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Review Article

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Effect of Varying Drip Irrigation Levels and Methods of NPK Fertilizer Application on Soil Water Dynamics, Water Use Efficiency and Productivity of Various Crops: A Review

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ABSTRACT

In today's world, where water resources are scarce in many regions, the irrigation industry is under pressure to improve water use efficiency and reduce environmental impacts. Drip irrigation is a very efficient irrigation method possessing potential to improve irrigation performance. Drip involves application of water drop by drop through closed network of plastic pipes at frequent intervals near to the root zone for consumptive use of the crop. Drip irrigation added with fertilizer, fertigation reduces the wastage of water and chemical fertilizers especially nitrogenous and subsequently optimizes the nutrient use by supplying them at critical stages, proper place and time, which finally increase water and nutrient utilization. Throughout the world, emphasis is being given for efficient utilization of harvested rain water by reducing deep percolation losses and maximizing benefits from the use of available water resources for sustainable crop production. One such popular way is to change the traditional flood irrigation method to most efficient micro irrigation methods like drip irrigation. In practice most of the studies are based on IW/CPE approach on the basis of which levels of irrigation are set. The effect of different levels of irrigation on morphology, growth, yield parameters and water use efficiency are studied. Also, in various studies comparison has been made between drip fertigation and broadcast fertilizer application without the use of drip and it is concluded that fertigated crops have shown promising results in growth, yield and quality parameters than traditional methods of fertilizer application. The results have shown that drip irrigation out performs the traditional methods in all aspects of crop production.

Key words: *Drip irrigation, Fertigation, IW/CPE, Water use efficiency.*

INTRODUCTION

Irrigation dates back to at least 6000 BC (Egypt and Mesopotamia). It is reported that in 2000 BC cement pipes were used by Romans to carry water to their fields. Irrigation helped them to open up arid soils and grow crops. Irrigation plays an important role in raising, stabilizing yield and maintaining quality of a crop. Water relations are very important to the basic metabolic functions of the crop, as water is the greatest component of plants by mass and almost all critical processes can be limited by inappropriate water status.

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The essential role of water makes it an inevitable input resource which plays an important role in regulating the variations in productivity. With the depletion in the availability of usable form of water and increase in its demand for agriculture and other sectors, it has become more important to use this valuable resource wisely and irrigate intelligently. About 80% of the water used in the world is for irrigation. We are at about 600,000,000 acres of irrigated land in the world. About 16% of farmed land is irrigated, which accounts for about 40% of productivity. Thus effective scheduling of irrigation is very important in decisions related to maximizing yields and improving quality. Irrigation scheduling requires knowledge of two crop characteristics, (i) how much water a crop needs at a particular time (ii) how it should be applied? Besides these characteristics, one additional point is considered that is how efficiently the needed water is applied to the potential root zone of the crop. Irrigation water use efficiency (IWUE) is the water used for plant growth and it has been found to be 30-50% in Surface, 70-90% in Overhead and 90-95% in Drip. Drip irrigation is of various types – Surface drip, Surface under plastic, Sub-surface drip etc.

Drip irrigation is the slow localized application of water drop by drop, at a point or grid of points on or just below the soil surface near the plant's root zone. Water is delivered to the plants via a set of plastic lateral tubes laid along the ground or buried just beneath it for protection. The lateral lines are connected to a buried main line that receives water from a head source. The trickling rate, generally in the range of 4-8 liters/ hour per emitter, must not exceed the soil's infilterability, if run off is to be avoided. It is considered best alternative to sprinkler or furrow methods of irrigating crops. Drip irrigation can be used for crops with high or low water demands and also helps to use water efficiently. A well-designed drip irrigation system loses practically no water to runoff, evaporation, or deep percolation in silty soils. Drip irrigation reduces water contact with crop leaves, stems and fruit, thus provides conditions less favorable for disease development. Irrigation scheduling can be managed precisely to meet crop demands, holding the promise of increased yield and quality. Growers and irrigation professionals often refer to "subsurface drip irrigation," or SDI. When a drip tape or tube is buried below the soil surface, it is less vulnerable to damage due to UV radiation, cultivation or weeding. With SDI, water use efficiency is maximized because there is even less evaporation or runoff. Soils with high as well as low transmission characteristics can be well irrigated by drip system. Added advantage of this system is that plant nutrients can also be applied to the crop plants through irrigation water (fertigation). Agricultural chemicals can be applied more efficiently through drip irrigation. Since only the crop root zone is irrigated, nitrogen already in the soil is less subject to leaching losses and hence applied fertilizer can be used more efficiently. In the case of insecticides, less product might be needed which can be easily managed through drip. Drip systems are adaptable to oddly shaped fields or those with uneven topography or soil texture. Drip systems also can work well where other irrigation systems are inefficient because parts of the field have excessive infiltration, water puddling or runoff problems. Drip irrigation can reduce weed populations or reduce weed problems in arid climates by keeping much of the soil surface dry. Despite all of drip irrigation's potential benefits, shifting to drip irrigation method can increase production costs, especially where an irrigation system already is in place. Ultimately, there must be an economic advantage to drip irrigation to make it worthwhile. Keeping in view the aforementioned facts, the topic, effect of varying drip irrigation levels and different methods of NPK fertilizer application on soil water dynamics, water use efficiency and productivity of different crops is reviewed.

