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Float system and crucial points of the method for seedling production and crop cultivation with or without organic fertilization

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Abstract. Float system is a less-intensive and low-cost technology that enables efficient control of the nutrition of the growing plants. The findings of experiments carried out under float system in various crops with or without organic fertilization need to be reviewed. The importance of float system for growing plants without inorganic fertilization and chemical pesticide use needs also to be pointed out. Float system can enhance root development of growing plants and control the height of produced transplants. This can result in increased yields and improved transplant quality, not only in tobacco transplant production systems but also in the case of vegetable crops such as tomato or lettuce. In the case of crops like tobacco and for the success of float system alkalinity and oxygen content of the water in the nutrient solution and selection of the growing media are crucial. Regarding vegetable crops, the combination of float system and organic fertilization can enhance root development in tomato as compared to the combination and lettuce resulting in high-quality products. Several aromatic and medicinal plants, including basil and spearmint, provide high yields and good product quality in floating systems especially along with organic fertilization. Conclusively, float system is a major method for producing high quality products or transplants. Further investigation is needed regarding the combined effects of organic fertilization and float system on more crops and under different climatic conditions.

Key words: Float system, organic fertilization, root growth, yield, agronomy.

INTRODUCTION

The term 'soilless culture' generally refers to any method of growing plants outside the soil (Savvas, 2003; Gruda et al., 2016). The main reason to deep on new systems avoiding soil use is due unfortunately to several soilborne pests and diseases posing as a major threat to productivity of important crops for human nutrition. Root diseases caused by soil fungi and nematodes occur with great frequency on field where major crops such as vegetables are cultivated (Sherf & MacNab, 1986). In general, all economically important crops can suffer from several diseases that can decrease not only crop yield but also the quality of the harvested products (Agrios, 1988). Given that the use of the soil fumigant to control pest and diseases, methyl bromide has been phased out in industrialized countries, research has been carried out in order to develop alternative crop production strategies that are not dependent on its use as soil sterilizer (Webster et al., 2001; Gilreath et al., 2004; Rosskopf et al., 2005).

Soilless agriculture practices can be a real and efficient alternative. They produce relatively health crops, satisfactory root growth; and consequently, increased yield and product quality can be attained by adopting a low cost and more environmentally-friendly crop production strategy (Gruda et al., 2018; Glatkova & Pacanoski, 2019). The term 'hydroponics' is frequently used as a synonym to 'soilless culture'. However, some scientists are referred to hydroponics as a group of soilless culture systems in which no chemically active growing media are used (Adams, 2002). Water culture systems with nutrient solution as root environment and cultivation on porous growing media are included in hydroponics. Regarding water culture systems, float system, the nutrient film technique (NFT) and the aeroponic system are more suitable to intense greenhouse production systems (Van Os et al., 2008). Float system has been stated as the least risky out of the three systems mentioned above. Increased buffering capacity is the trademark of floating system due to the high ratio of available nutrients per plant that is normally observed in the root zone (Brechner & Both, 1996). This growing system is commonly constituted by polystyrene trays whose surface is cut appropriately so as cells of suitable size are formed. The distance between the cells in the surface of the polystyrene tray is preassigned and the roots of the cultivated plants pass through the cells while the above-ground part of the plants remains above the level of the tray (Savvas, 2016). The trays are floated due to their low specific gravity in polystyrene tanks filled with nutrient solution to a depth of 15–20 cm at least (Resh, 1995) whereas in some cases it can reach the level of 80–100 cm in order to eliminate changes in the chemical composition of the nutrient solution. Increased depth of nutrient solution results in increased buffering capacity of the nutrient solution to the fluctuations of temperature and this trait is well desirable especially in warm regions and climates where high temperatures are observed in great frequency (Bouzo & Kuchen, 2012). Furthermore, the inner surface of polystyrene tanks must be veneered with a material that cannot be penetrated from water in order to avoid any contact between tank surface and the nutrient solution (Savvas, 2016). Regarding the dimensions of the polystyrene tanks, they can vary among different levels. For example, Jensen & Collins (1985) used large tanks of 70 m length, 4 m width and 0.3 m height in contrast with Resh (1997) who suggested the use of narrow tanks of 60 cm width.

