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Optimizing Growing Media for Enhancement to Vegetative Growth, Yield and Fruit Quality of Greenhouse Tomato Productionin Soilless Culture System

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Abstract: Soilless growing is becoming an attractive option because of the unpredictable problems of soildue to fluctuating temperatures, moisture holding capacity, obtainability of nutrients, salinity, root aeration, undesirable microbial activities and nematode, disease and pest to overcome these problemswith soilless. Since the growthmedium relates to every cultural practice in the soilless production stage, selection or formulationof medium is extremely important. However, the main objective of the study was to determine the effect of coco-peat andperlite media mixtures on vegetative growth, yield and fruit quality of tomato (*Solanumlycopersicon*Mill *var* K-21) seedlings in soilless system. Results of statisticalanalysis showed that growing mediahad a significant effect ($p< 0.01$) on vegetative growth, yield and fruit quality of tomato. The 50% coco-peat + 50% perlite media caused a higherchlorophyll content (64.16 SPAD unit) in leaves and this increase was accompanied with increase of plant growth, which produced highest weight and length aerial shoots by 1262 gr and 339.80 cm, respectively. The highest vegetative growthin seedling grown using 50% coco-peat + 50% perlite result in appearance inflorescence in tomato seedling later than other media. Early flowering was might be due to adverse vegetative growth and having proper physical properties in other media. So, the best result for air filled porosity and water hold capacity by 23 and 34% was displayed by 50 % coco-peat + 50% perlite media. The high yield and fruit number (4.51 kg plant $^{-1}$ and 40.2)and superior quality of fruits containing 7.31% dry matter content and 4.74 brix TSS results in a media mixture of as evidenced by thepositive physical properties and growth of tomato seedlings. From the results of this study itis recommended that 50% coco-peat + 50% perlite can be used on greenhousetomato seedling production.

Key words: Tomato · Hydroponic · Growing media · Coco-peat · Perlite · Soilless

INTRODUCTION

Hydroponics is the growing of plants without soil, as the knowledge of growing plantsutilizing a solution of appropriate nutrients in place of soil, whichthis can either be through the use of non-soil growingmediumor no growing medium at all [1]. Growing plants in soil, as natural media for cultivation of many crops, is unpredictable due to fluctuating temperatures, moisture holding capacity, obtainability of nutrients, changes acidity level, salinity, poor drainage, root aeration, undesirable microbial activities and nematode, disease and pestproblems [2]. To overcome to output of soil problems new methods are being introduced such ascultivation of crops under protected environments and growing media followed with appropriate physical-chemical properties, which allowed to the plants thrive on the nutrient-water solution alone [3]. However, eliminating soil fromproduction system can provide number of advantages inthe management of both plant nutrition and plantprotection compare to conventional soil based productionsystems [4]. The growing mediais totally inert and merely acts as a support for theplants and their root systems, whereas the nutrient solutionpasses freely.

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A good growing mediumwould provide sufficient anchorage or support to theplant, serves as reservoir for nutrients and waterproper to root functions, allowoxygen diffusion to the roots, permit gaseousexchange between the roots and atmosphere outside theroot substrate and provide the conditions for practical plant production e.g.easy to supply, suitable cost, easy processing, lightnessand homogenous plant production [5, 6]. Among the cultural inputs involved in greenhouse crop production, perhaps the most important is the type of growing media used.Different substrates have various materialsand structure which could have direct and/or indirecteffects on plant growth and development. While thesesubstrates can be used alone, mixtures of the substratessuch as peat and perlite; coir and clay, peat and compostare also be used widely.Currently, a wide range of soilless culture techniqueshave been developed and commercially introduced forintensive production of horticultural crops, particularlyvegetables under greenhouses condition. In soillessproduction system, various growing media orsubstrates such as Rockwool, perlite, vermiculite andpeat have been applied to grow many of crops and consequently were tested for their suitability as substrate for the hydroponic cultivation of vegetables [7]. Results obtained by Alifar *et al*., (2010) concerning effects of the application of different growing media on yield of cucumber fruithaveindicated that highest fruit yield was obtained by Coco-peat whereas thelowest one was obtained by Perlite-Coco-peat [8]. Theeffect of the substrate on yield and fruit quality of tomatoin soilless culture studied by Tzortzakis *et al*., (2008) showed that plants grown in pumice and perlitesubstrates obtained lower total yield; and higher yieldwas obtained from maize substrate [9]. Therefore, substrate selectionbetween the various materials is one of the most importantfactors affecting plant growth and developmentin the greenhouse and influencing vegetable quality [10]. Composition of plant growing media may vary depending on the several reasons. Main materials usedfor the composition of media are sawdust, peat, perliteand vermiculite.Since the growthmedium relates to every cultural practice in the production stage, selection or formulationof medium is extremely important [11]. Successful production of container-grown plants is dependent on the physical and chemical properties of the growing media selected. Therefore some critical physical and chemical properties need to be evaluated before making a media decision [12]. Physical and chemical properties commonly measured for container media and media components include total pore space, water holding capacity, air space, bulk density, particle size distribution, pH, soluble salts, cation exchange capacity (CEC) and the carbon to nitrogen ratio [13]. Greenhouse production is now an important sector in Iran. Studies on soil-free culture in Iran have advanced during the last decade. There is, however, lack of information regarding the suitability of organic and inorganic materials and their mixes as growing materials for hydroponic crops in soilless culture system [14]. Based on these results, the present study was focused on the evaluation of cultivatedperlite, coco-peat and their composition pressed as growing media for quantity and quality of tomato fruitsand was todetermine a suitable growing medium forhydroponic tomato production.

