Australian Journal of Crop Science AJCS

AJCS 5(12):1508-1514 (2011) ISSN:1835-2707

Effect of pyroligneous acid on growth, yield and quality improvement of rockmelon in soilless culture

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Abstract

Three fertilizer formulations namely; (M), a local formulation commonly used by farmers, the recommended Cooper standard (CS), and Benoit (BEN) suggested for the lower cost of production were evaluated in combination with four levels of pyroligneous acid (0, 10, 20 and 30%) for enhancement of growth, fruit yield and quality of rockmelon in soilless culture. The addition of 30% pyroligneous acid was toxic as most plants died at this concentration. Twenty percent (20%) pyroligneous acid increased the growth and yield of rockmelon plants, but the local formulation in combination with 10% pyroligneous acid gave the best results. This combination significantly improved plant growth, fruit weight, fruit diameter and sweetness of fruits. Hence the local formulation in combination with 10% of pyroligneous acid is recommended for good fruit yields in rockmelons.

Keywords: Pyroligneous acid, fertilizer formulations, rockmelon, growth, yield, quality,soilless culture.
Abbreviations: DAT-Days after transplanting PPM-parts per million; EC-electrical conductivity.

Introduction

Melon (*Cucumis melo* var. Cantalupensis) is an important commercial crop in many countries. It is mostly cultivated in the temperate regions of the world due to its good adaptation to temperate soil and climate. Rockmelon fruits are highly consumed in the summer and are popular because of it's sweet pulp and the pleasant aroma (Villanueva et al., 2004). In Malaysia, the cantaloupe type, especially the cultivar 'Glamour' (known locally as 'Golden Langkawi') with the striking golden yellow color is the favourite. Like other species of melons, cantaloupes thrives best in sandy, well-aerated, moistured soil in weed-free conditions (Zulkarami et al., 2010). Pyroligneous acid or wood vinegar is the crude condensate produced from the distillation of volatiles substances generated in the process of making charcoal. This by-product is rarely used and often disposed off as waste. Pyroligneous acid comprises of small amounts of cadmium (Cd), arsenic (AS) and plumbum (Pb). The synonyms for pyroligneous acid include pyrolysis oil, pyrolysis liquid, wood liquid, liquid smoke, liquid wood, bio-oil, bio-crude oil and wood distillate. Chemically, it occurs as a complex mixture of water, guaiacols, catecols, syringols, vanillins, furan carboxaldehydes, isoeugenol, pyrones, acetic acid, formic acid and other carboxylic acids. Major groups of compounds present in Pyroligneous acid includes; hydroxyaldehydes, hydroxyketones, sugars, carboxylic acids, and phenolics (Fengel and Wegener, 1983; Guille'n and Manzanos, 2002). Wood distillate have been used in traditional agriculture to increase seedling vigour and crop stands (Modi, 2002). In the past decade aqueous pyroligneous acid extracts have been used extensively as germination stimulants in a wide range of plants (Brown and Van Staden, 1997; Van Staden et al., 2000; Brown et al., 2003; Light and Van Staden, 2004). The use of aqueous smoke extracts have not been limited to seed germination. Promontory effects on flowering (Keeley, 1993), Roots (Taylor and Van Staden, 1996) and somatic embryogenesis (Senaratna, 1999) have also been reported. Pyroligneous acid have also been shown to induce new branches, elongate roots, and increase plant height and grain yield (Tsuzuki et al., 1989). Thus, wood distillates (pyroligneous acid) have great potential for utilization in horticulture, agriculture, weed management, habitat restoration and conservation practices (Roche et al., 1997; Boucher and Meets, 2004; Light and Van Staden, 2004). The aim of this study was to compare the effects of three fertilizer formulations (M, CS and BEN) in combinations with different concentrations of pyroligneous acid on plant growth, fruit yield and quality of rockmelon (*Cucumis melo* L. *cv*. 'Golden Langkawi').