The aim of this paper is to review the findings of experiments conducted under float system in various crops with or without organic fertilization and point out the importance of float system as a promising water culture system for several crops.

FLOAT SYSTEM METHOD FOR VARIOUS CROPS

Plant nursery management is considered to be one of the most labor-consuming and not enough mechanized fields of agricultural area. Therefore, the development and introduction of new progressive technologies of cultivation of seedlings is urgent in order to increase quality and productivity per area, as previously described by Klymenko et al. (2010) and Carrasco et al. (2003). The adoption of float system can result in higher yield, for leaf vegetables crops such as lettuce (*Lactuca sativa* L.), corn salad (*Valerianella locusta* (L.) Betcke) or spinach (*Spinacia oleracea* L.) (Nicola et al., 2002; Van Os et al., 2002). The adoption of floating system has been stated as more suitable for growing tobacco (*Nicotiana tabacum* L.) transplants in greenhouses as compared to the case of horticultural crops (Biernbaum, 1992; Bilalis et al., 2008; 2009). In tobacco transplant production, float system technology has been widely studied (Jialai, 1995; Chunlei et al., 1997; Leal, 2001; Jiye & Haiping, 2004; Bu et al., 2008). Moreover, float system is a common strategy adopted regarding either aromatic plants or tomato (*Lycopersicon esculentum* Mill.) transplants production (Wyatt, 1998; Incrocci et al., 2001; Saha et al., 2016). However, other scientists indicate that in special cases it can also be an alternative cultural practice of producing horticultural crops such as radish (*Raphanus raphanistrum* subsp. *sativus* (L.) Domin) because it is less labor intensive and is not harmful for the environment (Salerno et al., 2004).

Tobacco. The most common and recently developed strategy to develop tobacco transplants is the adoption of float system technology. In this system, Styrofoam trays filled with soilless media are floated on a large volume of nutrient solution (Maksymowicz & Palmer, 1993). Two different systems are the most dominant, the direct-seeded and the plug-and-transfer system (Smith et al., 1993). Water quality can have a major impact on the growth of seedlings. Key aspects determining the success of float system in tobacco transplant production are quality, alkalinity and oxygen content of the water in the nutrient solution (Pearce & Palmer, 1997; Reed, 2009). There is evidence that tobacco transplants in the float system can tolerate alkalinity up to 244 mg HCO^{3-} L^{-1}. However, potentially damaging levels of nitrate-N in the nutrient solution occur at high HCO^{3-} concentrations in the nutrient solution while the addition of Ca^{2+} can increase both the Ca and Mg concentrations in shoots, but decrease the concentrations of P and Fe (Pearce et al., 1999). Emphasis must be also given on the careful selection of the growing media. Typical tobacco media consist primarily of peat combined with vermiculite and perlite in various proportions (Fisher & Vann, 2017). In Chile, it was found that substrate selection in the float system did not affect significantly neither the fresh and nor the dry weight of the produced transplants. The same result was recorded for the parameters of stem length, stem diameter and following establishment of the finished transplants in the soil (Carrasco et al., 2000). Moreover, the effect of media selection on the physical properties of the media blends should be evaluated. According to Masaka et al. (2007), small and medium size pine bark particles the recorded porosity values were up to the level of 70% while for the no-pine bark particles the lower porosity were recorded.

