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Fertigation technology for enhancing nutrient use and crop productivity: An overview

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Abstract

Fertigation - a technique of application of fertilizers along with irrigation water, provides an excellent opportunity to maximize yield and minimize environmental pollution. Fertigation ensures availability of fertilizer nutrients in the root zone in readily available form and therefore, minimize fertilizer application rate and increases fertilizer use efficiency. The associated increase in yield with minimum fertilizer application rate, increases return on the fertilizer invested. Based on experimentation, it has been observed that fertigation leads to saving of fertilizer by 25-40%, increased returns and reduced leaching of the nutrients. The present paper is an attempt to review the work done on various aspects of fertigation technology.

Key words: Fertigation, NPK behaviour, Recommended doses of fertilizers, fertilizer saving

Sustained higher yield with high yielding varieties depends entirely on the sustainable use of the limited water and energy resources, specifically in developing countries with arid and semi-arid regions. Moreover, intensification of agricultural production to meet growing market demand requires the simultaneous application of irrigation water and fertilizers. Fertigation - a modern agro-technique provides an excellent opportunity to maximize yield and minimize environmental pollution (Hagin *et al*. 2002) by increasing fertilizer use efficiency, minimizing fertilizer application and increasing return on the fertilizer invested.

What is fertigation?

The practice of supplying crops in the field with fertilizers *via* the irrigation water is called fertigation. In fertigation, timing, amounts and concentration of fertilizers applied are easily controlled. Fertigation allows the landscape to absorb up to 90% of the applied nutrients, while granular or dry fertilizer application typically result in absorption rates of 10 to 40% (Table 1). Fertigation ensures saving in fertilizer (40-60%), due to "better fertilizer use efficiency" and "reduction in leaching" (Kumar and Singh 2002).

Drip irrigation is often preferred over other irrigation methods because of the high water-application efficiency on account of reduced losses, surface evaporation and deep percolation. Because of high frequency water application, concentrations of salts remain manageable in the rooting zone. The regulated supplies of water through drippers not only affect the plant root and shoot growth but also the fertilizer use efficiency. Fertigation through drip irrigation reduces the wastage of water and chemical fertilizers, optimizes the nutrient use by applying them at critical stages and at proper place and time, which finally increase water and nutrient use efficiency. Moreover, it is well recognized as the most effective and convenient means of maintaining optimal nutrient level and water supply according to crop development stage, specific needs of each crop and type of soil.

Table 1. Fertiliser use efficiency (%) in fertigation

Nutrient	Soil application	Drip + soil application	Drip + fertigation
N	30-50	65	95
P_2O_5	20	30	45
K_2O	60	60	80

Fertiliser Marketing News, 2010

Significance of fertigation

Deficiency of N, P and K is a major production constraint in sandy soils, which have inherent constraints like P fixation, rapid hydraulic conductivity, faster infiltration rate, leaching of basic cations and low CEC. Hence, the cultivated crop in this soil requires large quantity of nutrients to support its growth and yield. Considering the soil and crop constraints, fertilizers should be applied in synchrony with crop demand in smaller quantities during the growing season. The right combination of water and nutrients is a prerequisite for higher yields and good quality production. The method of fertilizer application is also important in improving the use efficiency of nutrients. Fertigation enables adequate supplies of water and nutrients with precise timing and uniform distribution to meet the crop nutrient demand. Further, fertigation ensures substantial saving in fertilizer usage and reduces leaching losses (Mmolawa and Or 2000).

Similar to frequent application of water, optimum split applications of fertilizer improves quality and quantity of crop yield than the conventional practice. Yield responses to the time of N and K application, either pre plant only or pre plant with fertigation, were dependent upon soil type. Less yield response resulted with fertigated N on heavier soils, compared to the lighter fine sands. Similar experiments on fine sands also indicated late season extra large and large fruit yields with 60% drip applied N and K compared to yield response with all pre-plant applied N and K. Researchers noted that drip-applied nutrients extended the season of large fruit harvest by maintaining plant nutrient concentrations late in the season. However, proper fertigation management also requires the knowledge of soil fertility status and nutrient uptake by the crop.

