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Evaluation of organic potting media enriched with *Trichoderma* spp. and their effect on growth performance of selected vegetables

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Abstract

Organic potting medium is an important source for growing of vegetable and ornamental plants. Use of *Trichoderma* spp. as bio control agents as well as growth promoters in agricultural systems has been identified as an effective methodology to minimize the use of agrochemicals. Present investigation was carried out to formulate a low cost organic potting medium enriched with *Trichoderma* spp. which can effectively control soil borne diseases and enhance the growth of selected vegetables i. e, *Abelmoschus esculentus* and *Amaranthus viridis*. *T. virens, T. harzianum* and *T. asperullum* were selected and mass produced separately, using sawdust as the carrier material. Three different potting media (coir dust+ invasive plants (2:3); T-1, rice husk + invasive plants (2:3); T-2 and coir dust + rice husk + invasive plants (1:1:3); T-3) were prepared. All the potting media were divided into two parts and one set was treated with *Trichoderma* spp. while the other set was used as controls, without adding *Trichoderma*. Physical and chemical properties of the four potting media were analyzed following standard methods. Effect of *Trichoderma* amended potting media on plant growth was evaluated using *A. esculentus* and *A. viridis* by measuring several growth parameters and disease incidence under greenhouse conditions. Of the four potting media, T-1 exhibited optimum physical and chemical properties. The highest growth performance of *A. esculentus* and *A. viridis* observed in plants treated T-1 medium with *Trichoderma* amendments with lower ($p<0.05$) disease incidence (5 %). *A. esculentus* and *A. viridis* planted without *Trichoderma* treatment in T-2 showed significantly lower ($p<0.05$) growth than T-1 and T-3 media. Based on the findings, T-1 medium with *Trichoderma* amendments could be recommended for growing vegetables which are suitable for urban agriculture and home gardening due to its cost effectiveness and environment friendly nature.

Keywords: Organic, potting medium, *Trichoderma*, vegetables

Introduction

A potting medium can be defined as a substance through which plant roots grow and extract water and nutrients (Massey *et al.,* 2011). Selecting a good potting medium is fundamental for good nursery management, home gardening and is the foundation of a healthy root system. Soilless potting media have been used for greenhouse production of bedding plants, vegetable transplants and container-grown ornamentals (Aklibasinda *et al.,* 2011). In the last few years, farmers and nursery workers have shown their interest on potting media, since they play an important role in plant production (Kashihara *et al.,* 2011). Soilless mixtures should be formulated with special attention on optimal physical, chemical and biological properties that promote germination and healthy seedling growth.

Topsoil is relatively heavy and dense, so it can contribute to poor aeration and drainage in a potting medium. In soilless medium, replaces the soil because the field soil is often poorly suited to cultivation due to unfavorable chemical (reaction, nutrient availability), physical (density, structure, water retention) and biological (presence of pathogens, exhaustion) limitations (Peter-Onoh *et al.*2015). The increase in utilization of available land for physical and infrastructural development, rapidly declines the supply of quality top soil. Therefore promoting the utilization of soilless materials in the production of horticultural crops is useful (Awang *et al.,* 2009).

An ideal media must be free of pests heavy enough to prevent the pot from tipping over, but light enough to allow ease of transport. The mix should retain sufficient water to reduce the need for frequent watering, but have enough porosity to allow for good drainage and to provide air for plant roots (Tsakaldimi and Ganatsas, 2016). The ideal amount of potting media would be the amount that adds the desired plant nutrients. A good potting medium will contain a mixture of ingredients with different particle sizes and characteristics which will balance out the aeration and water retention (Kuslu *et al.,* 2010).

