Australian Journal of Crop Science AJCS

AJCS 6(11):1494-1501 (2012) ISSN:1835-2707

Effects of bacteria and arbuscular mycorhizae inoculation at different electrical conductivity level on growth and yield of rockmelon (*Cucumis melo*) under soilless culture

B. Zulkarami[1], M.I. Tajul[1,3]*, A. Fariz [2], M.O. Husni,[1], A. Norazrin[1], O. Radziah [1,4], I. Mohd Razi [1,5] and M.Y. Rafii[1,5]

[1]Laboratory of Food Crops, Institute of Tropical Agriculture, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[2]Laboratory of Plantation Crops, Institute of Tropical Agriculture, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[3]Tokyo University of Agriculture and Technology, 2-24-16 Naka-cho, Koganei-shi, 184-8588 Tokyo, Japan
[4]Department of Land Management, Faculty of Agriculture, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[5]Department of Crop Science, Faculty of Agriculture, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

***Corresponding author: talukder.taj@gmail.com**

Abstract

Interaction between bacteria and arbuscular mycorhizae has been known to benefit growth of plants in over the world. An investigation was conducted to evaluate the growth and yield of rockmelon plant (*Cucumis melo*) as influenced by *Burkholderia cepacia* and *Glomus mossae* in a soilless culture (70% coconut dust+30% empty fruit bunch compost). Four treatments, control (un-inoculated), *B. cepacia*, *G. mossae* and mixtures of *B. cepacia* and *G. mossae (B. cepacia+G. mossae)*, and three electrical conductivity levels of fertilizer (1.5, 2.0 and 2.5 dS/m), were evaluated in a randomized complete block design with eight replicates. Leaf area meter and photosynthesis rate were the highest in *G. mossae* and mixture of *B. cepacia and G. mossae* with 7973 cm^2 and 14.66 µmol/m^2/s, respectively. The sweetness of the fruit in all the treatments in between 11-12% Brix to the control indicating that enough sugar content was accepted for market demand. Results showed that EC with 2.0 dS/m was the optimum for growth and yield of rockmelon. Interestingly, pH was increased by 0.5, 1.37 and 0.34% at 30 DAT and 0.17, 1.72 and 1.72% at 70 DAT in *B. cepacia*, *G. mossae* and *B. cepacia+G. mossae* compared than control, respectively. Individual fruit weights were increased by 22, 22 and 18% in *B. cepacia*, *G. mossae* and *B. cepacia+G. mossae* from the control, respectively. The result in this study suggests that addition of *G. mossae* and *B. cepacia* either separately or combination in soilless culture enhances the growth and yield by 18 to 22% of rockmelon plant. Our findings highlight the importance of *G. mossae* as bio-enhancer for growth and yield of rockmelon under soilless culture. *Glomus mossae* and *B. cepacia* will undergo field tests for their effect on rockmelon growth and yield.

Keywords: arbuscular mycorhizae; bacteria; *Burkholderia cepacia*; coconut dust; electrical conductivity; empty fruit bunch compost; *Glomus mossae*; rockmelon yield.
Abbreviations: ANOVA- analysis of variance; CFU- colony forming units; DAT- after transplanting; CEC- cation exchange capacity; EC- electrical conductivity; PDB- potato dextrose broth; PGPR- plant growth promoting bacteria; OMA- oatmeal agar; RCBD- randomized complete block design; UPM- Universiti Putra Malaysia; YG- yeast extract and glucose.

Introduction

Melon (*Cucumis melo* L.) is a commercially important crop in many countries. It is mostly cultivated in the temperate regions of the world due to its good adaptation to soil and climate. Rockmelon fruits are consumed in summer and are popular because of its sweet pulp and pleasant aroma (Villanueva et al., 2004). In Malaysia, the cantaloupe type, especially the cultivar 'Glamour' with the striking golden yellow colour is the most popular. Like other melons, cantaloupes grow best in sandy, well-aerated, well-watered soil and in weed-free conditions. Fertilizer is the major cost in agriculture sector in the world. In fertigation system, the plants are fed by water including fertilizer by drip system in soilless media. The appropriate electrical conductivity with combination other alternative (addition of fungus and bacteria) supposed to be apply by maximizes the usage of fertilizer for enhances the growth and yield of rockmelon. Usually the fertilizer consumption on fertigation system is not specific to the optimal electrical conductivity (EC) but a certain range is used. There is a lack of information on the influence of the microbes and specific EC on fruit weight and fertilizer consumption in the appropriate dose of rockmelon plant (Zulkarami et al., 2010). Soilless culture around roots contains microbes or funguses that are interact and influenced each other in growth and yield of the plant such as *Burkholderia cepasia* and *Glomus mossae*. Many of the rhizospheric bacteria have been developed as biofertilizer and biopesticides to minimize the excessive use of inorganic-fertilizers and to protect environment and plant health. *Burkholderia cepasia* has shown antagonistic activity against a broad range of plant pathogens (Hwang et al., 2002). It might be useful to increase or improve the fruit growth and yield when the plant is growing well and low infection of diseases. Mycorhizae ('fungus-roots') are symbiotic associations between specialized soil fungi and plants, which

improve soil quality and plant vigor (Wang et al., 1999). They play a crucial role in plant nutrient uptake, water relations, ecosystem establishment, plant diversity, and the productivity of plants. The fungi colonize the root system of a host plant, providing increased water and nutrient absorption capabilities while the plant provides the fungus with carbohydrates formed from photosynthesis. Mycorhizae also offer the host plant increased protection against certain pathogens (Schubler and Kluge, 2000). Plants benefit from the fungi because these acquire nutrients, which are inaccessible for the plant because of distance from the roots, location in pores that are too small for roots to access or occasionally occurring as forms that are unavailable to plants. Conversely, fungi are ensured a supply of carbon (C) derived from photosynthesis by the plant (Smith and Read, 2008). In view of describes above, its importance for reducing the cost of fertilizer by applying appropriate level of electrical conductivity and an alternative combination bacteria and or mycorhizae to maximizes the application of fertilizer in the soilless culture. In the present study, *G. mossae* and *B. cepacia* were used for improving growth and yield efficiency of rockmelon in a soilless culture. The aims are to reduce the cost of fertilizer and to improve the efficiency of fertilizer uptake by the plant through better growth and yield of rockmelon.

