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Water Use Efficiency and Flower Yield and Quality of Three *Matthiola incana* Cultivars Irrigated with Three Types of Water

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**Abstract:** The effect of three water types with different salinity levels; the effluent from Ramtha treatment plant EF (2.02 dS m$^{-1}$) and extra treated wastewater after Ultra Filtration membrane UF (1.91 dS m$^{-1}$) and Mixed water (50% after Reverse Osmosis membrane RO with 50% of UF; 1.15 dS m$^{-1}$) on flower production and quality and water use efficiency of *Matthiola incana* cvs. Cinderella Red, Cinderella Yellow and Cinderella Lavender planted in soil under the plastic house conditions was investigated during the year 2006. Water type had significant effects on matthiola flower yield and quality produced. In general, the three *Matthiola* cultivars produced the highest flower yields kg m$^{-2}$ when irrigated with the UF water type compared to the EF and Mix water treatments. The significantly highest flower yield was recorded for the yellow and lavender cultivars irrigated with the UF water type, while the lowest flower yields were recorded for the three cultivars irrigated with the Mix water treatment. This increase in flower yield weight was accompanied with better flower quality and higher percentages of tissue dry weight. At the end of the season, the highest macro and micro elements concentrations were recorded in soil plots irrigated with UF water type compared to the UF and Mix water treatments. In both soil depths, P, Ca and Mg showed very low levels while K highly accumulated. Mn and Cu showed high concentrations in soil plots irrigated with the EF and UF water types compared to the Mix water treatment. Fe and Zn highly exceeded the adequate levels in both soil depths when irrigated with EF and UF water types. The Mix water type showed much less salinity build-up compared to the EF and UF related to higher concentrations of Na in both soil depths. The three matthiola cultivars tolerated the medium salinity levels of the UF water type which seems to be optimal indicated by the highest cut flowers and quality produced. The highest calculated water use efficiency was given by three matthiola cultivars when irrigated with the UF water type while the least was recorded for Mix water treatment used for the three cultivars.

**Key words:** *Matthiola*, effluent, ultra-filtration, reverse osmosis

**INTRODUCTION**

Membranes of extra water treating such as Ultra Filtration and Reverse Osmosis reduce the adverse chemical impact on soil and plant (Tamimi, 2004) through their effects on improving the ultimate quality of water expanding the opportunity reuse of the low water quality reclaimed wastewater in more safe way for agriculture when it is available as of main water resource. This would diminish risks expected from the heavy metals impact emphasized by Water Corporation (2003), Amin (2001) and Kretschmer et al. (2002) creating new option of water for irrigation which consequently will positively serve in keeping our fragile rational water balance saving fresh water for more valuable uses such as drink, industry, or tourism. Reclaimed wastewater used in irrigating mainly field crops (Middle East Water Shortage, 2000), citrus trees in Florida (Parson et al., 1997) and highway landscapes in Egypt (Heliopolis, 2001).

Cut flower (non edible) crops offer a better agricultural option and give new dimensions on reclaimed water use since they are planted on profitable and sustainable bases. Among these cut flower crops *Matthiola incana* is of a commercial importance in Jordan market and worldwide. No classifying reference has been found in regard to salt tolerance of matthiola plants.

The objective of this study is to monitor and evaluate performance (cut flower production and quality) of three cultivars *Matthiola incana* irrigated with three types of reclaimed water (the effluent EF) and/or extra treated water after Ultra Filtration (UF) and Reverse Osmosis (RO) membranes and the chemical effects on plant tissue and soil under the plastic house conditions.

**MATERIALS AND METHODS**

The research was conducted during the year 2006 by the cooperation between the National Center for
Agricultural Researches and Technology Transfer NCARTT Jordan and funded by the USAID. Seeds of three *Matthiola incana* cv., Cinderella Red, Cinderella Yellow and Cinderella Lavender were purchased from a flower Agent in Jordan flower burs. All the seeds were nursered (germinated and grown) for 55 days, transplanted in soil under a plastic house of 360 m$^2$ area at Ramtha experimental station 50 km north of Amman at the end of March 2006. Experimental plots (raised beds) of 1×2 m area and 48 m$^{-2}$ transplants, planting density were used 96 plants/experimental plot. All plants were watered uniformly with three water types: W1: the Effluent of Ramtha WW treatment plant EF (2.02 dS m$^{-1}$); W2: after Ultra-Filtration membrane UF (1.91 dS m$^{-1}$); W3: mixed water (50% after Reverse Osmosis membrane RO with 50% of UF, 1.15 dS m$^{-1}$) by drip irrigation network, water chemical characteristics are shown in Table 1.

