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Supplementing organic biostimulants into growing media enhances growth and nutrient uptake of tomato transplants

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ABSTRACT

Addition of plant growth biostimulants may have great impact on physical characteristics of growing media and plant growth. The present study evaluated response of tomato (*Lycopersicon esculentum*, Mill.) transplants for growth, some physiological attributes and nutrient uptake to three different growing media containing peat (P) and vermiculite (Verm) supplemented with crushed maize grain (CMG) and/or humic acid (HA) for two growing seasons. Results showed that none of the media used affected seedling emergence and survival percentage, however, maximum increase in stem diameter and root system volume was observed when media supplemented with CMG and/or HA. Similar response was observed for transplant height, number of leaves and total leaf area per transplant, leaf and root dry weight and total dry weight per transplant. Maximum relative water contents (RWC) and membrane stability index (MSI) with reduced electrolyte leakage was found for HA + CMG supplemented media followed by HA free media but with CMG. Highest increase in N, P and K transfer ratios was also found in tomato transplants grown with HA + CMG, albeit N transfer ratio was statistically similar for CMG added with or without HA. In crux, supplementing HA together with CMG as plant biostimulant rich in minerals, hormones and secondary metabolites into standard growing media had stimulatory effects on tomato transplants, therefore, can be used as organic component for sustainable production of horticultural transplants.

1. Introduction

Rapid increase in use of growing media is of great concern for sustainability of horticultural industry. Among different substrates, peat moss, vermiculite and perlite are commonly used in greenhouses or nurseries growing media in under- and developed countries (Osman and Rady, 2014). Selection of appropriate growing substrate depends on the characteristics for which it determine the growth and survival rate of transplanted propagate (Bhat et al., 2013). For instance, peat moss is most common and primary component of vegetable transplant media due to high water holding capacity, low density and acidity. Likely, vermiculite with high cation exchange capacity (CEC), high water holding capacity and variable pH is important component of various media used for propagation in horticultural industry (Robbins and Evans, 2004).

Nonetheless, extensive use of each growing medium is restricted upon variable composition of salts present, water retention and nutrient release rate considered critical in production success (Bhat et al., 2013). Robbins and Evans (2004) reported that fine grade vermiculate is used for seed germination or to top-dress seed flats and its compaction upon wetting reduces water-holding capacity, drainage, aeration, the rate of water infiltration, and root penetration. Using natural bio-stimulating substances in production of greenhouse or nursery plants as growing medium can overcome the problem. For instance, supplementing humic acid (HA; 0.5 g L^{-1}) to growing media containing vermiculate and perlite in different ratio (50 or 35% v/v) improved the plant growth, tissue water status, membrane stability and nutrient transfer rate in tomato and eggplant transplants. Addition of HA, in fact, affects physical properties of the medium and enhanced root respiration, nutrient and water uptake, and hormone like substances such as auxin or cytokinin present in HA contribute to improve root and shoot growth. These effects on growth of transplants can't be observed in HA free media (Nardi et al., 2002; Zhang et al., 2004; Rady and Osman, 2011).

Together with HA, many researchers recently used some natural biostimulants such as the extracts of propolis (PE; a by-product of

Abbreviations: CMG, crushed maize grain; HA, humic acid; PE, propolis; MGE, maize grain extract; FM, fresh mass.

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honeybee), *Moringa oleifera* leaves or seeds, dry beans and maize grains. These extracts were used as seed soaking and/or foliar spray to increase plant growth and productivity under normal or stress conditions (Abd El-Hady and Hegazi, 2002; Abd El-Naem et al., 2007; Semida and Rady, 2014; Yasmeen et al., 2014; Osman and Rady, 2014; Rehman et al., 2015). These biostiumlants contain necessary phytohormones, antioxidants and plant secondary compounds, macro- and micro-elements; thereby affect physiological processes to improve plant growth and yield under biotic and abiotic conditions (Rady et al., 2013; Osman and Rady, 2014; Semida and Rady, 2014). Semida and Rady (2014) observed that pre-soaking common bean seed with PE and maize grain extract (MGE) increased salinity resistance by activation of antioxidant system, reducing lipid peroxidation and electrolyte leakage. Yasmeen et al. (2014) compared the response of foliar applied natural and synthetic cytokinin source on tomato growth and productivity and found that foliage applied moringa leaf extract (MLE) diluted to 30 times improve the number of vegetative and reproductive branches, number of flowers and produced heavier fruits than benzyl amino purine (BAP). Improved response to foliar applied moringa leaf extract was attributed to enhanced chlorophyll contents, total soluble proteins and antioxidants, totoal phenolics in leaves and fruit lycopene contents.

The above studies report the use of MLE, MGE or HA as seed pre-soaking, applied to foliage or supplements as natural biostimulants to improve plant growth and development and their physiological or biochemical basis (Semida and Rady, 2014; Yasmeen et al., 2014; Osman and Rady, 2012, 2014). However, the potential of these natural biostimulants in growing media in addition to peat moss and vermiculate have rarely been reported. The present study therefore was designed to evaluate the effect of different growing media containing peat moss and crushed maize grain as organic and vermiculite as inorganic component in different combinations supplemented with or without HA on performance of tomato transplants. In addition, seedling establishment and growth, plant water status, membrane stability and nutrient (N, P, K) transfer rate were used as indicators of performance of tomato transplants for two successive growing seasons under greenhouse conditions.

Table 1
Some of the chemical characteristics of the peat moss and vermiculite used in the experiments.

