Evaluation of a Cocopeat-Based Substrate System for Rose Production in Naivasha, Kenya

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Abstract

The current production system of roses in Kenya involves mostly the use of soil and open drip irrigation, which is inefficient as water and nutrients are lost through drainage. A recycling system can improve efficiency, as drainage water containing nutrients is re-used. A study was carried out from January to June 2013, at van den Berg Roses (a commercial rose farm) in Naivasha, Kenya, to evaluate a cocopeat-based system for rose production in comparison with a conventional soil-based production system. Net water use, stem production, stem length and economic benefits were assessed. Net water use in the cocopeat system and soil systems were 411 and 1098 L m^{-2}, respectively. The difference of 687 L m^{-2} equals 65% water saving as a result of using the cocopeat system. The cumulative number of harvested stems m^{-2} in the cocopeat system was 24% higher than in the soil system. Rose stems harvested from the cocopeat system were on average longer, with 64% of the stems falling in the 60 and 70 cm categories, while this was 46% for the stems harvested from the soil system. Average stem weights were 39.2 and 33.6 g in the cocopeat and soil system, respectively. The results show that a cocopeat system with re-use of drain water in a soil system results in water saving, higher yield and better rose flower quality. A total of 764 L m^{-2} containing 1482 g m^{-2} fertilizer was collected from cocopeat and used in soil system over the period. The fertilizer in the drain solution was valued at € 0.93 m^{-2}. Overall turnover from cocopeat was greater than soil system by € 3.15 m^{-2}. The higher amount of marketable weight can be attributed to the greater number of stems that were obtained from the cocopeat compared to the soil.

INTRODUCTION

Kenya is a water scarce country with an annual renewable fresh water supply per capita of 647 m^3 (Government of Kenya, 2007; Ministry of Water and Irrigation, 2006) against the recommended global benchmark of 1000 m^3 (Ministry of Water and Irrigation, 2006). The situation is expected to worsen as a result of climate change and increase in population (Institute of Economic Affairs, 2007; Marshall, 2011), hence, the need to ensure sustainable use of water. Besides the limited water supply, contamination of water resources reduces the amount of high quality water that can be used for various purposes.

Fertilizers provide plant nutrients but when used indiscriminately can contribute to contamination of water resources through leaching (Tang, 1999). Leaching also increases production costs since lost nutrients have to be replaced by addition of more fertilizers.

Lake Naivasha has experienced problems of declining water quantity and quality which have been blamed on horticultural activities around the lake (Kargbo et al., 2010). Nutrient enrichment of the lake may be due to inflow of sediments and nutrients from the lake catchment areas (Tang, 1999). Sustainable production system is necessary to ensure continued horticultural production around Lake Naivasha.

Rose (*Rosa hybrida*) is one of the most widely cultivated and important export

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flowers in Kenya. Rose flowers dominate the export market contributing about 70% of the total horticultural export volume from Kenya (Kargbo et al., 2010). It is estimated that Kenya provided up to 52% of roses to the EU market between 2000 and 2012 (Muhammad and D'Souza, 2013). Major production areas of roses in Kenya include Lake Naivasha, Kiambu, Thika, Kericho (Kargbo et al., 2010), with Lake Naivasha accounting for about 95% of the cultivated rose area. Irrigated rose production either alone or combined with hypericum or carnations covers 1778 ha which represents 40% of the area under irrigation. The occasional decline in water level and quality that affect lake Naivasha therefore poses a great threat to roses production and mitigation measures are required. Additionally, due to competition from other markets, it is necessary to lower costs of production in order to remain competitive.

Soilless production systems, which involves use of other materials instead of soil, are considered important for growing horticultural crops worldwide (Ahmad et al., 2013; Chimonidou et al., 2007; Das et al., 2012; Ehret et al., 2005; Jeong and Hwang, 2001). The systems have the potential to increase production while at the same time increasing sustainability through reuse of drain water and fertilizers (Massa et al., 2010). The use of soilless system instead of soil for rose cultivation in Kenya is low which could be due to lack of information on its performance under Kenyan conditions.