Results and discussion

Growth of rockmelon plant

Table 2 shows the plant height in different microbes and EC at 7, 14 and 21 day after transplanting (DAT). There was no significant effect ($p<0.05$) of microbial treatment on plant height at 7 and 14 DAT. Significantly different at d 21 DAT with the mixtures of *B. cepacia* and *G. mossae* and *B. cepacia* only slightly higher plant height were obtained which were 96.67 and 93.67cm, respectively. Electrical conductivity in 2.0 dS/m showed the highest plant height among other EC with 11.08, 34.92 and 101.00 cm at 7, 14 and 21 DAT, respectively. Twenty one day after transplanting, the highest plant height (96.67cm) was obtained in *B. cepacia+G. mossae*. In the case of number of leaves, significant different ($p<0.05$) was observed in *B. cepacia* and *B. cepacia+G. mossae* at 7 and 14 DAT with 33 and 96, respectively. No significant difference was observed in microbes at 14 DAT as shown in Table 2. Interestingly, significant difference in EC 2.0 dS/m at 14 and 21 DAT with 37.25 and 99.50 were obtained, respectively. In contrast, there was no significant difference in EC at 7 DAT. The leaf area meter was the highest in 2.0 dS/m EC with *G. mossae* at 30 DAT with 8379 and 7973cm^2, respectively (Fig. 1a). The similar result was obtained in photosynthesis rate, but in both EC (1.5 and 2.0 dS/m) were the higher (1413 µmol/m^2/s) (Fig. 1b). The highest photosynthesis rate was observed in *B. cepacia+G. mossae* with 14.66µmol/m^2/s. Seven day after transplanting, infection of *B. cepacia* on the root might be occurring according to the basic growth of microbes, where bacteria grow faster than fungus indicating better number of leaves was observed. The number of leaves increased 3.9% at treatment with *B. cepacia* as compared to the control. At early stage of growth, microbes need time to use the nutrient and root for symbiosis. *Glomus mossae* are beneficial associations between the growing root system of a plant, which is the host and a mycorrhizal fungus as a symbiont. These positive effects of *B. cepacia* and *G. mossae* symbioses have been attributed to an improved nutritional state (due to N supplied by bacteria and P by mycorhizae), which in turn leads to increased photosynthetic rates and improved plant growth (Kaschuk et al., 2009) as shown in *B. cepacia+G. mossae* resulted higher plant height, number of leaves at 21 DAT and photosynthesis rate at 30 DAT. The general assumption is that *B. cepacia+G. mossae* symbioses affect the whole plant photosynthesis because they improve plant nutrition and growth (by increasing total leaf area), but there is also an evidence that the rate of photosynthesis/unit of leaf area may be significantly increased (Kaschuk et al., 2009). Combination of *B. cepacia+G. mossae* resulted in higher response ratios of photosynthesis as described by Kaschuk et al. (2009). The higher plant height, leaf area meter, stems and leaves dried weight and photosynthetic rate at 30 DAT in treatment *G. mossae* because of efficient nutrient uptake. There is an evidence that *G. mossae* also play a role in up taking nitrate (NO^-_3) and ammonium (NH^+_4), which are assimilated and transported within the mycelium as reported by Smith and Read (2008). This resulted EC in number of leaves has no significant different was observed. Plant height need appropriate nutrient for growth as shown in Table 1. Nutrient might contained higher N in 2.0 dS/m EC as compared to other treatments. Constant plant height in earlier stage might be similar nutrient uptake by the microbes including the control. *B. cepacia*, *G. mossae* either combines or separately not affected in plant height as resulted almost similar reading to the control (un-inoculated). Harris et al. (1985) suggested that carbon sink strength of symbioses stimulated the rate of photosynthesis that has similar effect in EC 2.0 dS/m. Maximum growth rate and other growth parameters had occurred when EC was 2.0 dS/m, which was close to proposed EC for hydroponic cultivation of lettuce (Karimaei et al., 2004).

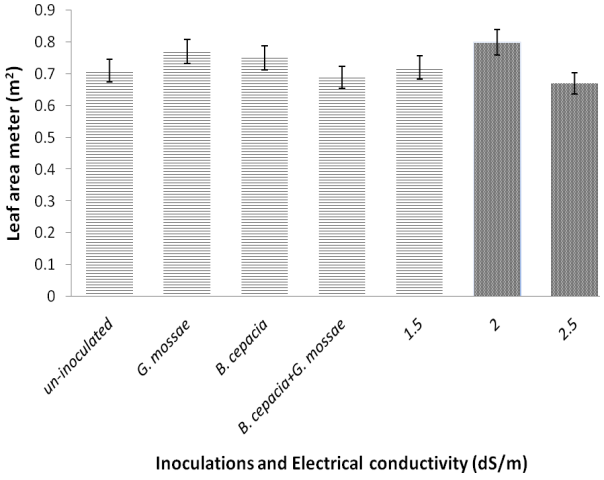
Electrical conductivity and pH in the media