Once the functions and characteristics of potting media ingredients are agreed an effective and inexpensive potting medium can be developed. Common organic ingredients include compost, coconut coir, peat moss, bark, rice hulls, sawdust and any other appropriate locally available material. These materials should be lightweight, have high water holding capacity, CEC and contain minor amounts of mineral nutrients. It reduces the use of expensive potting or bedding media like peat and vermiculate perlite. Coir dust, which has a high water holding capacity, is a by-product of coconut fiber milling industry (Awang *et al.,* 2009). Being one of the most commonly used agricultural by-products as a growing medium especially in tropical countries for bedding plant production, it is also widely used in foliage pot plants (Kularathne *et al.,* 2005). Among the green manure, invasive plants have been reported to contain considerable amounts of nutrients and some are problematic to the ecosystems (Weerakoon, 2008). *Tithonia diversifolia* with its high nutrient status is a potential soil improver to enhance the productivity and is recommended for use as a green manure or as a major component of compost manure (Olabode*et al*., 2007). Formulating an organic production would facilitate removing in a sustainable manner and could be used as a solution in the management of invasive plants and agricultural by-product.

Soil-borne diseases are the major limitation to crop production, particularly for ornamentals and vegetables. These diseases are caused by wide range of plant pathogens including bacteria, fungi and parasitic nematodes. Different soil-borne bacteria and fungi are able to colonize plant roots and have beneficial effects on plant growth. *Trichoderma* spp. is a well-known bio control agent which can be used to enhance the growth response of plants. *Trichoderma* sp. can reduce the severity of plant diseases by inhibiting plant pathogens in the soil through their potential antagonistic activities. Moreover, as revealed by research in recent decades, some *Trichoderma* strains can interact directly with roots increasing plant growth pretension, making them resistant to diseases and tolerant to abiotic stresses (Hermosa *et al.,* 2012). *Trichoderma* spp. control deleterious root microorganisms which are causing obvious diseases and they involve in direct production of growth stimulating factors such as plant hormones and growth factors. They increase the nutrient uptake through enhanced root growth or by promoting the availability of necessary nutrients. They help to reduce the concentrations of inhibitory substances of plant growth in soil. According to Altomare *et al.* (1999). *T. harzianum* strain 1295-22 increased the plant vigor part from the growth enhancement. Therefore it shows that it not only enhances the growth of plants but they increase the vigor of the plants.

Numerous studies show, *Trichoderma* fortified compost with different substrates were evaluated to reduce the pre-emergence and post-emergence seedling mortality, diseases of stem and root caused by several soil-borne fungal pathogens, including *Fusarium oxysporum, Rhizoctonia solani* and *Sclerotium rolfsii* at different growth stages in the field under natural epiphytotic conditions (Howell, 2013). In field experiment, subsequently it was used for inoculum preparation with colonized wheat grain and mixed with well-matured decomposed composting materials of saw dust, cow dung, tea waste, water hyacinth and poultry manure. Interestingly, all the treatments significantly increased but *Trichoderma* fortified compost with poultry manure was the best to boost seed yield and quality (Heydari and Pessarakli, 2010).

Potting media enriched with microbial active organic amendments have been reported to benefit the crops which results in improvement of physical, chemical and biological properties of the potting mix (Pal *et al.,* 2015, Espiritu, 2011). As mentioned by Kumar *et al.* (2012) many species of *Trichoderma* have multiple strategies for fungal antagonism and indirectly effects on plant health such as plant growth promotion and fertility improvements. As most of the *Trichoderma* spp. are strong opportunistic invaders, fast growing, prolific producers of spores and powerful antibiotic producers, they are important in designing effective and safe bio-control strategies.

Most of the multifaceted environmental and health issues associated with the heavy use of synthetic fertilizers and agrochemicals could be resolved by the adoption of organic agricultural practices with the objective of promoting and expansion of organic agriculture industry in Sri Lanka. Hence this research aims to formulate low-cost organic potting media using selected problematic invasive plants together with agricultural wastes enriched with *Trichoderma* amendment and evaluate measuring physico-chemical properties and pot experiment.

Materials and methods

Selection of *Trichoderma* spp.