Results and discussion

Plant height

At 17 Days after transplanting (DAT), the tallest plants were recorded in treatments with formulation M (188.83 cm), followed by BEN (177.29 cm), while the shortest plants were observed with the CS formulation (175.23 cm). The taller plants at 10 DAT were recorded with the 0, 10 and 20% concentration of pyroligneous acid (86.78, 95.90 and 86.06 cm, respectively). However, there were no significant

Table 1. Semi-volatile organics in pyroligneous acid (GC-MS fingerprinting using Agilent Tech 6890N GC with Agilent Tech 5973 inert MSD and HP 7694 headspace sampler)

No.	Identified	Hit list (%)
1.	Pyrogallol 1,3-dimethyl ether (ester group)	93†
2.	2-methoxy-benzeneethanol (alcohol group)	90
3.	1,2,3-trimethoxy-5-methyl benzene (ester group)	87
4.	Methyl 3-methoxy-4-hydroxybenzoate	72
5.	3-(o-Azidophenyl) propanol (alcohol group)	72
6.	N-(dimethylthiophosphinyl)-3-amino pyridine	72
7.	2-pyridinepropanoic acid (acid group)	64
8.	2,5-dimethylphenol (alcohol group)	64

†Values are means of 3 replications

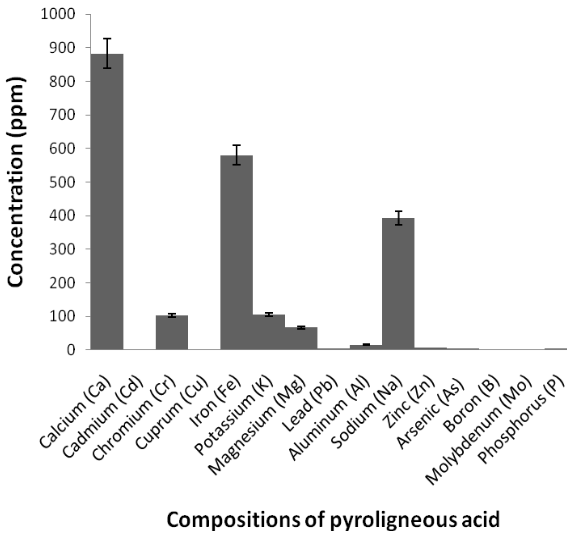


Fig 1. Quantitative analysis of pyroligneous acid using inductively coupled plasma-mass spectrometer (ICP-MS, Model DRC-e).

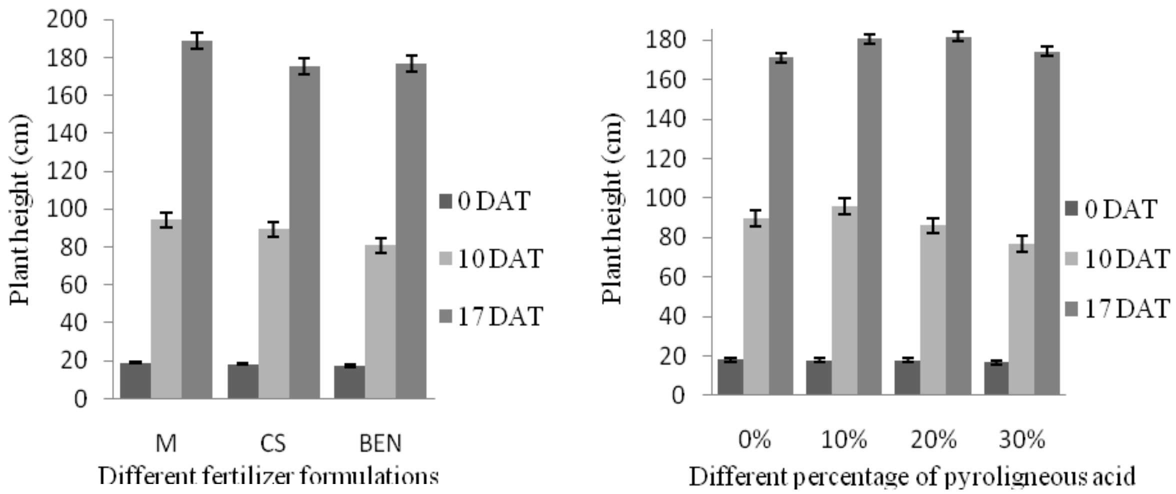
differences between the fertilizer formulations. The use of the local fertilizer formulation (M) resulted in taller plants compared to the other fertilizers applied throughout the growth stages, indicating that this fertilizer formulation and pyroligneous acid had positive effects on growth and development of rockmelon plants (Fig. 2). The increased plant height in M fertilizer formulation compared to other formulations was possibly due to the better growth conditions provided by the media (Shinde et al., 1999). The increased plant height can be attributed to the higher nutrient composition in M formulation, especially calcium nitrate, potassium nitrate, magnesium sulfate and mono potassium. Calcium is an important element for cell division and root development and functioning (Evans and Sorger, 1966; Zekri, 1995a: Zekri, 1995b). The high level of potassium in the M fertilizer formulation would have enhanced cell division and plant growth. There were significant increase in plant height with the addition of 10 % pyroligneous acid at 10 DAT. These results revealed that pyroligneous acid promoted growth. Similar results have been previously reported in three vegetable crops (tomato, okra and bean) with significant improvement in seedling vigour and growth in comparison to controls when treated with pyroligneous acid (Van Staden et al., 2006). In addition, pyroligneous acid is rich in nutritional components (Narwal, 2000; Tsuzuki et al., 1989) that attracts microbes including bacteria and fungus to roots of plants where symbiosis occurs. The positive effects of bacterial and mycorhizal symbiosis can be 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).

