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STUDY THE EFFECTS OF DIFFERENT CULTURE MEDIA ON GERMINATION, MORPHOLOGICAL, PHYSIOLOGICAL AND PHOTOSYNTHETIC CHARACTERISTICS OF TOMATO (*SOLANUM LYCOPERSICUM* L.)

FARNOUSH ROSTAMI [1], REZA SALEHI [2]*, ALI MOHAMMADI TORKASHVAND [3], PEJMAN MORADI [4] and SEPIDEH KALATE JARI [5]

[1, 3, 5] Science and Research Branch, Islamic Azad University, Iran.
[2] University of Tehran , Iran.
[4] Saveh Branch, Islamic Azad University, Iran.
Email: [1]farnoush.rostami@gamil.com, [2]salehir@ut.ac.ir (*Corresponding Author),
[3]m.torkashvand54@yahoo.comand, [4]pjmoradi@gmail.comand, [5]kalatejari@yahoo.comand

Abstract

The current study was aimed to investigate the effects of cocopeat, nipeat and perlite substrates on morphological, physiological and photosynthetic traits of tomato seedlings in a randomized complete block design. For this purpose, after preparing the seeds, they were sown in planting trays containing aforementioned substrates in different proportions. Seed germination percentage and rate were calculated and after the seedlings reached the stage of transfer to the field, morphological traits such as root length, stem diameter, stem length, number of leaves, stem fresh and dry weights, fresh and dry root weight as well as physiological parameters including chlorophyll a, b and total, carotenoids, the activities of antioxidant enzymes catalase, polyphenol oxidase and superoxide dismutase, and proline content and relative water content of leaves were measured. Also, photosynthetic performance parameters were calculated by fluorcam device. The results showed that 100% cocopeat substrate in tomato seedling cultivation leads to the highest vegetative yield of seedlings. However, when perlite was added to the culture medium, a decrease in the studied traits was observed. When cocopeat medium was used, the highest content of chlorophyll a, b and total, carotenoids and relative water content of leaf and the lowest amount of proline were reported. The application of perlite in the tomato seedling culture medium was lead to the decrease in photosynthetic yield indices. Therefore, according to the results obtained in the present study, it can be stated that the use of 100%cocopeat can lead to better growth of tomato seedlings.

Keywords: Cocopeat, Nipeat, Perlite, Substrate, Seedling.

1. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is a perennial plant from Solanaceae family and is one of the most important agricultural products that due to its significant amount of vitamins and minerals has a special place in the diet of many people in the world (Gerszberg et al., 2015). Germination and plant growth stage is usually the most critical stage of plant growth, so that the success rate of this stage has a significant effect on the development of other stages of plant growth and ultimately the acquisition of appropriate production (Rifna et al., 2019).

Poor germination and reduced seedling growth have been reported to lead to poor establishment and sometimes crop loss (Soltani and Soltani, 2015). Therefore, due to the position of this plant in global nutrition and the sensitivity of the seedling growth stage, it is necessary to further study the early stages of tomato growth and the factors affecting it. One of the factors affecting the development of plant growth stages, including seedling growth stage, is the culture medium. At present, much attention has been paid to the cultivation and production of tomatoes in soilless planting media (Meric et al., 2011).

These substrates have advantages such as controlling plant nutrition, increasing planting density, reducing the incidence of diseases and pests, and increasing the quantity and quality of the crop compared to soil cultivation, and have encouraged horticultural producers to use them (Martinez and Abad, 1992). In general, the materials used in the planting medium should have high water holding capacity, adequate ventilation, good drainage and high cation exchange capacity (CEC).

Different culture media each contain different substances that directly or indirectly affect plant growth and development; therefore, choosing the right culture medium in the production of products such as tomatoes is very important.

Cocopeat (CP) is a compound obtained from the processing of coconut fruit husks, which is physically spongy and peat-like material, composed of equal proportions of lignin and cellulose, and in recent years has been widely used in the horticultural industry in Europe, Australia, the United States and Canada (Noguera et al., 2000). Perlite is aluminosilicate of volcanic origin and does not have much cation exchange capacity.