The pH of the nutrient in the media was in-between 5.8-6.01 throughout the experiment (Fig. 2a). The highest pH was obtained in 2.0 and 1.5 dS/m EC with 6.01 and 5.85 at 30 DAT. There was no significant difference between the microbes at 30 and 70 DAT and also EC at 70 DAT. Interestingly, at 70 DAT, treatments with *G. mossae*, *B. cepacia* and *B. cepacia+G. mossae* showed the highest EC in the media with 0.69, 0.64 and 0.64 dS/m, respectively (Fig. 2b). The highest EC in media was shown in 2.5 EC with 0.63 dS/m. Combination of *B. cepacia+G. mossae* (1.27dS/m) gave the better EC among the treatments followed by control, treatment with *G. mossae* and *B. cepacia* with 1.18, 0.90 and 0.89 dS/m, respectively. The highest EC in media was 1.45 dS/m with EC in 1.5 dS/m in tank. Overall pH in the media was in acidic condition but close to pH 7.0 (neutral). The maximum growth rate of rockmelon was found at the highest pH (6.01), which was obtained by EC 2.0 dS/m (Fig. 2). This result corroborated the work of Knight and Mitchell (1983) who the proposed the pH (5.9) for lettuce cultivation. The optimum pH at 30 DAT (pH 6.01 with EC 2.0 dS/m) indicated higher in the leaf area meter, photosynthesis rates, leaves and root dry weight. This because of pH is a critical parameter that influences the bioavailability of many nutrients and toxic elements and the physiology of the roots and rhizospheric microorganisms (Hinsinger et al., 2003). Thus, in lower pH at 70 DAT, rockmelon growth was better and more nutrients were absorbed described by Karimaei et al. (2004). In addition, treatments with *B. cepacia+G. mossae* have an ability to bring insoluble soil phosphates into soluble forms resulting in lower pH (Afzal et al., 2005). Salt accumulation in the medium was considered the main reason for the EC increase at earlier stages of experiment (30 DAT)

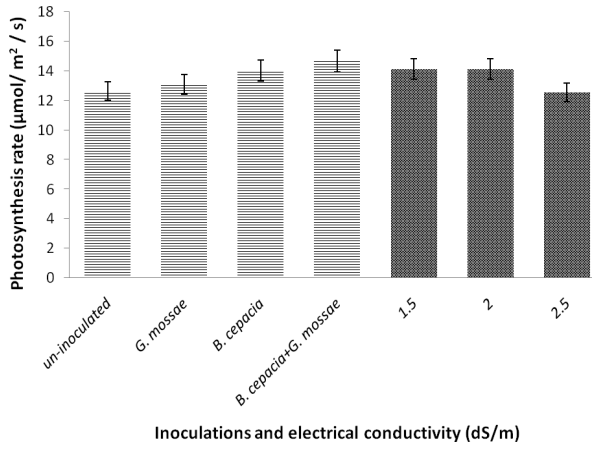
Table 1. Components in Cooper modified fertilizer formulations.

Elements	(ppb)
STOCK A	
Calcium nitrate	2115.74
Ferum chelate (EDTA)	7.05
Potassium nitrate	39.37
STOCK B	
Potassium nitrate	129.48
Magnesium sulfate	119.14
Manganese sulfate	0.88
Boric acid (Boron)	1.29
Cooper sulfate	0.29
Ammonium molybdate	0.03
Zinc sulfate	0.25
Monopotassium phosphate	19.02

ppb: parts per billion



(a)



(b)

Fig 1. (a) Leaf area meter (m^2) and (b) photosynthesis rate (µmol m^{-2} s^{-1}) in different microbes and electrical conductivity at 30 DAT.

compared with fruiting at 70 DAT. It has been reported that the supply of the nutrient solution with high EC for a long period resulted in a gradual EC increase and end up with higher of the initial solution EC by rising SO_4^- and Na^+ concentration in the medium (Cui et al., 2004).

Root infections and colonization of mycorhizae and bacteria

Table 3 shows the root infections by *G. mossae* and combination of *B. cepacia*+*G. mossae*. No significant difference was found between the microbes and EC. Treatment with *B. cepacia*+*G. mossae* showed 42.50% root infections followed by *G. mossae* alone (33.33% root infections) in the plant at 30 DAT. Colonies of bacteria in single culture shows more significant as compare to the mix with *G. mossae* with 5.0 x 10^8 CFU/g, respectively at 30 DAT. Result in 1.5, 2.0 and 2.5 dS/m EC showed 5.0 x 10^8, 4.8 x 10^8 and 5.0 x 10^8 CFU/g, respectively in Table 3. There were no significant differences in between different EC levels. Treatment with *B. cepacia*+*G. mossae* produced more spores and hyphae compared to treatment with *G. mossae* only affected the root infections in the plant. In the presence of *B. cepacia*+*G. mossae*, they could be more supporting and tolerating each other to survive in the media compared to *G. mossae* alone (Wang et al., 1999). Although the time course of the relationships between intensity of *G. mossae* infection alone and mixtures (*B. cepacia*+*G. mossae*) were complex and suggested a role for factors other than nutrition. The time course for the development of infection varied as reported by Berta et al. (1995). There was no significant difference between the treatments and EC in root infections. Better root length and root dry weight in *G. mossae* compared with *B. cepacia*+*G. mossae* at 30 DAT, resulted in less root infection. In the colonies of *B. cepacia*, the infection was slightly lower (4% lower) in single colony compared with *B. cepacia*+*G. mossae* were observed. It shows that in *B. cepacia*+*G. mossae*, slow bacteria growth as compared to single culture. It could be the source of food and space in the media were partition to bacteria and mycorhizae to grow together throughout symbiosis (Richardson et al., 2009). At 30 DAT, mixture culture of bacteria and mycorhizae that grew well in media was obtained as similar result reported by Berta et al. (1995) where mycorhizae induced enhancement of phosphate assimilation in mycorrhizal plants influences plant development.