Monitoring soil and plant nutrient status is an essential safeguard to ensure maximum crop productivity. Soil properties, crop characteristics and growing conditions affect the nutrient uptake (Mmolawa and Or 2000). Fertigation enables the application of soluble fertilizers and other chemicals along with irrigation water, uniform and more efficient. Nevertheless, the increasing uses of nitrogenous fertilizers have caused environmental problems, generally manifest in groundwater contamination. There is a direct relation between large NO_3-N losses and inefficient fertigation and irrigation management. Therefore, water and N fertilizer inputs should be carefully managed in order to avoid losses.

Improved water use efficiency under drip irrigation, by reducing percolation and evaporation losses, provides for environmentally safer fertilizer application through the irrigation water (Mmolawa and Or 2000). The overall problem is to identify economically viable practices that offer a significant reduction of NO_3-N losses, which also fit in the farming systems practised under a particular soil type and set of climate conditions. NO_3-N is very mobile and if there is sufficient water in the soil, it can move quickly through the soil profile. Careful application of nitrogen and water should be able to minimize the amount of nitrogen moving below the root zone.

The method of fertilizer application is very important in obtaining optimal use of fertilizer. It is recommended that fertilizer should be applied regularly and timely in small amounts. This will increase the amount of fertilizer used by the plant and reduce the amount lost by leaching (Shock *et al*. 2003).

Hypotheses for fertigation techniques

1. Fertigation enhances fertilizer use efficiency by 40-60%, hence recommended doses of fertilizers may be reduced proportionally
2. Drip irrigation promotes root growth in surface layer (about 70-80%), hence the nutrients from sub-surface layers may not be extracted
3. Drip irrigation leads to moisture content around/above

field capacity hence may promote leaching of nutrients

4. Use of water soluble fertilizers (WSF) may lead to leaching losses beyond surface layer, hence frequent split application of WSF is desirable
5. The frequency of fertigation may increase with fertilizers doses in order to avoid leaching losses or toxicity if any

Fertigation scheduling

Factors that affect fertigation module are soil type, available NPK status, organic carbon, soil pH, soil moisture at field capacity, available water capacity range, aggregate size distribution, crop type and its physiological growth stages, discharge variation and uniformity coefficient of installed drip irrigation system.

The efficient fertigation schedule needs following considerations *viz*.

1. crop and site specific nutrient management,
2. timing nutrient delivery to meet crop needs and
3. controlling irrigation to minimize leaching of soluble nutrient below the effective root zone.

In many situations, a small percentage of N and K (20 -30%) and most or all P is applied in a pre-plant broadcast or banded application especially in the areas where either initial soil levels are low or early season irrigation is not required. Pre plant application of P is common since soluble P sources (Phosphoric acid) are costlier than granular forms, to avoid the chemical precipitation in drip line and the movement of drip applied P away from the injection point is goverened by soil texture and soil pH. Movement of P is particularly restricted in fine textured and alkaline soil. When making a pre-plant application of any nutrient, it is important that the fertilizer be placed within the wet zone of the drip system.

A crop specific fertigation schedule can be developed using growing degree days implementation. A soil with high N supply capacity may require substantially low N fertilizers. Application of N and K in excess of crop requirement can have adhesive effect such as ground water contamination with nitrate N, appearance of blossom end rot in tomato or pepper with heavy ammonical N application, reduction in specific gravity of potato and size of straw berry fruit with excessive K fertilization.

Nutrient can be injected daily or bimonthly depending upon system design, soil type and farmer's preference. Frequent injection may be needed for sandy soil with poor water and nutrient capacity and grower who want to reduce injection pump size and cost. Since leaching is possible with drip irrigation, nutrient applied in any irrigation must not be subjected to excessive irrigation during that application or in subsequent irrigations. It is possible to irrigate nutrient in non continuous (bulk) or continuous (concentration) fashion. Fertilizer should be injected in a period such that enough time remains to permit complete flushing of the system without over irrigation. Water that moves below the active crop root zone carry nitrate N or K in substantial quantities. One cm of leachate at 100 mg nitrate N/litre would contain 10 kg N/ha.