Fertilizers commonly provide nitrogen from various combinations of nitrate, ammonium, and urea sources. Tobacco seedlings can use nitrogen in the nitrate and ammonium forms, but urea must be converted to ammonium before the nitrogen can be used by the plant (Fisher & Vann, 2017). Fertilizers containing urea affect negatively tobacco transplants grown in the float system. This can be justified by the findings of Pearce et al. (1998) who noted that no urea-N can be regained from the media solutions. Furthermore, the same authors reported that ammoniacal-N is decreased very slowly in the float water, but quickly nitrified in the media solution while Nitrite-N was accumulated from 60 to 80 mg L^{-1} at 2 to 3 wk after seeding, in float beds where 80% urea-N was applied. The sufficient levels of phosphorus (P) content in tobacco seedlings tissues have not been established. However, Miner and Tucker (1990) indicated that for mature plants, the sufficiency level varies from 2.0 to 5.0 mg g^{-1}. In float system it can be assessed that tissue P content over the level of 4 mg g^{-1} does not inhibit tobacco transplants growth and also that P deficit can put a negative effect on the produced transplants growth and quality. In the study of Masaka et al. (2008) deficiency of copper

(Cu), N, potassium (K), and P resulted in the creation of thin stems whereas the largest reduction in leaf emergence was recorded in sand media subjected to P and K deficiencies where a 64% reduction in leaf count was recorded. A boron deficiency causes bud distortion and death and has been observed in several float systems. In most cases, the water and the fertilizer did not contain any boron. The best solution to this situation is to choose a fertilizer such as a 20-10-20 with a guaranteed micronutrient charge if the water analysis indicates no boron (Fisher & Vann, 2017). Root and shoot weights, stem length, and flowering date of both transplant sources can be promoted by the transplant water fertilizer, but the effects generally are more consistent for transplants produced in the float greenhouse than for those produced in conventional nurseries (Fisher et al., 2001). Regarding the effects of applying organic fertilizers in float systems, it is well established that lower pH and electrical conductivity values of the nutrient solution are strongly related to organic float systems not only in tobacco transplant production but also in the cases of tomato and lettuce (Bilalis et al., 2009). Bilalis et al. (2010) reported that the production of oriental and flue-cured tobacco transplants with over 80% water content was attributed to the application of inorganic fertilizers in the nutrient solution. In the same study, the use of organic fertilizers resulted in greater total nicotine content and N concentration in the leaves of the transplants for both the tobacco types. In recent years, many growers have contracted to grow tobacco organically (Fisher & Vann, 2017). Regardless of it is about an organic or conventional tobacco float tray system, the appropriate distance among the cells in the tray surface is dependent on the needs and the targets of each crop grower. For instance, higher density trays are characterized by increased endurance in comparison to low density trays, but on the contrary their use increases the cost of seedlings production. However, inexpensive low density trays are more preferred by those who wish to sell well-developed plants and either face difficulties in getting trays returned or are concerned about disease issues often related to returned trays (Pearce et al., 2008). The results of Mundell et al. (2012) showed that no significant differences were detected in green-biomass yield among tobacco transplants grown in a tray with 595 cells and transplants grown in float trays with either 288 or 338 cells. The results of the study mentioned above showed that although plant maturation may not be promoted, the use of trays with a large number of cells offer an attractive option for float system by an economical aspect. Moreover, uniform germination and seedling emergence is of great importance in float system. Seeding should begin 50 to 55 days before the anticipated transplanting date using only high-quality, pelleted seeds. New trays should also be wet before filling because dry trays float higher than old trays and because it is difficult to keep the medium from falling through the hole in the bottom of the tray (Fisher & Vann, 2017). Regarding seed trays uniformity, it was indicated by Hartley et al. (2001) that even a 3 to 5 days delay in seeding 25% of the cells can decrease significantly the number of usable transplants produced. There is evidence that seeding date and N- or P-fertilizers application may not significantly affect early growth of roots or shoots in the field, but severe clipping one day before transplanting generally reduced shoot growth and delayed flowering of greenhouse transplants. Proper clipping is an important practice that can increase the number of usable transplants and improve transplant hardiness, stem-length uniformity, and stem diameter. Properly clipped plants with uniform stem lengths are needed to transplant seedlings at the proper depth, and excessive foliage disturbs the timing mechanism. Clipping can also be used to delay transplanting when field conditions are unfavorable (Fisher et al., 2001). There is also concern about the fact that although float system technology cannot be affected by soil pathogens, hazardous fungi such as Oomycete *Pythium myriotylum* (Drechs.) and Basidiomycete *Rhizoctonia solani* (Kühn) have been isolated from diseased plants in tobacco float systems (Anderson et al., 1997; Gutierrez et al., 1997). Except pathogens, attention should be also paid for the control of insects that can cause damage to the transplants and chemical control poses as a very effective strategy against their infestation. For instance, *Agrotis ipsilon*, *Faustinus cubae* and *Myzus persicae* were efficiently controlled by the application of a mixture of imidacloprid plus cyfluthrin in a conventional tobacco float system (Link et al., 2000).