Effect of drip based irrigation scheduling on soil water dynamics and productivity of different crops

Ponnuswamy and Santhi[21] studied the effect of drip irrigation on soil moisture distribution pattern in cassava and revealed that the moisture content from the surface and subsurface decreased from 33.8 to 23.8 per cent and 32.2 to 22.7 per cent for drip irrigation with 100 and 50 per cent of surface applied water, respectively. More water penetrated into the deeper layers in drip system of irrigation and the crop utilized the water very effectively. Padmavati and Lakshmamma[19] conducted an experiment to study the performance of safflower as influenced by levels of irrigation viz., 0.4, 0.6, 0.8 IW/CPE and phosphorus nutrition and found that seed yield and its components varied significantly due to irrigation and P application. A significantly higher seed yield of 1667 kg ha^{-1} was recorded with irrigation at 0.8 IW/CPE compared to 0.6 (1454 kg ha^{-1}) and 0.4 IW/CPE ratio (927 kg ha^{-1})

Antony and Singandhupe[2] studied the effect of different irrigation methods and schedules on morphology, yield and water use efficiency of capsicum (*Capsicum annum* L.) var. California Wonder. It was found that the plants grown under drip irrigation had more number of branches and plant heights compared to that of surface irrigated plants. Root mass was more in surface irrigated crop where as total root length was more in drip irrigated crop. Nilesh and Gulati[18] conducted a field experiment to evaluate the effect of drip system and conventional furrow system of irrigation on the growth, yield and water use efficiency of American cotton (*Gossypium hirsutum*) cv. LH-846. The study revealed that the average plant height was found to be maximum in drip system (158.9 cm) with a high level of irrigation (IW/CPE=1.0) as compared to furrow system (146.9 cm). The average number of bolls per plant were also found maximum in drip system (27.0 bolls per plant) as compared to the furrow system (20.3 bolls per plant). Result on seed-cotton yield was same as that for bolls production. The water use efficiency of 0.54 q $(ha\text{-}cm)^{-1}$ was found in drip system as compared to 0.37 q $(ha\text{-}cm)^{-1}$ in furrow system. Nitrogen use efficiency was found maximum in the drip system as compared to the furrow irrigation system.

Shirgure *et al*[31]., conducted a field experiment on irrigation scheduling based on pan evaporation through drip irrigation system. Four levels of open pan evaporation-based irrigations were scheduled (0.6, 0.7, 0.8 and 0.9 of open pan evaporation) and the incremental growth, leaf nutrient status, yields and fruit quality was recorded. The incremental growth of plant height (0.63 m), stock girth (5.63 cm) and canopy volume (7.07 m^3) were higher with the irrigation scheduled at 0.8 of open pan evaporation. The average fruit yield (14.08 kg/tree), fruit weight (37.9 g), total soluble solids (7.24° Brix), juice percentage (45.58%) and acidity (6.16%) of the lime was higher with drip irrigation scheduled at 0.8 of open pan evaporation.

Kumari *et al*[15]., conducted a field experiment to study the effect of drip irrigation at three levels of water application, i.e. 1.0, 0.8 and 0.6 of maximum evapo-transpiration and surface irrigation in combination with two mulches (black polyethylene and paddy husk) on the growth and yield of bell pepper cv. California Wonder. Results indicated that plants irrigated through drip on an average were taller at harvest by approximately 5.5 cm compared to those that received surface irrigation. Among all the treatments, the highest yield was obtained with drip 0.8 and black polyethylene mulch combination and the lowest was recorded in surface irrigation without mulch. Nalge[17] conducted an experiment to study yield and moisture use of cotton under drip irrigation in vertisols at eight replications under rainfed (T_1), 50 per cent (T_2) and 100 per cent (T_3) irrigation through drip. Seed cotton yield was lowest under rainfed (0.862 t ha^{-1}) and at par under 50 per cent (1.552t ha^{-1}) and 100 per cent (1.580t ha^{-1}) irrigation, respectively. Total water use efficiencies were 1.606, 2.092 and 1.915 kg ha^{-1} mm^{-1} under T_1, T_2, and T_3 treatments, respectively.

