4- RESULTS AND DISCUSSION

The effect of soil type namely calcareous, sandy and loamy sandy soil and soil treatments, *i.e.* unsterilized soil "control", sterilized soil, sterilized soil inoculated with mycorrhizae fungi "***Glomus australe***" or "***Glomus macrocarpum***" as well as the interaction between soil type and soil treatments on some seedling growth parameters namely stem length, stem diameter, number of lateral shoots per seedling, root length and number of roots per seedling of some citrus rootstocks namely Sour orange, Rangpur lime and Volkamer lemon during 1998 and 1999 seasons is presented in **Tables (3 – 11)**.

4.1. Sour orange rootstock

4.1.1. Seedling growth parameters

The response of growth of Sour orange rootstock seedlings to soil type namely calcareous, sandy and loamy sandy soil and soil treatments, *i.e.* soil sterilization, supported with soil inoculation with mycorrhizal fungi (***Glomus australe*** and ***Glomus macrocarpum***), besides soil sterilization provided with soil inoculation with mycorrhizae species and enriched with rock-phosphate fertilization (1 g/pot) as well as the interaction between soil type and soil treatments during 1998 and 1999 seasons is presented in **Tables (3,4 & 5).**

4.1.1.1. Stem length

Table (3) shows that Sour orange rootstock seedlings grown in calcareous soil produced the shortest plants (11.79 & 11.99 cm) as compared with the analogous ones grown in loamy sandy soil (15.53 & 15.76 cm) in 1998 and 1999 seasons, respectively. On the other hand, seedlings grown in sandy soil gave plants intermediate in their length (13.54 & 13.77 cm) as compared with the aforementioned two tested soil types in the first and second seasons, respectively. Generally, the differences in stem length between the three tested soil types were significant from the statistical standpoint.

As for the effect of soil treatments **Table (4)** demonstrates that Sour orange seedlings grown in sterilized or unsterilized soil 'control' gave comparatively and similarly the shortest plants. On the other side, supplementing sterilized soil with ***Glomus macrocarpum*** fungi produced longer plants as compared with the corresponding ones inoculated with ***Glomus australe*** in the first and second seasons. Moreover, fertilizing Sour orange seedlings grown in sterilized soil, inoculated with ***Glomus macrocarpum*** with rock-phosphate resulted in a high stimulative effect on stem length as compared with soil inoculated with ***Glomus australe*** and fertilized with rock-phosphate.

Furthermore, the interaction between soil type and soil treatments exerted a pronounced effect on Sour orange seedling height **(Table, 5)**. It is quite evident that all combinations of loamy sandy soil produced statistically higher values of stem length in both seasons as compared with the analogous ones grown in calcareous and sandy soils. Generally, Sour orange seedlings grown in loamy sandy soil, inoculated with ***Glomus macrocarpum*** and fertilized with rock-phosphate gave comparatively the longest plants. On the contrary, the interactions of calcareous soil showed to be the least effective combinations in exerting stimulative effect on stem length, particularly those grown in sterilized or unsterilized soil "control". On the other hand, the combinations of sandy soil produced inbetween values in this concern.

4.1.1.2. Stem diameter

Table (3) reveals that Sour orange rootstock seedlings grown in loamy sandy soil had thicker stems (0.31 & 0.35 cm) as compared with the analogous ones grown in calcareous soil (0.26 & 0.29 cm) in 1998 and 1999 seasons, respectively. On the other hand, seedlings grown in sandy soil gave plants intermediate in their diameter (0.29 & 0.32 cm) as compared with aforementioned two tested soil types in the first and second seasons, respectively. Generally, the differences in stem diameter between the three tested soil types were significant from the statistical standpoint.

As for the effect of soil treatments, **Table (4)** demonstrates that seedlings grown in sterilized and unsterilized soil 'control' gave comparatively and similarly the thinnest plants. On the other hand, inoculating the sterilized soil with mycorrhizae fungi produced enhancing effect on stem diameter. However, the differences between the two tested mycorrhizae species in this respect were lacking from the statistical standpoint. Furthermore, fertilizing sterilized and inoculated soil with mycorrhizae fungi with rock-phosphate resulted in exerting the most stimulative effect on stem diameter. Anyhow, inoculating sterilized soil, fertilized with rock-phosphate, with ***Glomus macrocarpum*** fungus surpassed the corresponding ones inoculated with ***Glomus australe*** fungus in producing the thickest stems.

Additionally, stem diameter of Sour orange rootstock responded remarkably to the interaction between soil type and soil treatments **(Table, 5)**. Generally, Sour orange seedlings grown in loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate proved to be the most effective treatment in enhancing stem diameter, followed descendingly by those grown in sandy soil inoculated with the previously mentioned mycorrhizae species and fertilized with rock-phosphate and the analogous ones grown in loamy sandy soil, inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate. On the contrary, Sour orange seedlings grown in sterilized or unsterilized calcareous soil produced the least positive effect on stem diameter in both seasons. Other tested combinations took intermediate positions between the previously two mentioned categories.

4.1.1.3. No. of lateral shoots/seedling

It is quite evident from **Table (3)** that in both seasons Sour orange rootstock seedlings grown in loamy sandy soil succeeded in increasing number of lateral shoots per seedling (1.89 & 1.96 cm) as compared with the analogous ones grown in calcareous soil (1.60 & 1.67 cm). On the other hand, seedlings grown in sandy soil gave plants intermediate in their number of lateral shoots per seedling (1.71 & 1.78 cm) as compared with the aforementioned two tested soil types in 1998 and 1999 seasons, respectively. Generally, the differences in number of lateral shoots per seedling between the three tested soil types were significant from the statistical standpoint.