This study was conducted to compare a cocopeat-based system to soil for rose production in terms of water use, water savings, fertilizer savings, stem production, stem quality and turnover.

MATERIALS AND METHODS

Treatments and Experimental Setup

Two treatments namely cocopeat and soil were tested in the study. Rose 'Upper Class' was planted between weeks 29 and 34, with 19th August 2012 as average date, at Van den Berg Roses, a commercial rose farm at Naivasha, Kenya (00°46'S, 36°43'E, 1900 m a.s.l.) to 1.6 ha of cocopeat substrate and 1.6 ha of soil. The area of the systems was laid side by side in one greenhouse. Rose plants in the soil were grown on beds on the ground while the cocopeat ones were raised 30 cm above the ground. There were a total of 224 rows of 100 m long for each treatment. Between and within-row plant spacing was 40 cm and 20 cm, respectively, in both systems, resulting in a plant density of 7.3 plants m^{-2}. Fertigation system applied nutrient solution through a drip irrigation systems in both soil and cocopeat treatments. Irrigation water was obtained from a 80 m deep well nearby that was treated through reverse osmosis. After mixing with nutrients in a fertigation unit, the nutrient solution was fed to the crop in the cocopeat treatment. The drain was collected in a drainage pit and mixed with reverse osmosis water and more nutrients added in the fertigation-mixing unit before being supplied to the crop in the soil treatment (Fig. 1).

Measurements

Observations were taken between January 1 and June 30, 2013. Weather variables including temperature, radiation and relative air humidity were recorded at 5 min interval by data sensors (Hoogendoorn, The Netherlands) placed at the centre of the greenhouse at 10 cm above the plants. Daily and monthly minimum, average and maximum values for temperature and relative air humidity were calculated for the experimental period. Total daily and total monthly values of radiation sum, and monthly minimum, maximum, average values of total daily radiation sums were computed.

Amounts of water applied to both systems, and drained by the cocopeat system were monitored from a central computer. Net water use by the cocopeat system was assessed as the difference between the amounts applied and drained. Net water use by the soil system was assessed as the total amount of water applied, as drain water could not be recovered. The difference in amounts of net water use was defined as the water saving by the cocopeat system in comparison to the soil system. The EC and pH values of supply and drainage solution were obtained from a central computer. Nutrient content of the drainage solutions were obtained from a commercial company. The nutrient content in mmols L^{-1} or mol L^{-1} were converted into g L^{-1} and summed up to obtain the concentration of composite fertilizer in the drain solution. The concentration of the fertilizer in the drain solution was multiplied by the drain volume to obtain the amount of fertilizer in the drain solution. The financial savings from re-using the drainage water was determined by multiplying the total amount of fertilizers in the drainage water with the average fertilizer price.

Crop measurements were taken in three sampling areas picked randomly for each system. Each sampling area measured 121 m^2 each, with 900 plants. Production was determined in terms of stem fresh weight (kg m^{-2}) and number of stems per m^2. Mature flower stems were harvested daily, and their quality was determined in terms of stem length, through sorting in length classes of 30, 40, 50, 60, 70 and 80 cm. The stems were counted and weighed separately per length class. Daily values were accumulated over the 6 months experimental period. Treatment differences in production data were analysed by a 2-tailed t-test using Genstat Version 14.

The number of marketed stems at the auction was multiplied by the auction prices per stem length category to obtain turnover. Rejected stems included stems that had gooseneck, bullheads, chemical scorching, botrytis, pest (mite, mealy bugs, caterpillar and thrips) damage, pale coloured, undersized (below 25 cm) and broken stems. The turnover per unit area was calculated for both systems and the difference was computed.