Kanan[14] conducted a research to determine the effects of different irrigation methods and drip irrigation regimes, and fertigation schedules on the growth and yield of medicinal coleus (*Coleus forskohlii*). The irrigation methods and drip irrigation regimes include: I1, drip irrigation at 100 % pan evaporation (PE); I2, 80 % PE; I3, 60 % PE; and a control (surface irrigation and soil application of fertilizer. The effects of the treatments on tuber yield per plant, tuber length, tuber girth, dry tuber yield, water use efficiency, nitrogen use efficiency and water productivity were studied. Irrigation water saving due to drip-fertigation compared to surface irrigation and soil application of fertilizer ranged from 14.7 to 48.1 %. An increase in tuber yield (24 %) was evident with drip irrigation compared to conventional method of surface irrigation

Sankar *et al*[27]., studied the effect of micro irrigation on productivity of onion and found that both drip and micro irrigation systems improved growth, yield and yield attributing parameters of onion. Also, there was a saving of irrigation water of 37.8 % in drip and 32.5 % in sprinkler system compared to surface irrigation scheduled at 50 mm cumulative pan evaporation with 7 cm depth. Barua and Phookan[3] evaluated the effect of drip irrigation and plastic mulch on yield of broccoli (*Brassica oleracea* L. *var. italica*) and the results showed 64 to 124 % yield increase due to drip irrigation. Among the different drip irrigation levels, 100 % of irrigation requirement met through drip showed highest yield. Highest net return was observed for the treatment where 100 % of net volume of water was met with drip irrigation and plants were mulched with black plastic mulch.

Mishra and Paul[16] studied the impact of drip irrigation with plastic mulch on yield and returns of brinjal crop and obtained the highest yield of 34.8 t ha^{-1} as compared to other treatment. An increase in yield (65 %) and net income (83 %) was recorded in drip irrigation with mulch as compared to conventional surface irrigation. The benefit cost ratio was highest (2.18) for drip alone. The highest yield and net profit per mm of water were observed in case of 0.6 net irrigation volume drip along with mulch.

Rathore[24] studied the optimization of nitrogen application and irrigation schedules in tuberose (*Polianthes tuberosa*). The study showed that irrigation applied at 0.8 IW/CPE ratio increased the number of florets per spike and bulb yield by 23 and 22 % over the control (flood irrigation) and by 30 and 44%, respectively, compared to the treatment receiving minimum water at 0.4 IW/CPE. Water productivity based on consumptive use (WPCU), irrigation water (WPIR) and total water (WPTW) applied through irrigation and rainfall significantly improved the vegetative growth, spike and bulb yield with increasing ratio of water application from 0.4 to 0.8 IW/CPE ratio but failed to increase beyond 0.8 IW/CPE ratio which indicated that water application beyond 0.8 IW/CPE ratio is not being utilized by crop. Irrigation through drip system at 0.8 IW/CPE saved water by 39 % and increased dry matter in florets by 45 % compared to the traditional flood method.

Ahmed *et al*[1]., conducted an experiment to study the effect of drip irrigation on growth, yield and quality of banana. They studied water quantity and efficiency with fertigation in comparison to farmer practice. The results indicated that the amount of applied irrigation water with drip irrigation system was lower than that needed under surface irrigation. The banana under drip irrigation system performed better in plant growth and flowered earlier in comparison with surface irrigation. Guohua *et al*[10]., studied the effect of different irrigation methods, namely border irrigation, sprinkler irrigation and surface drip irrigation on root development and profile water uptake in winter wheat. Results showed that the main root distribution zone moved upward under sprinkler and surface drip irrigation when compared to the traditional border irrigation. Due to the appropriate soil water and higher root density in the surface soil layer under sprinkler and surface drip irrigation, the main water uptake zone was concentrated in the upper layer.

