Effect of Biosolids and Roots Inoculated with Bio-fertilizer on Some Physiological Parameters of Pelargonium Peltatum

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***Abstract*—The objective of this research was to study the effect of different kinds of organic compounds derived from agricultural waste and municipal solid waste with phosphate bio-fertilizer (Barvar 2) on uptake of elements (zinc, iron, manganese and cupper) and some physiological attributes of ivy geranium (*Pelargonium peltatum*). This study was carried out based on a factorial experiment with two factors of Barvar 2 at two levels (non-application and application) and different media including garden soil, sand with a variety of organic compounds on randomized complete blocks design (RCBD) in 16 treatments, 4 replications, 64 experimental plots and 256 plants. Results showed that the interactions effects of both factors were significant on all traits. Generally, the results of this study showed that the application of organic compounds with Barvar 2 increased the ability of micro-nutrient uptake by plants. The use of Barvar 2 with media containing a variety of organic compounds such as sand + tea waste compost + cocopeat + water tank soil and garden soil + sand + municipal solid waste compost + water tank soil had greater impact on those traits. The measured media characteristics of sand + tea waste compost + cocopeat + water spreading soil were in desirable and appropriate level with the standard media in the ornamental plants. In general, the use of Barvar 2 along with this substrate could be effective in providing micro-nutrients for growing of ivy geranium**.

***Index Terms*—absorbent elements, microorganism, nutrition, organic compounds, ornamental plants**

I. Introduction

Today, application of organic compounds such as compost has been so attentions in plant grow because they include abundant zinc (Zn), iron (Fe), manganese (Mn) and cupper (Cu) that these elements are essential for plants [1]. Also, the use of bio-fertilizers to reduce or eliminate the consumption of chemical resources is important to fertility and improves product quality [2]. Biological fertilizers contain microorganisms that can be used in different forms, such as inoculum on plants or soil, and by increasing the nutrients availability to host plants and fuels plant growth. These fertilizers play a key role in soil fertility and sustainability while also appropriately protecting the environment [3]. Bio-fertilizers provide the most favorable conditions for improving beneficial soil microorganisms and, through the optimal absorption of macro- and micro-element minerals by roots [4]. Phosphate-solubilizing bacteria are microorganisms capable of converting soil-insoluble phosphorus into a soluble form, making it available for plants [5]. They produce organic acids as well, which causes a release of P, Mg, Zn, Fe, and Mn in non-absorbable forms in the soil, there by affecting plant performance with the favorable uptake of macro- and micro-nutrients by the roots [6]. Geranium is a genus of 400 species that are scattered throughout temperate and humid regions of the world [7]. This plant has the third highest rank among flowering potted plants in the world market of flowers and ornamental plants [8]. Geraniums are suitable for growing in soils containing heavy metals for the disposal of these elements from soils [9]. Selection and preparation of the media and proper nutrition for growth are the success factors in the production of this plant [10]. Reports have shown that the use of bio-organic fertilizers is associated with improved soil organic matter, minerals, soil structure, and a reduction in the use of chemical inputs and plant performance [11], [12]. Considering the reduction in the consumption of chemical fertilizers to prevent environmental pollution and the effect of organic wastes as fertilizer and with regard to environmental standards, this experiment investigated the use of various organic compounds on the physicochemical properties of media and its impact with Barvar 2 on improving the qualitative properties and micro-nutrient concentrations of ivy geranium.

II. Materials and Methods

The experiment was conducted as a two-factor factorial study consisting of Barvar 2 in two levels (with and without), the 8 types of media with 16 treatments and 4 replicates of 64 experimental units with 256 plants during 2011 to 2012. Ivy geranium (*Pelargonium peltatum*) cuttings were taken and planted in a greenhouse located in Sari city, Mazandaran province, northern part of Iran with a temperature of 18-23 ℃ and 60-70% RH. Cuttings used in this experiment were prepared from the terminal portion of the plants from F_1 seed, cv. 'Red Blizzard'. Rooted cuttings were transferred into the original media two months after planting the

Manuscript received September 29, 2014; revised January 23, 2015.