MATERIALS AND METHODS

Plant Material and Seed Germination: The investigation were carried out ina greenhousewithtemperature control (18/24°C, night/day)presented in Faculty ofAgriculture, the Technical University of Samngan, Bojnourd, Iran. The tomato seeds were obtained fromAgricultural Research Central of Torogh, North Khoransan (Iran). Healthy seeds of tomato (*Lycopersiconesculentum* Mill *var* K-21) were surface sterilized with ethanol 75% for 5 min followed by repeated washings with double distilled water to remove the ethanolresidue on the seed surface.The seedswere germinatedin sterile seed trays in the greenhouse condition at 27 ± 2°C usingpeat moss. After germination, the resulting 30 day old-seedlings were transplanted to growing mediaas described in Table 1, when they were achieved 5-7 leaf. At transplanting, peat moss around the roots of theseedlings was gently removed using running tap water.

Formulating Growing Media and Crop Cultivation: Growing media were prepared using different amount of coco-peat and perlite materials. Six growing media were prepared using certain amounts (by volume) of materials. After obtaining useable coco-peat, six growing media with differential ratio from combination coco-peat with perlite was formulated according to Table 1. Because of the majority greenhouse native farmers of Samnganoften have utilized combination from coco-peat with perliteas most common growth medium component forcontainer production. However, the 60 coco-peat: 40 perlite (60CP: 40PL) ratio was defined as control growing media. The disinfectedplastofoam pots were filled with well-uniform formulated growing media containing different ratiosof perlite: coco-peat. After the shootings of seedlings were

Table 1: Growing media and mixture rates of differential composition coco-peat with perlite used in the study

Growing media	Mixture rate (by volume)	Symbol
Cocopeat: Perlite	0-100	CP:PL (0:100)
Cocopeat: Perlite	25-75	CP:PL (25:75)
Cocopeat: Perlite	50-50	CP:PL (50:50)
Cocopeat: Perlite	75-25	CP:PL (75:25)
Cocopeat: Perlite	100-0	CP:PL (100:0)
Cocopeat: Perlite	60:40	CP:PL (60:40)

appeared, 5-7 leaf-seedlings (stem diameter, <5 mm) were planted to each 250 m^3 pot. The 30 number plots werearranged randomly in two row with 60 × 50 cm. Each row consistedof 15 pots. The six treatments (6 growing mediaformulations) were organized in a randomized complete block design (RCBD) withfive replications. Tomato was grown, using strings formaintenance, on wires 2.80 m directly above the ground. Theseedlings were irrigated daily through a drip tapwith a nutrient solution from 1 to 4 Liters per day, depending on the stage ofplant growth. Fertigation was applied 6 times daily for 5 minutes using drippers of 2 L hr^{-1} capacity. The management of thecrop, including the nutrient and irrigationregime, was the same for each medium.During the culture of hydroponic tomato production, insect pests were controlled by use of dimethoate and fungal diseases by use of bravo.

Physical Properties of the Growing Media: The air filled porosity (AFP) and water hold capacity (WHC), as two physical properties of growing media, were measured. The AFP andwater holding capacity (WHC) for each substrate was determined by the submersionmethod of Kreij De *et al*., (2001) and Shinohara *et al*., (1999), respectively at thebeginning of the experiment [15, 16].