Selected three *Trichoderma* spp. have been identified to the species level by the Genetech institute at Colombo, Sri Lanka in the previous studies and recognized as *T. asperellum, T. harzianum* and *T. virens.* Identified three *Trichoderma* spp. were obtained from culture collection in Department of Botany University of Kelaniya. They were re-inoculated into new PDA and incubated at room temperature (28 ^{o}C) for 7 days separately.

Mass production of *Trichoderma* spp.

Mass production of selected *Trichoderma* spp. were done on sawdust as carrier materials. Two kilograms of sawdust was sieved using a 3 mm mesh and 2.5 g of dry poultry manure and 2.5 g of sugar was added. The moisture level of the medium was adjusted to 40% by adding distilled water and mixed well. The prepared media were put in polypropylene autoclave bags

(15 x 20 cm), and all media were autoclaved at 121 ^{o}C (15 psi) for 25 minutes. Tetracycline was added at 500 mg per 250 g of media to inhibit bacterial growth. Afterward, each *Trichoderma* spp. grown on PDA mat (2×2 cm) was inoculated separately into carrier media under sterile conditions and incubated at room temperature (28^{o}C) for 20 days. Ten replicates were prepared for each *Trichoderma* mass culturing.

Preparation of potting media

Experiment was conducted at the Horticultural Research and Development Institute (HORDI) in Gannoruwa. Field with proper drainage was selected to prepare piles (2 m length and 1m width). Three different potting media (coir dust + invasive plants (2:3); T-1, rice husk + invasive plants (2:3); T-2 and coir dust + rice husk + invasive plants (1:1:3); T-3) were prepared. Next, all the potting media were separated into two parts and one set was treated with *Trichoderma* spp. while the other set was used as controls, without adding *Trichoderma* (Table 1).

Turning of the potting media piles

All the potting media were turned thoroughly at three week intervals by adding sufficient amount of water to keep the pile moist content at 40%. First turning was done 21 days after preparing the potting media. Temperature was measured at every turning stage of potting media preparation. After 90 days, decomposed different potting media were successfully prepared. Mass produced with *Trichoderma* spp. inoculum bags (250 g ×2) were incorporated with 100 Kg of selected organic potting media (T-1E, T.-2E, and T-3E) and covered with black polythene for 14 days to colonization.

Determination of physical and chemical properties of the potting media

Water content, bulk density, porosity and water holding capacity were measured as physical properties. Electrical conductivity (EC), pH, organic carbon, C/N ratio and essential macro and micro nutrients contents of each potting medium was determined as chemical properties, using standard analytical methods with relevant controls.

Determination of nutrients contents in potting media

Nutrients contents of prepared potting media were analyzed at the Horticultural Research and Development Institute (HORDI) in Gannoruwa and at CIC Soil, Plant and Water Analytical Laboratory in Dambulla.

Table 1: Composition of six different potting media

Potting media	Composition
T-1E	Coir dust + *P. maximum* + *T. diversifolia* + *M. scandens* + *Trichoderma* amendments (2:1:1:1)
T-1C	Coir dust + *P. maximum* +*T. diversifolia*+ *M. scandens* (2:1:1:1)
T-2E	Rice husk + *P. maximum* + *T. diversifolia* + *M. scandens* + *Trichoderma* amendments (2:1:1:1)
T-2C	Rice husk + *P. maximum* + *T. diversifolia*+ *M. scandens* (2:1:1:1)
T-3E	Coir dust + Rice husk + *P. maximum* + *T. diversifolia* + *M. scandens* + *Trichoderma* amendments (1:1:1:1:1)
T-3C	Coir dust + Rice husk + *P. maximum* + *T .diversifolia* + *M. scandens* (1:1:1:1:1)

Organic carbon contents were determined by Walkley- Black method (Walkley and Black 1934). The total nitrogen (N) and phosphorus (P) contents were determined by Kjeldahl (Kjeldahl 1883) and Vanado-molybdate method (Bernhart and Wreath 1955) respectively. Potassium contents was determined by Atomic Absorption Spectrophotometry (AAS).