RESULTS

The temperature in the greenhouse varied between 17.4 and 19.7ºC with an average of 18.7ºC over the experimental period (Table 1). The temperature in the greenhouse was slightly elevated compared to the outside which varied between 15.9 and 19.1ºC with an average of 17.6ºC. Total monthly radiation sum varied between 56,384 J cm^{-2} and 64,940 J m^{-2}. Average monthly radiation sum was 60,363 J cm^{-2} d^{-1} with a sum of 362,176 J cm^{-2} over the experimental period. The relative air humidity varied between 75.6 and 86.7% with an average of 81.6%.

Net daily water use in the cocopeat was lower than the soil system averaging 2.23 and 5.98 L m^{-2} d^{-1}, respectively (Fig. 2). Over the 6 months period, the gross amount of water supplied to the soil system was 1082 L m^{-2} while it was 1168 L m^{-2} in the cocopeat system (Table 2). The amount of solution drained and collected from the cocopeat system was high, ranging between 60 and 70%. Since the drainage water was collected and re-used, the net water use for cocopeat system was 404 L m^{-2} (Table 2). This resulted in a difference of 678 L m^{-2} in net water use between the cocopeat and soil system, which implies 63% water savings by the cocopeat substrate system.

The EC of the supply water ranged between 1.40 dS m^{-1} and 1.56 dS m^{-1} with an average value of 1.45 dS m^{-1} for the soil system while it ranged between 1.37 dS m^{-1} and 1.54 dS m^{-1} with an average value also of 1.45 dS m^{-1} for the cocopeat system (Table 3). The drainage solution had an elevated EC ranging between 1.82 dS m^{-1} and 2.12 dS m^{-1} with an average of value of 1.94 dS m^{-1}. The pH of the supply solution ranged between 5.31 and 5.70 with an average of 5.62 for the soil system while it ranged between 5.20 and 5.77 with an average of 5.51 for the cocopeat system. The drainage solution of the cocopeat system had a lowered pH ranging between 3.87 and 6.13 with an average of 4.79. The concentration of nutrients in the drain solution was estimated to be 1.21 g m^{-2}.

The amount of drain water was 764 L m^{-2} during the experimental period of 26 weeks (Table 4). With a mean EC of 1.94 dS m^{-1} for drain from cocopeat, the estimated amount of fertilizer in the drain solution during the experimental period was 924 g m^{-2}.

Harvested stem weight increased steadily from 0.59 and 0.45 kg m^{-2} for the cocopeat and soil treatments, respectively, in January. By the end of June 2013, the cumulative fresh weight of stems was 3.26 and 2.15 kg m^{-2} for the cocopeat and soil treatment, respectively. Cumulative fresh weight of stems in the cocopeat system was 52% significantly higher than in the soil system.

The cumulative number of harvested stems was 67.1 and 81.7 per m^2, respectively, for the soil and the substrate system (Table 5). The cumulative number of stems in cocopeat system was 24% higher than in the soil system. The number of harvested stems was also significantly higher for cocopeat system than for the soil system in the months of March, May and June (Table 5).

Rose stems grown in the cocopeat system were on average longer than those produced by the soil system with 64.1% of the stems being produced in cocopeat belonging to length categories 60 and 70 cm, while this percentage was 46.0% for the soil system (Table 6). The average stem weight was 39.2 and 33.6, respectively, for the cocopeat and soil system.

Based on the amounts of marketable stems and the average figures of the Dutch auction for the rose variety Upper Class, the difference in turnover was calculated as € 3.15 m^{-2} (Table 7). The amount of fertilizer in the drain solution was valued at € 0.93 m^{-2} based on an average price of € 1.01 kg^{-1} (Table 4).

DISCUSSION

The results show that rose in the cocopeat system performed better than in the soil system. The cocopeat system produced significantly more marketable stems and a higher cumulative stem weight, which resulted in a higher average stem weight. The higher cumulative weight and the greater number of stems that were obtained from the cocopeat system in comparison with the soil are possibly due to a higher total dry matter production as a result of better growth environment. Substrate cultivation offers the possibility to more directly control the availability of water and nutrients, and avoid temporal shortages.