Drip irrigation introduces possibilities for precise application of fertilizer and other chemicals. The restricted root growth necessitates the type of fertilizer application "fertigation", which prevents nutrient deficiencies. The high efficiency of water application reached in drip irrigation systems is ideal for the high efficiency of applied nutrients in fertigation. But, some of these potential benefits can reverse into disadvantages when the irrigation system design or management is not correct (non uniform nutrient distribution, over-fertigation, excessive leaching, clogging).

Behaviour of Plant Nutrients during fertigation

Nitrogen

In fertigation, applied urea travels with the water in the soil. Its distribution in the soil wet zone depends on the timing of its incorporation with the irrigation water. When added during the third quarter of the irrigation cycle, followed by the flushing of the remaining irrigation cycle, the fertigated urea on reaching the boundaries of the wet zone becomes susceptible to volatilization. Evaporation from the soil surface results in increased urea concentration near the soil surface. This residual urea at the soil surface is also certain to be lost to the atmosphere as ammonia. Ammonium (NH_4^+) carries a positive electric charge (cation) and is adsorbed to the negatively charged sites on clay and can also replace other adsorbed cations on the clay surfaces. These are mainly Ca and Mg that constitute the major sorbed cations in the soil. As a result of these interactions, ammonium is concentrated near the dripper and the displaced Ca and to a lesser extent Mg, travels with the advancing water. Within a few days, the soil ammonium is usually oxidized by soil bacteria to the nitrate form that is dispersed in the soil with further irrigation cycles. When either ammonium or urea is used as nitrogen source in fertigation, significant gaseous losses as nitrous and nitric oxide has also been recorded (Hoffman and Van Cleemput 2004).

Nitrate (NO_3^-) carries a negative electric charge (anion). It cannot, therefore, bind to the clay particles of basic and neutral soils which carry negative charges. However, nitrate binds to positively charged iron and aluminum oxides present in acid soils. As in the case of urea, nitrate travels with the water and its distribution in the soil depends on the timing of its injection to the irrigation line.

Phosphorous

Phosphorus (P) in solution is subject to interactions with inorganic and organic constituents in the soil. The $H_2PO_4^-$ ion remains stable in the solution inside the irrigation line as long as the pH is kept low. Once it is released to the soil it reacts very quickly with clay minerals like, montmorillonite and illite in basic soils and with kaolinite clay, iron and aluminum compounds in acid soils. P reacts mainly with lime ($CaCO_3$) in basic soil conditions. The range of relatively insoluble chemical products of P with soil constituents is so large that it is generally called "fixed P."

The rapid reactions of phosphate with Ca (lime rich soils) in basic soils and with Fe and Al in acid soils restrict the distance of movement of applied P in the soil. The higher the clay content or $CaCO_3$ fraction of the soil, the shorter is the distance of movement of P from the dripper. Even in sandy soils (Ben Gal and Dudley 2003), the distance travelled by P is quite limited as compared with the water. When the P is complexed by organic compounds like in manures, it does not react with soil constituents and therefore, can travel to considerable distances from its point of application in the soil. The leaching of P through the soil profile is commonly thought to occur only in coarsely structured soils due to the rapid infiltration of water and in sandy soils due to the absence of active sites for P sorption.