One irrigation level (frequency) treatment was applied every day at level of 100% of the Class A evaporation pan readings. Water types and Matthiola cultivars were distributed in a split plot with Randomized Complete Block Design (RCBD) with four replications. All the plants were irrigated and sprayed with a fungicide as a protective measure immediately after transplanting; pest and disease control program was followed during the experiment time in cooperation with specialists of NCARTT.

All plants received 1.6 kg mono ammonium phosphate during the first week after planting, after that fertilizing program performed by adding 40 g NPK +TE/plot/week for EF and UF irrigated plants and 80 g NPK+TE/plot/week for plants had the Mix water type. Flower stalk harvesting took place in the suitable stage of cluster development (%2/3rds of florets have opened) as outlined by Auman (1980).

Plant performance was recorded on the parameters of flower stalks weight (kg m$^{-2}$), flower stem length and cluster length and diameter. Plant tissue and soil chemical characteristics were estimated and recorded at the end of experiment.

All results were tabulated, statistically analyzed, comparisons were performed according to Least Significant Difference (LSD) 5% level of significance.

**RESULTS AND DISCUSSION**

All properties and nutrient contents of the three water types used in irrigation (Table 1) were within the Jordanian standards limits of 2002 for reclaimed domestic water allowed for agricultural irrigation. Water type had a significant effect on Matthiola flower yield and quality produced (Fig. 1 and Table 2). In general, the three cultivars produced significantly the highest flower yields kg m$^{-2}$ when irrigated with the UF water type compared to the EF and Mix water treatments (Fig. 1). The significantly highest flower yield was recorded for the yellow and lavender cultivars followed by the red one irrigated with the UF water type. While the lowest flower yields were recorded for the three cultivars irrigated with the Mix water treatment. The increase in flower yield weight was reflected of longer flower stalks and better flower quality produced by the three cultivars irrigated with UF compared to the other water types (Table 2). The lowest flower quality parameters were recorded for the three cultivars when irrigated with the Mix water treatment.

Although, the mixed water irrigated plants received higher fertilizing levels, it seems not enough to give flower yield and quality as those irrigated with EF or UF which is obviously reflected in higher dry weight percentage in the plant tissue when irrigated with these two water types. The highest calculated water use efficiency was given by

![Fig. 1: Flower yield response of three Matthiola cultivars irrigated with three water types planted in soil, 2006. *: Water types: EF = Effluent from treatment plant; UF = after Ultra Filtration membrane; Mix = (50% after Reverse Osmosis membrane RO with 50% of UF). Mean separation for each factor within bars by LSD, 5% level](image-url)
three * Matthiola* cultivars when irrigated with the UF water type while the least was recorded for Mix water treatment used for the three cultivars.

Significantly higher macro and micro nutrient concentrations were noticed in the tissue of the three * Matthiola* cultivars when watered with the UF type (Table 3). The lowest nutrient proportions were recorded in the Mix watered plants. However, we found no classifying reference in regard to optimal nutrient tissue contents of * Matthiola* plants to compare with.

The highest macro and micro elements concentrations were recorded in both soil depths of plots irrigated with EF type compared to the UF and Mix water treatments (Table 4 and 5). Phosphorus showed very low concentrations in both soil depths irrigated with the three water types compared to Bookens’s category 1984 (30-70 ppm) for the USA. Although, Potassium highly accumulated in both depths irrigated with the EF water type, however, the concentrations caused by the three water types exceeded the limits of the FAO 1980 (156 ppm) (Table 4).

