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Original Research Article

Effect of different growing Medias on Cucumber Production and Water Productivity in Soilless Culture under UAE Conditions

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Abstract

The aim of this study is to identify the best and most appropriate growing media for producing healthy, strong and homogeneous cucumber crop in greenhouse under UAE condition. A study was conducted with one cultivar of cucumber (Ziko F1) using four different growing medias in a Randomized Complete Block Design (RCBD) with 4 replications in UAE (Al Awair) during 2013 summer growing season. The effects of four different media based on 1:0, 1:1, and 1:2, v/v of Perlite and Coco-peat as well as cocopeat growbags were evaluated on quantity and quality of cucumber yields in soilless culture. Plants were fertilized by nutrient solution containing macro and micronutrients at EC 1.5 – 2.5 dS m^{-1}, pH 5.5-6.5. The results revealed that Perlite/Coco-peat (P/C) substrates 1:0 ratio (v/v) produced the highest class A yield with 87.6 ton ha^{-1}, while coco-peat growbag showed the lowest yield (46 ton ha^{-1}). In terms of water productivity the results also showed that produced cucumber yields had better conditions in perlite with the highest net profit and water productivity values. In addition, the results indicated that by mixing coco-peat with perlite in 1:1 ratio, the yield significant increased by 82% compare to cocopeat growbags.

Key words: Coco-peat, Cucumber, Perlite, Soilless, Water productivity.

INTRODUCTION

Arabian Peninsula (AP) is one of the driest regions of the world which characterized by low and variable rainfall, high evaporation rates, and limited renewable water resources. In AP water scarcity is the main challenge facing agricultural development. For instance, in UAE surface water resources are almost not in existence and groundwater resources are often nonrenewable. The scarcity of fresh water in UAE is becoming more challenging issue due to the increase in the population over the last few decades. Efficient water use is the most economically and environmentally preferable solution especially in drought conditions and increasing competition over limited water supplies. The underground water level has rapidly declined and due to sea water intrusion, it has increasing salt content.

Soilless production system can improve water use efficiency, as well as water and fertilizer management in crop production. The main objectives are to increase yield and quality per unit of water, land and manpower. The soilless production techniques, which developed and adapted by ICARDA in collaboration with National Agricultural Research and Extension Systems (NARSE) of seven AP countries, are being adopted in all region including United Arab Emirates. Since 2000, when the first soilless production system was installed at Dhaid Agricultural Research Station, UAE; ICARDA and NARES of seven AP countries have conducted several joint adaptive research and agro-economic studies on various soilless production systems with promising results. As a result, yields were increased significantly and productivity per unit of water increased by more than 70% compared to soil-based systems (APRP-ICARDA, 2002).

Nowadays, a wide range of soilless culture techniques have been developed and commercially introduced for intensive production of horticultural crops, particularly vegetables under greenhouses condition. However, in almost all the systems, soil as growing media are replaced with other media mostly due to plant protection concerns regarding soil borne pathogens as well as environmental regulations against groundwater pollution with nitrate and pesticides. Removing soil from production system can provide number of advantages in the management of both plant nutrition and plant protection compare to conventional soil based production systems. It helps to avoid problems related to monoculture of plants in the same land for years (Fecondini et al., 2011). Furthermore, it would address the problems related to proliferation of soil borne pathogen in the soil cultivation. Replacing soil with other growing media for growing vegetable crops especially cucumber, pepper, tomatoes etc. resulted better control of plant nutrition and eliminate of plant diseases that caused by soil (Olympios,1995).

In Arabian Peninsula, utilizing soil in protected agriculture is facing many limitations (Moustafa et al., 1998). Therefore, exploiting the soilless growing media is a logical alternative to the present conventional soil-based production systems in this region. In soilless production system, different types of growing media or substrates such as Rockwool, perlite, vermiculite and peat have been used to grow many kinds of crops (Raja Harun et al., 1991, Jarvis 1992, and Komada et al., 1997). The effects of different media on vegetable yield have been studied by various researchers. For instance, some researchers showed yield of tomatoes grown in coconut fiber substrates was higher than grown in other substrates, another researches did not show any difference in the yield (Carrijo et al. 2004, Vrrestarazu et al., 2003, Shinohura et al., 1999, Hallman and Kobryn, 2014).

