate of 250 kg per hectare with water soluble fertilizer with black polythene mulched recorded significantly higher number of flower cluster per plant (12.16), fruit per plant (48.33) and fruit yield (2.85 kg per plant). The maximum yield of 45.43 tonnes was obtained in Citrullus lanatus with irrigation level of 0.3 PE and fertigation level of 80 per cent (Kadam et al., 2009).

In okra nitrogen fertigation with 100 per cent recommended dose gave higher pod yield of 16.9 tonnes per hectare (Patel et al., 2009). Brahma et al. (2010) revealed that drip irrigation at 100 per cent evaporation replenishment along with supplementation of 100 per cent recommended N and K though fertigation, the pooled data averaged over the three years revealed that fertigation with 100 per cent
Effect of irrigation, plant geometry and economics in semi-determinate tomato cultivar Arka Abha. Results indicated that plant height, branch number, fruit setting percentage, fruit number per plant, individual fruit weight and marketable yield were maximum with 100 per cent fertigation of recommended dose of N and K at the rate of 75:60 kg/ha. Regarding the quality parameters, fruit length, fruit girth, percentage of placenta, edible portion, juice percentage, total soluble solid and ascorbic acid were highest, similarly in cent per cent fertigation level, whereas the highest titrable acidity was recorded by 50 per cent fertigation level (Brahma et al., 2010). The yield and yield attributes in tomato such as number of fruits per plant (40.71), average fruit weight (60.89 g), yield per plant, plot and hectare (2.36 kg, 53.84 kg and 56.98 tonnes, respectively) were maximum in fertigation 100 per cent recommended NPK through drip (Imamsaheb et al., 2011).

Effect of different levels fertigation on quality parameters:

Dharmatti et al. (1989) reported that due to the application of 120: 100: 60 kg of NPK per hectare along with the recommended dose of FYM, significant increase in fruit weight, pericarp thickness, fresh weight and dry weight of tomato var. Megha (L-15) were recorded compared to other NPK rates. Pansare et al. (1994) recorded the highest TSS in tomato with the application of N:P:K (150: 150: 100) fertilizers. In brinjal recorded the highest TSS at 150 kg N per ha as reported by Singh and Syamal (1995). Fertigation with 100 per cent recommended dose of macro and micro nutrients in water soluble form recorded the highest crop growth rate, total chlorophyll content, soluble protein content, nitrate reductase activity and minimum indole acetic acid oxidase activity in bitter gourd (Meenakshi and Vadivel, 2005). Sanchita Brhma et al. (2010) revealed that drip irrigation at 100 per cent evaporation replenishment along with supplementation of 100 per cent recommended N and K though fertigation recorded significantly highest ascorbic acid content were recorded by 100 per cent fertigation level.

Effect of different levels fertigation on economics:

Narayanan et al. (1994) conducted an experiment to evaluate the economic benefits of drip irrigation in sweet pepper and reported that maximum gross return was obtained with drip irrigation compared to furrow irrigation. It was reported that the net profit per ml of water used in tomato crop under drip irrigation and conventional system were 278.43 and 66.47, respectively and the water use efficiencies were 123.80 and 27.95 kg/ha-cm, respectively (Anonymous, 1995). The B:C ratio was much higher in tomato under drip irrigation when the water so saved was assumed to be utilized to cover additional area of the same crop than conventional irrigation (Hugar, 1996). Sivanappan (1996) reported that an extra income of Rs. 49,280 ha⁻¹ could be obtained under drip irrigation in tomato over surface irrigation and the payback period of drip system cost was only six months. Asokaraja (1998) recorded higher benefit cost ratio of 9.89 due to drip irrigation than surface irrigation (5.44) in tomato. The cost of micro irrigation system and optimization was performed to assess minimum input cost of tomato, considering the advent of mechanically moved portable drip sets, with every second day irrigation approximately 50 per cent saving on initial investment of drip set can be achieved as the same set will irrigate double the area (Dalvi et al., 1999). Khan et al. (1999) found that drip fertigation with 100 per cent water soluble fertilizers in potato has recorded higher net profit of Rs. 38,742 ha⁻¹ when compared to drip fertigation with 100 per cent normal fertilizer (Rs. 33,604 ha⁻¹) and furrow irrigation with 100 per cent normal fertilizer (Rs. 32,583 ha⁻¹). Application of water soluble fertilizers at higher level (300: 300: 300 kg NPK/ha) produced excellent quality fruits and resulted in higher profit of Rs. 22,930 per year with a cost benefit: ratio of 1:3.89 (Krishna, 2002). In tomato soil: FYM: coir pith as a growing media plus irrigation at 20 kPa plus NPK at the rate (50: 50: 50 kg /ha) as basal with straight fertilizer (250: 250: 250 kg/ha) through fertigation with water soluble fertilizer plus mulch fetched the net return of Rs. 4,23,596 and B:C ratio of 1.61(Natrajan et al., 2002). Shinde et al. (2002) reported that the highest seasonal cost of production (Rs. 1,47,415/ha) was recorded in drip irrigation with 125 per cent RDSS. Under drip fertigation system, 100 per cent recommended NPK registered the highest benefit cost ratio (2.17) in chilli (Tumbare and Bhoite, 2002). Drip irrigation at 100 per cent WRc with 100 per cent RDF registered the highest additional net income of Rs. 1,23,679 and BCR of 3.30 in chilli which was closely followed by drip irrigation at 80 per cent WRc with 100 per cent RDF registering an additional net income of Rs. 1,19,488 and BCR of 3.23 over surface irrigation (Selvakumar, 2006). Study on fertigation efficiency and economics of cultivation revealed that fertigation with 100 per cent recommended dose of N and K was the most efficient treatment with fertigation efficiency of 43.24 per cent and cost: benefit ratio of 1:2.28 (Brahma et al., 2010). Imamsaheb et al. (2011) reported fertigation level 100 per cent recommended NPK among with genotypes PTR-6 resulted in highest yield (63.78 t/ha) and net income (Rs.1,14,470.91/ha), gross income (Rs.1,59,450/ha) and B: C ratio of 3.22.

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