Vegetative growth of rose flower in cocopeat and soil in Naivasha, Kenya

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Abstract

Roses in Kenya are mostly grown in soil with an open drip irrigation system which is inefficient as water and nutrients are lost through drainage. A study was carried out from January to December 2013 at a commercial rose farm in Naivasha, Kenya, to evaluate the potential of a cocopeat-based system, which additionally enables re-use of the drain water in a soil-based system. Vegetative growth in both systems was assessed in terms of leaf expansion, number of leaves, stem length, chlorophyll content (represented by the measured SPAD value) and flower head expansion. The water used throughout the year was also measured. Leaf expansion was characterized by an initial slow expansion rate followed by a fast expansion rate before levelling off. Maximum leaf length reached was 63 mm in the cocopeat system, while it was 60 mm in soil system; however, the difference was not significant. The number of leaves did not differ between the soil and cocopeat system. The maximum number of leaves per stem was 20 for both systems. There was no significant difference in stem length of plants in cocopeat system (650 mm) and in soil system (630 mm). Measured SPAD value on plants grown in the cocopeat system were significantly higher than for plants grown in soil (P<0.01). Flower head length and width showed no significant difference between the two systems (P>0.01). Net water use for the cocopeat system was lower than for the soil system, with a difference of 1197 L m⁻² or 58%, due to the re-use of water in a soil system. There was a significant substrate effect on the number of stems m⁻² and measured SPAD value, which are associated with differences in leaf chlorophyll and nitrogen content. It is likely that the optimized fertigation regime in cocopeat system led to higher growth rates and enabled a higher stem production. Other parameters were not significantly affected by the substrate type under the same greenhouse climatic conditions.

Keywords: water re-use, leaf chlorophyll, hydroponics, leaf growth, Rosa hybrida

INTRODUCTION

Kenya is a water scarce country with an annual renewable fresh water supply per capita of 647 m³ (Government of Kenya, 2007) against the recommended global benchmark of 1000 m³ (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 good quality water that can be used for various purposes. Lake Naivasha has experienced 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 systems are necessary to ensure continued horticultural production around Lake Naivasha.

The cut flower industry is a key foreign exchange earner for Kenya. For instance, the earnings were US$ 764 million in 2012 (HCDA, 2013). Roses (Rosa hybrida) are among the major flowers valued at US$ 463 million, representing 61% of the value of flowers exported from Kenya. The majority of the production, about 39%, occurs in Nakuru county, where Naivasha is located (HCDA, 2013). The occasional declines in water level and quality that
affect Lake Naivasha therefore pose a great threat to rose production and mitigation measures are required.

Soilless production systems, which involve use of other materials instead of soil, are considered important for growing horticultural crops worldwide (Jeong and Hwang, 2001; Ehret et al., 2005; Chimonidou et al., 2007; Das et al., 2012; Ahmad et al., 2013). 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 substrate systems 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 carried out to demonstrate the benefits of growing a rose crop on cocopeat in comparison to growing in soil. The current study focused on vegetative growth parameters such as leaf expansion, stem length, number of leaves per stem, flower head expansion and leaf chlorophyll content. The amount of water used by each system was also assessed.

MATERIALS AND METHODS

Experimental setup
Dormant buds on rootstock of the rose ‘Upper Class’ were planted between weeks 29 and 34, with 19 August 2012 the 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.) in a polythene covered greenhouse with 1.6 ha of cocopeat and 1.6 ha of soil growing systems. Plants in the soil system were grown in 1 m wide beds on the ground while the cocopeat slabs were raised 30 cm above the ground. There were in total 224 rows of 100 m long per treatment. Between and within-row plant spacing in both systems was 400 and 200 mm, respectively, resulting in a plant density of 7.3 plants m\(^{-2}\). A nutrient solution was applied through a drip irrigation system in both systems. Irrigation water was obtained from a 80-m deep well near by and was purified through reverse osmosis. After mixing with nutrients in a fertigation unit, the nutrient solution was fed to the crop in the cocopeat system. The drain water from the cocopeat system was collected in a drainage pit and mixed with reverse osmosis water and additional nutrients in the fertigation mixing unit before being supplied to the crop in the soil system (Figure 1).