Quantity, Quality Fruits and Vegetative Growth Assay: The first harvesting of fruit seedling was implemented in April, 2015 at complete red ripping stage. Overall, this sampling was repeated three times during 3 weeks from April to May. The collected-fruits be up to each sampling were separately counted and then weighted. Finally, with calculating sum of three sampling, the yield fruit of single seedling (YSS) of tomato as kg plant $^{-1}$was obtained.

Fruits for each growing media were juiced separately and the juice was directly used for total soluble solid (TSS)using a digital refractometer (ATC1E-ATAGO, Japan)expressed as Brix.

To measure chlorophyll content of leaf seedlings, fresh leaf was randomly chosen and consequently, it was determined by handle chlorophyll meter (SPAD).

For Measurement of dry matter fruit (DMF), from each growing media were randomly chosen five fresh-fruit at complete-red ripping stage and then washed with distilled water. The three mixed-samples (100 g) was provided from five chosen-fruit for each growing media and weight of mixed-samples recorded as fresh fruit weight (FFW). Eventually, they were dried at 75°C for 75 h in a vacuum oven until dry fruit weight (DFW) was obtained. Andthe DFW was determined by using an electronic balance (model: Series 321 LT) with an accuracy of ±0.01 g. Using the initial weight of mixed- sample recorded prior to exposing vacuum oven, the DMFwere expressed by equation, i.e.{FFW-DFW}.

The interval between medium until primary in florescence from each growing media, after 20 day transferring seedlings into plots, were measured on a centimeter scale by means of wires and ruler withan accuracy of 1mm so as to obtain interval primary inflorescence (IPI). The length of aerial shootseedlings (LAS) were also determined to like this at end vegetative stage and consequently their weight (WAS) were ascertained by using an electronic balance.

Statistical Analysis: The experimental data were analyzed onthe basis of completely randomized design (CRD) with five replications. Data were subjected to analysis of variance (ANOVA) usingSAS Portable ver.9.4 software (Statistical Analysis System, SAS Institute Inc., 1985). Means were compared by least significant difference (LSD) test to analyze the difference between treatments and intervals at 99% confidence level of each variable.

RESULTS AND DISCUSSION

Tomato harvesting started on April, 2015 and continued until on May, 2015. The AFP, WHC, LAS, WAS, IPI, TSS, DMF%, YSS, fruit number (FN) and chlorophyll index (Chl) of tomato (*Lycopersiconesculentum* Mill *var* K-21*)* grown in different media demonstrated statistically significant ($P \leq 0.01$) differences depending on growing media (Table 2).

Physical Properties of the Growing Media: Organic and inorganic substrates used in a soil-free culture can differ remarkably in their physical properties. These physical properties affect the air content and retainedvolume of available water in the substrate. These differences need to be taken intoconsideration when growing greenhouse crops with changing demands for water andoxygen in the

Table 2: Analysis of variance for vegetative growth, yield and fruit quality of greenhouse tomato was exposed to growing media treatments in hydroponic culture system

		MS									
Source of variation	df	WHC	AFP	IPI	LAS	WAS	YSS	FN	TSS	DMF	Chl
Growing media treatemnts	5	45.5**	51.33**	481.62**	18009.24**	308085.33**	4.27**	277.60	2.58**	2.06*	1032.78**
Error	25	6.5	1.58	20.63	786.54	1614.03	0.25	14.83	0.33	0.41	57.51
Coefficient of variation		7.39	5.43	12.54	11.92	4.49	17.14	13.75	12.90	8.98	17.93

Note: The ** represent significant at 1% level

Table 3: The effects of six different growing media on vegetative growth of tomato seedling and physical properties of growing media utilized in greenhouse tomato culture

Growing media	WHC (% vol)	AFP (%)	Total porosity (%)	LAS (cm)	WAS (gr)	IPI (cm)
CP:PL	39a	19.00d	58ab	176.80c	590f	26.35d
CP:PL	37ab	25.50d	57.50b	198.11c	812d	30.65cd
CP:PL	34bc	23.00c	57b	339.80a	1262a	53.55a
CP:PL	32c	25.00b	57b	236.06b	958c	35.95cb
CP:PL	31c	28.00a	59a	196.80c	690e	30.35cd
CP:PL	34bc	23.50bc	57.50b	263.60b	1060.80b	40.50b