Sharma *et al*[29]., reported superiority of gravity fed drip irrigation system over conventional flood irrigation system in vegetable crops. They reported irrigation efficiency as high as 90-95 % with drip irrigation system. Woltering *et al*[36]., reported that total labour requirement for the drip irrigated African Market Garden was on average 1.1 man hours per day against 4.7 man hours per day for the Farmers Practice on a 500 m^2 garden. Popale *et al*[22]., studied the response of cauliflower to irrigation schedules under drip irrigation. Drip Irrigation schedules comprised of I_1 (0.4 CPE), I_2 (0.6 CPE), I_3 (0.8 CPE) and fertigation levels included F_1 (50 % RDF), F_2 (75 % RDF) and F_3 (100 % RDF). The control I_4 was furrow irrigation scheduled at 1.2 IW/CPW with 60 mm depth of irrigation. The study revealed that percentage of average water saving under drip irrigation system over surface irrigation was 43.45 % and it was 75.54 %, 63.87 % and 50.95 % under I_1, I_2 and I_3 irrigation schedules, respectively. The mean water use efficiencies under surface irrigation and drip irrigation schedules were 22.03 kg $ha^{-1}mm^{-1}$ and 73.48 kg $ha^{-1}mm^{-1}$, respectively.

Yadav *et al*[37]., studied the effect of drip irrigation and fertigation in sugarcane and the data revealed that drip irrigation at 60, 80 and 100 % PE increased cane yield by 14.4, 26.4 and 44.6 %, respectively over the cane yield obtained with border strip irrigation. In addition to yield increase, the respective water saving was 32.9, 17.1 and 1.4 %. Drip irrigation also improved the quality of cane and the commercial cane sugar increased by 46.4, 35.8 and 15.1 % as a result of drip irrigation at 60, 80 and 100 % PE, respectively over that obtained with conventional flood irrigation treatment.

Effect of Fertigation on growth and productivity of different crops

Srinivas and Prabhakar[32] conducted experiment with capsicum cv. California Wonder and noticed that N fertigation increased fruit yield, plant height, number of branches and fruit size .The highest fruit yield (111.3q per hectare) was obtained at 150 kg N per hectare. Kaniszewski *et al*[13]., compared the drip fertigation with traditional broadcast N fertilizer application and observed that the yield of celeriac was highest with one-third of the N applied before planting and two-thirds applied through the drip irrigation system and lowest with broadcast N application without drip irrigation. Fertigated 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. Chaudri *et al*[6]., conducted an experiment to determine the effect of drip fertigation on papaya. In solid fertilizer treatment (RDSF), the recommended dose was applied in equal splits at 1, 3, 5 and 7 months after transplanting. In liquid fertilizer treatment (RDLF), fertilizers were applied by liquid fertilizer grade in 8 equal splits with monthly schedule started from one month after transplanting. In surface irrigation (SI), IW/CPE ratio was used to schedule the irrigation with 5 cm depth of water. In drip irrigation (DI), alternate day irrigation was scheduled. The treatments comprised RDSF+SI, 50 % RDLF+DI, 75 % RDLF+DI, 100 % RDLF+DI and 125 % RDLF+DI. Results indicated that normal yield as that of RDSF+SI could be achieved with even 50 % reduction in recommended fertilizer dose, provided liquid fertilizers were used through drip.

Veeranna *et al*[35]., conducted field experiments to investigate the effects of broadcast applications and fertigation of normal and water soluble fertilizers at 3 rates through drip and furrow irrigation. Fertilizer use efficiency of 5.28 was obtained in drip fertigation with 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. Hebbar *et al*[11]., studied the effect of fertigation with sources and levels of fertilizer and methods of fertilizer application on growth, yield and fertilizer-use efficiency of hybrid tomato in red sandy loam soil. The investigations revealed that the total dry matter (TDM) production and leaf area index (LAI) were significantly higher in drip irrigation (165.8 g and 3.12 g) over furrow irrigation (140.2 g and 2.25 g). Water-soluble fertilizer (WSF) fertigation recorded significantly higher total dry matter and LAI (181.9 g and 3.69 g) over drip irrigation. The fruit yield of tomato was 19.9 % higher in drip irrigation (71.9 Mg ha^{-1}) over furrow irrigation (59.5 Mg ha^{-1}).