![Figure 1. Schematic representation of the water flow in the experimental setup.](image-url)
Measurements

Observations were taken between 1 January and 31 December 2013. Crop measurements were taken from three sampling areas per treatment, each measuring 121 m² and consisting of 900 plants. Five plants were selected randomly from each sampling area for measurements on stem length, leaf length elongation from the petiole along the midrib, flower head length and flower head width. Leaf length, flower head length and flower head width were recorded daily over a period of three weeks. Stem length and leaf number were assessed weekly for a period of six weeks since the development of these parts was slower. A total of five cohorts were analysed and averaged. Leaf chlorophyll content was quantified using a chlorophyll meter (SPAD-502Plus, model Konica Minolta from Minolta Camera Co. Ltd., Japan). Data were subjected to a 2-tailed t-test using Genstat Version 14 (Nelder, 2011).

Amounts of water applied to both systems, and drained from the cocopeat system were obtained from the fertigation computer. Gross water use was defined as the amount of water applied. Net water use for the cocopeat system was determined as the difference between the amounts applied and drained. Net water use for the soil system was determined as the amount of water applied, as drain water could not be recovered. Daily values were cumulated over the 12 month experimental period.

RESULTS

Average stem length reached 650 mm for the cocopeat system and 630 mm for the soil system, while the number of leaves reached 20 for both systems. Total stem length and total number of leaves per stem (df=10: \( p=1.0 \) and df=10: \( p=0.96 \), respectively) (Figures 2 and 3), were not significantly different between the two treatments. Average final leaf length was 63 and 60 mm for the cocopeat and soil system, respectively (Figure 4). Average final head length was 34.1 and 30.8 mm for the cocopeat and soil system, respectively, and average final head width was 25.4 and 23.2 mm for the cocopeat and soil system, respectively (Figure 5). However, leaf length and the flower head length and width (df=16, \( p=0.74 \); df=20, \( p=0.75 \) and df=20, \( p=0.78 \), respectively) (Figures 4 and 5) showed no significant difference between the two systems.

Figure 2. Stem length expansion of plants grown in soil and cocopeat systems. Vertical lines represent ± standard error.
Figure 3. Number of leaves per stem in plants grown in soil and cocopeat systems. Vertical lines represent ± standard error.

Figure 4. Expansion of leaves in plants grown in soil and cocopeat systems. Vertical lines represent ± standard error.

Figure 5. Flower head length and width in plants grown in soil and cocopeat systems. Vertical lines represent ± standard error.

Chlorophyll contents in the top and middle canopy of the plants grown in the cocopeat system were significantly higher than readings in the soil system (p<0.01) (Table 1).
Table 1. Leaf chlorophyll content (interpreted from measured SPAD value) of plants grown in soil and cocopeat systems.

<table>
<thead>
<tr>
<th>System</th>
<th>Measured SPAD value</th>
<th>N</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top leaves</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cocopeat</td>
<td>51.7</td>
<td>150</td>
<td>257</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Soil</td>
<td>48.2</td>
<td>150</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle leaves</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cocopeat</td>
<td>51.4</td>
<td>150</td>
<td>257</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Soil</td>
<td>49</td>
<td>150</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Gross water use of the cocopeat system was higher, while net water use of the soil system was higher. Over the 12 months period, gross water use by the soil and cocopeat system were 2074 and 2257 L m⁻², respectively, and net water use by the soil system and cocopeat system were 2074 and 877 L m⁻², respectively (Figure 6). The total net monthly water use for the soil system varied between 150 and 195 L m⁻², compared to 48 to 87 L m⁻² for the cocopeat system. The annual difference of 1197 L m⁻² in net water use between the cocopeat and soil system implies 58% water savings by the cocopeat system – if the water can be collected and re-used. If water re-use would not have been possible, the cocopeat system would have used 11% more water than the soil system.

Figure 6. Cumulative amount of water use for soil and cocopeat systems between January and December 2013.

The number of harvested stems increased steadily (Figure 7). The cumulative number of stems was greater in the cocopeat system than in the soil system. By the end of the 12-month period the cocopeat system had 241 stems m⁻² compared to 157 stems m⁻² in soil system, which represents 53% more stems.