Number of leaves

Irrespective of treatments, the number of leaves increased with increasing plant age (Table 5). However, M fertilizer formulation produced significantly higher number of leaves per plant compared with other fertilizer formulations, with mean values of 24 and 42 at 10 and 17 DAT, respectively. No significant variation in the number of leaves was observed with the pyroligneous acid treatments at 10 and 17 DAT. At 17 DAT, the lowest number of leaves was observed with the CS fertilizer formulation yielding an average of 37. The number of leaves per plant increased rapidly from 10 to 17 DAT. There was no significant variation observed in the number of leaves in different concentrations of pyroligneous acid. However, there were significant differences in pyroligneous treatments in combination with fertilizer formulations. It has also been previously reported that with nitrogen (N), phosphorus (P), potassium (K) and pyroligenous acid, more leaf biomass was obtained (Singh et al., 2009). In the present study plants treated with M formulation produced significantly higher number of leaves at 10 and 17 DAT. The higher leaf number recorded in the M formulation was probably because of the high calcium content in the medium, which boosted leaf production. Ruiz et al., (1999) had reported similar results in tobacco

Table 2. Chemical composition of fertilizer formulations

Elements	Local Formulation (%)	Cooper standard (%)	Benoit (%)
	Stock A		
Calcium nitrate	24.36	22.03	12.72
Ferum chelate (EDTA)	0.42	1.76	2.60
Potassium nitrate			0.12
	Stock B		
Potassium nitrate	22.26	12.98	3.32
Magnesium sulfate	12.54	11.41	3.20
Manganese sulfate	0.04	0.08	0.08
Boric acid (Boron)	0.14	0.14	0.14
Cooper sulfate	0.08	0.08	0.08
Ammonium molybdate	0.01	0.01	0.01
Zinc sulfate	0.08	0.08	0.08
Monopotassium	5.84	5.84	2.21
Potassium sulfate			0.29



Means over eight replications

Fig 2. Effect of (A) different fertilizer formulations, and (B) concentrations of pyroligneous acid, on height of rockmelon plants during the first 17 DAT. (M: Local formulation, CS: Cooper standard, BEN: Benoit fertilizer formulation).

(*Nicotiana tabacum* cv Sevilla) where the application of calcium chloride gave rise to greater production of leaf and root dry matter compared to the control.