The use of different organic and inorganic substrates allows to the plants for best nutrient uptake and sufficient growth and development to optimize water and oxygen holding (Verdonck et al., 1982). A good growing medium would provide sufficient anchorage or support to the plant, serves as reservoir for nutrients and water, allow oxygen diffusion to the roots and permit gaseous exchange between the roots and atmosphere outside the root substrate.

However, different substrates have various materials and structure which could have direct and/or indirect effects on plant growth and development. While these substrates can be used alone, mixtures of the substrates such as peat and perlite; coir and clay, peat and compost (Grunert et al., 2008; Vaughn et al., 2011, Nair et al., 2011, Bhat et al., 2013) are also be used widely. Therefore, selecting the best substrate among the various materials is imperative to the plant productivity (Olympios, 1995).

In Iran, Ghehsareh et al. (2012) revealed that higher amount of cucumber yield, biomass weight, plant height, root weight, Leaf Area Index (LAI) and fruit Total Soluble Solids (TSS) obtained when date-palm leafs used as media compared to the conventional soil system. Meanwhile there was no significant difference between above indicators when use perlite as media compare to date palm leafs. Permuzic et al (1998) showed the quality and quantity of tomato fruit in the organic media is better than inorganic media. The results of Inden and Torres (2004) on tomato when it cultured in the different substrates showed that the highest amount of total yield and number of fruit were related to Perlite + Rice hull and highest amount of total soluble solids (TSS) related to the Cocopeat substrate. Djedidi et al. (2001) evaluated five substrates (rockwool, perlite, and mixtures of perlite to zeolite 1:1, 1:2 and 2:1) in soilless culture with an open system on tomato plants and they observed that the highest yield performance obtained was by the mixture of perlite and zeolite with 1:1 ratio and highest flowering obtained by perlite substrate. The tomato plants that grown in perlite and zeolite with 2:1 ratio had the best distribution of fruit size, total soluble solid and sensorial quality and so highest dry matter of fruit was found in the perlite substrate. Alifar et al. (2010) investigated the effect of five different growing media including pure Cocopeat, Perlite-Cocopeat (50–50 v/v), Perlite-Cocopeat-Peatmoss (50-20-30 v/v and 50-30-20) and Perlite-Peat moss. Results showed the highest yield of cucumber fruit was obtained from Cocopeat and the lowest one was obtained from Perlite-Cocopeat. The effect of the substrate on yield and fruit quality of tomato in soilless culture studied by Tzortzakis et al. (2008) showed that plants grown in pumice and perlite substrates obtained lower total yield; and higher yield was obtained from maize substrate. Therefore, substrate selection is one of the most important factors affecting plant growth and development in the greenhouse and influencing vegetable quality.

Although number of trails were carried out by ICARDA and its partner in AP countries on growing media (APRP-ICARDA, 2014), still there are number of questions raised by researcher and growers regarding this subject which are needed to be answered.

As any other economic activity, the main objective of the growers is to increase their profit by invest the minimum possible on infrastructure and achieving the maximum yield. Therefore, this experiment aimed to study the impact of different growing Medias on yield and water productivity in relation with economic issues.

