# S U M M A R Y

Two-year-old seedlings of two citrus root-stocks, i.e. Cleopatra mandarin and sour orange were transplanted in woody boxes filled with clay loam soil disinfected with 2% Formalin solution (2 seedlings per each box).

The treatments used in this study involved :

1. Boxes left untreated as control.
2. Boxes fertilized with phosphorus at the rate of 5g $P_2O_5$ as superphosphate (control).
3. Boxes unfertilized with P but the soil was inoculated with Glomus macrocarpus fungi.
4. Boxes unfertilized with P but soil was inoculated with Glomus australe fungi.
5. Boxes fertilized with phosphorus at the rate of 5g $P_2O_5$ as superphosphate and the soil was inoculated with Glomus macrocarpus fungi.
6. Boxes fertilized with phosphorus at the rate of 5g $P_2O_5$ as superphosphate and the soil was inoculated with Glomus australe fungi.

On the other hand, other set of seedlings were planted in 30 cm diameter clay pots treated with mycorrhizae and fertilized with phosphorus with the same rate for boxes for the infection and intensity studies.

The obtained results could be summerized as follows :

## 5.1 Infection :

1. Mycelium and arbuscules of mycorrhizae fungi on roots of Cleopatra mandarin and sour orange started with low percentages in May followed by a gradual increase in July to reach the maximum (100%) in September. However, in both rootstocks vesicles percentages on citrus roots were almost 100% in all sampling dates.

2. Mycelium, vesicles, and arbuscules on roots of control rootstocks used were nil.

3. In May and July, seedlings inoculated with mycorrhizae fungi and unfertilized with phosphorus gave higher percentages of mycelium and arbuscules on their roots as compared to that of inoculated and fertilized ones.

4. Generally, in all sampling dates, Glomus australe fungi was associated with higher percentages of arbuscules than Glomus macrocarpus mycorrhizae.

## 5.2. Intensity :

1. Number of mycelium, vesicles, and arbuscules on roots of the two studied citrus rootstocks started with low numbers in May followed by an increase in July and a sudden increase in September.

2. Citrus seedlings inoculated with mycorrhizae and unfertilized with phosphorus had roots with higher number of mycelium, vesicles, and arbuscules as compared with those treated with mycorrhizae and fertilized with phosphorus.

3. Glomus australe fungi caused a higher increase in number of vesicles and arbuscules on roots of citrus rootstocks more than Glomus macrocarpus mycorrhizae. On the other hand, the effect of mycorrhizae species on mycalium number depended upon the rootstock used. In this respect, while Glomus australe fungi were superior in increasing number of mycelium on roots of Cleopatra mandarin seedlings as compared to Glomus macrocarpus, the picture was changed to the opposite when sour orange seedlings were concerned.

## 5.3. Mycorrhizal dependency ratio (MDR) :

1. Cleopatra mandarin depended slightly on mycorrhizae than sour orange rootstock.

2. Glomus macrocarpus fungi was more effective on MDR of seedlings than the Glomus australe fungi.

3. Applying phosphorus to citrus seedlings decreased visually MDR as compared to unfertilized plants.

## 5.4. Dry weight :

1. Higher values of dry weight parameters were observed for sour orange seedlings as compared to Cleopatra mandarin.

2. Mycorrhizae fungi treatments increased dry weight of different parts of seedlings and top/root ratio as compared to control plants. Glomus macrocarpus fungi was more promising in increasing dry weights of whole seedlings, leaves, stem and roots than Glomus australe. Such result was not clearly noticed for top/root ratio.

3. Applying phosphorus only to citrus seedlings caused a significant increase in dry

4. P unfertilized seedlings not only increased root number of different diameters but also the total number of roots than fertilized seedlings.

## 5.7. Leaf minerals content :

1. Generally lower amounts of N and Ca and higher levels of K and Zn were existed in leaves of sour orange rootstock as compared with those of Cleopatra mandarin. No statistical difference between the two rootstocks used was observed concerning leaf P and Mg contents.

2. Mycorrhizae species raised up Leaf N, P, K, and Mg contents and decreased leaf Ca and Zn contents in respect of control plants. *Glomus australe* fungi were more positive in stimulating leaf P, K, and Mg contents than *Glomus macrocarpus* specie. The significant difference was lacking in case of leaf N and Ca contents.