Biomass productions

Dry weight of stems and leaves were higher in all the treatments including control except in roots dried weight only higher in control (11.21 g) and T2 (9.29 g) at 30 DAT (Table 4). Dry weight of stems and leaves was the highest in 1.5 and 2.0 dS/m EC with 28.70 and 9.45 g, respectively. EC with 1.5 and 2.0 dS/m were the best for leaves dried weight was observed with 308.37 and 289.72 g, respectively. In root length, *G. mossae* was the highest with 22.67 cm. Root length was the highest in EC 2.5 dS/m with 18.13 cm. The use of *G. mossae* resulted in highest stem (28.92 g), leaves (315.23 g) dry-weight and leaf area meter (7973 cm^2) compared to the other treatments throughout the experiment, indicating that this treatment had positive effects on growth and development of rockmelon plant. Combination treatment with *B. cepacia*+*G. mossae* produced significantly higher photosynthesis rate compared with other treatments and control, with means values of

Table 2. Plant height (cm) and number of leaves in different inoculation and EC at 7, 14 and 21 DAT.

Inoculations	Plant height (cm)			Number of leaves		
	7 DAT	14 DAT	21 DAT	7 DAT	14 DAT	21 DAT
Un-inoculated	10.17a	28.67a	92.11b	31.33ab	30.56a	90.89b
G. mossae	10.33a	29.22a	93.22b	30.33b	31.11a	92.11b
B. cepacia	10.11a	28.00a	93.67ab	32.56a	28.56a	93.67ab
B.cepacia+*G. mossae*	10.22a	28.00a	96.67a	29.78b	28.00a	95.89a
EC (dS/m)						
1.5	9.67b	24.67b	96.67a	31.67a	27.08b	86.83c
2.0	11.08a	34.92a	101.00a	31.08a	37.25a	99.50a
2.5	9.87b	25.83b	87.67c	30.25a	24.33c	93.08b
CV	10.38	5.25	2.64	4.64	8.77	2.69

The values are the average of eight replications, EC: electrical conductivity, CV: coefficient of variation. Means within columns followed by the same alphabets are not significantly different at $p<0.05$ (Tukeys test).

14.66 µmol/m^2/s. The effects of EC on microbes are shown in Table 4. The leaves dry-weight (308.37 g) was the highest at 2.0 dS/m EC. Interestingly, treatment with *G. mossae* only had significance in increasing stems and leaves dry-weight with 6.3 and 10.8%, respectively. In contrast to the EC, stem and leaves dry-weight were suitable at 1.5 and 2.0 dS/m. Result showed that the root length were increased 128, 67 and 22% in treatment *G. mossae*, *B. cepacia*+*G. mossae* and *B. cepacia* compared with the control. These indicated that in present of *G. mossae*, *B. cepacia*+*G. mossae* and *B. cepacia* enhanced the root length in the media as described by Kloepper (2004), Ahmad et al. (2005), and Vessey (2003). Treatment with *G. mossae* showed significantly improved root length as compared to other treatments. Furthermore, sink stimulation of photosynthesis could possibly lead to an increased period of leaf activity or delayed senescence (Paul and Peliny, 2003), which in turn could increase the potential period for plant growth and fruit weight or yield. *Glomus mossae* was the most suitable in improving the root by colonizes around the roots system especially for up taking the nutrient and water as describe by Harper et al. (1991) in root system morphology influences root function. In addition, portioning of net assimilates contributes in all organ by approximately by dry weight of plant (Gifford and Evans, 1981) as describe above.

Composition of nutrient in the leaves and roots

The highest N, P, K, Ca, Mg, Fe, Cu and Zn in the leaves in different microbes were in *G. mossae*, control, *B. cepacia*, *B. cepacia*, *B. cepacia*, control, *B. cepacia*+*G. mossae* and control with 0.58, 15.87, 111.00, 34.29, 2.91, 0.32, 0.02 and 0.11 ppm, respectively were obtained (Table 5). In EC 1.50, 0.60, 15.00, 107.49, 0.31, 0.02 and 0.10 ppm were the highest in N, P, K, Fe, Cu and Zink. In contrast, Ca (34.49 ppm) and Mg (2.89 ppm) were the highest with EC 2.0 dS/m. In roots, the results showed Ca and Zn (5.11 and 0.13ppm) were the highest in control (Table 6). Treatment with *B. cepacia*, P, Fe, Cu and Zn (5.26, 12.87, 0.05 and 0.12 ppm) were the highest was obtained. Mixture of *B. cepacia*+*G. mossae*, the highest N, K and Mg (0.40, 10.83 and 2.08 ppm) was observed. Five elements were the highest in EC 2.0 dS/m as known as P, Mg, Fe, Cu and Zn with 5.63, 2.06, 11.75, 0.05 and 0.16 ppm, respectively. In contrast, N (0.39 ppm) the only one element highest in EC 2.5 dS/m was obtained. Potassium and Ca were the highest in EC 1.5 dS/m with 10.66 and 4.53 ppm, respectively.