Vegetable crops. Float systems are a successful strategy for the production of leaf vegetables with a short cultivation period such as lettuce, spinach and rocket (Van Os et al., 2002; Nicola et al., 2007) and are also promising for the cultivation of aromatic plants and herbs (Frantz & Welbaum, 1998; Miceli et al., 2003). Given that conventional tomato and lettuce transplant production is labor intensive (Thomas, 1993), the adoption of floating system poses as a low-cost attractive prospective as it eliminates the need for additional irrigation. Regarding vegetable crops, Bilalis et al. (2009) have reported that the combination of float system and organic fertilization resulted in 9–14% greater value of root surface in tomato as compared to the combination of float system along with the application of inorganic fertilizers. Even greater differences have been recorded in lettuce where root surface development was by 19–32% higher in the float system with use of organic fertilization (Bilalis et al., 2009). The positive effects of organic fertilizers application on tomato seedlings quality and growing potential in float systems have also been observed by Özer (2018). Similar were the results of a study carried out in melon (*Cucurbita pepo* L.) where under shade conditions, more efficient root development was observed for the transplants which were produced in the float system with organic fertilization in comparison to the corresponding development in the float system with inorganic fertilization. In tomato, brushing along with delayed phosphorus fertilization provided efficient height control and improved seedlings quality (Rideout & Overstreet, 2003).

For lettuce and tomato for processing, various mixtures of nutrient solutions can be utilized in a float system while it was also found that in the case of brassicas cell volume is another important parameter to consider in order to reduce the cost of float systems for vegetables. In the case of cauliflower, cabbage and broccoli it is possible to utilize a 20 cc/cell (Carrasco et al., 2003). Regarding *Brassica* spp., there is evidence that broccoli *(Brassica oleracea* Botrytis Group) and cabbage (*Brassica capitata* Group) transplants can be efficiently grown in tobacco transplant float systems (Niedziela & Gumbi, 1993). Float systems for the production of leaf vegetables have been increasing, but adequate nutrient solution concentrations are not yet available (Alberici et al., 2008). Regardless of their different composition, nutrient solutions contain high levels of dissolved nutrients with higher values than those generally observed in the natural soil environment (Marschner, 1995). The composition of the nutrient solution is an important aspect affecting the success of float systems and is dependent on the needs of each cultivated crop. For example, different solutions are used for lettuce (Coronel et al., 2009), lamb's lettuce (Gonnella et al., 2004) or rocket (Nicola et al., 2003). The role of electrical conductivity and oxygen content in the nutrient solution needs also to be evaluated when float system is applied in vegetable crops. In a tomato float system, it was noted that root length and branching of plants was promoted when plants were grown in areas of the trunk where EC value was increased (Tataranni et al., 2013). The interference of nutrient solution with organic or inorganic fertilization or chemical elements needs to be further investigated. Malorgio et al. (2009) pointed out that the addition of 0.5 and 1 mg Se L^{-1} in the nutrient solution of the float system leaded to higher leaf biomass per unit area both for lettuce and chicory (*Cichorium intybus* L.), especially during spring period, whereas both ethylene production and phenylalanine ammonia lyase activity were decreased due to Selenium addition. This comes in agreement with the findings of another study carried out in tomato whose conclusion was that the addition of Se in a nutrient solution can be an effective strategy for producing tomatoes with beneficial properties for public nutrition and health (Pezzarossa et al., 2014). The production of perennial vegetable crops in float system has also been studied. It was documented that for artichoke (*Cynara cardunculus* L. subsp. *scolymus* (L.) Hegi) and cultivated cardoon (*C. cardunculus* L. var. *altilis* DC), increased salinity on the nutrient solution reduced the ratio of leaves per plant by approximately 6–19% and leaf dry biomass by 17–28 %. However, improved quality of leaves was attributed to increased salinity in the nutrient solution (Rouphael et al., 2012). This is in full agreement with previous findings of other researchers who showed that an increase in nutrient solution electrical conductivity, through the use of floating system, can improve fresh-cut lettuce characteristics (Scuderi et al., 2011).