Constituents of pyroligneous acid fraction

Inductively Coupled Plasma Mass-Spectrometry (ICP-MS) analysis of the pyroligneous acid samples revealed the presence of 15 elements. The elements detected were calcium, cadmium, chromium, copper, iron, potassium, magnesium, lead, aluminum, sodium, zinc, arsenic, boron, molybdenum and phosphorus. Highest concentrations were recorded for calcium, iron and sodium with levels of 8.82, 5.80 and 3.93 ppm, respectively (Fig. 1). Cadmium, copper, lead, arsenic, zinc, boron, molybdenum and phosphorus were present at very low levels, while chromium, potassium, magnesium and aluminum were present at intermediate levels. Semi-volatile organic compounds detected in pyroligneous acid were pyrogallol 1,3-dimethyl ether, 2-methoxy-benzeneethanol, 1,2,3-trimethoxy-5-methyl benzene, 3-(o-azidophenyl) propanol, N-(dimethylthiophosphinyl)-3-amino pyridine, 2-pyridinepropanoic acid and 2,5-dimethylphenol. Compounds present in significant quantities were pyrogallol 1,3-dimethyl ether (93 %), followed by 2-methoxy-benzeneethanol (90 %), and 1,2,3-trimethoxy-5-methylbenzene (80 %), (Table 3). The pyroligneous acid comprised of several major volatile compounds such as pyrogallol 1,3-dimethyl ether, 2-methoxy-benzeneethanol and 1,2,3-trimethoxy-5-methyl benzene (Table 2), which accounts for the final aroma (Natera et al., 2002). The aroma component determines the quality of the pyroligneous acid. These include alcohols, esters, carbonyls, acids, phenols, lactones and acetals (Callejón et al., 2008). Although the chemical identity of the main active compounds in pyroligneous acid has only recently been discovered (Van Staden et al., 2004), the remarkable effect of smoke on seed germination is widely known and utilized in various ways (Roche et al., 1997: Brown and Van Staden, 1997; Van Staden et al., 2000).

Effect of treatments on fruit production

Fruit weights were recorded at 110 DAT (Table 6). Results revealed that fresh fruit weight was significantly higher with M fertilizer formulation, indicating that this formulation had positive effects in increasing fruit weight. The highest fruit

Table 3. Available macro and micro nutrients in the growth medium (**ppm**)

Media	N†	P	K	Mg	Ca	Fe	Zn
Coconut dust with empty fruit bunch (3:1, v/v)	7700††	900	8700	9000	11500	16.73	40.56

†Nitrogen=N, Phosphorus=P, Potassium=K, Magnesium=Mg, Calcium=Ca, Iron=Fe, Zinc=Zn.
††Values are means of 3 replications.

Table 4. Variation in electrical conductivity and pH of the different fertilizer formulations during the experiment.

Date	Cooper standard (CS)		Local formulation (M)		Benoit (BEN)	
	EC (dS/m)	pH	EC (dS/m)	pH	EC (dS/m)	pH
05.07.09	2.28	5.64	3.28	5.62	1.53	5.64
12.07.09	2.33	5.50	2.88	5.61	1.48	5.61
19.07.09	2.08	5.67	2.90	5.60	1.32	5.64
26.07.09	2.25	5.64	2.80	5.62	1.45	5.57
02.08.09	2.20	5.62	2.92	5.64	1.46	5.52
09.08.09	2.18	5.68	2.86	5.60	1.39	5.58
16.08.09	2.21	5.55	2.86	5.56	1.48	5.63
23.08.09	2.22	5.58	2.81	5.61	1.45	5.60
30.08.09	2.10	5.63	2.79	5.68	1.39	5.75
06.09.09	2.22	5.45	2.63	5.64	1.41	5.76

Values are means of 3 replications.