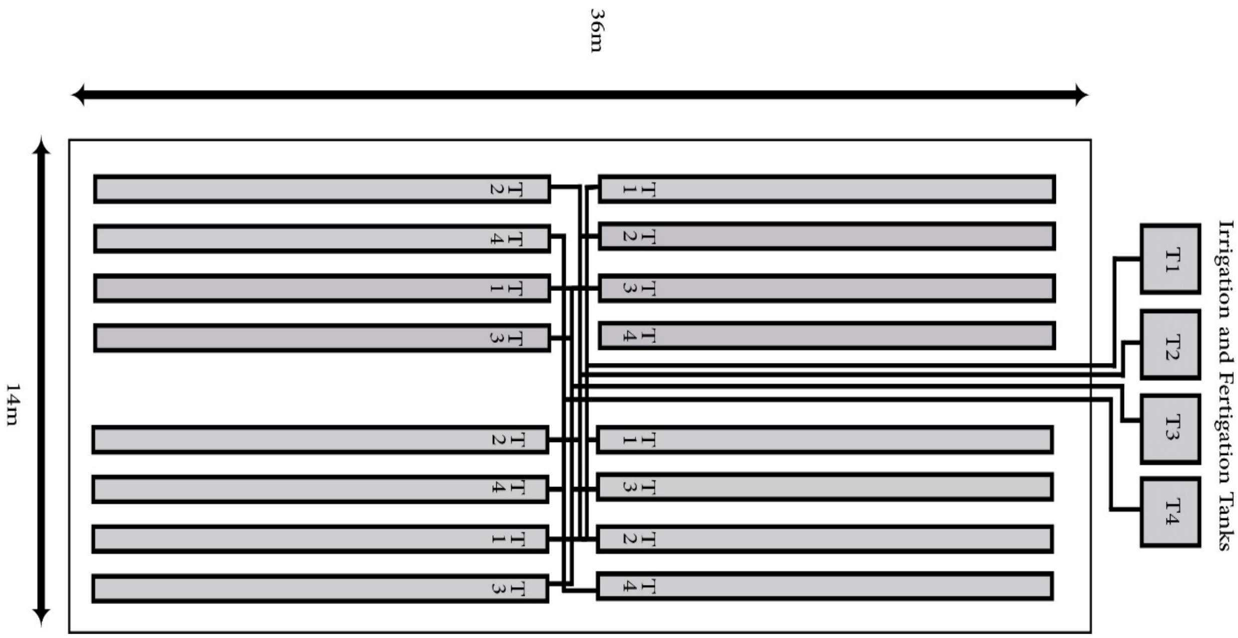

Figure 1. The experiment layout. Soilless Media: T1: perlite; T2: coco-peat slap (grow bag); T3: Mix perlite and coco-peat 1:1; T4: Mix perlite and coco-peat 1:2

MATERIALS AND METHODS

This experiment was conducted under greenhouse conditions at AL-Awair, UAE at a private farm during the period between 16 April and 23 July 2013. Average day and night temperatures in the greenhouse during the experiment period were 34˚C and 26˚C, respectively. The relative humidity varied between 60% and 85%. One cooled greenhouse (GH) has been selected for the study at the farm with total area of $576m^2$ (36m x 16m). The greenhouse height was 4meter. The Greenhouse walls were covered by polycarbonate while the top was roofed by Polyethylene sheet. The growing canals were made of black polypropylene sheets (3mm). The canals sizes were 16m length, 21 cm width and 25cm height. Each 4 canals supplied with a separate irrigation and drainage system to represent 4 replications for each media under the study. The treatments were arranged in a Randomized Complete Block Design (RCBD) with four different substrate treatments in four replicates (Figure 1). Four different growing media were consisted of:

- Perlite with polystyrene pots
- Mixtures of cocopeat and perlite (1:1)
- Mixture of cocopeat and perlite (2:1)
- cocopeat growbags (100 by 18 by 18 cm)

Cucumber plants (Zeco F1) as a recommended variety by the growers were planted in all growing media with plant density of 2.5 plant m^{-2}.

