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Improving water use efficiency in greenhouse cultivation: A review

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Abstract

Land and water are the two basic important natural resources, play an important role in agriculture production. After globalization, crop cultivation under greenhouse conditions has emerged to cultivate crops under controlled environmental conditions. Polyhouse is designed to provide all the needs of the plants throughout the year without considering the climatic changes and natural weather. Micro irrigation is essential under polyhouse conditions for the precise application of water and nutrients at frequent intervals matching with crop growth curve to achieve higher water and nutrient use efficiency. This review deals with the water use efficiency under controlled environmental conditions.

Keywords: Micro irrigation, greenhouse cultivation, water use efficiency, fertigation efficiency

Introduction

Land and water are the two basic important natural resources, play an important role in agriculture production. Water, air and sunlight are the main requirements of a plan system for photosynthesis and life processes. After globalization, crop cultivation under greenhouse conditions has emerged to cultivate crops under controlled environmental conditions to obtain qualitative and quantitative produces to meet the challenges faced by farming sectors and to obtain premium earnings.

Polyhouse is designed to provide all the needs of the plants throughout the year without considering the climatic changes and natural weather. Polyhouse environment can be retained with least amount of efforts automatic controls for the function of ventilation, humidity, artificial lighting, heating and water management, to save the time for polyhouse maintenance. Generally, polyhouse is to maintain the temperature and humidity to keep warm and suitable environment inside the polyhouse for the growth of the plants. For maintaining the suitable environment, polyhouse will be covered from all sides and must be provided with transparent roof, which will allow the sunlight inside the chamber and should have benefit of safety from the natural weather conditions and climate changes, which should never influence the plants growing inside the polyhouse. Normally, plastic material is used due to its quality to resist natural weather changes.

Micro irrigation is essential under polyhouse conditions for the precise application of water and nutrients at frequent intervals matching with crop growth curve to achieve higher water and nutrient use efficiency. Also, reduce the infestation of insect and pests as compared to surface irrigation. The profitable use of drip irrigation at the farm level requires previous development of local information, in order to reach all the benefits from its potential advantages. The high frequency of irrigation and localized water application to only part of the potential root zone are characteristic features of the drip irrigation method (Vermeiren *et al.*, 1980) ^[17], that make their operation and management different to those of conventional irrigation methods (Fereres, 1981) ^[10]. A good knowledge of the basic principles that determine movement of water and salts in drip irrigation especially, under controlled conditions, influenced by low flow rate and localized water application is necessary for salinity control and good water management. An efficient water use will be reached with a proper irrigation scheduling, which involves knowing the crop water requirements.

Sprinkler irrigation refers to the application of water to crops in the form of spray from above the crop like rain. It is also known as overhead irrigation. Sprinkler irrigation conveys water from the source through pipes under pressure to the field and distributes over the field in the

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form of spray of "rain like" droplets. Pumps, pipes and on-farm sprinkler equipment can carefully be selected to provide a uniform irrigation at a controlled water application rate with minimal irrigation skills required, provided simple operating procedures and design guidelines are followed. The main advantages include, highly suitable for sandy, shallow and steep soils, the water application efficiency is about 75 per cent, 25-50 per cent saving in irrigation water, 5 per cent land saving, prevent the frost damage and more uniform water application than surface irrigation. The disadvantage of the system is, High winds cause improper distribution of water, evaporation losses are high especially under high temperature and low relative humidity conditions, high initial investment and higher energy is required for operating the sprinkler system.

Drip irrigation is defined as the precise, slow application of water in the form of discrete or continuous or tiny streams of miniature sprays through mechanical devices called emitters or applicators located at selected points along water delivery lines. It is an efficient method of providing irrigation water directly into the soil at root zone of plants. It permits utilization of fertilizers, pesticides and other water soluble chemicals. The major advantages of drip system includes 30-70, 30-100, 40-60 and 44-47 per cent savings in water, yields, fertilizers and energy, respectively. It also resulted in better crop quality, high returns per unit area, saves labour cost and improved water penetration. Poor quality irrigation water can also be used safely under drip irrigation method. There are however, some disadvantages of this method such as high initial installation cost, losses of pipes due to direct effect of sun rays resulting into shortening of their usable life. Also, if the water is not properly filtered and equipment is not properly maintained then, it resulted into clogging of emitters which will affect the water use efficiency.