Beyaert *et al*[4]., evaluated the response of processing cucumber (*Cucumis sativus* L.) to irrigation and fertilization strategies on a loamy sand and found that dry matter accumulation, fruit yield, economic returns and water use efficiency were compared for (a) non-irrigated with conventional broadcast fertilizer applications, (b) overhead sprinkler irrigated with conventional broadcast fertilizer applications, (c) surface drip irrigated with fertigation and (d) subsurface drip irrigated with fertigation. All irrigation methods enhanced yields, with drip irrigation coupled with fertigation showed significant advantages in terms of yield and economic returns compared with overhead irrigation and conventional fertilization practices.

Sathya *et al*[28]., indicated higher availability of N, P and K nutrients in root zone area of drip fertigated plot. They also showed that fertigation frequency reduced the concentration of immobile elements such as P, K and trace elements in irrigation water and significantly increased saving of fertilizer nutrients up to 40 % without affecting the yield of crops compared to the conventional method of nutrient application. Ewias *et al*[9]., studied the response of onion (*Allium cepa* L.) to nitrogen fertigation compared to soil application frequencies at different levels of N (60, 80, 100 and 120 kg N) under sandy soil conditions. The results indicated that fertigation method significantly increased the dry weight of different parts of onion plant, i.e., leaves, bulb and whole plant, chlorophylls concentration in leaves, N, P and K concentrations in the different onion organs as well as yield and its components compared to soil application method. Fertigation of the highest dose of N (120 kg N/fed) being the best treatment recorded the highest significant increases in all the above mentioned parameters compared to low fertilizer level, i.e., 60 kg N/fed.

Sanchita *et al*[26]., found that fertigation has the potential to ensure that the right combination of water and nutrients is available at the root zone, satisfying the plants requirement of these two critical inputs. The experiment was conducted to study the effect of different levels of nitrogen fertigation on growth, yield and economics of the broccoli crop. The results revealed that there was significant improvement in growth, yield and fertilizer use efficiency of broccoli under drip irrigation and fertigation. Fertigation saved fertilizers to the tune of 40 % as compared to conventional fertilization to maintain the same yield levels in broccoli. Study on fertigation efficiency and economics of cultivation revealed that fertigation with 100 % recommended doses of N was the most efficient treatment with fertigation efficiency of 55.44% and 57.31%, respectively and cost benefit ratio of 1:4.41.

Hemalatha *et al*[12]., studied the effect of fertigation for crops and nitrogen fertigation for sugarcane and revealed that drip fertigation ensures required quantity, proper placement, proper time, and regular supply of water and fertilizer. Fertigation enhances the utilization of fertilizers and crop yield. Drip fertigation not only ensures proper utilization of irrigation water, but also is an effective way to improve the yield and quality parameters of crops.

Combined effect of Drip Based Irrigation Scheduling and Fertigation

Rajput and Patel[23] evaluated the response of three irrigation levels of 60, 80 and 100 % of the crop evapo-transpiration (ET) and four fertigation frequencies of daily, alternate day, weekly and monthly on yield of onion and reported that yield of onion was not significantly affected in daily, alternate day and weekly fertigation, though there was a trend of lower yields with monthly fertigation. The highest yield was recorded in daily fertigation (28.74 t ha^{-1}) followed by alternate day fertigation (28.4 t ha^{-1}). Lowest yield was recorded in monthly fertigation frequency (21.4 t ha^{-1}). Bhakare and Fatkal[5] evaluated the influence of micro irrigation and fertilizer levels through fertigation on growth, yield and quality of onion seed and they reported a saving of irrigation water (39.9 %) through drip system compared to surface irrigation. The water use and fertilizer use efficiency were maximum under fertigation treatments.

Cukaliev *et al*[7]., conducted the study to determine the best irrigation and fertigation practice for tomato crop (*Lycopersicon esculentum* Mill.) in order to achieve highest yield with maximum fertilizer use efficiency. Five experimental treatments included the following: The first three treatments (T1, T2 and T3) included a combination of drip irrigation and fertigation, treatment (T4) included drip irrigation, but with conventional application of fertilizer, and the fifth treatment, (T5), included furrow irrigation practice with conventional application of fertilizer. To determine fertilizer use efficiency, part of nitrogen was applied as labelled urea with ^{15}N stable isotope. The results of this study indicated that to obtain acceptable/maximum tomato yield with high nitrogen fertilizer use efficiency (NFUE) the practice of drip irrigation in combination of fertigation with irrigation frequency of either two (T1) or four (T2) days is recommended.