Figure 7. Number of stems produced in soil and cocopeat systems between January and December 2013.
DISCUSSION

As the two treatments were placed in the same greenhouse, air temperature was the same. As the number of leaves per stem is a developmental character that is mainly temperature-dependent (Pasian and Lieth, 1994; Marcelis-van Acker, 1995), no difference between the two treatments was observed. ROSESIM, a computer simulation model of the growth which uses day and night temperatures to simulate vegetative growth of roses, is also indicative of the role of temperature in the developmental period of a stem (Hopper et al., 1994).

The chlorophyll content in both systems differed significantly. This is associated with differences in leaf chlorophyll and nitrogen content (Wang et al., 2014). The cocopeat system offers better possibilities for an optimized fertigation regime and better nutrient availability leading to higher growth rates, and a higher total weight of stems (Wang et al., 2014). Production in the cocopeat system, in terms of number of stems (Figure 7) and in terms of total fresh weight (data not shown), was higher than in the soil system. However, crop management was of great influence. For instance, stems in the cocopeat system were initially (in 2012) longer than in the soil system in the first harvested flushes. Crop management was adjusted such that in 2013 stem length was similar for both treatments (driven by commercial motivation), but the number of stems in the cocopeat treatment was higher. Consequently, stem length, leaf length expansion, and flower head diameter and width did not differ significantly between both systems. The rose crop grown on cocopeat enjoyed a more favourable nutrient application regime, which resulted in a higher photosynthetic capacity, as shown by the higher SPAD values, as well as higher total stem weight.

Our findings are similar to those of (Jiao and Grodzinski, 1998), who did not find significant differences for flower size, number of nodes and internodes for roses grown in soil and tuff. However, the significant treatment difference in chlorophyll content from our study does not correspond with some reported results (Maloupa et al., 2001). These authors reported that there were no significant differences in net photosynthetic rate, stomatal conductance and intercellular CO₂ concentration for plants grown on different substrates. Also, Ahmad et al. (2013) did not find significant differences in total leaf chlorophyll of rose cultivars grown in the open field and greenhouse systems. On the other hand, the distinct differences between their two systems led to higher values for parameters such as plant height, number of leaves per branch, leaf area, days to flower, number of flowers per plant per flush and, flower diameter for greenhouse grown plants compared with field cultivated.

Water was saved from the cocopeat system through the collection of the drain water and its re-use in the soil system, hence a lower net use of water and savings on fertilizers in cocopeat. In a production system where water is not re-used, our findings would suggest a higher water use by the cocopeat system. This would depend on the fertigation strategy to maintain an EC level that is favourable to the crop. In the case of our experiment, a relatively high volume of drain was required to flush excess Na from the system. In practice, nearly always soil systems are nearby and, therefore, cocopeat cultivation does offer water and nutrient saving strategies.

The difference in net water use was defined as the water savings for the cocopeat. Plant water uptake in the cocopeat system was determined as the difference between water applied and drained. Plant transpiration was assumed to be equal to plant water uptake (which admittedly ignores the water in the crop itself). Plant water uptake in the soil system, which could not be directly measured, was assumed to be 90% of plant water uptake in the cocopeat system. Soil evaporation was assumed to be 10% of plant water uptake. Finally, water drained from the soil system was computed as the difference between water applied, and plant water uptake and evaporation.

At a first glance, a cocopeat system seems to be more profitable than a soil system: savings on water and nutrients, and more harvestable stems. However, Van der Maden et al. (2011) indicated that the costs of using a cocopeat-based irrigation system were higher than using soil in Ethiopia. More detailed information on the farming system from further research could provide more clarity and offer growers information to make an informed decision.
CONCLUSION

Growth parameters of rose plants were not significantly affected by substrate under the same greenhouse climatic conditions. However, there were significant differences for the number of stems and measured SPAD value, which were associated with leaf chlorophyll and nitrogen content. It is likely that the optimized fertigation regime in the cocopeat system led to higher growth rates and enabled a higher stem production. It is possible that water can be saved if drainage is collected and re-used, for example, an adjacent soil system.

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Literature cited