Each growing block canal contain 50 Polystyrene pots (7 L) with a total of 100 plants. For cocopeat growbag same number of plant considered. The space between two pots was 30cm (center to center). Cucumber seeds were planted directly in the media on16 April 2013, and were daily irrigated with water only during the first week. After first week, all of the growing media were irrigated with a nutrient solution. Drip irrigation supplied a standard nutrient solution to the plants. During plant growth, Papadopolus (1994) formula with fertigation method was used for plant nutrition. The irrigation solutions were prepared for each treatment in a separate 1,500 litter tank. Stock A and stock B were added into the tank at 1:1 ratio until the required Electrical Conductivity (EC) was achieved. The EC of the fertigation solution was between 1.5 and 2.5 dS m^{-1} while the pH was maintained between 5.5 and 6.5 using Nitric acid solution. All plants were irrigated with the same quantity of water but with different frequency according to the water holding capacity of each substrate with minimum drainage (20-30%). The plants were irrigated 2 -12 times a day until the end of experiment. Irrigation frequency was based on growing media and stage of plant growth in greenhouse. The irrigation scheduling was automatically implemented by a digital timer. During the plant growth irrigation rate, temperature, humidity and pest control were similar for all treatments. The daily irrigation and fertilizer volumes per each treatment were collected. In each pot two cucumber seeds were planted. Two lateral lines for each canal were installed and each pot supplied by two pressure compensating drippers with 4L h^{-1} discharge of each. Four (4) flow water meters were installed to measure the water delivered to each treatment which connected with flout valves that supply waters in the irrigation tank according the crop water requirements.

Table 1. Effects of different growing medias on cucumber yield

Media	Class A production ton ha^{-1}	Class B production ton ha^{-1}	Total Yield ton ha^{-1}	Class B /Total yield %
Perlite	87.60 a	24.4 b	112.1 a	21.8 b
cocopeat bag	46.0 d	16.3 c	62.3 b	26.4 a
Perlite-Cocopeat 1:1	82.4 b	30.43 a	112.9 a	27.1 a
Perlite-Cocopeat 2:1	71.4 c	27.0 ab	98.4 a	27.4 a
LSD	4.8	4.5	18.6	2.3
CV%	12.7	11.6	12.1	5.6

Mean values in the same column followed by the same letter are not significantly different at $p \leq 0.05$.

Cucumber fruits were harvested from 17 May to 23 June 2013 on each interval days. The fruits were classified in two classes of A and B based on their marketing quality by the grower. The total yield and quantity of each class for of each replicate were recorded separately.

Data obtained were subjected to statistical analysis using analysis of variance (ANOVA) procedures to test the significant effect of all the variables investigated using MSTC. Means were separated using Least Significant Deference's Test (LSD) as the test of significance deference's at $p \leq 0.05$.

RESULTS AND DISCUSSIONS

Cucumber harvesting started on May 17, 2013 and continued until July 23, 2013. Statistical analysis of variance indicated that different growth Medias were significantly different at 5% level for each parameter considered (Table 1). The best result for early yield was obtained with Perlite. Based on the results of Table 1, the highest cucumber class A yield (87.6 ton ha^{-1}) was observed in the perlite media that had highly significant differences compared to other media treatments. This is due to the fact that Perlite provided better root-zone aeration than the other media under study. The lowest yield, water, land and fertilizer productivity was observed in growbags filed with pure coco-peat media. Overall, the highest total cucumber yield was obtain in mixture of 1 perrlite: 1 cocopeat and the lowest yield was belong to the coco-peat growbags. The obtained results were agreed with Yoosefian et al. (2009) who observed the greatest cherry tomato node and leaf number and shoot fresh and dry weight in perlite 95% + hydrogel 5% mixture and the highest stem length and root fresh and dry weight in perlite 100% medium. This result is also in line with Djedidi et al., (2001) when he compared perlite with ziolite and mixed substrates. He found that the highest flowering rate and dry matter of tomato fruit was achieved when perlite used as growing media. While these results are inconsistent with Neamati et al. (2010) findings where the highest leaf, stem and root dry weight; leaf area and stem length obtained in peat media whereas the highest inter-node number and seedling emergence percent in coco-peat media. While anther study suggested that addition of maize to perlite and pumice could improve properties of inorganic substrates for tomato soilless culture, leading to higher yields and better of quality fruit (Tzortzakis et al., 2008).