doi: 10.12720/jomb.5.1.37-40

cuttings on 24 April 2012. Before planting, half of the plants were removed from their pots, and their roots were placed in a solution containing phosphorus bio-fertilizer at a concentration of 2.5 g l^{-1} of water for 20 min. Combinations of media based on the volume ratios listed were poured into the pots, and plant materials planted into the media were absolutely identical (Table I). To prevent fungal diseases and pest control, a fungicide was sprayed on the plants. An insecticide as a solution with a concentration of 2:1000 was applied to plants every 15 days from the transfer of plants to the media and at the end of the experiment. Irrigation was performed once every three days from the time of transfer to the media until the end of the experiment. To prevent the loss of vegetative growth, all buds appearing on the plant were cut upon emergence in the first month after transfer to media. To check physical, chemical, and nutrient contents, plant substrates were tested (Table I). Plant traits were measured at the end of the experiment and at the end of the first flower shed. In this study, the nutrients contained in the plant, plant fresh and dry weight, chlorophyll and anthocyanin content were evaluated. Plant fresh weight was measured with a digital scale. Then, they were placed in an oven at 120 ℃ for 24 h to dry completely, and the dry weights were measured. Chlorophyll content of the leaves and anthocyanin content of the petals were calculated by Reference [13] methods. Micro-elements were measured using atomic absorption spectroscopy. The data collected in this experiment was analyzed by SPSS software. Mean comparisons between treatments were performed using the Duncan multiple range test (DMRT) at a 5% level.

TABLE I: DIFFERENT CULTIVATION BEDS AND THEIR SYMBOL USED FOR IVY GERANIUM.

Symbol	Full names of soil treatments
M_1	garden soil + sand (1:1 v/v)
M_2	garden soil + cocopeat + solid waste compost (1:1:1 v/v)
M_3	garden soil + sand + water tank soil (1:1:1 v/v)
M_4	garden soil + cocopeat + water tank soil (1:1:1 v/v)
M_5	garden soil + sand + solid waste compost (1:1:1 v/v)
M_6	garden soil + sand + solid waste compost + water tank soil (1:1:1:1 v/v)
M_7	sand + leaf mold + cocopeat + solid waste compost (1:1:1:1 v/v)
M_8	sand + tea compost + cocopeat + water tank soil (1:1:1:1 v/v)
B_0	non-application of bio-fertilizer
B_1	application of bio-fertilizer

III. RESULTS AND DISCUSSION

Maximum absorption of Zn in leaves of the geranium was related to treatment M_6B_1 (application of bio-fertilizer and bed of garden soil + sand + solid waste compost + water tank soil) with an average of 55.97 mg kg^{-1} leaf dry weight (Table II). The application of biological phosphorus fertilizer significantly increased the amounts of absorbable Fe, Mn, and Cu in geranium leaves in the medium of sand + tea waste compost + cocopeat + water tank soil (M_8B_1) with averages of 279.73, 18.60, and 7.20 mg kg^{-1} leaf dry weight, respectively, compared to the other treatments (Table II). Absorbable Fe, Mn, and Cu in leaves of plants cultivated in the medium of garden soil + sand (M_1) without inoculation with phosphate-solubilizing microorganisms were significantly lower than the other treatments (Table II). The highest fresh weight in the combined effect was observed with inoculation in phosphate-solubilizing microorganism in the medium M_8 (sand + tea compost + cocopeat + water tank soil) with an average of 31.85 g (Table II). Plants grown in M_2B_0 (non-application of bio-fertilizer and garden soil + cocopeat + solid waste compost) with an average of 3.61 g wet weight had the lowest fresh weight in the plants, respectively (Table II). The M_6B_1 (application of bio-fertilizer and garden soil + sand + solid waste compost + water tank soil) treatment had the highest effect on dry weight of plants (12.85 g) (Table II). According to the results, the plants treated with the garden soil + cocopeat + municipal solid waste compost media without the use of bio-fertilizer (M_2B_0) with averages of 0.64 g had the lowest dry weight in plants, respectively (Table II). The highest chlorophyll content in the interaction of two factors was related to treatment M_8B_1 (application of bio-fertilizer and sand + tea compost + cocopeat + water tank soil) with an average of 5.37 mg in fresh weight of leaf (Table II). Treatment M_2B_0 (non-application of bio-fertilizer and cocopeat + solid waste compost) with an average of 2.01 mg g^{-1} fresh weight had the lowest impact on leaf chlorophyll content among treatments (Table II). The interaction between two factors revealed that plants inoculated with phosphate solubilizing microorganisms in the medium of garden soil + sand + municipal solid waste compost (M_5B_1) and M_6B_1 (application of bio-fertilizer and garden soil + sand + solid waste compost + water tank soil) with a mean of 118.15 and 116.92 mg 100 g^{-1} petals DM and M_1B_0 (non-application of bio-fertilizer and garden soil + sand) with a mean of 46.17 mg 100 g^{-1} DM had the highest and least petals anthocyanin content, respectively (Table II).