Rekha and Mahavishnan[25] reported increased growth and yield with drip irrigation in several crops ranging between 7-11.2 % depending on the crops / varieties and method of irrigation. Also, the water and fertilizer saving through drip fertigation have been reported to be 40-70 and 30-50%, respectively. Shedeed *et al*[30]., evaluated the effect of method and rate of fertilizer application under drip irrigation system on growth, yield and nutrient uptake by tomato grown on sandy soil. Drip irrigation recorded significantly higher total dry matter production (3.60 t ha^{-1}) and leaf area index (3.15) over furrow irrigation (2.86 t ha^{-1} and 2.27), respectively. The fruit yield of tomato was 28 % higher in drip irrigation (43.87 t ha^{-1}) over furrow irrigation (34.38 t ha^{-1}). Fertigation with 100 % NPK water-soluble fertilizers increased tomato fruit yield significantly (58.76 t ha^{-1}) over furrow irrigated control.

Tanaskovik *et al*[33]., studied the best irrigation and fertigation practice for tomato crop (*Lycopersicon esculentum* Mill.) in order to achieve highest yield with maximum water use efficiency (WUE). Five experimental treatments tested in this study included the following: the first three treatments (T1, T2, and T3) included a combination of drip irrigation and fertigation, treatment four (T4) included drip irrigation, but with conventional application of fertilizer, and the fifth treatment, (T5), included furrow irrigation practice with conventional application of fertilizer. The results of this study show that the drip fertigation treatments (T1, T2, and T3) gave significantly higher tomato yields in comparison with treatments T4 and T5, almost 24 % and 39%. Treatments under drip fertigation showed almost 28 % more water use efficiency in comparison with the treatment with conventional application of fertilizer and drip irrigation.

Ugalde-Acosta *et al*[34]., conducted the study to determine the effect of fertigation on bean crops in the central and southern areas of the state of Veracruz, Mexico. Three treatments were evaluated: (1) Gravity irrigation and solid manual fertilization (regional treatment) (RR-40), (2) Drip irrigation and solid manual fertilization (RG-40); in both treatments the fertilizer was applied at 15 days after the emergence of the crop, and (3) Drip irrigation and soluble fertilization, (RG-60). In the evaluation stage, with the RG-60 treatment the water consumption was reduced in 85 per cent and the highest average yield (2256 kg ha^{-1}) was obtained, which surpassed in 145 per cent to that obtained with RG-40, and in 186 per cent to RR-40 (regional treatment).

Dingre *et al*[8]., conducted an experiment to study the feasibility of fertigation scheduling through drip on growth and yield of onion seed (*Allium Cepa* L). The study revealed that 100 % water soluble fertilizers in 12 equal splits up to 2 months was found significantly superior in respect of growth and quality parameters of onion seed. The fertigation applied in 12 splits up to 2 months produced significantly higher seed yield (602 kg ha^{-1}). The lowest value of growth and seed yield was recorded when irrigation applied by surface method with conventional fertilizer (347 kg ha^{-1}). The study showed that drip fertigation resulted into 12 to 74 % increase in the productivity of onion seed as compared to conventional method. It can be concluded that drip fertigation of 100 % water soluble fertilizers in 12 weekly splits up to 2 months duration was found effective for growth, yield and quality for onion seed production.

Pawar *et al*[20]., conducted a study on the effects of drip fertigation on growth, yield and economics of sugarcane (*Saccharum officinarum* L.).The experiment comprised of 100, 80 and 60 % of recommended fertilizer dose in water soluble form. The 100 % drip fertigation showed 41.8 % increase in yield. Yield increased 25.3 % by applying only 'N' through drip as against conventional method (133.4 t ha^{-1}). Fertigation also resulted into 40 % fertilizer saving. The drip irrigation used less quantity of water (103.7 mm) and saved 57 % water over surface irrigation method.

CONCLUSION

Drip based irrigation scheduling results in higher soil water content, water use efficiency and saving in irrigation water in comparison to conventional method of irrigation. Fertigation enables precise nutrient application, reduces the likelihood of nutrient leaching and increases crop production. Drip system of irrigation with NPK fertigation leads to favourable soil moisture regime to produce better root and shoot growth, higher relative leaf water content, marketable yield, NPK uptake. Improved quality parameters like TSS, ascorbic acid content, chlorophyll content and fertilizer use efficiency with respect to N P K and other nutrient elements is associated with drip system of irrigation and fertigation. Moreover an area where water is scarce and costly and where high value crops are cultivated, drip system is the most efficient system of irrigation.