3. Phosphorus fertilizer either added for sour orange or Cleopatra mandarin seedlings increased leaf P, K, and Ca contents and decreased leaf N, Mg, and Zn levels.

5.8. **Root minerals content :**

1. Control seedlings fertilized with phosphorus had roots with higher amounts of N and P and lower levels of K and Mg as compared with unfertilized control plants. No clear trend or difference was noticed in case of Zn and Ca nutrients.

2. Roots of sour orange seedlings contained higher amounts of N, K, Ca, Mg, and Zn than those of Cleopatra mandarin seedlings which were more rich in root P content.

3. Mycorrhizae fungi decreased root P, Ca, Mg, and Zn contents and in the same time increased N and K levels as compared with non inoculated seedlings (control). Glomus australe fungi had increased root N and Zn contents and decreased root P, K, Ca, and Mg levels. No significant difference was observed between the two species of mycorrhizae in their effect on root minerals content.

4. Phosphorus fertilization increased N and P contents of citrus rootstocks whilst it had no

effect on root K, Ca, Mg, and Zn since the difference was small.

## 5.9. Leaf chlorophyll and carotene contents :

1. Leaves of sour orange seedlings contained higher amounts of chlorophyll (A) and total chlorophyll and lower level of carotene in respect of Cleopatra mandarin. Citrus species had no statistical effect on leaf chlorophyll (B).

2. Mycorrhizae species used were promising in building up more leaf chlorophyll and carotene over the control. Meanwhile, Glomus australe fungi as compared with Glomus macrocarpus decreased leaf chlorophyll (A) and carotene whilst they increased leaf chlorophyll (B) and total chlorophyll. Such effect was not statistically observed in case of leaf total chlorophyll.

3. Seedlings receiving phosphorus were inferior in their leaf chlorophyll and carotene contents. However, significant differences were lacking when leaf chlorophyll (B) and carotene contents were concerned.

**5.10. Leaf sugars and stem total carbohydrates :**

1. Sour orange seedlings had leaves with higher amounts of non reducing and total sugars as well as stem total carbohydrates in respect of those of Cleopatra mandarin. Leaf reducing sugars of sour orange were slightly less than those of Cleopatra mandarin.

2. *Glomus australe* fungi decreased significantly leaf non-reducing and total sugars and slightly reducing sugars than the control.

3. Applying phosphorus to citrus plants induced a significant decrease in leaf non-reducing sugars but it had no statistical effect on leaf reducing and total sugars as well as stem total carbohydrates.

**5.11. Leaf nitrogen fractions :**

1. Leaves of Cleopatra mandarin seedlings contained higher amounts of soluble nitrogen, rest nitrogen, and ammonium nitrogen and lower level of crystalloid nitrogen as compared with those of sour orange. Citrus rootstocks had no statistical effect on leaf nitrate content.

2. Comparing *Glomus macrocarpus* fungi treatment with the control, it significantly decreased leaf crystalloid nitrogen and nitrate contents as well as increased leaf rest nitrogen but without any effect on leaf soluble nitrogen and ammonium nitrogen contents. *Glomus australe* fungi, from other hand , increased leaf crystalloid nitrogen and ammonium nitrogen and decreased leaf rest nitrogen and nitrate contents.

3. Phosphorus application decreased leaf soluble nitrogen, rest nitrogen and nitrate contents and increased leaf ammonium nitrogen. Phosphorus, by all means, had no effect on leaf crystalloid nitrogen.

## 5.12 Root nitrogen fractions :

1. Roots of sour orange seedlings were more rich in soluble nitrogen and poor in nitrate content in respect of Cleopatra mandarin. No visual difference was observed between sour orange and Cleopatra mandarin regarding root crystalloid nitrogen, rest nitrogen, and ammonium nitrogen contents.

2. Mycorrhizae fungi fluctuated in their effect

on root nitrogen fractions content. In this concern, Glomus australe fungi succeeded in increasing root soluble nitrogen, crystalloid nitrogen, rest nitrogen, and nitrate contents whereas Glomus macrocarpus fungi raised up only root rest nitrogen, and nitrate contents. Both two mycorrhizae fungi used in this study failed to increase root ammonium nitrogen over the control.