The higher production of stem could be due to the elevated EC which was observed in cocopeat as was shown in lettuce where higher EC resulted in more nitrate and total reduced-N and lettuce grew faster (Gent, 2003). Assessment of the drain solution indicated accumulation of nitrates by 29% compared to the supply solution. The effect of EC on production of marketable stems could be through its effect on leaf nitrate which plays the role of an osmoticum (Gent, 2003).

Recirculation of drain irrigation water has been shown to result in negative effects on rose production unless amendments are made (Ehret et al., 2005). It is therefore possible that the use of drain water in the soil could have contributed to lower performance. However, since no treatment where soil without reuse of drain was included this cannot be confirmed. The reuse of drain water contributes to sustainable production since the drain water is reused avoiding its discharge into ground water. The nutrients in the drain water are further used in the soil system reducing the amount of additional fertilizers required for production.

The maximum EC of the substrate system was 0.1 higher than that of the soil system, which could be due to the buffering effect of the soil. It could also be due to the higher amount of nutrient solution applied to the cocopeat (1168 L m^{-2}) compared to the soil (1082 L m^{-2}).

The EC of the drain solution was higher than that of the supply solution of cocopeat, which indicates that the relative uptake of water has been higher than the relative uptake of nutrients. For example, a linear correlation between fertilizer EC and begonia leachate EC was observed (Erin and Marc, 2001). However, the rise in EC was not strong enough to affect growth and production of roses since it has been shown that some rose cultivars can tolerate EC values of up to 7.5 dS m^{-1} (Raviva and Blom, 2001). The pH of the drain was lower probably due to accumulation of fertilizers which have been shown to decrease pH of leachate (Erin and Marc, 2001). The supply solution pH ranging between 5.2 and 5.7 was within suitable range used for rose production (Ehret et al., 2005).

Higher production and quality of roses were observed with less water and savings on fertilizers in cocopeat compared to soil. However, more data is required to ascertain the economic benefits of using cocopeat because a report indicate that the costs of using cocopeat based irrigation system were higher than soil in Ethiopia (van der Maden et al., 2011).

CONCLUSION

The cocopeat system performed better than soil in terms of number of stems and weight of stems harvested. The cocopeat system also had more long stems compared to soil. The cocopeat system resulted in higher turnover and the drain from the system was used in the soil. This contributes to sustainable production since the drain water is reused avoiding its discharge into ground water.

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Tables

Table 1. Weather variables inside the greenhouse during the experimental period (January – June 2013).

Month	Temperature (ºC)		Relative humidity (%)	Radiation sum (J cm^{-2})
	Inside	Outside		
January	18.6	18.0	81.0	64,940
February	18.8	18.3	75.6	63,081
March	19.7	19.1	80.6	59,366
April	19.3	17.6	86.7	56,384
May	18.3	16.7	84.2	63,355
June	17.4	15.9	81.8	55,050
Average	18.7	17.6	81.6	60,363
Sum	-	-	-	362,176

Table 2. Water supplied, used and drained in the cocopeat and soil systems between January and June 2013.

Month	Cocopeat				Soil
	Supply (L m^{-2})	Drain (L m^{-2})	Use (L m^{-2})	Drain (%)	Supply (L m^{-2})
January	202	120	82	60	178
February	200	138	63	69	192
March	217	131	86	60	195
April	193	131	62	68	169
May	189	125	64	66	191
June	167	119	48	70	157
Total/Average	1,168	764	404	65	1,082

Table 3. The EC and pH of nutrient solution to soil and cocopeat systems and drainage solution from cocopeat systems between January and June 2013.