Also the results showed that the class B to total yield ratio was the lowest when using perlite alone in comparison with the other treatments, which means that the best cucumber yield quality was achieved when using perlite substrate. The lowest results were obtained when using coco-peat as soilless media, this is because coco-peat has been recognized to have a poor air-water relationship, leading to low aeration within the media, which affected oxygen diffusion to the roots (Abad et al., 2002). The results in Table 1 are indicated that by mixing coco-peat with perlite in 1:1 ratio, significant increase in the class A and total yield of cucumber by 79% and 82% were obtained, respectively. This is because the perlite is highly porous material that enhanced the aeration in the mixed media. The low bulk density and the high porosity of perlite media allowed the plant root to penetrate in substrate easily and it could use more volume and space of media, thus available water was sufficient for plants grow up. This result was disagreed also with Alifar et al. (2010) whose indicated that yield of cucumber fruit, plant stem diameter, biomass, fruit's number and fruit's size and diameter was obtained from Cocopeat media compared with other media such as Perlite. This obesity in results was might due to similar irrigation scheduling were used to all medias while perlite need shorter irrigation interval with more frequent irrigation in comparison with cocopeat, another reason related to the wide different between the two experimental locations climatic conditions, the temperature and relative humidity in Turkey are much lower than AUE conditions which has a hyper arid conditions in addition to that the white color of perlite reduces the media temperature in the root zone while the

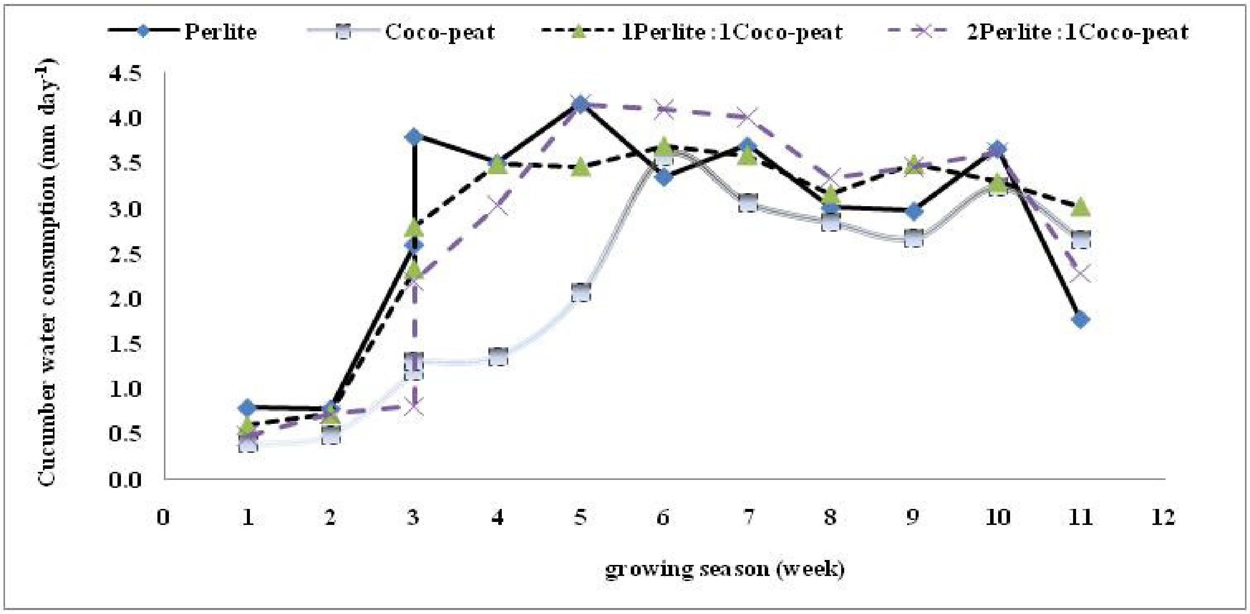

Figure 2. Cucumber water consumptive use under different soilless media at AL Aweer-UAE during 2013 growing season.