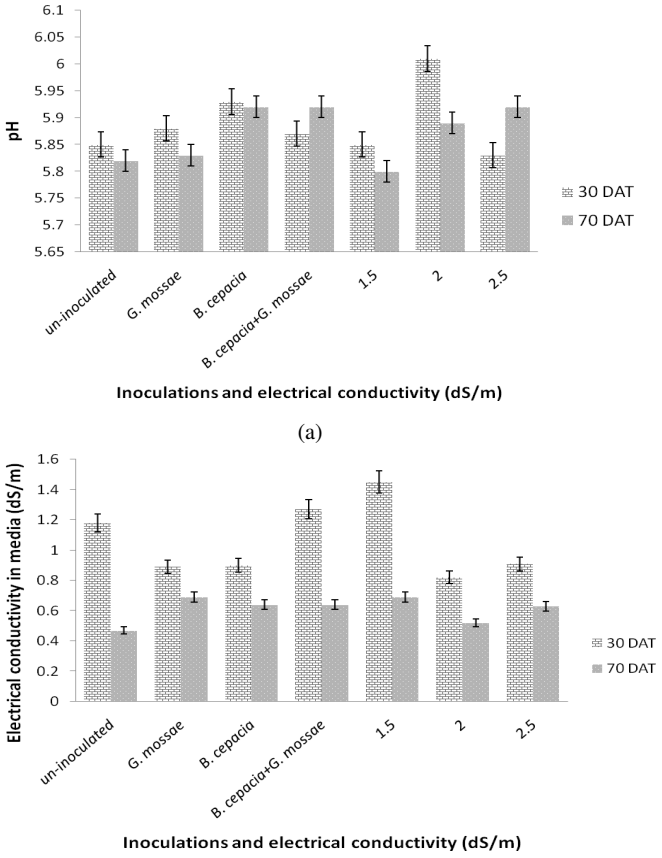


Fig 2. (a) pH in different microbes and (b) electrical conductivity (EC) in the media at 30 and 70 DAT.

Result shows that the highest level of N and Cu in the leaves at treatment *G. mossae* improved the leaves area meter, stem, leaves, root dry weight as well as root length. It suggested that the addition of *G. mossae* attribute the higher uptake of nutrient in the leaves for better growth and fruit weight at 30 DAT. In treatments mixtures of *B. cepacia*+*G. mossae*, similar results were found with *B. cepacia* only (highest of N, P and Mg contents) but in the root. The characteristics of *G. mossae* similar with function as PGPR where it contributes in higher root dry weight and nitrogen fixation (Yazdani et al., 2009). It suggests that EC level at 1.5 was more effective in producing the leaves and especially

Table 3. Plant root colonization by mycorhizae and bacteria at 30 DAT.

Inoculations		Root infections in mycorhizae (%)	Colonies of bacteria (cfu g^{-1} soil)
Un-inoculated		N/A	N/A
G. mossae		33.33a	N/A
B. cepacia		NA	5.0 x 10^8 a
B. cepacia+*G. mossae*		42.50a	4.8 x 10^8 b
EC (dS/m)			
	1.5	43.75a	5.0 x 10^8 a
	2.0	37.50a	4.8 x 10^8 a
	2.5	32.50a	4.9 x 10^8 a

The values are the average of eight replications. Means within columns followed by the same alphabets are not significantly different at $p<0.05$ (Tukeys test). *NA:* did not analyze.

Table 4. Effect of inoculation and EC on stem (g), leaves (g), roots (g) dried weight and root lengths (cm) at 30 DAT.

Inoculation		Stem dry weight (g)	Leaves dry weight (g)	Roots dry weight (g)	Root length (cm)
Un-inoculated		27.21ab	284.50ab	11.21a	10.00c
G. mossae		28.92a	284.50ab	9.29a	22.67a
B. cepacia		26.95ab	289.40ab	3.15b	12.17c
B.cepacia+*G. mossae*		25.71b	289.40ab	4.61b	16.67b
EC (dS/m)					
	1.5	28.70a	289.72ab	7.37b	15.50b
	2.0	26.44b	308.37a	9.45a	12.50c
	2.5	26.44b	259.68b	4.38c	12.50c
CV		5.30	9.69	16.42	9.50

The values are the average of eight replications. CV= coefficient of variation. DAT= days after transplanting.Means within columns followed by the same alphabets are not significantly different at $p<0.05$ (Tukeys test). EC: electrical conductivity, DAT= days after transplanting.

especially EC at 2.0 dS/m in producing more on roots of the rockmelon plant. In general, crop productivity may be increased or decreased depending on inhibitory or stimulatory effects of different factors on each other under non-limiting growth resources, such as light, water, nutrients and space (Narwal, 2000).

Fruit weight, diameter of fruit and sweetness

Results revealed that total fruit weight was significantly higher in all treatment compared to the control (Table 7), indicating that these microbes have positive effects in increasing the fruit weight. The higher fruit weight of 1.78 kg was observed in *B. cepacia*, 1.77 kg with *G. mossae* and 1.71 kg with combination of *B. cepacia*+*G. mossae*. The EC with 2.0 dS/m is the most fruit weight and fruit diameter as shown in Table 5 with 1.98 kg and 47.6 cm, respectively. There was no significant difference between fruit diameter and microbes. Among the treatments, no significant differences in sugar content (% Brix) of rockmelon were observed. All the treatments with the different microbes and EC had the same levels of sugar (Table 7). Symbiosis between microbes and root resulted in higher fruit weight in all the treatments except for control (Table 7) also reported by Brundrett (2002). There were 22.5, 22.1 and 17.9% increased of fruit weight in treatment with *B. cepacia*, *G. mossae* and combination with *B. cepacia*+*G. mossae*, respectively. Furthermore, sink stimulation of photosynthesis could possibly lead to an increased period of leaf activity or delayed senescence (Paul and Peliny, 2003), which in turn could increase the potential period for plant growth and fruit weight or yield. These interactions require communication between numerous organisms involved in rhizosphere (referred to bacteria and mycorhizae were supplied to the soilless culture) processes was explained by Lambers et al. (2009). Previous researches have shown the practicality of introducing PGPR into commercial peat-based substrates for vegetable production in order to increase plant vigor, control root diseases and increase yields (Kokalis-Burelle et al., 2003a, 2003b; Kloepper et al., 2004) was reported similar result in addition of *B. cepacia*+*G. mossae*. Combination with 2.0 dS/m EC and microbes attributed to the better root system produced with all treatments. Large amounts of assimilates produced (Gifford and Evans, 1981) and the associated high sink strength are important factors in determining high yields in crop production as shown in the *B. cepacia*, *G. mossae* and combination *B. cepacia*+*G. mossae*. In terms of commercial overview, 2.0 dS/m EC is more reliable and practically in cost and fruit yield. Similarly, Zulkarami et al. (2010) reported an improvement of fruit yield of rockmelon plant in response to EC. Fruit diameter and fruit sweetness had no significant difference when different microbes were used. However, both fruit weight and fruit diameter significantly differed at 2.0 dS/m EC. Electrical conductivity at 2.0 dS/m was the appropriate nutrient for their growth and yield of rockmelon plant in treatments with microbes.