Evaluation of different potting media on the growth of selected crops (pot experiment)

Abelmoschus esculentus var. "Haritha" and *Amaranthus viridis* var. "Green" were used for the pot experiment. Prepared potting media (2 Kg) were filled in to same sized pots (20×25 cm) with drainage holes and selected crop seeds were established separately. The experiment was carried out in Completely Randomized Design (CRD) and each treatment consisting of selected two crops with five replicates. All the treatments were watered every two days and other fertilizers were not used within the duration of the experiment. After 45 days of seeding, the growth parameters; plant height, number of flowers per plant, leaf area, fresh weight and disease incidence (%) were measured.

Statistical analysis

Data obtained were analyzed statistically with the MINITAB 16 Version using one-way analysis of variance (ANOVA, $p<0.05$) followed by Tukey's pair-wise multiple comparison test to identify the means of different treatments that are significantly different.

Results and discussion

Physical properties of organic potting media

The results of the present study indicate that the T-1E and T-C1 have optimum physical properties (water content, bulk density, porosity and water saturation capacity) than the other potting media. The statistical analysis of the results using one way ANOVA proved that there is a significant difference ($p<0.05$) between water content of T-1and T-2 media. The lowest bulk density (0.42 g/cm^3) was observed in T-2E potting medium that was significantly different from T-3E medium. The highest porosity (62.77%) was obtained in potting medium T-2E which was significantly different from T-1E medium. The highest water saturation capacity (52.04%) was observed in T-1E medium and it was also significantly different from T-2E medium (34.89%) and T-2C medium (28.35%) (Table 2).

Table 2: Physical properties of different potting media

Potting media	Physical properties			
	Water content (%)	**Bulk density (g/cm^3)**	**Porosity (%)**	**Water saturation capacity (%)**
T-1E	65.47±1.25^a	1.04±0.05^a	52.25±1.75^a	52.04±4.78^a
T-1C	59.48±2.34^a	1.21±0.06^a	48.30±2.20^a	47.48±4.40^a
T-2E	39.08±1.86^b	0.42±0.03^b	62.77±3.56^{ab}	34.89±2.45^b
T-2C	37.28±3.05^b	0.50±0.03^b	58.65±4.78^{ab}	28.35±2.58^b
T-3E	52.45±2.68^{ab}	0.76±0.04^{ab}	36.48±3.08^b	54.46±3.42^{ab}
T-3C	49.20±4.35^{ab}	0.84±0.03^{ab}	41.90±3.55^{ab}	44.62±4.10^{ab}

Each data point represents the mean of five replicates ± standard error. Values within a column followed by same letter are not significantly different at ($p\leq0.05$)

Bulk density of different potting media was significantly different ($p<0.05$). Incorporation of coir dust (T-1C) increased the bulk density of the media (1.21 g cm^{-3}) and the value is significantly different from T-2E which comprised of rice husk. Result obtained in the current study is inconsistent with the observations of Sharkawi *et al*, (2014). They reported that the bulk density of loose rice husk charcoal was significantly lower than the bulk density of coir dust. Low bulk density media may be required for frequently irrigated greenhouse to avoid oxygen deficiency. Mixing and transportation of low bulk density media are much easier than those of high bulk density. However, media with a low bulk density may not provide adequate support for the plant and the plant may be too heavy. In this respect plants grown in media containing coir dust would be more stable.

Aeration depends mainly on the size of pores in a medium. Irrigating media to the point of saturation fills the total pore space with water. As the media drains by the force of gravity, smaller pores remain filled with water while larger pores get emptied and filled with air. However, materials with small particles such as coir dust tend to fill up the pores, thus lowering the porosity. The importance of physical properties of media as the factor in determining plant development in soilless media has been assessed by Awang (2009).

Differences in results obtained here is most likely due to the variation in particle sizes of the carrier material (coir dust and rice husk). Variability in physical properties of soilless media is common. A good potting medium will contain a mixture of ingredients with different particle sizes and characteristics, which will provide sufficient aeration and water retention. Results indicated that addition of coir containing potting media showed acceptable levels of physical properties which are suitable to plant growth and development.