Potassium

Drip irrigated crops under strict water control usually develop restricted root volume. The amounts of K present as exchangeable cation on clay surfaces or as K within the crystal lattice of illite clay particles in the soil might not be sufficient to completely meet plant needs for K**.** Since high K contents are present in harvested fresh vegetables, fruits, fresh leaves, tubers and root crops, large amounts of K are exported from the field. A continuous supply of K during fertigation is, therefore, required to ensure plant growth, quality and yield. In practice, the exact distribution of K in the soil from the drip point is of less importance since the roots can grow and find the K in the wet root zone. The efficiency of the plant roots to take up K is so high that whenever the root meets a K source it is easily taken up. In sand dunes with low soil K content, fertigation with daily supply of K and N is needed to ensure their supply to plants, particularly if there is restricted root volume. When the soil does not adsorb K due to low level of clay content, K distribution is typically larger than that of P distribution, but less than that of N. This was demonstrated in a fertigated field grown tomato on soil containing 95% calcium carbonate with low CEC (Kafkafi and Bar Yosef 1980).

Crop response to fertigation

All crops respond to fertigation. However, much work has been concentrated on high value crops (Solaimalai *et al.* 2005) such as potato (Badr *et al*. 2011), capsicum (Brahma *et al*. 2010; Gupta *et al.* 2009; Srinivas and Prabhakar 1982), onion (Ewais *et al*. 2010), medicinal coleus (Kennam 2008), cucumber (Moujabber *et al*. 2002), Broccoli (Sanchita *et al*. 2010), tomato (Shedeed *et al*. 2009), pointed gourd (Singandhupe *et al*. 2007), turmeric (Syed Sadarunnisa *et al*. 2010), tomato (Tan *et al*. 2009; Tanaskovik *et al*. 2011) and some leafy vegetables (Ueta *et al*. 2009). Fertigation gave 40% saving of fertilizer nutrients without affecting the yield of crops compared to the conventional method of nutrient application (Sathya *et al*. 2008). Keng *et al*. (1979) showed that the yields from broadcast fertilizer treatments were 15.8% lower than that from fertigation and 12.3% lower than that from banded fertilizer application.

Sweet pepper: 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%) as compared with conventional irrigation.

Lady's finger: Rekha and Mahavishnan (2008) reported the water and fertilizer saving by 40-70 and 30-50%, respectively through drip fertigation in lady's finger.

Celery: 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.

Cauliflower: 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, marketable yield of cauliflower and benefit cost ratio but decrease in fertilizer expense efficiency. Drip based irrigation along with fertigation in general had higher fruit yield but lower benefit cost ratio in comparison to flood and conventional fertilizer application. At Palampur fertigation using water soluble fertilizers increased marketable yield in cauliflower by 21.3% as compared to conventional application of fertilizers (Table 2).

Broccoli: At Palampur fertigation using water soluble fertilizers increased marketable yield in broccoli by 21.4% as compared to conventional application of fertilizers (Table 2). However, when 25% nutrients were applied as basal through conventional fertilizer and 75% nutrient through fertigation using water soluble fertilizers increase in marketable yield in broccoli was 12.3% as compared to conventional application of fertilizer (Table 3).

Brinjal: At Palampur, when 25% nutrients were applied as basal through conventional fertilizer and 75% nutrient through fertigation using water soluble fertilizers increase in marketable yield in brinjal was 15.4% as compared to conventional application of fertilizer (Table 3).

Chilli: Veeranna *et al*. (2001) reported that 80% water soluble fertilizer (WSF) was effective in producing about 31 and 24.7% higher chilli 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. However, average weight of fruit increased significantly with increasing levels of P up to 150 kg N/ha. Average weight of fruit and yield increased significantly with increasing levels of P up to the treatment 30 kg P/ha, whereas length of fruit and number of fruits per plant was increased significantly up to the 60 kg P/ha. Considering the combined effect of nitrogen and phosphorus, the maximum yield was recorded in the treatment combination of 150 kg N and 30 kg P /ha. At Palampur fertigation using water soluble fertilizers increased marketable yield in capsicum by 15.1 as compared to conventional application of fertilizers (Table 2). The fertigation schedule was developed for protected conditions and 4.6 B.C ratio was obtained with capsicum (Table 4).

Tomato: Hebbar *et al*. (2004) showed that fertigation with 100% water soluble fertilizers (WSF) increased the tomato fruit yield significantly over furrow-irrigated control and drip irrigation. The fertigation schedule was developed for protected conditions in tomato and a B.C ratio of 5.4 was obtained (Table 4).