Materials and methods

Plant materials

The experiments were conducted under the rain-shelter facilities (temperature in between 24- 34°C, relative humidity around 62%, 65-70% of light intensity and the plant growth space was within 2ft in between row and 1ft in between line) at the Research University Park during October-December 2010, Universiti Putra Malaysia (UPM), Selangor, Malaysia. The experimental site is geographically situated at 3.3^0N latitude and 101.5^0E longitudes with an elevation of 21m (71ft) from sea level at the west coast of Peninsular Malaysia.

Growth conditions

Clean and healthy matured seeds of rockmelon (*C. melo* cv. 'Glamour') with a germination rate of >90% were pre-germinated in seed trays containing peat-moss as sowing medium. Trays were watered twice daily (80%; w/v) by use

Table 5. Effect of inoculation and EC on nutrient level (ppm) in the leaves at 30 DAT.

Nutrient elements	N	P	K	Ca	Mg	Fe	Cu	Zn
Inoculation								
Un-inoculated	0.48c	15.87a	86.35c	27.72d	2.79c	0.32a	0.01b	0.11a
G. mossae	0.58a	14.00c	95.52b	33.54b	2.89b	0.27b	0.02a	0.10b
B.cepacia	0.42d	13.72d	111.00a	34.29a	2.91a	0.25c	0.02a	0.09c
B.cepacia+G. mossae	0.54b	14.27b	82.72d	30.25c	2.80c	0.24c	0.01b	0.09c
EC (dS/m)								
1.5	0.60a	15.00a	107.49a	31.99b	2.87b	0.31a	0.02a	0.10a
2.0	0.41c	13.53c	94.28b	34.49a	2.89a	0.28b	0.01b	0.09b
2.5	0.50b	14.86b	80.68c	27.87c	2.78c	0.21c	0.01b	0.09b
CV	0.28	0.49	1.40	0.34	0.27	2.94	1.33	4.00

The values are the average of eight replications. CV= coefficient of variation. DAT= days after transplanting. Means within columns followed by the same alphabets are not significantly different at *p<0.05* (Tukeys test). N: Nitrogen, P: phosphorus, K: potassium, Mg: magnesium, Ca: calcium, B: boron, Fe: iron, Mn: manganese Cu: copper and Zn: zinc. EC: electrical conductivity, DAT= days after transplanting.

Table 6. Effect of inoculation and electrical conductivity on nutrient level (ppm) in the roots at 30 DAT.

Nutrient elements	N	P	K	Ca	Mg	Fe	Cu	Zn
Inoculation								
un-inoculated	0.33d	3.49d	8.08d	5.11a	1.89c	9.15c	0.03c	0.13a
G. mossae	0.35c	4.03c	8.75b	3.89b	1.87d	7.49d	0.04b	0.07c
B.cepacia	0.38b	5.26a	8.34c	1.36d	1.96b	12.87a	0.05a	0.12a
B.cepacia+G. mossae	0.40a	5.15b	10.83a	2.16c	2.08a	10.73b	0.04b	0.10b
EC (dS/m)								
1.5	0.38b	2.80c	10.66a	4.53a	1.77c	7.11c	0.03c	0.07c
2.0	0.31c	5.63a	7.35c	2.33c	2.06a	11.75a	0.05a	0.16a
2.5	0.39a	5.01b	8.99b	2.53b	2.01b	11.32b	0.04b	0.09b
CV	0.12	0.51	0.98	0.17	0.39	0.52	0.49	3.92

The values are the average of eight replications. CV= coefficient of variation. DAT= days after transplanting. Means within columns followed by the same alphabets are not significantly different at *p<0.05* (Tukeys test). N: Nitrogen, P: phosphorus, K: potassium, Mg: magnesium, Ca: calcium, B: boron, Fe: iron, Mn: manganese Cu: copper and Zn: zinc. DAT= days after transplanting. ppm=part per million

Table 7. Effect of inoculation and electrical conductivity on fruit weight, fruit diameter and sweetness of the rockmelon at 70 DAT.

Inoculation	Fruit weight (kg)	Fruit Diameter (cm)	Sweetness (% Brix)
un-inoculated	1.45b	39.70a	11.93a
G. mossae	1.77a	45.86a	11.60a
B.cepacia	1.78a	45.93a	11.47a
B.cepacia+G. mossae	1.71a	45.79a	11.04a
EC (dS/m)			
1.5	1.56b	43.87ab	11.23a
2.0	1.98a	47.60a	12.21a
2.5	1.57b	41.49b	11.10a
CV	11.95	11.73	12.88

The values are the average of eight replications. CV= coefficient of variation. DAT= days after transplanting. Means within columns followed by the same alphabets are not significantly different at *p<0.05* (Tukeys test). N: Nitrogen, P: phosphorus, K: potassium, Mg: magnesium, Ca: calcium, B: boron, Fe: iron, Mn: manganese Cu: copper and Zn: zinc. DAT= days after transplanting.

of a small hand sprayer until wet to ensure healthy seedling germination and growth. After one week of establishment, the seedlings were transplanted one and a half cm in depth (approximately) into 30 x 25 cm polybags [white disposable polybags with 20 x 20 inches (Fajama Trading Sdn Bhd, Selangor, Malaysia)] with one seedling per bag and grown for 30 days.

