Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(5): 2937-2942
Received: 16-07-2020
Accepted: 19-08-2020

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Effect of fertigation on crop productivity and Nutrient use efficiency

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Abstract
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. In other side 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. A modern agro -technique which can solve the above issue is, Fertigation - a technique of application of fertilizers along with irrigation water, provides an excellent opportunity to maximize yield and minimize environmental pollution (Hagin *et al*. 2002). Fertigation ensures availability of fertilizer nutrients in the root zone in readily available form and therefore, minimize fertilizer application rate and increase fertilizer use efficiency. The associated increase in yield with minimum fertilizer application rate, increases return on the fertilizer invested. Fertigation resulted increased in crop yield by 20 to 30 % (Sandal *et al*.) Fertigation enables adequate supplies of water and nutrients with precise timing and uniform distribution to meet the crop nutrient demand. Reported that fertigation applied N and P fertilizer increased wheat grain yield by 16% over top dressed N (Vishandas *et al*. 2006). 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%. Fertigation ensures saving in fertilizer (40-60%), due to “better fertilizer use efficiency” and “reduction in leaching” (Kumar *et al*. 2002).

Keywords: Fertigation, nutrient use efficiency, nutrient availability, drip irrigation

Introduction
Fertigation with drip irrigation practice is gaining higher momentum in present day crop production. Because water is the vital source for crop production and is the most limiting factor in Indian agricultural scenario. Though India has the largest irrigation network, the irrigation efficiency does not exceed 40%. Due to water scarcity, the available water resources should be very effectively utilized through water saving irrigation technologies. The need of the hour is, therefore, to maximize the production per unit of water and nutrients as well. Therefore, while giving fertigation, it is very important to consider how much fertilizer to be given and when to give the fertigation and also the crop stage and its nutrient demand, thereby one can achieve higher water and nutrient efficiency, higher yield and economic returns.

What is fertigation?
The practice of supplying crops in the field with water soluble fertilizers *via* the irrigation water is called fertigation. It is an efficient and agronomically sound method of providing soluble plant nutrients directly to the active plant root zone. Fertigation permits improved efficiency of irrigation and nutrient use and reduces application costs. It improves plant growth and nutrient uptake and limits nutrient losses. 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%. Fertigation ensures saving in fertilizer (40-60%), due to “better fertilizer use efficiency “and “reduction in leaching” (Kumar and Singh 2002) [17].

Why we need fertigation?

1. Uneven growth in fertilizer consumption resulting in state-wise crop-wise variation in consumption.
2. Mining of nutrients from the soil at alarming rate (soil fertility depletion due to inadequate and imbalanced fertilizer use).
3. Decline in crop response to fertilizer.
4. Stagnation in fertilizer production.
5. Weakening relationship between fertilizer use and food grain production.
6. Increasing dependence on fertilizer imports

Significance of fertigation

Fertigation is an effective tool to control placement, timing and the type of fertilizer needed according to the soil fertility status and the growth stage of the crop. When combined with an efficient irrigation system, both nutrients and water can be manipulated and managed to obtain the maximum possible yield of marketable production from a given quantity of these inputs. Continuous small applications of soluble nutrients, distribution of added nutrients and other chemicals around plant roots and enhance the rate of nutrient uptake by the plants. The potential advantages of this method include improved fertilizer use efficiency, flexibility in timing of fertilizer use in relation to crop demand, increased crop yields, improved quality of the produce and saving in labour. The hypothesis is that nitrogen use efficiency can be influenced by a fertigation scheme, because movement and transformations of fertigated nitrogen are affected by applications. 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. It is an effective means of controlling the timing and placement of fertilizers and improving fertilizer use efficiency. Similar to frequent application of water, optimum split applications of fertilizer improve 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 fruitharvest 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) [21]. 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 (MmolawaandOr 2000) [21]. 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) [32].

Advantages

1. In drip fertigation, fertiliser application is synchronized with plant need which varies from plant to plant in drip fertigation, the amount and form of nutrient supply is regulated as per the need of the critical stages of plant growth.
2. Saving in amount of fertiliser applied due to better fertiliser use efficiency and reduction in leaching.
3. Optimisation of nutrient balance in soils by supplying the nutrients directly to the effective root zones as per the requirement.
4. Reduction in labour and energy cost by making use of water distribution systems for nutrient application.
5. Better yield and quality of products obtained.
6. Timely application of small but precise amounts of fertilisers directly to the roots zone, this improves fertiliser use efficiency and reduces nutrient leaching below the root zone.
7. Ensures a uniform flow of water and nutrients.
8. Improves availability of nutrients and their uptake by crop.
9. Safer application method, as it eliminates the danger affecting roots due to higher dose.
10. Soil and water erosion are prevented.