Some physical and chemical properties of the potting media related to the ability to adequately store and supply air, water and nutrients to the plants were measured, which are important parameters for successful plant growth. The optimum physical properties were observed in T-1E and T-1C potting media which were formulated using coir dust. Water content, bulk density, porosity and water holding capacity were ideal for plant growth and development. Higher water content and water holding capacity were observed in T.E-1 and T.C-1 potting media containing high proportion of coir dust. Coir dust has a high water saturation capacity due to micropores. Low water content and water holding capacity were observed in rice husk containing potting media (T-2E and T-2C) due to higher amount of macropores compared to the micropores. Water-saturation capacity varies by the types and sizes of the potting medium ingredients. Coconut coir has many desirable qualities: high water-holding capacity, excellent drainage, absence of weeds and pathogens, slow decomposition, easy wettability, acceptable levels of pH, CEC, and electrical conductivity. Coir is very similar to peat in appearance and structure, like peat physical and chemical properties of coir can vary widely from source to source. Coir is low in nitrogen, calcium, and magnesium but can be relatively high in phosphorus and potassium (Fernando and Amarasinghe, 2017).

Chemical properties of prepared potting media

The chemical properties of the prepared potting media were shown in table 03.There were no significant differences in pH, electrical conductivity (EC) and nitrogen content (%) between different potting media ($p> 0.05$). The highest EC (1.50 ds/m) and nitrogen content (149%) were observed in T-2C and T-1E media respectively.

The highest amount of organic carbon content was observed in T-1E medium (17.22%) and the lowest organic carbon content was observed in T-2C (8.52%) medium. Organic carbon contents of T-1E, and T-1C media was significantly different from T-2E and T-2C potting media. The highest phosphorus content (0.53%) and potassium content (1.48%) were observed in the T-1E potting medium which was significantly different from T-2E and T-2C. The highest C/N ratio (15.8) was obtained for T-1E potting medium which was significantly different from T-2E and T-2C potting media according to one way ANOVA (P<0.05) (Table 3).

The initial pH and EC of the media are two important properties of potting media as they indicate the inherent nutrient status in the media and influence its availability. Variations in composition of the media markedly affected the initial pH and EC values of the media. Although different plant species (and cultivars) prefer different soil pH for optimal growth, overall the optimum pH of the soilless media for good availability and uptake of nutrients is around 6.0. It was also observed, that media combinations having low electrical conductivity (EC) displayed higher plant growth and development. High levels of electric conductivity showed poor plant growth. Peter-Onoh *et al*. (2015) recommended ideal EC values for media used for container grown plants should range between 0.63 to 1.56 dSm^{-1} and EC values higher than 3.5 dSm^{-1} can have adverse effects on seedling growth. Low EC value indicates insufficient amount of nutrients to support healthy plant growth. Higher EC in burnt rice hull is an indication of relatively high concentration of soluble salts, which could be beneficial for plant growth. The acceptable range of initial EC of a good soilless medium should be between 0.4-1.5 dSm^{-1}.

Nitrogen is a vital plant nutrient and it is apparent from results that media combinations differed from one another with regards to the total nitrogen content. Differences in the nitrogen contents might be due to variation in organic matter contents in the different components of potting media. Total N, P, K in T.E-1 and T.C-1 were higher than other potting media. The related literature suggested that the optimum C/N ratio for container substrate generally considered to be around 25:1 to 15:1 (Clark and Cavigelli, 2005). In this study, C/N ratio of only T-1E and T-1C potting media were in recommended range while others showed comparatively low C/N ratios. Different combinations of media did not give significant effects on leaf nutrient contents. The compositions of nutrients recorded in this study were in the normal range found in different potting media.