Preparation of bacterial strain

Isolated bacteria, *B. cepacia* and *G. mossae*, were used in this study. *Burkholderia cepacia* was grown on OMA plates (7.25% oatmeal agar, Difco Co., Detroit, MI, USA), in PDB (2.4% potato dextrose broth, Difco Co.), or in YG (0.5% yeast extract, 2% glucose) at 25°C or 28°C. The bacterial suspension was prepared as described by Dhirga and Sinclair (1995).

Experimental design, microorganisms, growth medium and electrical conductivity

Four treatments [control (uninoculated), *B. cepacia, G. mossae* and mixture of *B. cepacia* and *G. mossae (B. cepacia+G. mossae)*], 3 different EC of liquid fertilizer (1.5, 2.0 and 2.5 dS/m) by using fertigation system were evaluated in a randomized complete block design (RCBD) with 8 replicates. Ten grams of *G. mossae* containing 64 spores/10 g and 5g (6.8 x 10^8 colony forming units) of encapsulated *B. cepacia* beads from symptomless oil palm root tissues and mixture 5g of *B. cepacia* beads with 10g of mycorhizae were added after one week of transplanting (Palumbo et al., 1971). The mycorhizae was then added to the bottom of root of rockmelon (3 cm depth) and bacteria were spread on the surface of the media. The UPM- fertilizer formulation was used in this experiment (Table 1).

The growth medium (total 2 kg of media was used) was a mixture of coconut dust and empty fruit bunch composted (3:1; v/v basis). In each fertilizer storage tanks, the EC of the solutions were 1.5, 2.0 and 2.5 dS/m, respectively. The nutrient solutions were pumped through a drip-fertigation system twice a day with a total of 2 L/plant. The surroundings of the rain shelter and inside the polybags were weeded once in a month to ensure the normal plant growth without weed competition. Insecticides (malathion, chloropyrifos and deltamethrin) and fungicides (chlorothalonil, thiram and mancozeb) were applied once a week by battery sprayer (model Top-M, 16L, Malaysia) in alternate sequence as and when necessary to control insect pests and diseases. In order to ensure randomization, the positions of the polybags were rearranged every 5 day under the light phase.

Measurements of plant and fruit growth parameters

Root infection determination of mycorhizae (Phillips and Hayman, 1970) and colonizes of bacteria (Palumbo et al., 1971) were performed after one month of transplanting. Crop growth and fruit characteristics including plant height (cm) at 7, 14 and 21 DAT, number of leaves, root length (cm) at 7, 14, 21 DAT, fresh fruit weight at 70 DAT (kg), total fresh fruit weight/plant (kg), diameter of fruits (cm), sugar content of the fruit (% brix, by Pocket Refractometer PAL-1, Model Atago, Japan), EC (HI 98311 portable Hanna EC meter) and pH (Bench top pH meter, Model HI 223 Hanna) in the media at 30 and 70 DAT were recorded. The average dry-mass of roots and shoots (stem and leaves) from each pot was determined after heating the samples at 60°C for 1 hour, and compared between plants with inoculated and uninoculated soil treatments. Photosynthesis rate ($\mu mol/m^2/s$) and leaves area meter (cm^2) were measured using portable photosynthesis machine (Li-Cor 6400, USA) and bench top leaf area meter (Li-Cor 3100C, USA). Soils were sampled at the top 10 cm depth to determine available (nitrogen: N, phosphorus: P, potassium: K, calcium: Ca, magnesium: Mg, iron: Fe, cupper: Cu, and zinc: Zn) nutrients in the media. Five ml of sulfuric acid were added to 0.5g of sample in a flask on the digestion block. The nutrient analysis was performed according to Cresser and Parsons (1979). Atomic absorption spectrophotometer (Perkin Elmer 3110, Malaysia) was used for the determination of macro and micro elements.

Statistical analysis

The data were statistically analyzed using the analysis of variance (ANOVA) procedure in the SAS Statistical Software Version 9.0, using a RCBD. Tukey studentized range test was used to compare variation among the treatments ($p<0.05$). To confirm the results, each experiment was repeated with 8 replications. Bacterial population values were transformed to Log10 before subject to statistical analyses.

Conclusion

On the basis of obtained results, we conclude that EC at 2.0 dS/m would be the optimum nutrient requirement for the growth and yield of rockmelon plant. The microbes that substantially improved the yield of rockmelon as compared with the control could be used as soil/seed-treating agents for the growth and development of rock melon. The sugar content in all treatments was in-between 11-12% Brix, therefore, potential use of these soil/seed-treating microbes and EC for crop production should be focused on future research.

Acknowledgements

This research was supported by the Universiti Putra Malaysia (UPM) Research University Grant and SCIENDFUND R&D PERTANIA, MOA, Malaysia (RUGS 91563 and 5450550). The authors highly thank N.M. Nik Rodzha, M.Y. Nor Rafidah, M. Adzan, A.M. Desrafiel, M. AZ, A. Ummi Kalthum, K. Mohd Khoiri and S. Ramley for their kind help in the experimental field and laboratory assays.

References

Afzal A, Ashraf M, Saeed AA, Faroo M (2005) Effect of phosphate solubilizing microorganisms on phosphorus uptake, yield and yield traits of heat (*Triticum aestivum* L.) in rainfed area. Intl J Agric Biol 2:207-209.

Ahmad I, Sheikh MY, Ahmad F (2005) Microbial diversity of rhizospheric soil with special reference to plant growth promoting isolates of *Azotobacter*. Biosci Biotech Res Asia 3:51-58.