Cucumber: Ibrikci and Buyuk (2002) obtained higher yield and leaf N, P and K content in drip fertigated cucumber than furrow irrigated plants. Beyaert *et al*. (2007) showed that drip irrigation coupled with fertigation showed significant advantages in terms of yield and economic returns of cucumber compared with overhead irrigation and conventional fertilization practices. The fertigation schedule was developed for protected conditions and 3.3 B.C ratio was obtained with cucumber (Table 4).

Table 2. Fertilizer schedule without basal doses & 100% RDF through fertigation

Crop	Growing season	Fertigation dose per spilt (g/m^2)*			No of splits	Fertigation frequency (days)	Increase in yield compared to conventional fertilizer	B.C ratio
		19:19:19	0:0:50	Urea				
Cauliflower	Oct- Feb	2.9	0.3	1.5	10	8-10	21.3 %	2.1
Broccoli	Oct-Feb	4.0	-	1.6	10	8-10	21.4 %	3.7
Capsicum	Apr- July	3.0	-	1.5	10	8-10	15.1%	3.9

*No basal dose is applied and fertigation is initiated from 15 days after transplanting and fertigation doses are completed before flowering / fruit setting

Table 3. Fertilizer schedule with 25% of RDF through basal and 75% of RDF through fertigation

Crop	Basal doses			Fertigation dose per spilt (g/m^2)*			No of splits	Fertigation frequency (days)	Increase in yield compared to conventional fertilizer	B . C ratio
	Urea	SSP	MOP	19:19:19	12:61:0	Urea				
Broccoli	8.2	15.7	2.3	2.0	0.8	3.1	7	8-10	15.4 %	3.1
Brinjal	5.4	9.4	2.1	2.7	0.2	8.6	7	8.10	12.3 %	2.6

*25% of RDF applied as basal doses and fertigation is initiated from 30 days after transplanting and fertigation doses are completed before flowering / fruit setting

Table 4 . Drip fertigation schedule under protected cultivation

Crop	Basal dose (g/m^2)			Fertigation dose/spilt (g/m^2)				Fertigation interval (days)	B.C ratio
	Urea	SSP	MOP	19:19:19	12:61:0	Urea	No of splits		
Tomato	14*	34	4	1.2	0.4	0.7	28	5 -7	5.4
Capsicum	10	22	4	1.2	0.1	0.3	28	5 -7	4.6
Cucumber	12	18	6	3.0	2.3	1.2	10	5 -7	3.3

Onion: Chopade *et al*. (1998) found that drip irrigation with the recommended rate of solid fertilizer in two applications gave the highest onion bulb yield while drip fertigation at 50% of the recommended rate gave the highest bulb quality. Rumpel *et al*. (2004) obtained higher marketable onion yields when the 50 kg/ha N rate was applied through drip fertigation (41% increase) and highest after applying 150 kg ha^{-1} N through fertigation (79% increase) as compared to the control (without fertigation and irrigation). 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. Rajput and Patel (2006) recorded the highest onion yield in daily fertigation followed by alternate day fertigation. Lowest yield was recorded in monthly fertigation frequency. Bhakare and Fatkal (2008) showed that the onion seed yield increased and yield contributing characters improved with fertigation levels with maximum in 125% recommended dose of fertilizer (RDF) fertigation treatment which was at par with 100% RDF fertigation treatment. The treatment 75% RDF through fertigation was significantly superior to application of 100% RDF through conventional fertilizer and as such, there could be a saving of 25% of the added fertilizer..

Pea: Singh *et al.* (2006) showed that the increase in N through fertigation caused increased in green pea yield at all the levels of drip irrigation (0.5 Epan, 0.75 Epan and 1.0 Epan), but the magnitude of increase was highest at lowest level of water supply.