Table 3: Chemical properties of different potting media

Potting media	Chemical properties						
	pH	EC ds/m	Organic carbon %	Total			C/N Ratio
				N%	P %	K%	
T-1E	6.82±0.8[a]	0.89±0.3[a]	17.25±1.8[a]	1.49±0.08 [a]	0.53±0.06 [a]	1.48±0.08[a]	15.8±1.9 [a]
T-1C	6.15±0.7[a]	0.93±0.3[a]	15.46±1.5[a]	1.38±0.06 [a]	0.41±0.05 [a]	1.04±0.06[a]	14.3±1.3 [a]
T-2E	7.43±1.2[a]	1.04±0.4[a]	9.36±0.8[b]	0.98±0.05 [a]	0.26±0.02[b]	0.81±0.03[b]	8.4±1.1[b]
T-2C	7.77±1.3[a]	1.50±0.5[a]	8.52±0.9[b]	0.78±0.05 [a]	0.10±0.02[b]	0.74±0.0[b]	9.7±0.8[b]
T-3E	6.92±0.9[a]	0.73±0.2[a]	10.90±1.3[ab]	1.08±0.07 [a]	0.38±0.01[ab]	1.13±0.06[ab]	10.1±0.7[ab]
T-3C	7.73±1.2[a]	0.78±0.2[a]	9.69±0.8[ab]	0.85±0.05 [a]	0.29±0.01[ab]	1.04±0.08[ab]	11.4±1.2[ab]

Each data point represents the mean of five replicates ± standard error. Values within a column followed by same letter are not significantly different at ($p \leq 0.05$)

(b)

Effect of different potting media on the growth of selected crops

Evaluation of efficacy of the different potting media on *A. esculentus* var. "Haritha"

According to the results obtained, the highest average plant shoot height (67.3 cm), number of flowers per plant (14) and fresh weight (48.2 g) were observed in the T-1E potting medium and there was no significant difference with T-1C medium ($p>0.05$). However, the T-1C potting medium also showed comparatively higher growth parameters (Table 02). There were no significant difference among the other four potting media (T-2E, T-2C, T-3E and T-3C) that observed lower growth parameters and they were significantly different from T-1E and T-1E potting media ($p<0.05$). The lowest average plant height (25.2 cm) and number of flowers per plant (03) were observed in T-2C medium. The lowest fresh weight (18.7 g) was observed in T -2C potting medium as control. *A. esculentus* treated with *Trichoderma* amended potting media showed a significantly lower ($p\leq0.05$) disease incidence compared with untreated potting media (Table 4).

Evaluation of efficacy of the different potting media on the growth of *A. viridis* var. "Green"

Growth of *A. viridis* var. "Green" in T-1E and T-1C potting media were significantly higher than that with the other different potting media (T-2E, T-2E, T-3E and T-3C). According to Turkey's pair wise comparison with 95% confidence interval, the values obtained for T-1E and T-1C were not significantly different. Plant height, leaf area and fresh weight of *A. viridis* in T-2E, T-2E, T-3E and T-3Cwere significantly lower than T.C-1 and T.E-1 media. The highest shoot height (51.5 cm), leaf area (34.8 cm^2) and fresh weight (38.5 g) were obtained with the application of *Trichoderma* amended (T-1E) potting medium, However, the potting medium without *Trichoderma* amendments (T-1C) showed approximately similar growth parameters. The least plant shoot height (27.8 cm) and leaf area (22.3 cm^2) were observed for the control (T-2C) potting medium. Among the potting media, the lowest fresh weight (22.3 g), was observed without *Trichoderma* amended potting medium (T-3C). *A. viridis* grown in *Trichoderma* amended T-1E medium showed a significantly lower ($p\leq$ 0.05) disease incidence (05%) compared with untreated controls (T-1C, T-2C and T-3C).