weight of 1.86 kg was observed with 10% of pyroligneous acid in combination with the M formulation followed by CS and BEN fertilizer formulations and 20, 30 and 10% pyroligneous acid treatments, respectively. The lowest fruit weight of 1.43 kg was obtained with BEN fertilizer formulation without pyroligneous acid. Fruit diameter was significantly different in different fertilizer formulations. Fruit diameter varied significantly with different application percentages of pyroligneous acid (Table 6). The larger fruit diameter of 14.43 and 14.25 cm were recorded in M and CS fertilizer formulation with 10 and 20% of pyroligneous acid, respectively. The smallest fruit diameter of 13.24 cm was recorded in BEN fertilizer formulation with 0% pyroligneous acid. M and CS fertilizer formulations resulted in sugar contents of 12.68, 12.63% (Brix) (Table 6). The results on sugar content (% Brix) of rockmelons revealed significant differences between treatments. Pyroligneous acid treatments at 10, 20 and 0% resulted in fruit sugar contents of 13.00, 12.89 and 12.64% Brix, respectively. Higher fruit weights produced with the 10% pyroligneous acid is attributed to the better root system produced with this treatment. A similar increase in fruit yield obtained in fertigation with 100% water-soluble fertilizer (WSF) was attributed to lesser leaching of nitrate-N and K to deeper layers of soil (Hebbar et al., 2004). Fruit weight and size were better in the M fertilizer formulation probably due to presence of more nutrients than in other fertilizer formulations. These include calcium nitrate, potassium nitrate, magnesium sulphate, and monopotassium phosphate. Highest fruit weight, fruit size and sweetness in M fertilizer treatments was attributed to the beneficial effects of pyroligneous acid, which enhanced fruit production and quality (Fig. 1 and Table 3). Large amounts of assimilates produced (Gifford and Evans, 1981) and the associated high sink strength were important factors in determining high yields in crop production as shown in the M fertilizer treatments with 10% of pyroligneous acid. Fruit weight increased by 37.3 and 27.5% with 10 and 20% pyroligneous acid compared with control, respectively. Pyroligneous acid is known to be rich in nutritional components that increase fruit yield and size (Narwal, 2000; Tsuzuki et al., 1989). The local formulation resulted in only a 4% increase in fruit weight compared to the CS fertilizer formulation. However, the BEN formulation resulted in 21% lower fruit weight than the M fertilizer formulation. Interestingly, pyroligneous acid enhanced the fruit weight of rockmelon plant due to the better root system, flowering and growth of the plant. 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. Harris et al. (1985) suggested that C sink strength of symbioses stimulated the rate of photosynthesis. The pyroligneous acid contains several esters, alcohols, acids and several heavy metals which may have contributed to better growth and production (Fig. 1 and Table 3). Previous studies have also shown that pyroligneous acid interacts with gibberellins, cytokinins, abscisic acid and ethylene in photoblastic and thermodormant seeds (Van Staden et al., 2000). It has also been suggested that the active principles in pyroligneous acid behaves in a manner similar to that of other plant growth regulators (Senaratna et al., 1999; Gardner et al., 2000). However, it is not yet clearly understood how pyroligneous acid promotes growth or how it interacts with other plant hormones. 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). The sugar content in all fertilizer formulation treatments in combination with pyroligneous acid were between 12 to13%. In terms of cost, CS fertilizer formulation is more costly followed by M and BEN. The highest total weight of fertilizer used was the local formulation with almost 33 kg. The lowest total weight of fertilizer used was with the BEN fertilizer formulation (14 kg). With the higher total weight of fertilizer extra transportation cost will be involved. In terms of nitrate content, BEN fertilizer formulation was more environmental friendly, followed by CS and M with 13, 17 and 24 kg, respectively.

Residual nutrients in the media

Residual nutrients in the media at 73 DAT showed that the BEN fertilizer formulation had the largest number of

Table 5. Effect of fertilizer formulations and pyroligneous acid on number of leaves produced per plant.

Fertilizer formulations	0 DAT	10 DAT	17 DAT
M	13a	24a	42a
CS	12a	23ab	37b
BEN	12a	23ab	40ab
Pyroligneous acid (%)			
0	12a	23a	40a
10	12a	22a	37a
20	12a	23a	41a
30	12a	22a	39a
CV	14.98	17.39	10.76

M=Local formulation, CS=Cooper standard, BEN=Benoit fertilizer formulation and CV= Coefficient of variation.
Values are means of eight replications; Means within columns followed by the same letters are not significantly different at *P<0.05* (Tukeys test).

Table 6. Effect of fertilizer formulations and pyroligneous acid on fruit yield and quality

Treatments	Fertilizer formulations			Pyroligneous acid (%)				CV
	M	CS	BEN	0	10	20	30	
Fruit weight (kg)	1.73a	1.66b	1.43c	1.34d	1.86a	1.71b	1.52c	4.46
Fruit diameter (cm)	14.43a	14.25a	13.77b	13.24c	14.62a	14.64a	14.08b	2.76
Sweetness (%BRIX)	12.68a	12.63ab	12.25b	12.64a	13.00a	12.89a	11.53b	2.97

Values are means of eight replications; Means within columns followed by the same letters are not significantly different at *P<0.05* (Tukeys test).
M=Local formulation, CS=Cooper standard, BEN=Benoit fertilizer formulation and CV= Coefficient of variation.