Both Calcium and Magnesium showed very low concentrations in both soil depths when irrigated with the three water types and no accumulation was recorded according to the FAO limits 1980 (17.6-40 meq L⁻¹ for the Ca and 8-38 meq L⁻¹ for Mg). Although Sodium reached high levels in soil depths irrigated with the EF water type compared to the UF or Mix treatments, however, it still very low than the levels emphasized by Bookers (1984) (32 meq L⁻¹) for the USA (Table 4).

EF and UF irrigated plots showed higher concentrations of Manganese and Copper compared to the Mix watered plots (Table 5). These two micro elements showed no accumulation in both depths of soil irrigated with the three water types and still in the lower limits according to the FAO (1980) (25 and 5 ppm) for both elements respectively. Iron concentrations highly exceeded limits declared by FAO (1980) (>4 ppm), while Zinc showed much higher levels than adequate according to the FAO limits (1.6 ppm).

Less salinity build-up was observed in both soil depths when irrigated with the Mix water type compared
Table 4: Macro element levels in two depths of soil planted to three matthiola cultivars irrigated with three water types, 2006

<table>
<thead>
<tr>
<th>WT/cultivar</th>
<th>N (%)</th>
<th>P (ppm)</th>
<th>K (ppm)</th>
<th>Ca (meq L⁻¹)</th>
<th>Mg (meq L⁻¹)</th>
<th>Na (meq L⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-20</td>
<td>20-40</td>
<td>0-20</td>
<td>20-40</td>
<td>0-20</td>
<td>20-40</td>
</tr>
<tr>
<td>EF Cinderella Red</td>
<td>0.045c</td>
<td>0.054a</td>
<td>22.4a</td>
<td>16.9a</td>
<td>221.3a</td>
<td>301.9a</td>
</tr>
<tr>
<td>Cinderella Yellow</td>
<td>0.047a</td>
<td>0.053a</td>
<td>23.2a</td>
<td>16.9a</td>
<td>221.1a</td>
<td>301.0a</td>
</tr>
<tr>
<td>Cinderella Lavender</td>
<td>0.040b</td>
<td>0.053a</td>
<td>22.4a</td>
<td>16.6a</td>
<td>221.0a</td>
<td>302.1a</td>
</tr>
</tbody>
</table>

UF Cinderella Red | 0.034e | 0.043b | 19.4b | 12.7b | 214.1b | 243.9bc | 6.6a | 5.5b | 6.7bc | 5.1d | 10.9b | 9.2c |
| Cinderella Yellow | 0.033F | 0.043b | 19.3b | 12.1b | 214.2b | 241.8c | 6.5a | 5.5b | 6.3cd | 5.2cd | 10.8b | 9.4c |
| Cinderella Lavender | 0.035d | 0.043b | 19.1b | 12.3b | 215.0b | 245.1bc | 6.6a | 5.4b | 6.4bc | 5.1d | 10.7b | 9.7b |

Mix Cinderella Red | 0.024b | 0.040c | 16.9c | 9.4c | 194.0c | 227.3c | 3.6d | 4.7c | 5.7cd | 5.3c | 3.3c | 1.8d |
| Cinderella Yellow | 0.025c | 0.040c | 16.8cd | 9.5c | 194.5c | 225.4d | 3.7d | 4.7c | 5.7de | 5.3c | 3.4c | 1.8d |
| Cinderella Lavender | 0.024b | 0.040c | 15.8d | 9.2c | 193.5c | 225.1d | 3.5d | 4.6c | 5.5de | 5.3c | 3.8c | 1.8d |

LSD* | 0.001 | 0.0017 | 1.08 | 0.97 | 3.93 | 2.49 | 0.55 | 0.17 | 0.62 | 0.13 | 1.02 | 0.36 |

*Water type: EF = Effluent of treatment plant; UF = After Ultra-filtration membrane; Mix = (50% After Reverse Osmosis membrane+50% UF). Mean separation for each factor within columns by LSD test, 5% level

Table 5: Micro element and electrical conductivity levels in two depths of soil planted to three matthiola cultivars irrigated with three water types, 2006