Perlite increases the drainage of the culture medium and improves its ventilation. Successful production of crops in soilless cultivation in greenhouses requires adequate storage of nutrients in different culture media at each stage of plant growth (BÃhme, 1994). Bagasse is a fibrous material that is extracted from sugarcane in the form of wood chips that contain 55-50% water (Rasul et al., 1999).

The structure of bagasse consists of cellulose (35%), hemicellulose (24%), lignin (22%) and about 20% ash containing other minerals (Alves et al., 2010). It seems that this material has the potential to be used as a culture medium in the production of soilless greenhouse products and studies in this field can be of great importance. Therefore, the aim of this study was to investigate the effect of soilless culture media on biochemical, physiological and biological responses of tomato in greenhouse conditions.

2. MATERIALS AND METHODS

2.1. Study Design

Factorial randomized complete block design was used in order to investigate the biochemical, physiological and biological reactions of tomato seedlings to different compositions of cultural media in the cropping year 2020-21 in Karaj-Iran.

Experimental treatments included 6 culture medium as follow:

1) 100% Cocopeat (CP_{100})
2) 100%Nipeat (NP100)
3) Cocopeat 50% + Nipeat 50% (CP_{50} + NP_{50})
4) 25% cocopeat+50% Nipeat+ 25% perlite ($CP_{25}NP_{50}P_{25}$)
5) 50% Nipeat +50% perlite (NP_{50} + P_{50})
6) 70% Nipeat +30% perlite (NP_{70} + P_{30}).

After preparing the beds, pots with a diameter of 12 cm and a height of 10 cm were prepared. Then, 3 tomato seeds cv. Canyon were planted in each pot. Irrigation was done daily.

2.2. Evaluation of Germination and Morphological Parameters

We evaluated germination and morphological parameters including germination percentage, germination rate, root length, stem diameter, stem length, number of leaves, fresh weights of stem and root and root, stem dry weights.

Seeds with root lengths of 2 mm or more were considered as germinated seeds. Germination percentage (GP) was determined based on the formula PG = 100 (n / N) in which n is the number of germinated seeds and N is the total number of seeds sown.

Germination rates (GR) of tomato seeds were determined according to the following equation:

$$GR= (a/1) + (b-a/2) + (c-b/3) +\ldots + (n-m-1/N)$$

Where a, b,…n are the number of germinated tomato seeds after 1, 2, 3,…,N days from the beginning of sowing.

Root and stem length were measured using a millimeter ruler and stem diameter was measured using a caliper. Stem and root fresh weight was measured using an accurate digital scale. To measure the dry weight of roots and stems, they were first placed in an oven at 70 ° C for 48 hours and finally their dry weight was measured using a digital scale.

2.3. Physiological Parameters

2.3.1. Chlorophylls and Carotenoids

To measure the amount of chlorophyll, 1 g of leaf was extracted in a mortar with 20 ml of 80% acetone and then stored in the refrigerator for 24 hours. From the upper part (floating part) of the obtained extract, sampling and adsorption rate were read by spectrophotometry at wavelengths A_{645}, A_{663} and A_{470} (Shaoyun et al., 2009).

2.3.2. Catalase, Polyphenol oxidase and Superoxide Dismutase

Leaf extract catalase activity was measured by spectrophotometry based on reduced adsorption of hydrogen peroxide for 30 seconds at a wavelength of 240 nm. The reaction mixture contained 50 mM potassium phosphate buffer (pH = 7), 15 mM oxygenated water and 100 µl of enzyme extract. The reaction was started by adding H2O2 and the adsorption decrease was measured for 30 seconds. The amount of decomposed hydrogen peroxide was calculated using a quenching coefficient of 40 mM / cm (Velikova et al., 2000).

PPO enzyme activity based on Asadi Sanam et al. (2015) by 2 mL of 1 mM sodium phosphate buffer (pH 6.8), 0.5 mL of 100mM methylcatechol and 0.5 mL of enzyme solution and the absorption intensity was read by a spectrophotometer at 420 nm (Asadi-Sanam et al., 2015).