Month	EC (dS m^{-1})			pH		
	Cocopeat	Soil	Drain	Cocopeat	Soil	Drain
January	1.44	1.40	1.90	5.71	5.70	4.14
February	1.41	1.43	1.89	5.77	5.67	4.66
March	1.47	1.40	2.12	5.53	5.66	3.87
April	1.37	1.46	1.82	5.20	5.66	4.54
May	1.47	1.46	1.90	5.43	5.71	5.44
June	1.54	1.56	2.00	5.43	5.31	6.13
Average	1.45	1.45	1.94	5.51	5.62	4.79

Table 4. Estimated savings on fertilizers by reusing drain solution over 26 weeks period.

Variable	Value
Concentration of fertilizer in drain solution (g L^{-1})	1.21
Total drain solution collected per m^2 over 26 weeks (L)	764
Amount of fertilizer re-used per m^2 over 26 weeks (g)	924
Average price of composite fertilizer (€ per kg)	1.01
Savings (€/m^2)	0.93

Table 5. Weight and number of harvested stems in soil and cocopeat system over time.

Month	Stem weight			Number of stems		
	Cocopeat	Soil	*p*	Cocopeat	Soil	*p*
Jan	0.59±0.10	0.45±0.10	0.385	12.2±2.0	12.3±2.3	0.984
Feb	1.15±0.02	0.77±0.05	0.002	24.4±0.6	21.6±2.02	0.256
March	1.89±0.05	1.20±0.01	< 0.001	43.1±1.0	37.2±0.68	0.007
April	2.38±0.04	1.51±0.10	0.001	56.3±0.2	46.9±2.9	0.084
May	2.79±0.08	1.78±0.07	< 0.001	68.4±1.8	56.1±2.1	0.011
June	3.26±0.07	2.15±0.08	< 0.001	81.7±1.4	67.1±2.2	0.006

Table 6. Distribution of stem lengths categories over the 6 months experimental period.

Production system	Proportion for each stem length (%)					
	30 cm	40 cm	50 cm	60 cm	70 cm	80 cm
Cocopeat	0.4	7.0	20.8	34.6	29.5	7.7
Soil	2.4	16.5	33.7	32.6	13.4	1.4

Table 7. Number of marketed stems and turnover for soil and cocopeat systems.

	Number of marketed stem by length							Production
	35	40	50	60	70	80	Total	per m^2
Marketed stems								
Soil	9660	228735	288082	287485	18640		832602	52.04
Cocopeat	3220	170430	314817	366515	117200	2400	974582	60.91
Turnover								
Price (€/stem)	0.12	0.14	0.20	0.28	0.32	0.32	-	
Amount (€)								
Soil	1,159.2	31,794.2	58,480.7	79,633.4	5,890.2	-	176,957.6	11.06
Cocopeat	386.4	23,689.8	63,907.8	101,524.5	37,035.2	758.4	227,302.1	14.21
Difference (€ m^{-2})								3.15
Difference (%)								28