Parameter (units)	Peat moss	Parameter (units)	Vermiculite
N ($g\,kg^{-1}$)	11.04	SiO_2($g\,kg^{-1}$)	439.9
P ($g\,kg^{-1}$)	0.24	Al_2O_3($g\,kg^{-1}$)	129.8
K ($g\,kg^{-1}$)	0.31	Fe_2O_3($g\,kg^{-1}$)	80.1
Ca ($g\,kg^{-1}$)	2.99	CaO ($g\,kg^{-1}$)	16.8
Mg ($g\,kg^{-1}$)	0.40	MgO ($g\,kg^{-1}$)	199.7
S ($g\,kg^{-1}$)	1.20	Na_2O ($g\,kg^{-1}$)	28.8
Fe ($g\,kg^{-1}$)	2.09	K_2O ($g\,kg^{-1}$)	42.6
NH_4- ($g\,kg^{-1}$)	0.21		
NO_3- ($mg\,kg^{-1}$)	4.88		
P_2O_5($mg\,kg^{-1}$)	2.29		
K_2O ($mg\,kg^{-1}$)	58.48		
Zn ($mg\,kg^{-1}$)	3.62		
Cu ($mg\,kg^{-1}$)	2.30		
Mn ($mg\,kg^{-1}$)	12.66		
Moisture (%)	4.92		
Ash (%)	5.11		

Table 2
Some of the chemical characteristics of the crushed maize grains (CMG) used in the experiments.

Parameter (units)	CMG
Soluble sugars ($g\,kg^{-1}$)	25.43
Protein ($g\,kg^{-1}$)	98.15
Total free amino acids ($g\,kg^{-1}$)	2.46
Free proline ($g\,kg^{-1}$)	0.24
Ascorbic acid ($g\,kg^{-1}$)	0.16
N ($g\,kg^{-1}$)	15.74
P ($g\,kg^{-1}$)	1.25
K ($g\,kg^{-1}$)	12.84
Fe ($mg\,kg^{-1}$)	514.25
Mn ($mg\,kg^{-1}$)	331.92
Zn ($mg\,kg^{-1}$)	216.53
Cu ($mg\,kg^{-1}$)	98.36
Phytohormones ($\mu g\,kg^{-1}$):	
Gibberellins	0.86
Indole-3-acetic acid	0.64
Zeatin	0.97

2. Materials and methods

2.1. Source and analysis of humic acid (HA), peat moss, vermiculite and maize grains

The HA, added at $250\,mg\,l^{-1}$ to each growing medium, was procured from Alpha Chemika, Mumbai, India. Peat moss from Latvia (FAVORIT; SAB Syker Agrarberatungs-und Handels GmbH & Co., Syke, Germany), vermiculite (ECPV; El-Masryya Co., Cairo, Egypt) were analyzed according to the standard procedures recommended by Black et al. (1965). The main physico-chemical characteristics of the peat moss and vermiculite were, respectively: total porosity, 91 and 79% (v/v); bulk density, 0.07 and $0.17\,g\,m^{-3}$; air space after drainage, 15 and 7% (v/v); water-holding capacity, 690 and $290\,ml\,l^{-1}$ medium; pH, 3.2 and 8.5; electrical conductivity (EC), 0.18 and $0.06\,dS\,m^{-1}$; and C:N ratio, 46:1 and trace. The other chemical characteristics of the peat moss and vermiculite used in this study are presented in Table 1. In addition, Table 2 shows the main chemical components of crushed maize grains (CMG). These components were determined as follows: total soluble sugars were extracted and their concentration in CMG was determined according to Irigoyen et al. (1992). Protein concentration was estimated in CMG by dye binding assay (Bradford, 1976). Total free amino acids were extracted from CMG and their concentration was measured according to the method of Dubey and Rani (1989). Free proline concentration was measured in CMG using the method described by Bates et al. (1973). Ascorbic acid (AsA) concentration was determined in CMG using the 2, 6-dichloro-indophenol method (Helrich, 1990). The concentrations of macro- and micro-nutrients [i.e., nitrogen (N), phosphorus (P), potassium (K), Iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu)] were determined in CMG as follows: N concentration was determined by using micro-Kjeldahl method described in the A.O.A.C. (1995), P concentration was measured using the molybdenum-reduced molybdophosphoric blue colour method (Jackson, 1967), K concentration was measured using a Perkin-Elmer Model 52-A flame photometer (Glenbrook, Stamford, CT, USA) as described by Page et al. (1982), and Fe, Mn, Zn and Cu concentrations were determined using a Perkin-Elmer Model 3300 Atomic Absorption Spectrophotometer (Chapman and Pratt 1961). The CMG was analyzed for endogenous levels of gibberellic acid (GA_3) and indole-3-acetic acid (IAA). The extraction and purification were made following the method of Kettner and Doerffling (1995). An extraction and quantification protocol for zeatin content was conducted as described by Pan et al. (2010).

The main characteristics of the HA were: net HA content, 90.29% (w/w) on a dry weight (DW) basis; total N, 0.95% (w/w); total P, 1.04% (w/w); total K, 1.46% (w/w); total Ca, 2.81% (w/w); total Mg, 0.92% (w/w); total S, 0.48% (w/w); Fe, $615\,mg\,kg^{-1}$ DW; Mn, $348\,mg\,kg^{-1}$ DW; Zn, $301\,mg\,kg^{-1}$ DW; Cu, $112\,mg\,kg^{-1}$ DW; and Na, $210\,mg\,kg^{-1}$ DW.