Table 7. Effect of fertilizer formulations and pyroligneous acid on residual nutrient levels in the growth medium at harvest after 73 DAT (mg/L).

Treatment	N	P	K	Ca	Mg	Fe	Cu	Zn
Fertilizer formulations								
M	31.38c	3.32b	18.53a	3.13a	6.29a	18.91b	0.08c	0.28b
CS	37.06b	4.18a	18.02a	2.52b	5.45b	28.60a	0.16b	0.26c
BEN	44.55a	4.37a	16.08a	1.23c	5.76b	28.52a	0.24a	0.32a
Pyroligneous acid (%)								
0	38.57a	3.77b	16.77ab	2.39a	5.27b	32.55a	0.25a	0.35a
10	36.06a	4.12a	15.37b	2.12a	6.32a	23.66b	0.14b	0.28b
20	38.46a	4.43a	18.54ab	2.55a	5.81ab	24.34b	0.13b	0.25c
30	37.56a	3.49b	19.49a	2.12a	5.92a	20.83b	0.13b	0.26bc
CV	8.78	6.30	15.61	20.44	7.61	12.26	24.05	7.91

Nitrogen=N, Phosphorus=P, Potassium=K, Magnesium=Mg, Calcium=Ca, Iron=Fe, Cuprum=Cu and Zinc=Zn.
M=Local formulation, CS=Cooper standard, BEN=Benoit fertilizer formulation.
Values are means of eight replications. Means within columns followed by the same letters are not significantly different at *P<0.05* (Tukeys test).

nutrients at significantly high levels (Table 7). Significantly high residual levels of nitrogen (N), phosphorus (P), iron (Fe), copper (Cu) and zinc (Zn) were observed with BEN formulation at 73 DAT with 44.55, 4.37, 28.52, 0.24 and 0.32 mg/L, respectively. Higher amounts of P (4.15 mg/L) and Fe (28.60 mg/L) were retained in CS treatments, while higher levels of Ca (3.13 mg/L) and Mg (6.29 mg/L) were retained in treatments with the M fertilizer formulation. High levels of Fe, Cu and Zn were retained in control treatments without pyroligneous acid with 32.55, 0.25 and 0.35 mg/L, respectively. Ten and twenty percent pyroligneous acid treatments resulted in phosphorus and potassium residues of 4.12 and 19.49 mg/L, respectively. Both of these elements remaining in the 20% pyroligneous acid treatments were 4.43 and 18.54 mg/L. The nutrient uptake was better in M and CS fertilizer treatments than in the BEN formulation treatment. Consequently, this resulted in better fruit weights in these fertilizer treatments. The dark green color of leaves in M fertilizer treatments is attributed to the high N content, which was essential for good cell division, growth and respiration (Evans and Sorger, 1966; Zekri, 1995a: Zekri, 1995b). However, in CS fertilizer treatments, the lower residual K was associated with a higher chlorophyll reading. This was attributed to the important role of K in stomatal movements, and in many physiological functions such as formation of sugars and starch, and synthesis of proteins (Evans and Sorger, 1966; Zekri, 1995a: Zekri, 1995b). Residual elements such as Mg, Zn, and N in the media affected growth and fruit weight of rockmelon plants. Ten percent pyroligneous acid treatment resulted in lower residual K in the media and higher fresh fruit weight, which suggests higher K uptake by the plants.