References

Badr MA, Taalab AS and Tohamy El WA. 2011. Nitrogen application rate and fertigation frequency for drip irrigated potato. *Australian J Basic and Applied Sci* **5**: 817-825

Ben Gal A and Dudley LM. 2003. Phosphorus availability under continuous point source irrigation. *Soil Sci. Soc. Am. J.* **67**:1449-1456.

Beyaert RP, Roy RC and Coelho BBR. 2007. Irrigation and fertilizer management effects on processing cucumber productivity and water use efficiency. *Canadian J Plant Sci* **87**: 355–363

Bhakare BD and Fatkal YD. 2008. Influence of micro irrigation and fertilizer levels on growth, yield and quality of onion seed. *J Water Mangnt* **16**: 35-39

Brahma S, Saikia L, Barua P, Hazarika T and Sharma B 2010. Studies on effect of fertigation with different levels of N and K fertilizers on growth, yield, quality and economics of early season capsicum (*Capsicum annum* L. *var. grossum*) under cover. *Veg Sci* ***37*** :160-163.

Chopade SO, Bansode PN, Hiwase SS and Bhuyar RC 1998. Effect of drip fertigation on physiological growth of onion. *Annals Plant Physio* **11**: 45-48

Dingre SK, Pawar DD and Kadam KG 2012. Productivity, water use and quality of onion (*Allium cepa*) seed production under different irrigation scheduling through drip. *Indian J Agron* **57**:186-190

Ewais MA, Mahmoud AA and Khalil AA. 2010. Effect of nitrogen fertigation in comparison with soil application on onion production in sandy soils. *Alexandria Jf Agri Res* **55**: 75-83

Gupta AJ, Chattoo MA and Bhat FN 2009. Techno-economic evaluation of drip irrigation and fertigation practices in capsicum under Kashmir conditions. *Veg*

*Sci **36*** :309-314.

Hagin J, Sneh M and Lowengart-Aycicegi A 2002. Fertigation – Fertilization through irrigation. IPI Research Topics No. 23. Ed. by A.E. Johnston. International Potash Institute, Basel, Switzerland.

Hebbar SS, Ramachandrappa BK, Nanjappa HV and Prabhakar M. 2004. Studies on NPK drip fertigation in field grown tomato (*Lycopersicon esculentum* Mill.). *European J Agron* **21**: 117-127

Hofman GJ and Van Cleemput O. 2004. Soil and plant nitrogen. International Fertilizer Industry Association (IFA), Paris, France.

Ibrikci GS and Buyuk H. 2002. Yield and elemental composition of cucumber as affected by drip and furrow irrigation. *Acta Hort* **571**: 51-57.

Kafkafi U and Bar-Yosef B. 1980. Trickle irrigation and fertilization of tomatoes in high calcareous soils. *Agron. J.* 72:893-897.

Kaniszewski S, Rumpel J and Dysko J. 1999. Effect of drip irrigation and fertigation on growth and yield of celeriac (*Apium graveolens* L. var. *rapaceum* (Mill.) *Gaud*). *Veg Crops Res Bulletin* **50**: 31-39

Kannan K. 2008. Effect of irrigation method, drip irrigation regimes and fertigation schedules on growth and yield of medicinal coleus (*Coleus forskohlii*). *Indian J Agri Sci* **78** : 614-617

Kapoor R, Sandal SK, Sharma Sanjay K, Kumar A and Saroch K. 2013. Effect of varying drip irrigation levels and NPK fertigation on soil water dynamics, productivity and water use efficiency of cauliflower (*Brassica oleracea* var. *Botrytis)* in wet temperate zone of Himachal Pradesh. *Indian J Soil Cons* **42**: 249 -254

Kaushal A, Lodhi AS and Singh KG. 2011. Economics of growing sweet pepper under low tunnels, *Prog Agri* :67-72.

Keng JCW, Scott TW and Lugo LMA 1979. Fertilizer management with drip irrigation in an Oxisol. *Agron J* **71** : 971-980.

Kumar A and Singh AK 2002. Improving nutrient and water use efficiency through fertigation. *J Water Mangnt* **10**: 42-48.