Superoxide dismutase activity was measured based on Giannopolitis and Ries (1977) method (Giannopolitis and Ries, 1977). For this purpose, 0.5 g of fresh leaf tissue was placed in liquid nitrogen and then 3 ml of HEPES-KOH buffer with pH 7.8 containing 0.1 mM EDTA was extracted. The resulting homogenate was centrifuged at 15,000 rpm for 15 minutes at 4 ° C and the supernatant was used to measure spectrophotometrically SOD activity at 560 nm.

2.3.3. Proline and Relative Water Content

Proline content of leaf was evaluated based on the method described by Zang et al. (2010) and the results were expressed in µg/g of fresh weight (Zhang et al., 2010).

To measure the relative water content (RWC), leave samples were prepared, weighed and their fresh weight was recorded. The samples were placed overnight in distilled water at 4 °C. After removing the surface moisture, swollen weights were recorded by a digital scale. The samples were then dried in an oven at 70 ° C for 48 hours and their dry weight was measured. Finally, the relative amount of leaf water was calculated using the following equation (Paknejad et al., 2007).

$$\mathrm{RWC}\ (\%) = \mathrm{F_W\text{-}D_W/S_w{=}D_w} \times 100$$

In this equation, F_w was the leaf weight immediately after sampling, D_w was the dry weight of the leaf after being placed in the oven, and S_w was the saturated weight of the leaf after being placed in distilled water.

2.4. Chlorophyll Fluorescence

Young leaves developed at the end of the course were used to measure the maximum quantum efficiency of the photosystem (Fv / Fm) using the FC 1000-H Handy flourCam FC 100H, Photon (Systems Instruments, PSI, Czech Republic) systems. The plants were adapted for 20 minutes in the dark, after that leaf samples were taken to measure Fv / Fm, then Fv / Fm was calculated using a special protocol. At the end of the short flashes, the samples were exposed to a saturated pulse of light (3900 mmol m^{-2} s^{-1}), which led to photochemical saturation and reduction of the first receptor quinone in photosystem 2. (Genyu et al., 1989). After the fluorescence reached steady state, two consecutive series of data were expressed numerically and averaged, the first series was obtained during short-term flashes in the dark (Fo) and the second during the saturation pulse (Fm). Two photos were obtained from these two data sets. Fv is expressed using the relation Fv = Fm- Fo. Then Fv / Fm was obtained using the ratio (Fm-Fo) / Fm. Calculations for each photo were calculated using version 7 of FlourCam software.

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The OJIP test is performed using the PAR-flourPen 100-MAX device on young leaves that have adapted for 20 minutes in the dark. After adaptation in the dark, Fo was measured at 50 ms fluorescence intensity at 3 ms (stage J), fluorescence intensity at 30 ms (stage I) and 300 ms (stage P). Finally, the calculations were performed using PAR-Fluorpen software version 1.

2.5. Statistical Analysis

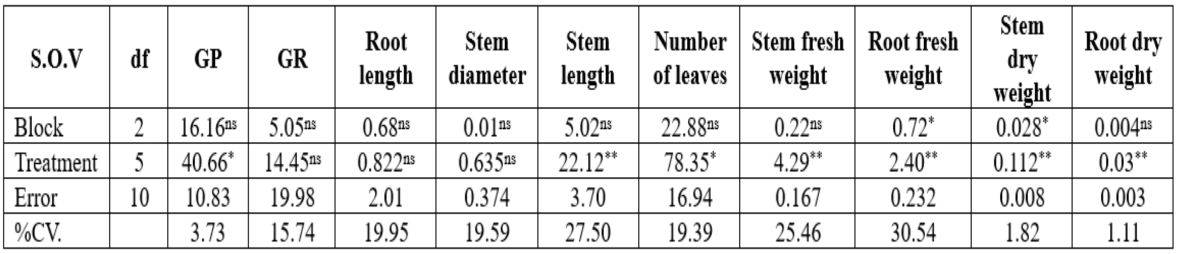
The data obtained from the experiment were analyzed based on the statistical design used by SAS software and Duncan test was used at 5% probability level to compare the means.