TABLE II: MEAN COMPARISON OF THE INTERACTION EFFECT OF DIFFERENT SUBSTRATES AND APPLICATION OF BIOFERTILIZER ON IVY GERANIUM PARAMETERS.

Treatments	Zn (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Cu (mg kg^{-1})
M_1B_0	16.28^{i}	103.10^{fg}	7.72^{g}	2.70^{g}
M_2B_0	19.01^{fg}	85.15^{g}	10.08^{e}	2.90^{fg}
M_3B_0	22.03^{e}	137.25^{ef}	8.61^{ef}	3.02^{f}
M_4B_0	17.30^{hi}	209.62^{bcd}	10.27^{e}	3.00^{f}
M_5B_0	38.05^{c}	192.43^{d}	10.37^{e}	2.70^{g}
M_6B_0	48.00^{b}	210.05^{bcd}	11.64^{de}	6.35^{c}
M_7B_0	17.25^{hi}	156.61^{fg}	13.08^{cd}	4.50^{d}
M_8B_0	11.25^{f}	186.80^{de}	14.00^{c}	6.75^{b}
M_1B_1	17.02^{hi}	216.91^{bc}	8.00^{fg}	3.25^{ef}
M_2B_1	19.25^{fg}	125.00^{e}	13.92^{cd}	3.72^{e}
M_3B_1	36.21^{b}	202.08^{cd}	9.00^{ef}	3.77^{e}
M_4B_1	22.14^{e}	233.61^{abc}	10.27^{e}	3.65^{e}
M_5B_1	47.21^{b}	221.37^{bc}	13.39^{cd}	3.72^{e}
M_6B_1	55.97^{a}	241.07^{abc}	15.86^{bc}	7.10^{a}
M_7B_1	19.95^{f}	252.37^{ab}	16.06^{b}	4.80^{d}
M_8B_1	25.00^{d}	279.73^{a}	18.60^{a}	7.20^{a}

In each column, means with the similar letters are not significant difference at 5% level of probability using dmrt

The use of organic compounds in the cultivation medium can increase access to food inaccessible in the soil for plants [14]. Increasing the organic matter and microorganism activity in the soil leads to improved physical and chemical properties of soil and increased nutrient absorption from the soil by plants [15]. Phosphate-solubilizing bacteria used from root exudates and with a change in pH and organic acids increased the solubility of sparingly-soluble inorganic phosphates. In addition, microorganisms available in bio-fertilizer phosphorus enhanced elements such as Zn, Fe, Mn, and Mg in the soil through the production of organic acids [5], [16]. Studies have shown that organic waste naturally contains large amounts of micronutrients that, due to the high organic matter, become organic chelate and enhance the solubility and absorbency of these nutrients in the soil [17]. Thus, the presence of organic matter in the medium, the use of bio-fertilizer with the increased microorganisms around the roots followed by increased absorption of nutrients in the medium, and the improved condition of the medium and increased root efficiency in food uptake could explain the increased nutrient uptake in plants [18]. Reference [19] in their study on parsley (*Tagetes patula*) showed that the application of organic fertilizers in the medium increased nutrients in the plant. Reference [20] in their experiment on soybean (*Glycine max* L.) stated that the application of bio-fertilizer and organic matter increased micronutrient concentrations in plants. Application of organic compounds in the medium increases soil organic matter and microorganisms improve soil structure, increases the cation exchange in the medium, and therefore, root development and increased uptake of nutrients available from the soil by plants is followed by increased vegetative growth [15], [21]. There is a direct relationship between the increased nutrient uptake by plants and photosynthesis and dry matter that corresponds with the present results. This relationship can be attributed to the use of bio-fertilizer and organic compounds [22]. The substances secreted by microorganisms in the bio-fertilizer and organic compounds, by improving soil physical and chemical conditions and increasing absorption of water and nutrients, can increase plant dry/fresh weight. Organic compounds in plant media increased dry matter through increased soil fertility and improved food availability [23]. Reference [24] in a study on marigold (*Tagetes erecta* L.) demonstrated that the different methods of applying bio-fertilizer phosphate (Barvar 2) increased dry/fresh weights compared with the control. Reference [12] studied the summer squash (*Cucurbita* spp.) and revealed that the application of bio-fertilizers with organic fertilizers and each separately led to increased plant dry/fresh weight compared to the control.