<table>
<thead>
<tr>
<th>WT/cultivar</th>
<th>Mn (ppm)</th>
<th>Fe (ppm)</th>
<th>Zn (ppm)</th>
<th>Cu (ppm)</th>
<th>EC (dS m⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-20</td>
<td>20-40</td>
<td>0-20</td>
<td>20-40</td>
<td>0-20</td>
</tr>
<tr>
<td>EF Cinderella Red</td>
<td>15.6a</td>
<td>12.7a</td>
<td>19.8a</td>
<td>23.2a</td>
<td>42.5a</td>
</tr>
<tr>
<td>Cinderella Yellow</td>
<td>15.4a</td>
<td>12.5ab</td>
<td>18.5b</td>
<td>23.1a</td>
<td>42.6a</td>
</tr>
<tr>
<td>Cinderella Lavender</td>
<td>16.1a</td>
<td>12.8a</td>
<td>20.1a</td>
<td>22.8a</td>
<td>40.6b</td>
</tr>
</tbody>
</table>

UF Cinderella Red | 15.6a | 12.1bc | 18.6b | 18.6b | 35.5c | 28.1c | 2.46c | 0.91bc | 2.67b | 2.59bc |
| Cinderella Yellow | 15.5a | 11.8c | 18.3b | 18.5b | 35.2c | 28.5c | 2.73b | 0.96b | 2.71b | 2.56c |
| Cinderella Lavender | 15.6a | 12.0bc | 18.2b | 18.7b | 35.8c | 28.0c | 2.53bc | 0.93b | 2.61b | 2.66b |

Mix Cinderella Red | 12.3b | 10.4d | 14.0c | 14.4c | 24.5d | 22.1d | 1.80d | 0.86c | 0.97c | 0.97d |
| Cinderella Yellow | 12.6b | 10.4d | 14.1c | 14.1c | 24.6d | 22.3d | 1.73d | 0.86c | 0.94c | 0.96d |
| Cinderella Lavender | 12.3b | 10.4d | 14.4c | 14.3c | 24.6d | 22.6d | 1.80d | 0.88c | 0.97c | 0.97d |

LSD* | 1.11 | 0.52 | 0.86 | 0.68 | 1.03 | 0.92 | 0.26 | 0.07 | 0.14 | 0.09 |

*Water type: EF = Effluent of treatment plant; UF = After Ultra-filtration membrane; Mix = (50% After Reverse Osmosis membrane+50% UF). Mean separation for each factor within columns by LSD test, 5% level

to the higher levels recorded for the EF and moderate levels of UF irrigated plots (Table 5). This was coincided with higher concentrations of Sodium in plots irrigated with each water type. However, at the end of the season, soil salinity caused by EF or UF water types still within the slightly saline category of the USDA 1969 (2-4 dS m⁻¹). While it is much less than that in plots irrigated with the Mix water treatment.

CONCLUSIONS

Water type had a significant effect on Matthiola flower yield and quality produced. In general, the three matthiola cultivars produced the highest flower yields kg m⁻² when irrigated with the UF water type compared to the EF and Mix water treatments. The significantly highest flower yields were recorded for the yellow and lavender cultivars irrigated with the UF water type. While the lowest flower yields were recorded for the three cultivars irrigated with the Mix water treatment. This increase in flower yield weight was accompanied by better flower quality and higher percentages of tissue dry weight.

At the end of the season, the highest macro and micro elements concentrations were recorded in soil plots irrigated with EF water type compared to the UF and Mix water treatments. In both soil depths, P, Ca and Mg showed very low levels while K highly accumulated. Mn and Cu showed high concentrations in soil plots irrigated with the EF and UF water types compared to the Mix water treatment. Fe and Zn highly exceeded the adequate
levels in soil plots when irrigated with EF and UF water types. The Mix water type showed much less salinity build-up compared to the EF and UF which related to higher concentrations of Na in both soil depths. However, there was no classifying reference was found in regard to salt tolerance of Matthiola plants to compare with, the three *Matthiola* cultivars tolerated the medium salinity levels of the UF water type which seems to be optimal indicated by the highest cut flowers and quality produced. The highest calculated water use efficiency was given by three *Matthiola* cultivars when irrigated with the UF water type while the least was recorded for Mix water treatment used for the three cultivars.

**REFERENCES**