REFERENCES

1. Ahmed, B.A., Mohammed, A.A. and Ihsan, M.I., Effect of drip irrigation system and fertigation on growth, yield and quality of banana cv. Grand Nain (Musa AAA). Biennial Regional Conference,Entebbe, Uganda. P.609-613 (2010).
2. Antony, E. and Singandhupe, R.B., Impact of drip and surface irrigation on growth, yield and WUE of capsicum (*Capsicum annum* L.). *Agric Water Manag.*, **65:** 121-132 (2004).
3. Barua, P. and Phookan, D.B., Effect of drip irrigation and plastic mulch on yield of broccoli (*Brassica Oleracea* L. *var. italica*). *J. Water Mngt.t.*, **17:** 9-13 (2009).
4. Beyaert, R.P., Roy, R.C. and Coelho, B.B.R., Irrigation and fertilizer management effects on processing cucumber productivity and water use efficiency. *Can. J. Plant Sci.* **87:** 355–363 (2007).
5. Bhakare, B.D. and Fatkal, Y.D., Influence of micro irrigation and fertilizer levels on growth, yield and quality of onion seed. *J.Water Mngt.*, **16:** 35-39 (2008).
6. Chaudhri, S.M., Shinde, S.H., Dahiwalkar, S.D., Danawale, N.J., Shirsath, H.K. and Berad, S.M., Effect of fertigation through drip on productivity of papaya. *J. Maharashtra Agric.Univ.*, **26:** 18-20 (2001).
7. Cukaliev, O., Tanaskovik, V., Kanwar, R.S., Heng Lee Kheng, and Mukaetov, D., Irrigation and fertigation effects on nitrogen use efficiency and tomato yield. *Int. Agric. Eng. J.*, **17:** 19-25 (2008).
8. Dingre, S.K., Pawar, D.D. and Kadam, K.G., Productivity, water use and quality of onion (*Allium cepa*) seed production under different irrigation scheduling through drip. *Indian J. Agron*., **57:** 186-190 (2012).

9. Ewais, M.A., Mahmoud, A.A. and Khalil, A.A., Effect of nitrogen fertigation in comparison with soil application on onion production in sandy soils. *Alexandria J. Agric. Res.*, **55(3):** 75-83 (2010).
10. Guohua Lv, Yaohu Kang, Lan, L. and Shuqin, W., Effect of irrigation methods on root development and profile soil water uptake in winter wheat. *Irrig. Sci.*, **28:** 387-398 (2010).
11. Hebbar, S.S., Ramachandrappa, B.K., Nanjappa, H.V. and Prabhakar, M., Studies on NPK drip fertigation in field grown tomato (*Lycopersicon esculentum* Mill.). *Eur. J. Agron.*, **21:** 117-127 (2004).
12. Hemalatha, S., Maragatham, S., Radhika, K. and Kathrine, S.P., Fertigation for Crops and Nitrogen Fertigation for Sugarcane: A Review Res and Rev: *J. Agric. and Allied Sci RRJAAS*., **2(2):** (2013).
13. Kaniszewski, S., Rumpel, J. and Dysko, J., 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 (1999).
14. Kannan, K., Effect of irrigation method, drip irrigation regimes and fertigation schedules on growth and yield of medicinal coleus (*Coleus forskohlii*).*Indian J. Agric. Sci*.**78:** 614-617 (2008).
15. Kumari, P.V.L.R., Prasadini, P.P., Rao, M.S. and Shivshankar, M., Effect of drip irrigation and mulches on growth and yield of bell pepper (*Capsicum fruitesens* L.*). Ann. Agric. Res.*, **27(2):** 179-182 (2006).
16. Mishra, J.N. and Paul, J.C., Impact of drip irrigation with plastic mulch on yield and return of brinjal. *J. Water Mngt.*, **17:** 14-17 (2009).
17. Nalge, D.N., Deogirkar, A.A., Konde, N.M. and Damre, P.R., Performance of cotton under drip irrigation on vertisols. *J. Soil Crops.* **17:** 299-303 (2007).
18. Nilesh, B. and Gulati, H.S., Effect of drip and sprinkler irrigation system on growth and yield of American cotton (*Gossypium hirsutum* L.). *Bioved*, **16:** 33-37 (2004).
19. Padmavathi, P. and Lakshmamma, P., Optimizing irrigation in relation to phosphorus nutrition in safflower (*Carthamus tinctorius* L). *Sesame and Safflower Newsletter* **18:** 102-106 (2003).
20. Pawar, D.D., Dingre, S.K. and Surve, U.S., Growth, yield and water use in sugarcane (Saccharum officinarum) under drip fertigation. *Indian J. Agron.*, **58:**396-401 (2013).
21. Ponnuswamy, K. and Santhi, P., Effect of drip on soil moisture distribution pattern in cassava (*Manihot exculenta Crantz*). *J. Water Mngt.*, **6:** 1-2 (1998).
22. Popale, P.G., Khedkar, D.D., Bhagyawant, R.G. and Jadhav, S.B., Response of cauliflower to irrigation schedules and fertilizer levels under drip irrigation. *Int. J. Agric. Eng.*, **5(1):** 62-65.
23. Rajput, T.B.S. and Patel, N., Water and nitrate movement in drip-irrigated onion under fertigation and irrigation treatments.*Agric. Water Manag.*, **79:** 293-311 (2006).
24. Rathore, A.C. and Singh, J.N., Optimization of nitrogen application and irrigation for improved growth and spike production of tuberose (*Polianthes tuberosa* Lin.). *Ind. J. Soil Cons.*, **37(1):** 45-49 (2009).
25. Rekha, B.K. and Mahavishnan, K., Drip fertigation in vegetable crops with emphasis on lady’s finger (*Abelmoschus esculentus* (L.) *Moench*) – A Review.*Agricu. Rev.* **29:** 298 – 305 (2008).
26. Sanchita, B., Phooken, D.B., Kachari, M., Hazarika, T.K. and Das, K., Growth, yield and economics of broccoli under different levels of nitrogen fertigation. *Ind.J. Hort.*, **67:** 279-282 (2010).
27. Sankar, V., Lawand, K.E. and Tripathi, P.C., Effect of micro irrigation on growth, yield and water-use efficiency of onion (*Allium cepa*) under western Maharashtra conditions. *Ind. J. Agric. Sci.* **78:** 584-588 (2008).