Table 4: Effect of potting media on growth performances and disease incidence of *A. esculentus*

Potting media	Growth parameters			
	Plant height (cm)	**Numbers of flowers/ plant**	**Fresh weight (g)**	**Disease incidence (%)**
T-1E	67.3 ± 2.5^a	14 ± 1.3^a	48.2 ± 2.3^a	10 ± 2.8^a
T-1C	62.4 ± 2.3^a	10 ± 1.0^a	45.6 ± 2.1^a	35 ± 3.5^b
T-2E	28.6 ± 1.7^b	05 ± 0.8^b	20.5 ± 1.6^b	20 ± 2.8^a
T-2C	25.2 ± 1.6^b	03 ± 0.7^b	18.7 ± 1.4^b	40 ± 3.7^b
T-3E	34.5 ± 1.8^b	06 ± 0.8^b	21.3 ± 1.5^b	15 ± 2.1^a
T-3C	31.7 ± 1.8^b	04 ± 0.5^b	18.6 ± 1.4^b	35 ± 3.2^b

Each data point represents the mean of five replicates ± standard error. Values followed by different letters in each column are significantly different at $p \leq 0.05$

Table 5: Effect of potting media on growth performances and disease incidence of *A. viridis*

Potting media	Growth parameters			
	Plant height (cm)	**Leaf area (cm^2)**	**Fresh weight (g)**	**Disease incidence (%)**
T-1E	51.5±2.8^a	34.8±2.5^a	38.5±2.9^a	05±0.8^a
T-1C	48.6±2.6^a	30.5±1.8^a	35.8±2.6^a	40±4.3^b
T-2E	30.3±2.0^b	24.8±1.7^b	22.6±2.0^b	05±0.8^a
T-2C	27.8±1.8^b	22.3±1.3^b	20.4±1.9^b	38±3.6^b
T-3E	31.5±2.1^b	24.7±1.6^b	23.7±1.7^b	05±0.7^a
T-3C	29.2±1.9^b	23.6±1.5^b	22.3±1.7^b	30±3.1^b

Each data point represents the mean of five replicates ± standard error. Values followed by different letters in each column are significantly different at $p \leq 0.05$

According to the results and observations of the pot experiment, it was clear that coir dust media with two different treatments (T-1Eand T-1C) had showed significant effect on plant height, number flowers, leaf area, plant fresh weight and disease incidence of *A. esculentus, and A. viridis*. Numerous studies have addressed the use of coir dust in organic media in nursery plant production, and have analyzed the chemical, physical and biological properties the increased plant growth and supplied soluble salts (Dumroese *et al*., 2011; Awang *et al.*, 2009). Formulation of potting media with coir dust media directly affect the physical properties such as porosity, aeration, water saturation capacity and water content. Those characters influence growth and development of selected crops, by enhancing water and nutrient, supply and absorption.

In rice husk treated potting media, less plant development (plant height, number flowers, leaf area and plant fresh weight) was observed, probably due to lack of water content, water saturation capacity and organic carbon content. In addition to that, nutrients leachate was observed in rice husk containing media due to their high percentage of porosity (T-2E; 62.7%; T-2C, 58.6%) and low water saturation capacity (T-2E; 34. 8%; T-2C, 28.3%).

Trichoderma spp. mass produced with inoculum bags (250 g ×2) were incorporated with 100 Kg of selected organic potting media. According to Kumar *et al.* (2014) Colony Forming Units (CFU) of *Trichoderma* should be at a minimum number of 2 x 10^6 CFU per ml or gram, in selective medium of *Trichoderma* formulations as highly effective. In the present study, number of CFU of *Trichoderma* in selected carrier materials were maintained10^7 CFU/g level before incorporated in to potting media.

In the present study, there was a no significant difference ($p>0.05$) in all growth parameters for T-1E and T-1C potting media. However, T-1E and T-1C potting media had more or similar growth performances. T-1E potting medium was prepared from coir dust, *P. maximum, T. diversifolia* and *M. scandans* volume ratio of 2:1:1:1 and *Trichoderma* amendments. Therefore, higher growth and development with diseases free plants were performed by *Trichoderma* amended in T-1E potting medium. In addition, *Trichoderma* treated potting media plants did not show any elemental deficiency or toxicity symptoms (diseases free) and appeared to be high vigor plants (Barari*et al.*, 2016).