Mmolawa K and Or D 2000. Root zone solute dynamics under drip irrigation: A review. Plant and Soil 222:163-190. Netherlands, 27 pp.

Moujabber EI, Atallah M and Darwish T. 2002. Crop modeling and water use efficiency of protected cucumber. *Int Atomic Energy Agency Tech Documents* **1266**: 61-67

Rajput TBS and Patel N. 2006. Water and nitrate movement in drip-irrigated onion under fertigation and irrigation treatments. *Agric Water Mangnt* **79**: 293-311

Rekha BK and Mahavishnan K. 2008. Drip fertigation in vegetable crops with emphasis on lady's finger (*Abelmoschus esculentus* (L.) *Moench*) – A Review. *Agri Rev* **29** : 298 – 305.

Roy SS, Khan MSI and KK Pall 2011. Nitrogen and phosphorus efficiency on the fruit size and yield of capsicum. *J Expt Sci* **2**: 32-37.

Rumpel J, Kaniszewski S and Dysko J. 2004. Effect of drip irrigation and fertilization timing and rate on yield of onion. *J Veg Crop Production* **9**: 65-73

Sanchita B, Phooken DB, Kachari M, Hazarika TK and Das K. 2010. Growth, yield and economics of broccoli under different levels of nitrogen fertigation. *Indian J Hort* **67**: 279-282

Sathya S, Pitchai JG, Indirani R and Kannathasan M. 2008. Effect of fertigation on availability of nutrients (N, P & K) in soil – A Review. *Agri Rev* **29**: 214-219

Shedeed SI, Zaghloul SM and Yassen AA. 2009. Effect of method and rate of fertilizer application under drip irrigation on yield and nutrient uptake by tomato. *Ozean J Applied Sci* **2**: 139-147

Shock CC, Feibert EB, Saunders LD and James SR. 2003. Umatilla Russet' and `Russet Legend' Potato Yield and Quality Response to Irrigation. *Hort Sci* 38: 1117 -1121.

Singandhupe RB, James BK, Edna A and Nanda P. 2007. Response of drip irrigation and mulching on growth and fruit yield of pointed gourd (*Trichosanthes dioica*). *Indian J Agri Sci* **77**: 8-13

Singh KG, Siag M and Mahajan G. 2006. Water and nutrient requirement of drip irrigated green pea. *Haryana J Hort Sci* **35**: 320-322

Solaimalai A Baskar, Sadasakthi M A and Subburamu K 2005. Fertigation in high value crops, *Agriculture Review **26*** :1-13.

Srinivas K and Prabhakar BS. 1982. Response of capsicum to nitrogen fertilization. *Veg Sci* **9**: 71-74.

Syed Sadarunnisa, Madhumathi C, Rao GS and Sreenivasulu B 2010. Effect of fertigation on growth and yield of turmeric cv. Mydukur. *J Hort Sci* **5** : 78-80.

Tan CS, Zhang TQ, Reynolds WD, Warner J and Drury CF. 2009. Farm-scale processing tomato production using surface and subsurface drip irrigation and fertigation. *Acta Hort* **823** : 77-81.

Tanaskovik V, Cukaliev O, Romic D and Ondrasek G. 2011 The influence of drip fertigation on water use efficiency in tomato crop production. *Agriculturae Conspectus Scientificus* **76**: 57-63.

Ueta T, Ikeba T, Ahn-DongHyuk, Kato K, Kawano T and Matsumoto E. 2009. Effects of drip fertigation on yield and quality of leaf vegetables and on efficiency of nitrogen fertilization in outdoor plant. *Japanese J Soil Sci and Plant Nutrition culture.* **80**: 477-486.

Veeranna HK, Kgalak abdul, AA, Sujith GM. 2001. Effect offertigation with normal and water soluble fertilizers compared to drip andfurrow methods on yield, fertilizer and irrigation water use efficiency in chilli.*Micro Irrigation* pp. 461-466.