3. RESULTS

3.1. Germination and Morphological Parameters

The results of analysis of variance of the effect of different treatments of culture medium on tomato seedlings indicate their significant effects on germination percentage ($P < 0.05$) morphological traits such as stem length ($P < 0.01$), number of leaves ($P < 0.05$), stem fresh weight ($P < 0.01$), root fresh weight ($P < 0.01$), stem dry weight ($P < 0.01$) and root dry weight ($P < 0.01$) (Table 1).

Table 1: Variance Analysis of the Effect of Different Culture Media on Germination and Morphological Characteristics of Tomato Plant

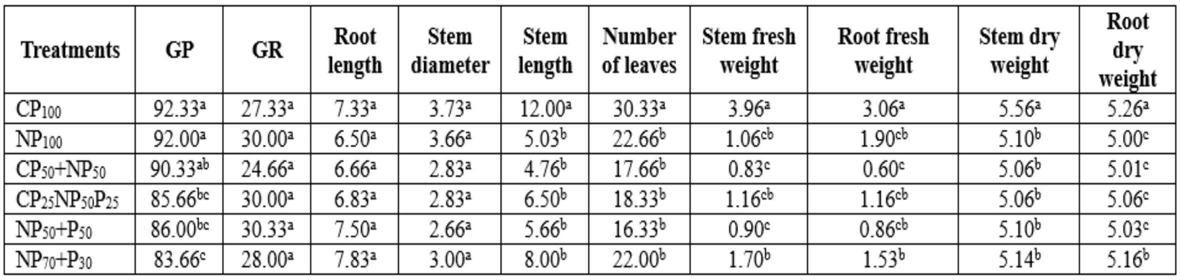


S.O.V	df	GP	GR	Root length	Stem diameter	Stem length	Number of leaves	Stem fresh weight	Root fresh weight	Stem dry weight	Root dry weight
Block	2	16.16^{ns}	5.05^{ns}	0.68^{ns}	0.01^{ns}	5.02^{ns}	22.88^{ns}	0.22^{ns}	0.72^{*}	0.028^{*}	0.004^{ns}
Treatment	5	40.66^{*}	14.45^{ns}	0.822^{ns}	0.635^{ns}	22.12^{**}	78.35^{*}	4.29^{**}	2.40^{**}	0.112^{**}	0.03^{**}
Error	10	10.83	19.98	2.01	0.374	3.70	16.94	0.167	0.232	0.008	0.003
%CV.		3.73	15.74	19.95	19.59	27.50	19.39	25.46	30.54	1.82	1.11

ns: non-significant; * and ** are significant differences at the probability levels of 5% and 1%, respectively.

The results of comparing the mean morphological traits of tomato seedlings in different substrate treatments are shown in Table 2.

Table 2: The Mean Comparison of Morphological Traits of Tomato Seedlings in Different Substrate Treatments According to LSD Test



Treatments	GP	GR	Root length	Stem diameter	Stem length	Number of leaves	Stem fresh weight	Root fresh weight	Stem dry weight	Root dry weight
CP_{100}	92.33^{a}	27.33^{a}	7.33^{a}	3.73^{a}	12.00^{a}	30.33^{a}	3.96^{a}	3.06^{a}	5.56^{a}	5.26^{a}
NP_{100}	92.00^{a}	30.00^{a}	6.50^{a}	3.66^{a}	5.03^{b}	22.66^{b}	1.06^{cb}	1.90^{cb}	5.10^{b}	5.00^{c}
$CP_{50}+NP_{50}$	90.33^{ab}	24.66^{a}	6.66^{a}	2.83^{a}	4.76^{b}	17.66^{b}	0.83^{c}	0.60^{c}	5.06^{b}	5.01^{c}
$CP_{25}NP_{50}P_{25}$	85.66^{bc}	30.00^{a}	6.83^{a}	2.83^{a}	6.50^{b}	18.33^{b}	1.16^{cb}	1.16^{cb}	5.06^{b}	5.06^{c}
$NP_{50}+P_{50}$	86.00^{bc}	30.33^{a}	7.50^{a}	2.66^{a}	5.66^{b}	16.33^{b}	0.90^{c}	0.86^{cb}	5.10^{b}	5.03^{c}
$NP_{70}+P_{30}$	83.66^{c}	28.00^{a}	7.83^{a}	3.00^{a}	8.00^{b}	22.00^{b}	1.70^{b}	1.53^{b}	5.14^{b}	5.16^{b}

As can be seen, in 100%cocopeat treatment (CP), the highest percentage of germination, stem length, number of leaves, fresh and dry weight of the stem, fresh and dry weight of the root were obtained. After that, the perlite-containing culture mediums such as Nipeat 50% + perlite 50% or Nipeat 70% + perlite 30% high values of morphological traits were observed. There was no significant difference in root length, stem diameter and germination rate of tomato seedlings in different substrate treatments used in the present study.