Figures

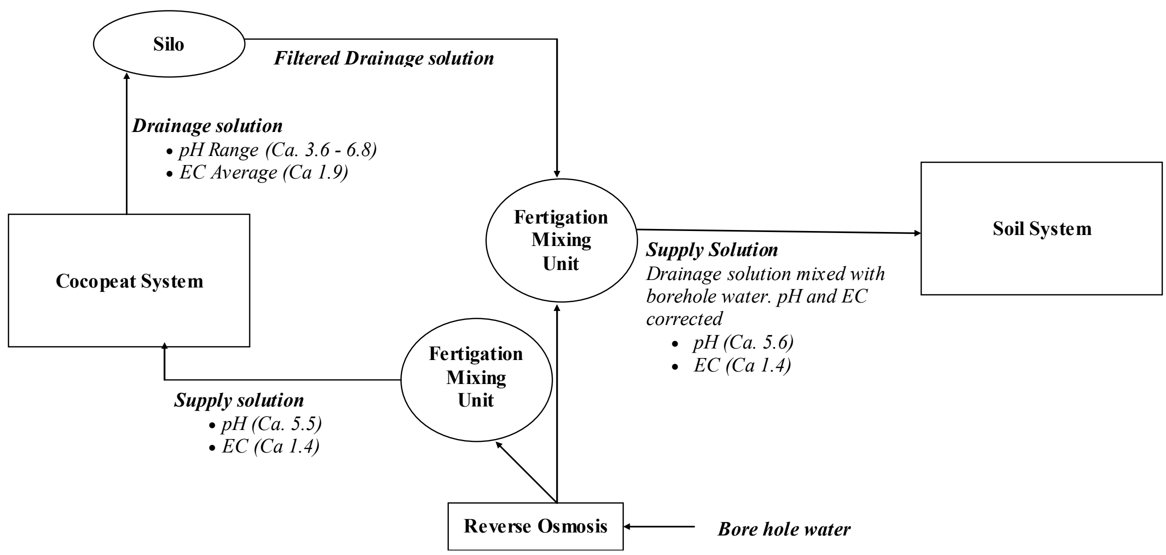

Fig. 1. Schematic representation of the water flow in the experimental setup.

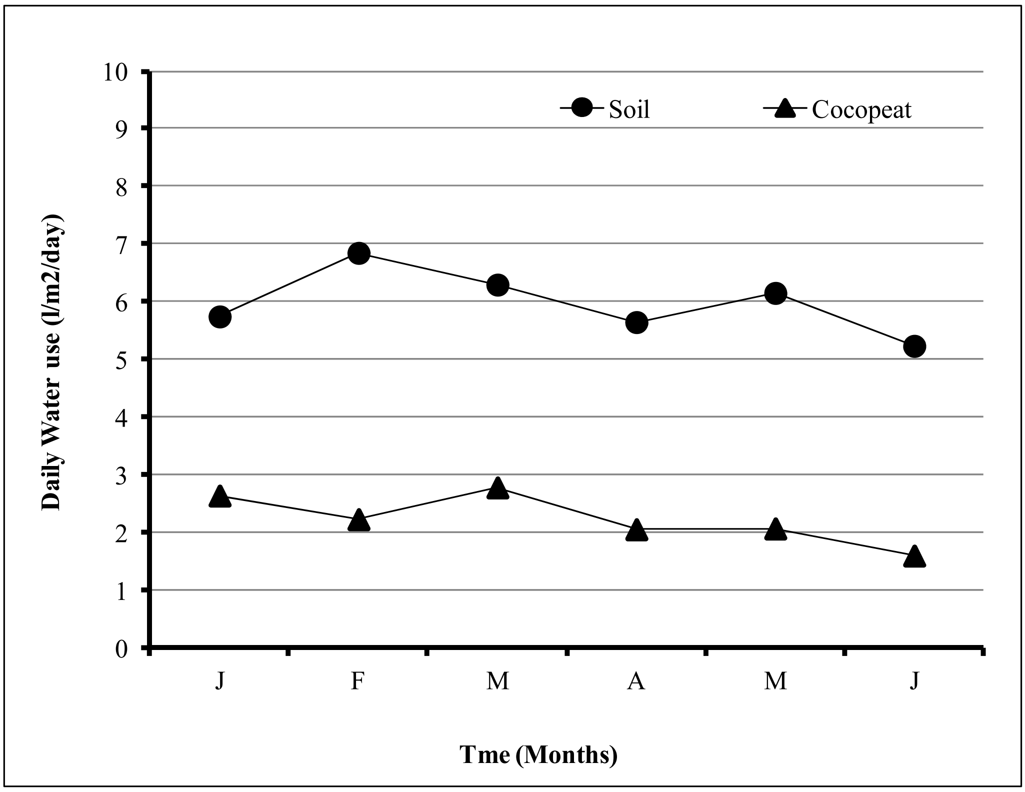

Fig. 2. Average daily water use for soil and cocopeat between January and June 2013.