Aromatic and Medicinal Plants. Float systems are also promising for the cultivation of aromatic plants and herbs (Thomas, 1993; Miceli et al., 2003). The positive effects of adopting float system instead of soil cultivation on the yields of basil (*Ocimum basilicum* L.) and arugula (*Eruca vesicaria* (L.) Cav.) have been well demonstrated by Incrocci et al. (2001). *E. sativa* showed also good adaptability to floating system and its yield was slightly influenced by different EC levels (D'anna et al., 2003). There is also evidence that in rocket crop under float system, the use of a biostimulant resulted in yield and chlorophyll content regardless of the dose of standard or reduced nutrient solution was used (Vernieri et al., 2005). This finding indicates that the use of biostimulants along with float system technology can reduce the dependence of greenhouse production on the use of inorganic fertilizers. The combined effects of float system and organic fertilization has been well demonstrated by Akoumianaki-Ioannidou et al. (2015) who noticed that dry weight of shoots and leaves as fresh and dry weight of roots of basil seedlings were increased under float system than in seed beds, whereas in spearmint (*Mentha spicata* L.) there was also seed germination ability was favored by the adoption of float system. In addition, float system along with organic fertilization resulted in increased leaf area per plant in basil, whereas this combination did not favor several growth attributes of spearmint.

The results of Kiferle et al. (2013) suggested that the standard N concentration used in hydroponic culture could be significantly reduced, with important implications from the environmental aspect. This conclusion was justified by the facts that root dry weight of basil plants was significantly increased at 0.5 mol m^{-3} NO^{-3} and also that plants grown with 5.0 mol m^{-3} NO^{-3} contained more rosmarinic acid in root and leaf tissues than those grown with higher NO^{-3} concentration. According to Miceli et al. (2003), basil plants developed well in a floating system. There is evidence that several herbs, including basil and spearmint, provide high yields and good product quality when cultivated in soilless systems and in particular in floating systems (Thomas, 1993; Treadwell et al., 2011). Another finding was that keeping plants in the nutrient solution until the harvest, resulted in increased content of NO^{-3}. In the experiment of Saha et al. (2016) submerged basil seedlings were held in polyethylene tanks and were developed in a float raft system. The findings of this study revealed that aquaponic basil plants were higher than hydroponic basil plants and produced 56% more fresh weight but no significant differences were detected regarding either plant quality or concentration of leaf nutrient contents.

CONCLUSION

In summary, float system can certainly be a satisfactory alternative of the cultivation in the soil. It is considered to be a less-intensive and low-cost technology that enables the farmer to control efficiently the nutrition of the growing plants. Furthermore, diseases caused by soil pathogens are reduced when float system technology is adopted. Float system can significantly increase root development of growing plants and control the height of produced transplants. Increased yields and improved transplant quality (and consequently lower transplanting stress) can be achieved through float system technology for various crops like tobacco, vegetables, aromatic and medicinal crops. In all cases, it is crucial to mind about issues such as water quality, oxygen content and salinity, the substance of the growing media and the concentrations of nutrients in the nutrient solution. Float system along with organic fertilization can optimize float system technology and result in higher yields and excellent quality of produced transplants for tobacco, vegetables, aromatic and medicinal crops.

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