3.2. Physiological Parameters

Variance analysis of the effects of different culture media on physiological traits of tomato seedlings are given in Table 3 and the results indicate their significant effects on chlorophyll a, b and total content ($P < 0.01$), carotenoids ($P < 0.05$), catalase, Superoxide dismutase and polyphenol oxidase ($P < 0.05$) activities, proline content ($P < 0.01$) and relative leaf water ($P < 0.01$).

Table 3: Variance Analysis of the Effects of Different Culture Media on Physiological Characteristics of Tomato Plants

S.O.V	df	Ch_a	Ch_b	Ch_{total}	Car	Cat	PPO	SOD	Proline	RWC
Block	2	0.02^{ns}	0.01^{ns}	0.07^{ns}	0.03^{ns}	0.009^{ns}	0.21^{ns}	0.012^{ns}	243.2^{ns}	276.6^{ns}
Treatment	5	0.09^{**}	0.04^{**}	0.15^{**}	0.11^{*}	0.018^{*}	0.63^{*}	0.032^{*}	475.12^{**}	518.72^{**}
Error	10	0.007	0.005	0.003	0.032	0.006	0.018	0.003	1.55	1.39
%CV.		10.45	12.56	14.78	19.32	8.43	5.88	23.08	9.96	10.73

* And ** are significant differences at the probability levels of 5% and 1%, respectively.

The highest chlorophylls a (Cha), b (Ch_b) and total (Ch_{total}) of leaves of tomato seedlings was obtained in NP_{100} treatment and the lowest in $NP_{50}+P_{50}$ treatment. The highest carotenoid content of leaves was observed in the treatments of CP100, NP100 and $CP_{50}+NP_{50}$ and the lowest in the treatment of $NP_{50}+P_{50}$. Although the highest catalase activity was obtained in the treatments of $CP_{50}+NP_{50}$, CP_{100} and NP_{100} treatments. However, low polyphenol oxidase activity was observed in these treatments. Also, in CP_{100} treatment, the highest activity of SOD and proline content was obtained and the lowest was seen in NP_{100} treatment. $CP_{25}+NP_{50}+P_{25}$ resulted in the highest relative water content of tomato seedlings (Table).

3.3. Chlorophyll Fluorescence and Photosynthetic Function

The results of variance analysis of the effect of different culture media on fluorescent chlorophyll and photosynthetic yield are shown in Table 4.

Table 4: Variance Analysis of the Effect of Different Culture Media on Chlorophyll Fluorescence and Photosynthetic Function of Tomato Seedlings

S.O.V	df	F_v	V_j	V_i	F_v/F_0	Φ_{Po}	Φ_{Eo}	Φ_{Do}	PIabs	ABS/RC	TR_0/RC	ET_0/RC	Di_0/RC
Block	2	4×10^{5ns}	0.0005^{ns}	0.0008^{ns}	0.233^{ns}	0.0006^{ns}	0.0007^{ns}	0.0006^{ns}	0.157^{ns}	0.015^{ns}	0.0006^{ns}	0.002^{ns}	0.01^{ns}
Treatment	5	$20\times10^{7*}$	0.001^{*}	0.002^{*}	0.286^{*}	0.0007^{*}	0.001^{*}	0.0007^{*}	0.23^{*}	0.029^{ns}	0.014^{ns}	0.0066^{ns}	0.009^{*}
Error	10	6.6×10^{7}	0.0005	0.0007	0.19	0.0005	0.0006	0.0005	0.11	0.026	0.02	0.005	0.005
%CV.		24.61	5.44	3.45	11.14	3.01	5.99	11.65	20.04	5.45	6.16	5.89	12.45

As can be seen, these substrates had significant effects on all parameters except absorption flux per reaction center (ABS/RC), electron transport flux per RC (TR0 / RC) and electron transfer per RC (ET0/RC).