3. Adding phosphorus to citrus seedlings increased only root nitrate content whilst it decreased the other root nitrogen fractions determined in this study.

5.13 **Leaf and root amino acids content :**

1. Cleopatra mandarin seedlings generally gave higher values of leaf and root amino acids content than those of sour orange.

2. P unfertilized but mycorrhizae inoculated plants of both rootstocks were higher in their values of leaf amino acids content than corresponding uninoculated ones. The opposite was true when mycorrhizal fungi and fertilized seedlings were compared with fertilized control ones.

3. *Glomus australe* fungi resulted in an increase in leaf amino acids content than *Glomus macrocarpus* mycorrhizae.

4. Leucine and Isoleucine, Proline, and Hydroxy Proline existed in citrus leaves with higher amounts whereas leaf Valine, Tyrosine, Threonine, Glysine, Arginine, and Histidine showed an opposite trend.

5. Cleopatra mandarin and sour orange seedlings fertilized with phosphorus and inoculated with *Glomus macrocarpus* fungi gave higher values of root amino acids content than those unfertilized and inoculated with the same mycorrhizae fungi.

6. Mycorrhizae fungi treatments increased root amino acids level as compared to non-inoculated control plants. At all events, *Glomus macrocarpus* fungi were more promising in increasing root amino acids content than *Glomus australe*.

7. Applying phosphorus to citrus seedlings induced a general increase in root amino acids content as compared with unfertilized ones. That

was true in either inoculated or non-inoculated plants.

8. Leucine and Isoleucine, Proline, and Hydroxy Proline were higher in roots of citrus seedlings whilst Valine, Threonine, Glysine, Arginine, and Histidine were inferior in roots of citrus rootstocks studied in this research.

5.14 **Leaf cytokinins content :**

1. Applying phosphorus to control seedlings decreased leaf cytokinins content in June but in September the effect was changed to the reverse. Such result was more clear in case of Cleopatra mandarin rootstock.

2. Inoculating P unfertilized plants with mycorrhizae increased leaf cytokinins content in both June and September samples. In sour orange rootstock such effect was not so strong as in Cleopatra mandarin.

3. Applying phosphorus to inoculated seedlings of both citrus rootstocks increased leaf cytokinins content in September as compared with P

unfertilized and inoculated plants. The picture was changed to the reverse in June.

4. *Glomus macrocarpus* fungi raised up leaf total cytokinins content in June in respect of *Glomus australe* fungi. The opposite was generally true when leaves were sampled in September.

5. Leaf total cytokinins content was highest in June then decreased remarkably in September.

## 5.15 Soil properties :

1. At the termination of the experiment, analysis of soil showed that phosphorus fertilization for Cleopatra mandarin resulted in an increase in available N and a decrease in P, K, Ca, and Mg nutrients. In the case of sour orange, phosphorus fertilization decreased soil available N, P, and Ca contents and increased available K.

2. Adding *Glomus macrocarpus* fungi for unfertilized soil of Cleopatra mandarin induced an increase in its contents of available N, P, and Ca and a decrease in soil K and Mg levels. In

addition, Glomus australe was superior in increasing soil available nutrients discarding P. Moreover, inoculating unfertilized soil of sour orange with mycorrhizae generally increased available macro-nutrients in the soil.

3. Soil fertilized with phosphorus and treated with Glomus macrocarpus fungi contained higher levels of available N, P, and Ca.

Similarly, Glomus australe mycorrhizae caused an increase in soil available N, P, and Ca contents and a decrease in soil K level.

Generally, inoculation of Cleopatra/ mandarin and sour orange seedlings grown in sterelized soil with endomycorrhizal fungi enhanced vegetative growth, root growth and distribution, and chemical constituents of both Cleopatra mandarin and sour orange seedlings. Furthermore, Glomus australe fungi and no phosphorus fertilization for Cleopatra mandarin seedlings and Glomus macrocarpus fungi and no phosphorus fertilization for sour orange plants gave the best results of seedlings growth.

Therefore, Glomus macrocarpus or Glomus australe fungi could be used as bio-fertilization for citrus seedlings in fumigated clay loam soil for producing good seedlings free from diseases.