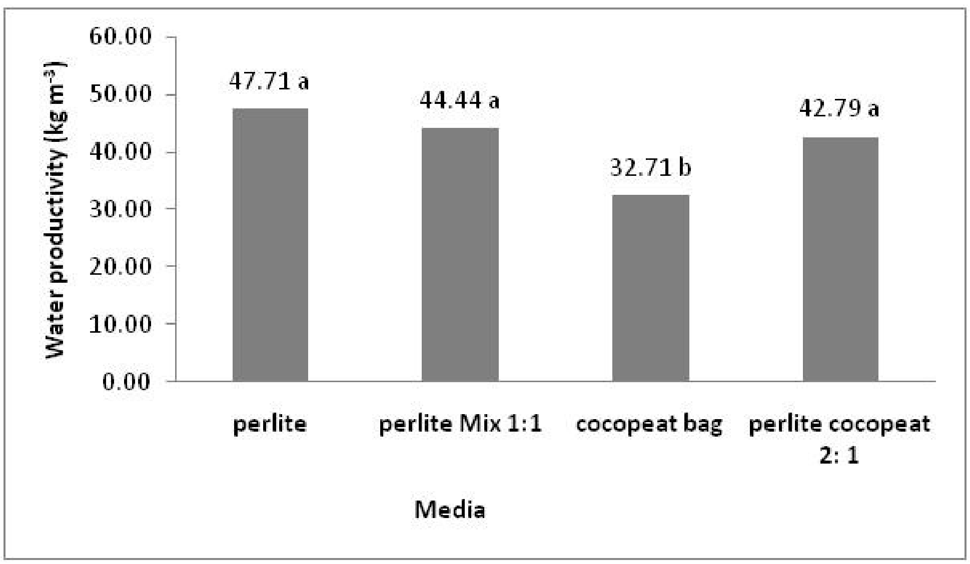

Figure 3. Cucumber water productivity (kg m^{-3}) under different soilless media

cocopeat which has dark color increases the temperature which affect adversely the crop yield.

The total crop water consumption for each growing media measured separately in this study where records show 246 mm in Perlite and Perlite+cocopeat (1:1) mixture, 254 mm Perlite+cocopeat (2:1) mixture, and 190 mm in Cocopeat growbags.

Figure 2. show the average cucumber water consumption (mm day^{-1}) in weekly basis for different growing medias. All water consumption values are low during initial stage and increased steeply during the development stage and reached its highest values at the med season stage then reduced at the end of growth stage. It's clear from the figure that Coco-peat consumed less water during all crop growth stages this due mainly to its high water holding capacity which causes poor air-water relationship, leading to low aeration within the medium, thus affecting the oxygen diffusion to the roots which affect adversely the crop canopy and the yield.

Water productivity was calculated by dividing the total fresh yield on the water applied (Lovelli et al., 2007). The highest crop water productivity value of 47.7 kg m^{-3} was for Perlite followed by mixed Perlite and Cocopeat (1:1 and 2:1) (Figure 3).

Table 2. Comparing the increase in capital cost for different media

Capital cost	Media (US$/crop)	Pots (US$/crop)	Total (US$/Crop)	Total (US$/crop m^{-2})
perlite	19.6	4.3	23.9	0.19
Perlite-Cocopeat1:1	37.0	4.3	41.3	0.33
cocopeat bag	29.0	0.0	29.0	0.23
Perlite-cocopeat1:2	42.8	4.3	47.1	0.37

For each year 3 crop rotations were considered.

Table 3. Comparing the cost of irrigation water for four media under study

	Water consumption (m^3 $crop^{-1}$)	cost (US$ $crop^{-1}$)	Total cost (US$ $crop^{-1}$ m^{-2})
perlite	31	35.03	0.28
Perlite-Cocopeat 1:1	32	36.16	0.29
cocopeat bag	24	27.12	0.22
perlite cocopeat 1: 2	29	32.77	0.26

Compare the feasibility of growing media based on partial budget

A partial budget helps to evaluate the financial effect of new technology or innovations. To calculate a partial budget only those variables will be considered that will be changed. It does not consider the variables that are left unchanged. Only the change under consideration is evaluated for its ability to increase or decrease income in the farm business (Tigner, 2006).

In this study, the partial budget to compare the feasibility of different growing media for cucumber production conducted based on data collected during the study and interview with the grower. The indicators consisted of increase in capital cost, cost of irrigation water, cost of fertilizer and total income for each media. All data converted to US$$m^{-2}$. For depreciation costs, the economic life of all media considered as two growing seasons with three crops per year. For calculating the budget the market price of production and agricultural inputs are used without calculating the variables such as environmental issues and subsidies paid by government for adoption of the soilless techniques.