The mean comparisons of the traits related to chlorophyll fluorescence and photosynthetic yield of tomato seedlings in different substrate treatments are given in Table 5. The highest variable fluorescence intensity (F_V) was obtained in the treatments of CP_{100}, CP_{25} + NP_{50} + P_{25}, NP_{50} + P_{50} and NP_{70} + P_{30}. The relative variable fluorescence in the intermediate stage J (FV) was the highest in the treatment of NP_{70}+P_{30} and the lowest in treatment of NP_{50}+P_{50}. However, the relative variable fluorescence in intermediate stage I was highest at CP_{100} treatment. The maximum efficiency of the water-splitting complex on the donor side of PSII (Fv / F0) was obtained in NP_{70}+P_{30} treatment and the lowest was obtained in NP_{50}+P_{50}. However, the maximum efficiency of photosystem II (ΦPO) and the quantum yield of electron transfer (ΦEo) were highest in 5 NP_{50}+P_{50} treatment. The quantum yield of energy dissipation (ΦDo) was the highest in CP_{50}+NP_{50} and was the lowest in NP_{50}+P_{50} treatments. However, in the later treatment, the highest performance index per absorbed photon (PIabs) was obtained. Maximum energy dissipated per reaction center (Di0 / RC) was observed in CP50+NP50 and minimum in NP_{50}+P_{50} (Table 5).

Table 5: The Mean Comparison of Traits Related to Chlorophyll Fluorescence and Photosynthetic Performance of Tomato Seedlings in Different Culture Media Treatments According to LSD test

Treatments	F_v	V_j	V_i	F_v/F_0	Φ_{PO}	Φ_{Eo}	Φ_{Do}	PIabs	ABS/RC	TR_0/RC	ET_0/RC	Di_0/RC
CP_{100}	40953^a	0.45^{ab}	0.86^a	3.87^{ab}	0.79^{ab}	0.43^{ab}	0.205^{ab}	1.52^b	3.12^a	2.48^a	1.36^a	0.641^{ab}
NP_{100}	27220^{ab}	0.46^{ab}	0.81^{ab}	3.94^{ab}	0.79^{ab}	0.43^{ab}	0.202^{ab}	1.59^{ab}	2.94^a	2.34^a	1.27^a	0.595^{ab}
CP_{50}+NP_{50}	19300^b	0.44^{ab}	0.78^b	3.40^b	0.76^b	0.42^b	0.234^a	1.42^b	1.98^a	2.29^a	1.26^a	0.698^a
$CP_{25}NP_{50}P_{25}$	38742^a	0.43^{ab}	0.78^b	4.10^{ab}	0.80^{ab}	0.46^{ab}	0.196^{ab}	1.96^{ab}	2.96^a	2.38^a	1.35^a	0.584^{ab}
NP_{50}+P_{50}	37117^a	0.41^b	0.78^b	4.33^a	0.81^a	0.47^a	0.187^b	2.14^a	2.84^a	2.30^a	1.34^a	0.533^b
NP_{70}+P_{30}	35621^a	0.46^a	0.81^{ab}	3.82^{ab}	0.79^{ab}	0.42^b	0.208^{ab}	1.47^b	3.03^a	2.39^a	1.27^a	0.930^{ab}

4. DISCUSSION

In addition to the need to produce high quality seedlings, farmers need to reduce operating costs. One of the alternatives that should reduce the costs of producing quality seedlings is the use of organic compounds in the production area. Excessive use of agricultural soils, especially soils derived from horticultural products, reduces organic matter and nutrients. A suitable substrate should not contain soil, as pathogens and weed seeds are abundant in it. Also, the use of soil in growing seedlings can lead to damage to seedlings during their transfer to the mainland (Boaro, 2013). Therefore, the use of soilless substrates in growing seedlings of plants, especially high-consumption vegetables including tomato can be of great importance. A good substrate for seedlings should have physical, chemical and biological properties that provide suitable conditions for germination, seedling development, root and stem growth (Andrino, 2018).