Localized wetting patterns produced by drip systems can induce limit to nutrient uptake, making necessary to apply the fertilizers through drip system, operation known as fertigation, injecting them. The small-diameter emitters and low flow rates induce accumulation of materials that can clog the system, partially or totally. It is, therefore imperative to filter water adequately and to prevent clogging problems by injecting various chemicals, depending on the type clogging. Greenhouse cultivation reduces evapotranspiration (ET) to the extent of 70 per cent as compared to open field. Therefore, improving water use is relative to unprotected cropping (Stanghellini, 1993) ^[16].

In drip-irrigated soils, normally the soil water distribution is obtained around soil surface wetted area that is small relative to the total soil surface area. In point source emitters, the water distribution into the soil follows a three dimensional infiltration pattern, different from the one dimension (vertical) infiltration type of conventional irrigation systems, where soil surface wetted area (through which water penetrates into the soil) is the whole soil surface area (Bressler, 1977) ^[6]. The high frequency of irrigation, typical of drip systems, involves that the infiltration process prevails, relative to other irrigation systems, over the soil water extraction phase of the irrigation cycle. The discharge rate of emitter, the hydraulic characteristics of the soil and evaporation rate from the soil surface determine size of the horizontal soil surface wetted area through which infiltration takes place (Bressler, 1977) ^[6]. The evaporation rate has practical importance in the infiltration process only when the evaporation is very high and the ability of soil to conduct water is very low (Bressler, 1977) ^[6]. The size of saturated soil surface area will increase

when the rate of water application is increased and when ability of soil to conduct water (dependent on the soil texture, among other factors) is low, with a corresponding decrease in vertical direction. These aspects have a great importance for the type and density of emitters' choices.

Water use efficiency under drip irrigation

Two basic questions must be answered for drip irrigation scheduling, 1) When to irrigate? (Frequency), 2) How much water to apply? The amount of water to be applied must replenish the evapotranspired water, once corrected by the application efficiency. In conventional irrigation, soil water depletion must be maintained below certain thresholds (available soil water depletion) in order to avoid crop transpiration reductions that can induce yield decrease. A proper irrigation frequency will avoid excessive depletion. In drip systems, good management will always be based on very high irrigation frequency, even several times each day especially when using saline water, being the water storage role of the soil unimportant relative to conventional irrigation methods. Different plant and soil parameters have been suggested to schedule the irrigation frequency. A wide range of plant based measurements more or less sophisticated (sap flow, stem diameter, water potential, plant temperature) have been suggested to detect stress, using plant as a biosensor. The leaf water potential method, reliable when used in conventional irrigation systems, is not practical in drip irrigated vegetable crops. Plant temperature based methods of water stress detection are more accurate in greenhouse than in open field (Stanghellini, 1993) ^[16] but they must be developed and locally adapted. The crop water stress index, based on the higher temperature of the crop when suffering from water stress, has been suggested as a more reliable method (Idso *et al.*, 1981) ^[12], but it is not easy to use.

Hatfield and Dold, 2019 ^[11] suggested that Water Use Efficiency can be improved by reducing soil water evaporation, diverting water for transpiration through mulching, crop residue management, row spacing and irrigation practices. The spatial variability of soil-water contents in drip-irrigated soils limits the interest of methods based on soil water content measurements (available soil water depletion). The soil water matrix potential measurement, in drip irrigated soils, using tensiometers is a reliable way for monitoring soil water conditions in the wetted zone, in order to fix irrigation frequency and to confirm the adequacy of applied water amount. Two tensiometers at least, should be placed in each observation point installed at two depths, a few centimeters away from the emitter, depending on soil water distribution and rooting patterns. Sanchez *et al.*, 2005 ^[15] studied the effects of salinity, fruit yield, plant water uptake and water use efficiency (WUE) on tomato under greenhouse and found that Water Use Efficiency was independent of salinity level. Colla *et al.*, 2009 ^[9] found that the photosynthetic and biomass WUE in the winter season were higher than those recorded during the spring season in the cultivation of geranium crop under greenhouse. Abdrabbo *et al.*, 2006 ^[1] studied that different irrigation levels to improve Water Use Efficiency and reported that 80% irrigation level gave the highest water use efficiency In Maize cultivation compared to 100% irrigation level.