Therefore, this is more financial rather than economic analysis. While some of the actual tools are the same, financial analysis focus on private profitability and financial flows related to some indicators such as market price, depreciation, interest rate, credit, etc. (EC, 1997).

Increase in capital cost

Based on interview with growers, the economic lifecycle of all growing media under the study, as well as Polystyrene pots for lose media, considered two growing season with 3 crops in each season (6 crop in total). A total of 64 coco-peat were used in the greenhouse while for each of the other media 1200 litter were used to fill the 50 polystyrene pots. The following table shows the estimated costs based on data collected from growers and market. (Table 2)

Based on the price collected from UAE market the lowest capital costs required is belong to perlite followed by cocopeat grow bag. The relatively lower cost for growbags is as a result of omitting the pots from system.

Cost of irrigation water and fertilizers

Difference in cucumber water productivity in different media can be translated to cost of irrigation water. Based on the desalination unit costs, maintenance and production capacity each cubic meter of water calculated at 1.13US$ under UAE conditions. Cocopeat growbags shows the lowest water costs. (Table 3)

Almost all of crop production and protection activities were the same for all media which can be omitted in this study. However, amount of fertilizer used for each treatment were different which also translated to US$ $crop^{-1}$ m^{-2} based on the market price of 0.54 US$ $Litter^{-1}$. As it presented by Table 4, perlite has highest cost of fertilizer while cocopeat growbags shows the lowest costs among the four media under study.

Total and Net income

Total income calculated based on amount of class A and B production per square meter of green house. The market price reported by grower as \$0.54 and \$0.27 for class A & B respectively. (Table 5)

As it is presented by Table 6, the highest total and net

Table 4. Comparing the cost of fertilizer for the media under the study

Fertilizer	Fertilizer (A+B) (Litter crop^{-1})	Cost (US$ crop^{-1})	Total cost (US$ crop^{-1} m^{-2})
perlite	190	103.26	0.82
Perlite-Cocopeat 1:1	176	95.65	0.76
cocopeat bag	168	91.30	0.72
perlite cocopeat 1: 2	172	93.48	0.74

Table 5. Comparing the income for the media under the study

	Yield Class A (kg)	Yield Class B (kg)	Cost (US$ crop^{-1})	Total cost(US$ crop^{-1} m^{-2})
Perlite	1,156	323	716	5.68
Perlite-Cocopeat 1:1	1,038	384	669	5.31
cocopeat bag	580	205	371	2.94
Perlite-cocopeat 2: 1	901	340	582	4.62

Table 6. Comparison of the growing media feasibility based on partial budget (US$m^{-2} crop^{-1})

	Perlite	Perlite-Cocopeat 1:1	cocopeat growbag	Perlite-Cocopeat 1:2
Increase in Capital cost	0.19	0.33	0.23	0.37
Cost of irrigation water	0.28	0.33	0.22	0.26
Cost of fertilizer	0.82	0.76	0.72	0.74
Total income	5.68	5.31	2.94	4.62
Net Income	4.40	3.89	1.77	3.24

income are achieved when using perlite substrate which has better feasibility compared to other media under the study. In this regard, perlite are followed by Perlite-Cocopeat Mixture (1:1) and (1:2). The cocopeat grow bag shows the lowest net benefit, although has the lowest cost as well which shows the effect of lower yield.

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, this study is clearly showed that the perlite compared with the other media under study has the maximum yield with higher quality (class A) of cucumber while the lowest yield was obtained when using coco-peat growbag, but when mixing the coco-peat with perlite in 1:1 ratio, the cucumber total yield increased by 82%. It was found that also there were significant differences in yield and plant water productivity with respect to perlite growing media.

Although the study found that the perlite as growing media would have excellent performance for cucumber production with the best net profit, there is a need for the study to continue for at least one complete growing season to check the effect of temperature and other environmental issues on the media. Furthermore, the economic life cycle of each media are needed to be study for longer periods.

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