Materials and methods

Plant materials

The experiment was conducted in the rain shelter facilities of Kumpulan Pertanian Kelantan Berhad, Bachok, Kelantan, Malaysia (Latitude: 6.067, Longitude: 102.400). Rockmelon seeds (*Cucumis melo* L, *cv*. 'Glamour') were planted in seed trays containing peat-moss as sowing medium. Trays were watered twice daily (1 liter per tray) to ensure healthy seedling germination and growth. After one week of establishment, seedlings were transplanted into 30 x 25 cm polybags with one seedling per bag. The pyroligneous acid from MM Charcoal Company in Taiping, Perak, Malaysia is a by-product resulting from the burning of mangrove wood to produce charcoal. Samples were taken in triplicate to determine heavy metals by Inductively Coupled Plasma Mass-Spectrometry (ICP-MS; Model DRC-e, PerkinElmer Inc.) and analysis of semi-volatile organics by Gas chromatography-Mass spectrometry (GC-MS) fingerprinting (Agilent Tech 5973, Inert MSD and HP 7694 Headspace Sampler) (Table 1).

Experimental design

The three types of fertilizer formulations evaluated were; a local formulation (M), Cooper Standard (CS) and Benoit (BEN) (Table 2). The growth medium was a 3:1 v/v mixture of coconut dust and empty oil palm fruit bunch fibres (Table 3). Dilutions were carried out by adding 10, 20 or 30 ml of concentrated pyroligneous acid to 90, 80 or 70 ml of distilled water respectively, to obtain 10, 20 and 30% concentrations of pyroligneous acid. Ten ml of 0, 10, 20 or 30% of pyroligneous acid was added once a week to the planting media from transplanting to the third week of crop growth. In all fertilizer storage tanks, the electrical conductivity (EC) of the solutions were maintained within the range of 1.0 to 3.0 dS/m, while the pH of the solution was recorded (Table 4). The nutrient solutions were pumped through a drip fertigation system, twice a day with a total of two litres per plant. The polybags were weeded once per month to ensure normal plant growth without weed competition. Insecticides (malathion, chloropyrifos and deltamethrin) and fungicides (chlorothalonil, thiram and mancozeb) were applied in alternate sequence as and when necessary to control insect pests and diseases. Treatment combinations of four levels of pyroligneous acid (including control) and the three fertilizer formulations were arranged in a randomized complete block design with eight replicates. Preliminary quantitative and qualitative analysis of semi-volatile organics present in pyroligneous acid was performed. Crop growth and fruit characteristics recorded includes; plant height (at 0, 10, 17 days after transplanting), number of leaves, fruit weight, diameter of fruits, and fruit sugar content (% Brix). Media (CD+EFB) were sampled at the top 10 cm depth to determine available nutrients in the media. The samples were oven-dried at 46 ^{o}C for 72 hours. Five ml of sulfuric acid were added to 0.5 g of dried sample in a flask on the digestion block. After 7 minutes, 20 ml hydrogen peroxide were added and stood for 3 to5 minutes till the solution became clear. The solution was allowed to cool and transferred quantitatively after adding 100 ml of distilled water. The digest was then ready for nutrient analysis (Cresser and Parsons, 1979). Atomic absorption spectrophotometer (Perkin Elmer, 3110) was used for the determination of macro and micro elements. Samples were analyzed for the following nutrients: nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca), boron (B), iron (Fe), manganese (Mn), copper (Cu) and zinc (Zn).

Statistical analysis

The data were statistically analyzed using the ANOVA procedure in the SAS Statistical Software Version 9.0, using a randomized complete block design. Tukey's studentized range test was used to compare differences among/within treatments.

Conclusion

In conclusion, the addition of pyroligneous acid was effective in increasing fruit yield. Addition of ten percent pyroligneous acid was suitable for increasing fruit weight of rockmelons in combination with M fertilizer formulation. The M formulations in combination with 10% pyroligneous acid had the ability to improve the productivity of rockmelon. Better fruit size and sweetness was also obtained in combinations of M and CS formulations with 10 and 20% of pyroligneous acid.

Acknowledgements

This research project was funded by RUGS grant (No. 91563) of the Institute of Tropical Agriculture, UPM. The authors would like to thank Mr. Wan, Mr. Iskandar, Mrs. Nor Rafidah M. Y., Ms. Ummi Kalthum, A., Mr. Desrafiel, A. M., Mr. Zulhelmi, Z., Mr. Mohd Khoiri, K. and Ms. Siti Suliza, S. for their technical support in plant cultivation, fruit harvest, and sample preparations during the period of this study.

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