Fertilizer Use Efficiency

Fertigation is the application of chemical fertilizers with irrigation water. Drip irrigation provides possibilities for

precise application of fertilizer and other chemicals. The high efficiency of water application reached in drip irrigation systems is ideal for the high efficiency of applied nutrients in fertigation (Bressler, 1977) ^[6]. This improved use efficiency of fertilizers (Bar-Yosef *et al.*, 1976) ^[5], reducing nutrient losses due to leaching (Bressler, 1977) ^[6], thereby limiting groundwater pollution, better control of the soil solution nutrient contents (Bar-Yosef, 1971), reducing soil solution salinity due to fertilizers and ease of application, reducing labour and saving energy, are the prevailing potential advantages of 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). Therefore, it is most important for a proper fertigation to reach an adequate and efficient irrigation. Two types of injectors can be used. The power injector regulates precisely the injection at constant concentration. A cheaper solution is the differential pressure injector, but a uniform distribution is difficult to achieve. The distribution of nutrients dissolved in the water into the soil is obviously related with the uniformity of irrigation. The type of fertilizer and soil characteristics will determine the fertilizer distribution into the soil (Bar-Yosef, 1977) ^[4].

Urea and nitrate will move immediately downward in soil with the water, while ammonium is held by soil particles and will not move so far in the soil profile as nitrate or urea, limiting N leaching (Bacon *et al.*, 1982-b) 1980 ^[3]. Movement of phosphorus in soils is very limited. However, drip irrigation improves notoriously the mobility of phosphorus (P) in soil, relative to conventional irrigation, when it is applied at low rates (Bacon *et al.*, 1982-a) ^[2]. Potassium (K) moves to a limited extent in the soils but drip irrigation improves its mobility (Kafadafi *et al.*, 1980) ^[13]. Clogging is not a problem with the normal K-fertilizers use. Nutrient uptake efficiency is increased in crops irrigated with drip system, inducing much higher fertilizer use efficiency. The chemicals form of the nutrient (and balance between the NH_4/NO_3 ratio), its concentration and frequency of application are relevant aspects of the information that must be developed for efficient management of fertigation.

Water use efficiency under protected cultivation

From the practical point of view, normally the greenhouse grower is not especially interested in water saving. The scarce knowledge about the irrigation requirements among growers induce them to over irrigate (in order to avoid potential yield reductions), in case of doubt about the quantity of water to apply. Proper information on the irrigation requirements, spread at the farm level, can help to overcome this lack of interest to reduce the water demand. Different measures to save water and improve its use, at the farm level, include reducing the water requirements, increasing the water availability and raising the yields.

The use of mulching (plastic sheet sand. etc has been widely spread to limit the evaporation of soil water and reduce evapotranspiration (ET). Sub-surface drip irrigation can reach similar results. Various cultural practices affect the water demand. The use of transplants instead of direct seeding, multiple cropping, varying plant density, electing the cycles, pruning, are effective, when properly managed, to save water and increase the yield quantity and quality. An adequate greenhouse environmental management can reduce the water demand, increase the crop yields and, therefore, improve the water use efficiency. Manipulating ventilation, misting,

shading and carbon dioxide (CO_2) injecting are effective techniques for that purpose, but not always possible in the simple and poorly equipped plastic houses (Stanghellini, 1993 and Castilla, 1994) ^[16, 8].

Protected cultivation improves the water productivity due to reduction in ET rate and larger outputs of protected growing (Stanghellini, 1993) ^[16]. Drip irrigation also increases the water productivity as compared to conventional irrigation practices in greenhouses (Casteitlla, 1994). The 20 kg of yield per cubic meter (m^3) of applied water quantified in open field tomato growing in the Mediterranean area can be increased to 33 kg per m^3 in unheated plastic house (Castilla *et al.*, 1990) ^[7], far from the 65 kg per m^3 obtained in sophisticated greenhouses, with soilless culture and very long cycles, in Holland. The use of re-circulating soilless culture can improve the water productivity but, the poor quality of water, the high cost of the equipment (for quantifying the ion concentration and disinfecting there circulating solution) and the absence of proper information at the farm level, limits its use.

Conclusion

A wide range of techniques and cultural practices to reduce water requirements, to increase the water availability and to raise the yields can contribute to improved water use efficiency and productivity. Proper and suitable water management can be profitable to a greater extent. Growers' report says that reduced inputs of fertilizer compounds with better irrigation practices results in better crops. By using these effective water management techniques we can manage our poly house properly and increase productivity in the poly house. Always keep in mind that an effective water management technique for the poly house is an essential one to consider.

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