Berta G, Trotta A, Fusconi A, Hooker JE, Munro M, Atkinson D, Giovanetti M, Morini S, Fortuna P, Tiserrant T, GlaninAzzi-Pearson V, Gianinazzi S (1995) Arbuscular mycorrhizal induced changes to plant growth and root system morphology in *Prunus cerasifera.* Tree Physiol 15:281-293.

Brundrett MC (2002) Coevolution of roots and mycorhizae of land plants. New Phytol 154: 275-304.

Cresser MS, Parsons JW (1979) Sulfuric-perchloric acid digestion of plant material for the determination of nitrogen, phosphorus, potassium, calcium and magnesium. Analytica Chimica Acta 109:431-436.

Dhirga OD, Sinclair JB (1995) Basic Plant Pathology Methods (2nd Ed). CRC Press. Evans RD, Johnsen DL (1999) Microbiotic crusts and ecosystem processes. Critical Rev Plant Sci 18:183-225.

Gifford RM, Evans LT (1981) Photosynthesis, carbon partitioning, and yield. Annu Rev Plant Physiol 32:485-509.

Harper, JL, M. Jones and NR Hamilton (1991) The evolution of roots and the problems of analyzing their behavior. *In* Plant Root Growth. An Ecological Perspective. Ed. D. Atkinson. Blackwell Scientific Publications, Oxford, p 3-24.

Harris D, Pacovsky RS, Paul EA (1985) Carbon economy of soybean–rhizobium–glomus associations. New Phytol 101:427-440.

Hinsinger P, Plassard C, Tang C, Jaillard B (2003) Origins of root-mediated pH changes in the rhizosphere and their responses to environmental constraints: A review. Plant Soil 248**:**43–59.

Hwang J, Chilton WS, Benson DM (2002) Pyrolnitrin production by *Burkholderia cepacia* and biocontrol of Rhizoctonia stem rot of poinsettia. Biol Control 25:56-63.

Karimaei MS, Massiha S, Mogaddam M (2004) Comparison of two nutrient solutions' effect on growth and nutrient levels of lettuce (*Lactuca sativa* L.) cultivars. Acta Hort 644:69-76.

Kaschuk G, Thomas W, Kuyper B, Peter A, Leffelaar A, Hungria MC, Giller KE (2009) Are the rates of photosynthesis stimulated by the carbon sink strength of rhizobial and arbuscular mycorrhizal symbioses? Soil Biol Biochem 41:1233-1244.

Kloepper JW, Reddy MS, Kenney DS, Vavrina C, Kokalis-Burelle N, Martinez-Ochoa N (2004) Applications for rhizobacteria in transplant production and yield enhancement. Acta Hort 631:219-229.

Kokalis-Burelle N, Vavrina CS, Reddy MS, Kloepper JW (2003a) Amendment of muskmelon and watermelon transplant media with plant growth-promoting rhizobacteria: effects on disease and nematode resistance. Hort Technol 13:476-482.

Kokalis-Burelle N (2003b) Effects of transplant type and soil fumigant on growth and yield of strawberry in Florida. Plant Soil 256:273-280.

Lambers H, Mougel C, Jaillard B, Hinsinger P (2009) Plant-microbe-soil interactions in the rhizosphere: an evolutionary perspective. Plant Soil 321:83-115.

Narwal SS (2000) Allelopathic interactions in multiple cropping systems. In: SS Narwal et al. (eds), 141-157. *Allelopathy in ecological agriculture and forestry*. Kluwer Academic Publishers, Netherlands.

Paul MJ, Peliny TK (2003) Carbon metabolite feedback regulation of leaf photosynthesis and development. J Exp Bot 54:539-547.

Palumbo SA, Johnson MG, Rieck VT, Witter LD (1971) Growth measurements on surface colonies of bacteria. J Gen Microbiol 66:137-143.

Phillips JM, Hayman DS (1970) Improved procedures for clearing roots and staining parasitic and vesicular-arbuscular mycorrhizal fungi for rapid assessment of infection. Trans Br Mycol Soc 55:158-161.

Richardson AE, Barea J-M, McNeill AM, Prigent-Combaret C (2009) Acquisition of phosphorus and nitrogen in the rhizosphere and plant growth promotion by microorganisms. Plant Soil 321:305–339.

Schubler A, Kluge M (2000) Geosiphon pyriformae, an endocotosysmbiosis between fungus and cyanobacteria, and its meaning as a model system for Arbuscular mycorrhizal research. In: Hock B (ed) The mycota IX fungal associations, Springer, Berlin Germany, pp 151-161.

Smith SE, Read DJ (2008) Mycorrhizal Symbiosis, 3rd edn. Elsevier Ltd, London.

Vessey JK (2003) Plant growth promoting rhizobacteria as biofertilizers. Plant Soil 255:571-586.

Villanueva MJ, Tenorio MD, Esteban MA, Mendoza MC (2004) Compositional changes during ripening of two cultivars of muskmelon fruits. Food Chem 87:179-185.

Wang DYC, Kumar S, Hedges SB (1999) Divergence time estimates for the early history of animal phyla and the origin of plants, animals and fungi. Proceedings of the Royal Society of London B 266:163-171.

Yazdani M, Bahmanyar MA, Pirdashti H, Esmaili MA (2009) Effect of phosphate solubilization microorganisms (PSM) and Plant Growth Promoting Rhizobacteria (PGPR) on yield and yield components of corn (*Zea mays* L.). World Acad Sci Eng Technol, 49:91-92.

Zulkarami B, Ashrafuzzaman M, Razi MI (2010) Morphophysiological growth, yield and fruit quality of rockmelon as affected by growing media and electrical conductivity. J Food Agric Environ 8:249-252.