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The results of the present study showed the improvement of germination and vegetative traits of tomato seedlings grown in pure cocopeat. After that, CP_{50}+NP_{50} and NP_{100} culture media resulted in high yield of germination and vegetative traits. However, when perlite added to media, the vegetative yield of tomato seedlings was reduced.

One of the factors involved in the quality of the greenhouse product is the type of soilless cultivation medium (Peyvast et al., 2010). The availability of nutrients in the culture medium plays an important role in the growth and development of plants in greenhouse. Organic growing media such as cocopeat, bagasse, etc. slows down the release of nutrients over time, thus acting as a nutrient buffer that improves greenhouse crop growth (Trevisan et al., 2010). The increase in vegetative and germination traits in tomato plants observed in the present study in CP_{100} medium may be due to the fact that CP provides a high water, aeration, and nutrient storage capacity during the growing of seedlings (Sarkar et al., 2021). In one study, CP was found to have maximum water, aeration and EC storage capacity and provides a good food source for the growth of bitter gourds (Rahman et al., 2018), which is in line with the findings of the present study. Vegetative growth, and biomass, is associated with nutrients stored in leaves, shoots, or roots. The amount of nutrients stored in plant organs is directly proportional to the vegetative yields and biomass of plants. On the other hand, cultivation beds with better water retention and aeration capabilities leads to vigorous plant growth and increases photosynthetic potential by the leaves. The porosity of cultural media that lead to strong root growth and also the water holding capacity play an important role in the growth and development of crops (Raviv et al., 2019). The dry biomass of the plant is also influenced by the performance of photosynthesis and the accumulation of photosynthates accumulated in the vegetative organs, which can explain the high vegetative performance of tomato seedlings in the CP culture medium in the present study. As mentioned, the combination of NP with CP or NP_{100} led to high germination and vegetative traits tomato seedlings. The culture medium of seedlings greatly affects the development of the root system and this effect is mainly attributed to the amount and size of the constituent particles and thus provides the necessary aeration for optimal root growth (Dutra et al., 2017). However, the cation exchange capacity of this culture medium is low, which can lead to reduced plant growth in this medium. For example, Samiei et al. (2005) stated that the use of sugarcane bagasse as a culture medium for Aglaonema plant increases the length of the stem, which is a negative trait in this plant and reduces the market value of this plant. In their study, they stated that CP is the best culture medium for this plant (Samiei et al., 2005).

In the present study, it was observed that the addition of perlite leads to a reduction in important yield traits tomato seedlings, which can be attributed to the reduction of water holding capacity in this substrate. However, due to its 3 to 4 time water absorption capacity, pH 6-8, perlite has many applications in seedling cultivation. It has been stated that perlite size affects plant growth and yield (Asaduzzaman et al., 2013) and its combination with other culture media can provide good benefits for plant growth. In the present study, when perlite was added to the seedbed culture medium, the vegetative yield of seedlings decreased, which can be attributed to the low cation exchange capacity and thus reduction of nutrient supply to seedlings.

The results of the present study showed an increase in the content of chlorophyll a, b and total, carotenoids and relative water content as well as a decrease in the proline content of tomato seedlings grown in CP_{100} and NP_{100} media. However, when perlite was added to the culture medium, a decrease in chlorophyll a, b and total content, carotenoids and relative water content and an increase in proline were observed in these seedlings. The increase in chlorophyll a, b and total content of carotenoids in the leaves of tomato seedlings in CP_{100} substrate can be attributed to the improvement of seedling nutritional status and reduction of proline (Li et al., 2006). Increasing chlorophyll a content can also increase photosynthetic efficiency and improve photosynthates accumulation, which ultimately leads to better seedling yield (Takai et al., 2010). Plant growth conditions (stressful or non-stressful) strongly affect the chlorophyll and carotenoid content of leaves, and in the meantime, the sufficient availability of nitrogen element in the plant plays an important role in their development. The uptake of nitrogen by the plant depends on the type of cultivation substrate, and those with aeration and high water holding capacity lead to an increase in nitrogen uptake and its accumulation in the plant, and as a result, improve the chlorophyll and carotenoid content in the leaves (Rahman et al., 2018). When the seedlings grow and develop, less chlorophyll accumulates in the leaves, which reduces plant yield. In this study, when perlite was added to substrates of the tomato seedlings, a decrease in chlorophyll and carotenoid content and an increase in leaf proline content were observed, indicating damage to seedlings. However, in the CP_{100} and NP_{100} media, an increase in chlorophyll and carotenoid content and a decrease in proline were observed, which indicates the suitable growing conditions for seedlings. Therefore, the improvement in functional traits observed in seedlings grown in CP_{100} and NP_{100} substrates can be attributed to the increase in photosynthates content and thus the improvement of plant conditions. Therefore, in the cultivation of tomato seedlings, CP_{100} and NP_{100} or a combination of them are recommended.