The increased amount of chlorophyll in the leaves can be attributed to the use of bio-fertilizer. The rate of photosynthesis in plants inoculated with phosphate-solubilizing microorganisms increased due to the supply of more phosphorus [25]. Biological integration can also increase the number of chloroplasts and the photosynthetic capacity of plants [26]. Enhancing concentrations of elements such as Mg, Fe, and Mn with organic materials and bio-fertilizer and the easier absorption of these materials by root can increase leaf area and leaf chlorophyll. It can also cause an increase in pigments in superior treatments [27]. Reference [28] showed that Fe is involved in producing chlorophyll. The researchers found a direct relationship between the increase in Fe in the plant with the number of photosynthetic pigments and the content of leaf chlorophyll. Reference [12] showed that the application of bio-fertilizers with organic fertilizers and each separately increased chlorophyll content in the leaves of summer squash (*Cucurbita* spp.) compared with the control. Organic fertilizers such as composted municipal solid waste can lead to an increase in the anthocyanin content. This material may increase the availability of Zn in soil and this in turn increase the plant anthocyanin content. This phenomenon is due to the high concentration of Zn in the presence of organic fertilizers in the soluble and exchangeable forms [29]. Reference [30] found that by using medium containing compost from agricultural wastes as peat substitutes in growing croton (*Codiaeum variegatum*), the amount of red color rose in leaf increased that is associated with increased concentrations of anthocyanins. The reason to increased anthocyanin by phosphate biofertilizer can attributed to increase absorbable form of Zn and Mn in the medium by microorganisms in fertilizer by reducing the pH and secretion of organic acids in the medium [31]. Reference [32] in a study on the rose (*Rosa* × *hybrida* L. 'KOR Crisett') concluded that plants planted in medium with a lower pH had more anthocyanins. Thus, the addition of organic compounds to substrates increase organic matter and improve chemical characteristics and available micro-nutrients in cultivation bed. Bio-fertilizers with medium containing a variety of organic compounds such as sand + tea compost + cocopeat + water tank soil and garden soil + sand + solid waste compost + water tank soil had a better yield compared with other treatments.

TABLE II: CONTINUED

Treatments	Plant fresh weight (g)	Plant dry weight (g)	Total chlorophyll (mg g^{-1} FW)	Total anthocyanin in petal (mg $100g^{-1}$ DW)
M_1B_0	8.18^{g}	2.41^{i}	2.78^{de}	49.82^{ef}
M_2B_0	3.61^{h}	1.71^{j}	2.01^{e}	57.87^{c}
M_3B_0	17.08^{e}	6.75^{f}	3.83^{bc}	68.25^{de}
M_4B_0	23.81^{d}	5.93^{g}	3.45^{cd}	65.75^{de}
M_5B_0	23.08^{e}	8.64^{d}	3.55^{cd}	104.92^{d}
M_6B_0	22.61^{de}	5.64^{g}	3.57^{cd}	90.17^{c}
M_7B_0	18.01^{e}	3.48^{hi}	4.39^{b}	46.17^{f}
M_8B_0	27.21^{c}	5.45^{g}	5.12^{a}	55.92^{e}
M_1B_1	13.08^{ef}	4.47^{h}	3.42^{cd}	50.17^{ef}
M_2B_1	3.71^{h}	1.96^{j}	2.95^{d}	57.37^{e}
M_3B_1	24.81^{d}	10.71^{b}	4.01^{bc}	95.47^{bc}
M_4B_1	26.51^{c}	7.52^{e}	3.84^{bc}	82.42^{cd}
M_5B_1	31.51^{b}	12.85^{a}	3.78^{bc}	118.15^{a}
M_6B_1	30.18^{b}	7.54^{e}	3.97^{bc}	116.92^{a}
M_7B_1	30.85^{b}	7.12^{e}	4.85^{b}	53.40^{e}
M_8B_1	39.90^{a}	9.41^{e}	5.37^{a}	75.47^{d}

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