Disadvantages

1. Both the components (drip and water-soluble fertiliser) are very costly.
2. Maintenance of drip irrigation is difficult. There is possibility of theft and rat infestation.
3. Good quality water is very essential. Clogging of emitters may cause a serious problem.
4. It needs water soluble fertilisers, the availability of these types of fertilisers is limited.
5. Adjustment of fertilisers to suit the need is not easy.
6. Infestation of insect pest and diseases increases.
7. Area under micro irrigation is now increasing mainly because of subsidy in micro irrigation, if subsidy is withdrawn, the area under micronutrient may also reduce. So also, would be the fate offertigation.

Fertigation Equipment

Fertiliser can be injected into drip irrigation system by selecting appropriate equipment. Commonly used fertigation equipments are:

1. Venturi pumps
2. Fertiliser tank
3. Fertiliser injection pump

Dosification

There are two types of fertigation the type of fertigation chosen which depends on the crop grown, the soil type and farm management system.

- Quantitative fertigation
- Proportional fertigation

Proportional

- The nutrients are is applied in a constant and proportional ratio to the water sheet, so that the irrigation water takes a fixed concentration of the applied fertilizer.
- In this case the fertilizers are applied by direct injection through fertilizer pumps.

Quantitative fertigation

- It is the application of the plant nutrients in predetermined concentrations to the irrigation system.
- The fertilizer is applied in a pulse after a certain water sheet without fertilizer using a fertilizer tank.**t**

Fertilizer suitable for Fertigation:
more harm than good. Fertigation is a costly technique.

Nutrient	Water soluble fertilizers	Nutrient content
Nitrogen	Urea Ammonium Nitrate Ammonium Sulphate Calcium Nitrate Magnesium Nitrate Urea Ammonium Nitrate Potassium Nitrate Monoammonium Phosphate	46-0-0 34-0-0 21-0-0 16-0-0 11-0-0 32-0-0 13-0-46 32-0-0
Phosphorus	Monoammonium Phosphate Monopotassium Phosphate Phosphoric Acid	12-61-0 0-54-32 0-82-0
Potassium	Potassium Chloride Potassium Sulphate Potassium Nitrate Potassium Thiosulphate Monopotassium Phosphate	0-0-60 0-0-50 13-0-46 0-0-25 0-52-34
Micronutrients	Fe EDTA Fe DTPA Fe EDDHA Zn EDTA Ca EDTA	13 12 6 15 9.7

Fertigation scheduling

Fertigation scheduling is one of important factor responsible for efficient fertigation and better crop growth and nutrient use efficiency. Fertigation scheduling depend on many factors like EC, pH, soil organic etc but for efficient scheduling of fertigation, we have to keep following point into consideration *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.

Fertigation scheduling allows for the greater degree of flexibility in effecting changes in quantity as well as frequency. Fertigation events can be scheduled as often as irrigation at an interval of a week, a fortnight or a month (Thompson *et al*., 2003) [37]. Tumbare and Bhoite (2002) [38] concluded that weekly fertigation through drip irrigation in 14 equal splits starting from the first week of transplanting was beneficial for green chilli grown in a sandy clay loam soil. While appropriate frequency of fertigation at weekly or biweekly or monthly was the best to maximize the nutrient uptake by crop depending on the soil type (Hochmuth and Smajstrla, 2000) [14]; higher irrigation frequency might provide desirable condition for water movement in soil and for uptake by roots (Segal *et al*., 2000) [31].

Interaction between fertilizers and irrigation water

The water with high content of carbonates and bicarbonates of calcium and magnesium as usually seen in tube well waters, results in precipitation in fertilizer tanks especially that of phosphates and clogging in the system due to increase in pH. On the other hand, water with low pH and high content of iron and aluminium as in tropical climate can cause toxicity due to these elements in addition to precipitation of phosphorus. Hence it is mandatory to use water with near neutral pH for fertigation.

Effect of fertigation on crop yield

Rice

A field experiment was conducted during summer season of 2016 at College of Agriculture, UAHS, Shivamogga having Randomized Complete Block Design (RCBD) comprising 3 replications and 12 treatments concluded that soil application of 25 per cent RDF with 75 or 100 per cent RDF through fertigation scheduled for 8 splits from 10 to 80 DAS with 1.0 PE in summer found ideal for achieving higher yield potentiality (Yamuna *et al*., 2018) [41].