There is no statistical difference between means represented by the same letter in the same column (P<0.01)

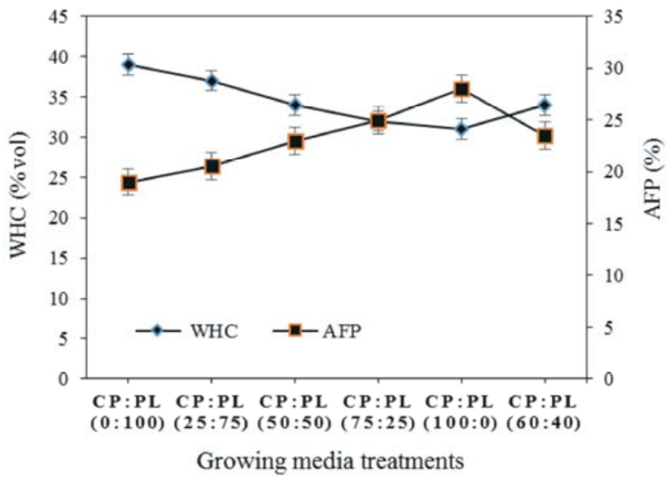

Fig. 1: Effect of perlite, coco-peat and their composition as growing media on air filled capacity (AFP) and water holding capacity (WHC)

root zone of tomato [14]. Therewas anexcessive difference in the physicalproperties of the planned growing media (Table 3). The WHC and AFPvalue indicated hugelydifferent (P $\leq$ 0.01). The AFP of growing media oscillated between 18 and 28% by volume whereas the amount of WHC was between 30 and 39% by volume for six growing media, depending on the composition. The highest AFP value was obtained by pure coco-peat while the highest WHC value was obtained by pure perlite. In contrast, the lowest AFP and WHC value was calculated for pure perlite (19%) and pure coco-peat (31%), respectively. The total porosity of the investigated growing media differed significantly from each other. As such, the highest total porosity was caused by 100CP:0PL (59 vol %), followed by growing mediummake up 0CP:100PL (58 vol %), which did not differ significantly from each other (Table 3). Nevertheless, all growing media were in the range of the mentioned optimum values concerning the total pore space (> 85 vol %) as validated by De Boodt and Verdonck (1972) [17]. Container media should contain 50 to 85% pore space. For total porosityof container the media is important, butperhaps more vital than this is the portionthat is AFP versus WHC. Some plants preferwet soils while others prefer dry soils. Altland (2006) proved that onaverage, 10 to 30% of the container volumeshould be composed of air space while 45 to 65% should be water [18]. A reverse significant relationship was detected between AFP and WHC for different grades of perlite composed with coco-peat (P $\leq$ 0.01). Also, this reverse significant relationship was