Similar results were reported on plant growth of cereals and legume crops after application of *Trichoderma gamsii.* The increase of plant growth might be associated with the secretion of auxins, gibberellins and cytokinins by *Trichoderma* (Jamali *et al.*, 2016). The effectiveness of inoculation of tomato plants treated with *Trichoderma viride,* antagonists is evident as they resulted in reduction of diseases and increased the yield as reported by Barari *et al.* (2016).

T. asperellum is one of the most effective bio-control agents which can be used to increase the growth of the plant. They produce phosphatases and phytase and activities of those enzymes involve in phosphate solubilization and they enhanced the growth response of several plants such as bean, cucumber, maize and tomato (Harman, 2000). It is due to the ability of producing secondary metabolites such as harzianolide, anthraquinoues, T 39 butenolide. They also produce IAA, gibberellic acid (GA) and abscisic acid (ABA), which are involved in plant growth regulation. Altomare *et al.,* (1999) mentioned that *T. harzianum* strain 1295-22 have the ability to improve nitrogen use efficiency in maize. It may be due to the solubilizing ability of *Trichoderma*spp. *Trichoderma* spp. can solubilize a number of poorly soluble nutrients such as Mn^{+}, Fe^{3+} and Cu^{2+}.

In *Ceratonia siliqua* significant increase of plant growth treated with *T. harzianum* was observed in terms of plant height, root extension and leaf area in *Trichoderma* treatments compared to non-treated potting media. The enhanced growth response of several plants following application of *Trichoderma*spp. has also been well documented (Sriram and Savitha,2015). The compounds produced by the BCA in the fungal culture filtrates contained various secondary metabolites, like peptaibols, which may also act as elicitors of plant defense mechanisms against pathogens (Sriram and Savitha, 2015).

Many secondary metabolites produced by *Trichoderma* have antibiotic activity and have been demonstrated to play a role in biological control against various phyto-pathogens (Veeken, *et al*., 2005). They have found that some *Trichoderma* compounds, such as 6-pentyl-α-pyrone (6PP) act as effectors on plant growth, possibly by acting as an auxin like manner or by stimulating the hormone production in the plant, thus enhancing growth of the root system and plant size.

Trichoderma isolates have important economic implications on plant development such as shortening of the plant growth period, as well as improving plant vigor to overcome biotic and or abiotic stresses, resulting in increased plant productivity and yields. Present investigation revealed that *Trichoderma* treated plants produce longer roots and higher shoots and an improved plant vigor. These results are in accordance with those of Kowalska *et al.* (2014). The aerial part of the plants presented significantly enhanced growth characteristics, mainly in plants treated with *Trichoderma* fungi, in comparison with non-treated (control) plants. Plants treated with *Trichoderma* suspension followed by infecting with pathogen *A. alternata,* showed a higher growth compared with the plants from the control *A. alternate* alone and the others without infection respectively.

Mastouri*et al.* (2010) reported that when plants are under stress, the content of reactive oxygen species may increase to toxic concentrations. The *Trichoderma* treatments enhance the activity of these pathways, in part by enhancing the expression of genes encoding the component enzymes. Several mechanisms have been suggested to explain the phenomenon of increased plant growth including: control of deleterious root microorganisms, those were not causing obvious diseases, direct production of growth stimulating factors (plant hormones or growth-factors), increased nutrients uptake through enhanced root growth or promoted availability of necessary nutrients, and reduction of the concentration of substances in soil that are inhibitory of plant growth (Altomare *et al.*, 1999). Above findings were proven to enhance the growth performance of vegetable plants which are healthy and good vigor.

Conclusion

Trichoderma amendments improved the physical, chemical and biological properties of the selected potting media. Present study demonstrated the growth enhancing potentials of *Trichoderma* amendments with coir dust organic potting medium on the growth of *A. esculentus* and *A. viridis*.

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