Wheat

Two field experiments were carried out at the Agricultural Production and Research Station, National Research Centre (NRC), El Nubaria Province, Egypt, during the two successive winter seasons 2010/2011 and 2011/2012, to investigate the effects of irrigation requirements (IR) and fertigation levels on growth, yield and water use efficiency in wheat (Sakha 93 cv) having split plot design with three replicates was used where the fertigation (100%, 75% and 50% from recommend fertilizer rates of NPK) was allocated in the main plots while the irrigation treatments (100%, 75% and 50% irrigation requirements) were applied in the subplot concluded that 75% NPK recommended fertilizers + 100% irrigation requirements surpassed the other treatments in number of spikelets/spike, number of spike /m, grain yield/faddan (Abdelraouf *et al*., 2013) [1].

Maize

Field experiment was conducted at Agricultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore having randomized block design replicated thrice. Four fertigation frequencies and two fertilizer levels concluded that scheduling of drip fertigation with 150 per cent of RDF supplied once in six days could be the optimal management practice for getting maximum yield by growing maize crop in sandy clay loam soils with moderate fertility (Sampathkumar *et al*., 2013) [29]. Bibe *et al*. (2013) [6] reported that maize crop under drip should be irrigated at 1.0 PE and fertigated with 75 per cent RDF through drip (WSF) for obtaining higher grain and fodder yield, net returns.

Pigeon pea

Manikandan and Sivasubramaniam (2015) [20] revealed that drip fertigation with 100% recommended dose of fertilizer through water soluble fertilizers + foliar feeding with 0.5% ZnSO4, could record the highest yield, mainly due to greater and consistent availability of nutrients, growth hormones and soil moisture which led to better crop growth, physiological characters and seed yield components, reflected on the seed yield at Agricultural College and Research Institute, Madurai, Tamil Nadu, India. Kakade *et al.* (2018) [17] Maximum pigeon pea grain yield (3866 $Kgha^{-1}$) was recorded where 125% N + 100% P+ 100% K was applied in five splits through drip irrigation.

Green gram

Shravani *et al.* (2019) [34] reported that application of liquid biofertilizers and mineral fertilizers with drip fertigation in treatment with 100 % RDF + liquid based biofertilizers drip fertigation registered significantly higher number of number of pods $plant^{-1}$, number of seeds pod^{-1}, test weight (g), Seed yield (kg ha^{-1}) and haulm yield (kg ha^{-1}).

Cotton

Harish *et al.* (2018) [14] reported that the paired row planting (0.75 - 1.5 x 0.75 m) of Bt cotton in an Inceptisol with the application of water soluble fertilizers (N, P, K @ 90: 45: 45 kg ha^{-1} respectively) and apportioning them through drip irrigation (fertigation) in equal weekly splits at 11 to 30 DAP (NPK @ 18, 9, 4.5 kg ha^{-1}), 31 to 60 DAP (NPK @ 36, 22.5, 18 kg ha^{-1}) and 61 to 100 DAP(NPK @ 36, 13.5, 22.5 kg ha^{-1}) could help in increasing the yields, in saving of fertilizers up to 25 per cent along with maximum movement of nutrients in soil, when compared with that of conventional fertilizers (N, P, K @ 120: 60: 60 kg ha^{-1} respectively) with surface irrigation. similar result was reported by Bhakare *et al.*, 2015 [4]. Jayakumar *et al.* (2014) [16] Drip fertigation with 150 per cent recommended dose of NPK and bio-fertigation recorded the highest seed yield of 3395 kg ha^{-1}.

Potato

Chongtham *et al.* (2016) [11] reported that drip fertigation of 100 per cent of recommended dose of N and K at 9, 16, 23, 30, 37, 43, 51, 58 and 65 days after planting markedly increased growth attributes like plant emergence and plant height and ultimately gave significantly higher quality tubers (">75 g grade" potato tuber) and total tuber yield of potato over conventional method. Further, this method improved crop productivity, water and nutrient use efficiency along with net return and benefit-cost ratio, which were much higher than conventional method (275:140:275 kg N: P_2O_5 : K_2O ha^{-1}) at Field experiments conducted for 3 consecutive seasons at Potato Research Station, SDAU, Deesa (Gujarat).

Sweet clover

Drip irrigation with 100 per cent evaporation replenishment of water along with supplementation of 100 per cent recommended N and K through fertigation recorded 61.09 per cent yield increase over conventional fertilization in bell pepper along with significantly higher ascorbic acid content and the highest cost benefit ratio of 1:1.72 at Jorhat, Assam (Brahma *et al*., 2010) [7].