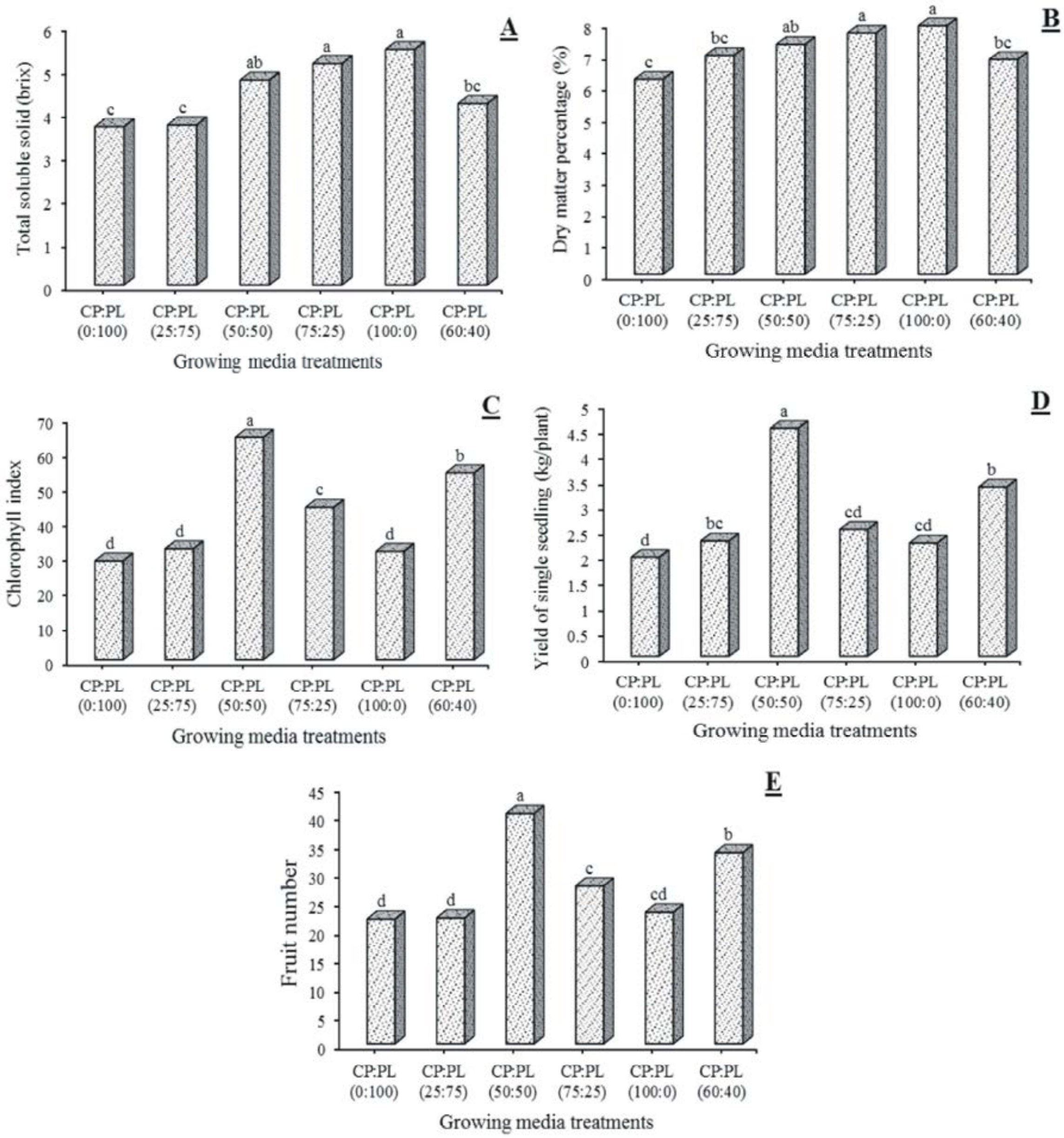

Fig. 2: Results of growing media containing alone pure coco-peat, pure perlite and theircomposition on cumulative yield of single plant, chlorophyll index, total soluble solid, fruit number and dry matter fruit percentage of hydroponic tomato production

observed for different grades of coco-peat (Fig. 1). There was a trend of increasing AFP and decreasing WHC with increasingcoco-peatto perlite ratio compared to perlite in composition media or vice versa. The same trend hasbeen stated by Wada *et al*. (2005) and Samadi (2011) [14, 19]. Adding perlite substrate from 25 to 100% to growing media decreased AFP whereas adding coco-peat substrate from 25 to 100% to growing media led to increase AFP and itvice versawas confirmed for WHC. All of the growing media except pure perlite did not markedly affect WHC compared to control. The pure coco-peat only could increase AFP; however (0CP:100 PL) and (25CP:75PL)significantly decreased AFP compared control (Table 3).

Vegetative Growth of TomatoSeedling, Quantity and Quality Fruits: Thevegetative growthparameters of tomatohydroponic seedlings including chlorophyll content, length and weight of aerial shoots (LAS and WAS) were alsosignificantly affected by the growing media (Table 2, P ≤ 0.01). As presented in Table 3, the LAS, WAS and IPI values in the mixture with 50% coco-peat + 50% perlite (50CP: 50PL) were found statistically higher than othergrowing media. When the effect of media on LAS parameter is considered, significant decrease wasseen between pure perlite, pure coco-peat and their mixtures except to 50CP: 50PL compared to control medium. However, numerically the longest of LAS seedlings wereobtained as 339.80 cm in 50CP: 50PL treatment. The maximum WAS parameter were also obtained in the samemixture. Indeed, this is confirm to direct relationship between LAS and WAS parameter. Actually, with the increase perlite to coco-peatratio from 50 to 100% or with the increaseratio ofcoco-peatto perliteratio from 50 to 100% in growing media, the LAS and WAS decreased, so that the only 50CP: 50PL produced the highest LAS and WAS and consequently, the primary inflorescence was appeared later than other growing media in tomato seedlings (Table 3). The good results obtained with the 50CP: 50PL mixture are probably related to the physical characteristics, in particular, to its higher water holding capacity (WHC= 34 vol %) and air filled porosity (AFP= 23 vol %). The earliest inflorescence as the lowest of IPI value was observed in tomato grown using alone perlite andcoco-peat, respectively. The chemical analysis for the chlorophyll content of the leaves showed that bymixing coco-peat with perlite in 1:1 ratio, significantincrease in chlorophyll content of tomato leaves by 64.16 (SPAD unit) were obtained comparison with control medium (Fig. 2C). The visible symptom decrease inchlorophyll content is the loss of green color. This phenomenonis caused by chlorophyll degradation that is catalyzed by the chlorophyllase that converts the chlorophyll a and b to chlorophyllide and phytol [20]. In thepresent study, the chlorophyll degradation was accelerated in leaves of plants grown using all growing media except 50CP: 50PLso that significant decrease in chlorophyll content was observed in comparisonwith the control (Fig. 2C).

