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RESEARCH ARTICLE :

Fertigation technology for enhancing nutrient use efficiency in hybrid chilli (*Capsicum annuum* L.)

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SUMMARY : A study was undertaken by the Tamil Nadu Agricultural University at Thalampallam village, Dharmapuri district, Tamil Nadu to standardize fertigation for chilli 'TNAU Chilli Hybrid CO 1' to contribute the content of nutrient use efficiency factors. The experiment was laid out in Randomized Block Design with nine treatments including three levels each of water soluble and straight fertilizers *viz*., 125, 100 and 75 per cent of recommended dose of fertilizers along with liquid biofertilizers which were replicated thrice. 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 fertilizer use efficiency of fertigation technology.

KEY WORDS :
Fertigation, NPK, Recommended doses of fertilizers, Fertilizer saving

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BACKGROUND AND OBJECTIVES

Chilli (*Capsicum annuum* L.) is an important spice cum vegetable crop cultivatedextensively in India. India contributes one fourth of world's production of chilli with an average annual production of 12.89 lakh tonnes in an area of 7.59 lakh ha. Globally, India is leading country in context ofarea covered in chilli production making it most dominant player in the world chilli market. Water is an important input for growing this crop during this season. Chilli fruits, despite their fiery hotness, are one of very popular vegetables known for medicinal and health benefiting properties. 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 agrotechnique provides

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an excellent opportunity to maximize yield and minimize environmental pollution by increasing fertilizer use efficiency, minimizing fertilizer application and increasing return on the fertilizer invested.

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 upto 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".

Drip irrigation is often preferred over other irrigation methods because of the high wate rapplication 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.

Nutrient management is the most important agrotechnique, which controls growth, yield and quality of a crop. Nutrient use efficiency is only 50 per cent in conventional practices of soil application. Sustainability of any system requires optimal utilization of resources such as water, fertilizers and soil. Apart from the economic considerations, the adverse effect of injudicious use of water and fertilizers on the environment can have far reaching implications. There is a need to standardize agrotechniques, which will help in sustaining the precious resources and maximizing crop production, without any detrimental impact on the environment. Location specific nutrient management practices are essential for increasing nutrient use efficiency besides optimizing the fertilizer input and maximizing the productivity and profitability.

RESOURCES AND METHODS

The experiment was conducted during June-December, 2010 (season I) and January-May, 2011 (season II) in a farmer's field at Thalampallam village in Dharmapuri district. A recently released chillihybrid 'TNAU Chilli Hybrid CO 1' was selected for the experiment. The experiment was laid out in a Randomized Block Design with nine treatments replicated thrice. A plot size of 7.5 m^2 (7.5 m x 1.0 m) was followed for each treatment. The treatments T_1 to T_3 included 125, 100 and 75 % RDF with water soluble fertilizers, respectively + liquid biofertilizer (*Azospirillum*+ Phosphobacteria), treatment T_4 had 100% RDF with water soluble fertilizers alone, T_5 to T_7 included 125, 100 and 75 % RDF with straight fertilizers, respectively along with liquid biofertilizer,T_8 had100% RDF with straight fertilizers alone and T_9 was the control with soil application of 100% RDF and flood irrigation. The recommended dose of fertilizers adopted wasNPK @ 120:80:80 kg ha^{-1} and liquid biofertilizer used was Azophosmet containing *Azospirillum*, phosphobacteria and Methylobacterium species.The drip system consists of filters (sand and screen), venture attachment for fertigation, pipeline (PVC main supply pipe, size 30 mm, sub main LLDPE laterals size 12 mm), and dripper size 0.6 PEE with the water discharge apacity of 2 l/h. The sub-main laterals were fixed at 60 cm apart and drippers were fixed at 30, 45 and 60 cm along the laterals. All sub-main laterals were controlled by gate valve system. Nitrogen was provided by ventury system of fertigation. The drip system was operated at alternate days or at two days interval for 10 min. Flood irrigation was provided by using plastic pipes (2 cm size) as per need or moisture content. The data were recorded and calculated in randomly selected 3-5 plants in each plot.