Pea

Singh *et al*. (2006) [36] 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.

Onion

Chopade *et al*. (1998) [10] 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) [28] 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) [23] 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) [5] 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.

Sugarcane

Pawar *et al* (2014) reported that highest yield of 187.75 tonnes/ha was recorded in 100% fertigation through schedule with 26 splits as per crop growth stages however, it was on par with cane yield under 100% fertigation schedule with 12 uniform fortnightly splits (178.59 tonnes/ha) and 80% fertigation through schedule with 26 splits as per crop growth stages (168.80 tonnes/ha).

Banana

Mahendran *et al* (2013) [18] revealed that subsurface drip fertigation of 100 per cent recommended dose of fertilizers (Urea, 13:40:13, KNO_3) + liquid bio fertilizers at six days interval is an ideal practice in enhancing many of the growth, yield attributes, fruit quality and yield of banana.
Pawar and Dingre (2013) [25] reported that application of 100 per cent recommended dose of fertilizer through drip as per crop growth stages showed 46.22 per cent increase in yield (83.62 Mg ha^{-1}).

Bajra Napier hybrid

Paired row planting of bajra napier hybrid with irrigation at 100 per cent PE and fertigation at 125 per cent recommended dose of nitrogen recorded a green fodder yield of 368.17 and 349.83 Mg ha-[1] respectively in Tamil Nadu (Alagudurai and Muthukrishnan, 2014) [2].

Effect of fertigation on nutrient use efficiency (NUE)

Nutrient use efficiency is defined as the amount of dry matter produced per unit of nutrient applied or absorbed. Nutrient use efficiency (NUE) is a critically important concept in the evaluation of crop production systems. It can be greatly impacted by fertilizer management as well as by soil- and plant-water management. Veeranna *et al*., (2000) [39] reported that decreasing fertilizer level by 20 per cent than the recommended level especially under fertigation may not affect the yield level in chilli because of improved fertilizer use efficiency. Water and fertilizer saving to the extent of 30 and 70 per cent respectively with comparable yield levels were possible under the trickle fertigated crop as compared to the furrow irrigated crop of potatoes. Highest yield, 36.29 t ha^{-1} of fresh tubers was obtained under trickle irrigation as compared to 21.5 t ha-1 for the furrow irrigated crop (Chawla and Narda, 2001) [8]. Singandhupe *et al*. (2003) [34] revealed that application of nitrogen through drip irrigation in ten equal splits at 8 days intervals saved 20- 40 per cent nitrogen in tomato as compared to the furrow irrigation where nitrogen was applied in two equal splits (at planting and one month there after). Solaimalai *et al*. (2005) [36] reported that the amount of fertilizer lost through leaching can be as low as 10 per cent in fertigation whereas it is 50 per cent in the traditional system. In tomato, the yield was increased linearly upto 50 kg P ha^{-1} application through broadcast. But fertigated treatment saved 25 kg P ha-1 i.e. 50 per cent of P was saved due to increased FUE (Carrijo and Hochmuth, 2000) [14]. Patel and Rajput (2000) [23] observed that drip fertigation in onion resulted in 60 per cent saving of fertilizers for achieving the same level of production as compared to conventional method along with higher FUE of 5.28 kg N, P and K^{-1}. Lara *et al*. (2003) [26] 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. Application of 50 per cent recommended dose of fertilizer improved the fertilizer use efficiency of nitrogen, phosphorous and potassium. Reverse was the trend, when the fertilizer dose was increased to 100 per cent recommended dose (Singandhupe *et al*., 2008) [35]. Anant (2006) [2] reported that the highest yield of tomato was noticed when N (urea) was supplied in 8 or 10 split doses with 100 per cent ETo through drip irrigation. Satyendra Kumar *et al*. (2009) [30] observed that in potato crop fertilizer use efficiency was the highest (71 kg kg^{-1}) in micro-sprinkler followed by drip (67 kg kg^{-1}) and furrow irrigation (48 kg kg^{-1}).

Conclusion

- Fertigation applied through micro-irrigation systems is undoubtedly one of the most effective strategies to improve nutrient use efficiency in agricultural systems.
- The use of supplying nutrients at a low rate and high frequency improves plant nutrient uptake and nutrient availability in the root zone, to reduce risk of nutrient loss.
- It is concluded that fertigation could play significant role in farming not only to increase the yield and increase WUE &NUE.
- This requires creating better awareness and educating both extension workers and farmers
- In other words, we can say that fertigation technology is now the need of the hour.

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