Environmental factors strongly affect the photosynthesis of plants, and studies use fluorescent chlorophyll variable to understand their effect on photosynthesis performance (Faseela et al., 2019). In this experiment, an increase in V_j in tomato seedlings grown in perlite-containing medium indicates damage to the PS II electron transfer pathway, and electron transfer blocked in PS II leads to increased Q_A accumulation (Henmi et al., 2004). Also, in these treatments, the increase in F_0 was associated with the chlorophyll reduction, decreasing the energy absorbed in each reaction center. Because blocked electron transfer is associated with an increase in Vj, it is also shown to decrease ψo, which means more energy to reduce high QA- accumulation (Zhang et al., 2018). A decrease in φEo indicates a reduction in the energy used to transfer electrons. The quantum φDo scattering is closely related to the consumption of active electrons and in the present study, reductions in φPo, φEo and ψo in pearlite treatments indicate continuous decrease in photosystem II transmission capacity, which is consistent with another finding of the study (Van Heerden et al., 2003).

Stress-sensitive indicators of photosystem II (Fv and Fm) are sensitive to stress. With this in mind, the performance of the PIabs and Pics indices, which have three independent parameters of light energy absorption, capture and electron transfer, may be ideal for reflecting the mechanism of plant photosynthesis (Strasser et al., 2004). Reduction of PIabs under culture medium containing perlite could indicate damage to the photosynthetic apparatus, reduced optical energy conversion efficiency, and limitations in normal photosynthesis. Also in these substrates, an increase in ABS/RC, TRo/RC and TRo/CSo can indicate an increase in light energy absorption. Increased DIO / RC can also indicate the activation of the reaction center defense mechanism, which distributes excess energy to reduce its damage to the plant. Increasing DIo / CSo, like DIo / RC, indicates that tomato seedlings can reduce damage by actively dispersing excess energy. Therefore, selecting a suitable culture medium such as pure cocopeat for growing tomato seedlings can improve photosynthetic yield and thus increase the yield of these plants.

5. CONCLUSION

In general, it can be concluded that one of the important factors in growing tomato seedlings is the type of culture medium and CP and NP or their combination can be a good option. These substrates improved important functional traits as well as physiological and photosynthetic parameters in these plant. Therefore, CP, NP or their combinations are suitable for commercial producers of these seedlings.

Authors' Contribution Statement

Farnoush Rostami conducted the experimental section of research and writing the draft. Ali Mohammadi Torkashvand and Sepideh Kalate Jari revised the manuscript and done the data analysis. Pejman Moradi done the validation of data and assisted in data analysis and Reza Salehi has done project management, proofreading and data analysis.

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Conflict of Interest

Please check the following as appropriate:

- ☑ All authors have participated in
  - (a) Conception and design, or analysis and interpretation of the data;
  - (b) Drafting the article or revising it critically for important intellectual content; and
  - (c) Approval of the final version.
- ☑ This manuscript has not been submitted to, nor is under review at, another journal or other publishing venue.
- ☑ The authors have no affiliation with any organization with a direct or indirect financial interest in the subject matter discussed in the manuscript
- ☑ The following authors have affiliations with organizations with direct or indirect financial interest in the subject matter discussed in the manuscript:

Data Availability: All data generated or analysed during this study are included in this published article.

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