OBSERVATIONS AND ANALYSIS

Efficient use of fertilizers is necessary for optimum growth and yield and a knowledge about the availability of nutrients in the soil is very essential. A clear understanding of specific nutrient requirement of the crop during various stages of growth will substantially reduce the possible wastage of applied nutrients and improve both the potentiality of the plant and nutrient use efficiency. During vegetative stage, the plant vigorously absorbs nutrients to build up the plant frame work and some excess nutrients are stored within the plant and translocated to the fruit for further development. Fertilizer use efficiency is the basis for economic and environmental efficiency, andan effective agro-ecosystem management practice, improving nutrient use efficiency, is a crucialchallenge for a more sustainable production of horticultural, industrial and cereal crops.

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.

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 com-pared 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. 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 practiced 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).

Movement 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. 116 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. How-ever, 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 tooccur 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 strictwater 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).

Nutrient use efficiency is a measure of utilization of applied nutrients for crop growth and economic yield.

Table 1 : Effect of fertigation on nutrient use efficiency of chilli 'TNAU Chilli Hybrid CO 1'

Treatments	Nutrient use efficiency (kg kg^{-1} NPK)		
	Season I	Season II	Mean
T_1	54.93	49.98	52.46
T_2	59.88	55.03	57.46
T_3	51.47	50.70	51.09
T_4	55.59	47.20	51.40
T_5	48.82	44.43	46.63
T_6	45.24	42.03	43.64
T_7	38.30	34.28	36.29
T_8	42.34	36.38	39.36
T_9	27.33	25.01	26.17

T_1 - 125% RDF as water soluble fertilizers + liquid biofertilizers
T_2 - 100% RDF as water soluble fertilizers + liquid biofertilizers
T_3- 75% RDF as water soluble fertilizers + liquid biofertilizers
T_4 - 100% RDF as water soluble fertilizers
T_5- 125% RDF as straight fertilizers + liquid biofertilizers
T_6 - 100% RDF as straight fertilizers + liquid biofertilizers
T_7 -75% RDF as straight fertilizers + liquid biofertilizers
T_8 - 100% RDF as straight fertilizers
T_9 - Control – soil application of 100% RDF with flood irrigation

Drip fertigation with 100 per cent recommended dose of water soluble fertilizers along with liquid biofertilizer recorded the highest nutrient use efficiency. The possible reason for the increased yield might be due to better availability of plant nutrients and irrigation water throughout the crop growth period under drip fertigation system. Water and nutrients are the main limiting factors affecting agricultural production in tropical and subtropical regions. Improving the efficiency of these factors is, therefore, the target for improved management. The method of application is one of the several factors that affect fertilizer use efficiency (Mohammad *et al*., 1999). Feigin *et al*. (1982) reported fertigation as the most efficient method of fertilizer application. Drip irrigation has gained widespread popularity as an efficient method for fertigation because both time and rate of nutrients can be controlled to meet the requirements of a crop at each physiological growth stage (Bar-Yosef, 1977; Papadopoulos, 1988 and Mmolawa and Or, 2000).

Nutrient losses were reduced and higher fertilizer recovery was also achieved by this way (Miller *et al*., 1981 and Papadopoulos, 1985). The mobility of applied nutrients through the drip irrigation system depends on the form in which it is presented (Haynes, 1990). It has been reported that movement and transformation of fertigated nutrients were influenced significantly by the time of fertilizer application in an irrigation cycle (Hou *et al*., 2003). In the present investigation, the water was allowed for first15 minutes, followed by the fertilizer solution for 30 minutes. The water was again allowed for another 15 minutes. This is in accordance with the Li *et al*. (2004).The possible reason for this phenomenon might be due to better availability of plant nutrients and irrigation water through out the crop period resulting in higher fruit yield under drip fertigation system. The increased nutrient use efficiency under drip fertigation was also reported by Chakraborty *et al.* (1999) in broccoli, Veeranna *et al.* (2000) in chilli and Shobana (2002) in radish.

Conclusion :

From the above discussion, it could be concluded that fertigation with 100 per cent RDF through water soluble fertilizers along with liquid biofertilizer resulted in the highest nutrient use efficiency the most promising fertigation practice for chilli hybrid in terms of enhanced growth, physiological, nutritional and quality parameters and productivity. It may be concluded that drip fertigation with 100 per cent RDF through water soluble fertilizers along with biofertilizer is highly profitable and economically viable for cultivation of chilli hybrid, which can be recommended for adoption by the farmer.

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