28. Sathya, S., Pitchai, J.G., Indirani, R. and Kannathasan, M., Effect of fertigation on availability of nutrients (N, P & K) in soil – A Review. *Agric. Rev.*, **29:** 214-219 (2008).
29. Sharma, P.K., Kapur, O.C., Kumar, R., Masand, S.S., Saroch, K. and Sandal, S., *Water for Hill Agriculture- Unlocking Potential*. Published by Westville Publishing House, Pachim Vihar New Delhi. p 28 (2010).
30. Shedeed, S.I., Zaghloul, S.M. and Yassen, A.A., Effect of method and rate of fertilizer application under drip irrigation on yield and nutrient uptake by tomato. *Ozean J. App. Sci.*, **2:** 139-147 (2009).
31. Shirgure, P.S., Srivastava, A.K., Shyam Singh, and Pimpale, A.R., Soil water management (Irrigation and Drainage). *Ind. J. Agric. Sci.***74**: 92-94 (2004).
32. Srinivas, K. and Prabhakar, B.S., Response of capsicum to nitrogen fertilization. *Veg. Sci***. 9:** 71-74 (1982).
33. Tanaskovik, V., Cukaliev, O., Romic, D. and Ondrasek, G., The influence of drip fertigation on water use efficiency in tomato crop production. *Agriculturae Conspectus Scientificus*, **76:** 57-63 (2011).
34. Ugalde-Acosta, F.J., Tosquy-Valle, O.H., Lopez-Salinas, E. and Francisco-Nicolas, N., Productivity and profitability of the common bean crop with fertigation. *Agronomia Mesoamericana*, **22:** 29-36 (2011).
35. Veeranna, H.K., Kgalak abdul, A.A. and Sujith, G.M., Effect of fertigation with normal and water soluble fertilizers compared to drip and furrow methods on yield, fertilizer and irrigation water use efficiency in chilli. *Micro Irrigation*, pp. 461-466 (2001).
36. Woltering, L., Ibrahim, A., Pasternak, D. and Ndjeunga, J., The economics of low pressure drip irrigation and hand watering for vegetable production in the Sahel. *Agric. Water Mngt.*, **99:** 67-73 (2011).
37. Yadav, B.S., Bhati, A.S., Chauhan, R.P.S. and Bhuniya, S.R., Studies on drip irrigation and fertigation in sugarcane in irrigated north western plain zone of Rajasthan. India Water Week 2012 – Water, Energy and Food Security: Call for Solutions, New Delhi. (2012).