Results indicated thatthe growing medium affected the dry matter content (DMF) and total soluble solid (TSS) as well a s quality of tomato as judged (P ≤ 0.01). In the present study, it was found that produced the highest DMF and TSS of tomato seedling grown in pure coco-peat, 75CP:25PL and50CP: 50PLrespectively, compared to control medium (Fig. 2A, B). As the coco-peat amount increasedin the media, anincrease was observed in DMF and TSS content. In contrast, increase in perlite amount in the media, a decrease was measured in DMF and TSS content so that the pure perlite produced lowest them. However, this decrease was not statistically significant for most of them compared to control medium.

It was demonstrated that the growing medium also affected the yield of single seedling (YSS) and fruitnumber (FN) as well as quantityfruit of tomato as judged (P ≤ 0.01). The further YSS (4.51 kg plant^{-1}) and FN (40.20 fruit) of tomato fruits was achieved when fruits from plant grown in 50% coco-peat + 50% perlite (50CP: 50PL) as growing media (Fig. 2D, E). While the other growing media were significantly resulted in decreased YSS and FN of fruits compared to control medium. Hence, this decrease was not statistically significant for pure perlite or pure coco-peat and their composition except to 50CP: 50PL.The results were in accordance with the finding of Dilmaghaniand Hemmati. (2011) indicatedthat highest yield of strawberry fruitand fruit's number wasobtained by 50% coco-peat + 50% perlitecompared with other growing media [21].

CONCLUSION

Overall, in the present study, it was found that positive results wereobtained in seedling production of tomato (*Lycopersiconesculentum* Mill *var* K-21) with optimizing growing media toa certain level of perlite and coco-peat substrates. It was suggested that healthy, high qualityand quantity fruits can be attained by 50% coco-peat + 50% perlite (50CP: 50PL) in growing mediato hydroponictomato production. This output of results mightbe due to combination of thesetwo substrates affects nutrient holding capacity, betterelement exchange and optimum distribution of moisture and airin root zone which consequently, affects the formationof rooting system, absorption of nutrientsand plant growth [22]. Hence, the high porosity (57 vol %) of coco-peat: perlite (1:1) ratio media allowed thetomato seedling root topenetrate in substrate easily and it could usemore volume and space of media, thus available waterwas sufficient for tomato seedlings grow up.Results obtained have shown that among the growing media tested, application of coco-peat: perlite (1:1)ratio media not only enhanced the hydro-physical properties but also vegetative growth parameters of tomato. The high weight and length aerial shoots and further chlorophyll content by 1262 gr, 339.80 cm and 64.16 SPAD unit, respectively were calculated forcoco-peat: perlite (1:1)ratio (Table 3, Fig. 2C). The suitable vegetative growth result in appearance of inflorescence in tomato seedlings grown using coco-peat: perlite (1:1)ratio media later than other growing media. Physiologically, early flowering or appearance inflorescence happens in water deficit, salinity, low nutrition, insufficient oxygen, and other stress condition for flowering plants, which have represented to adverse vegetative growth. However, the decrease LAS, WAS and chlorophyll content in all growing media except 50CP:50PL imply on this subject. According tothese reasons, the best yield and fruit number attained by tomato seedling grown using coco-peat: perlite (1:1) ratio media (Fig. 2D, E). Overall, these findings suggested that optimized coco-peat and perlite in 1:1 ratio growing media could be used as successful particle method for enhancing suitable vegetative growth, high yield and best quality fruits to hydroponic tomato production (*Lycopersiconesculentum* Mill *var* K-21).

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