As for the effect of soil treatments **(Table, 4)** demonstrates that seedlings grown in sterilized or unsterilized soil "control" proved to be the least effective treatment in this respect. On the other hand, inoculating the sterilized soil with mycorrhizae fungi produced positive effect on number of lateral shoots per seedling. However, the differences between the two tested mycorrhizae species in this respect were lacking from the statistical standpoint. Furthermore, supporting sterilized soil, inoculated with mycorrhizae fungi with rock-phosphate fertilization succeeded in exerting the most stimulative effect on number of lateral shoots per seedling. Anyhow, inoculating sterilized soil, fertilized with rock-phosphate with ***Glomus macrocarpum*** fungus surpassed significantly the corresponding ones inoculated with ***Glomus australe*** fungus in increasing number of lateral shoots per seedling.

Additionally, number of lateral shoot per seedling of Sour orange rootstock responded remarkably to the interaction between soil type and soil treatments **(Table, 5)**. Generally, Sour orange seedlings grown in loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate succeeded in increasing number of lateral shoots per seedling followed descendingly by those grown in the same soil inoculated with ***Glomus australe*** fungus fertilized with rock-phosphate and the analogous ones grown in sandy soil inoculated with ***Glomus macrocarpum*** fungus fertilized with rock-phosphate. On the contrary, Sour orange seedlings grown in sterilized or unsterilized calcareous soil produced the least positive effect on number of lateral shoots per seedlings in both seasons. Other tested combinations took intermediate positions between the previously two mentioned categories.

4.1.1.4. No. of leaves/seedling

It is clear that in 1998 and 1999 seasons, that Sour orange rootstock seedlings grown in calcareous soils had the lowest number of leaves per seedling (9.38 & 8.77) followed descendling by Sour orange rootstock seedlings grown in sandy soil (10.56 & 9.88) in the first and second seasons, respectively

(Table, 3). On the other hand, seedlings grown in loamy sandy soil succeeded in increasing number of leaves per seedling (11.78 & 11.11) in both seasons, respectively. Generally, the differences in number of leaves per seedling between the three tested soil types were obvious to be significant.

As for the effect of soil treatments, **Table (4)** demonstrates that seedlings grown in sterilized soil and inoculated with ***Glomus macrocarpum*** fertilized with rock-phosphate surpassed the corresponding ones inoculated with ***Glomus australe*** in producing higher number of leaves per seedling. On the other hand, seedling grown in sterilized or unsterilized soil "control" proved to be the least effective treatment in this respect. Furthermore, sterilized and inoculated soil with mycorrhizae fungi produced enhancing effect on number of leaves per seedling. However, the differences between the two tested mycorrhizae species in this respect were insignificant.

Additionally, number of leaves per seedling of Sour orange rootstock responded remarkably to the interaction between soil type and soil treatments (**Table, 5**). Generally, Sour orange seedlings grown in loamy sandy soil, inoculated with ***Glomus macrocarpum*** and fertilized with rock-phosphate succeeded in increasing number of leaves per seedling followed descendingly by the analogous ones inoculated with ***Glomus australe*** in the same soil. On the contrary, sterilized or unsterilized calcareous soils produced the least positive effect on number of leaves per seedling in both seasons. Other tested combinations took intermediate positions between the previously two mentioned categories.

4.1.1.5. Root length

Table (3) reveals that in both seasons Sour orange rootstock seedlings grown in loamy sandy soil produced longer roots (22.88 & 22.57 cm) as compared with the analogous ones grown in calcareous soil (18.71 & 18.29 cm) in 1998 and 1999 season, respectively. On the other hand, seedlings grown in sandy soil gave plants intermediate in their length as compared with the aforementioned two tested soil types (20.79& 20.41 cm) in the first and second seasons, respectively. Generally, the differences in root length between the three tested soil types were significant.

As for the effect of soil treatments, **Table (4)** demonstrates that seedling grown in sterilized or unsterilized soil (control) gave comparatively and similarly the shortest roots. On the other side, supplementing sterilized soil with mycorrhizal inoculation with ***Glomus macrocarpum*** produced longer roots as compared with the corresponding ones inoculated with ***Glomus australe*** in the first and second seasons. Moreover, fertilizing seedlings grown in sterilized soil, inoculated with ***Glomus macrocarpum*** with rock-phosphate induced high stimulative effect as compared with soil inoculated with ***Glomus australe*** and fertilized with rock-phosphate.

Additionally, root length of Sour orange rootstock responded remarkably to the interaction between soil type and soil treatments (**Table, 5**). Generally, Sour orange seedlings grown in loamy sandy soil, inoculated with ***Glomus macrocarpum*** and fertilized with rock-phosphate produced longer roots followed descendingly by those grown in the same soil inoculated with ***Glomus australe*** fertilized with rock-phosphate and analogous ones grown in sandy soil inoculated with ***Glomus macrocarpum*** fertilized with rock-phosphate. On the other hand, Sour orange seedlings grown in sterilized or unsterilized calcareous soil produced the shortest roots in both seasons. Other tested combinations took intermediate positions between the previously two mentioned categories.

4.1.1.6. No. of roots/seedling

In both seasons in (**Table, 3**) Sour orange rootstock seedlings grown in calcareous soil had the lowest number of roots per seedling (3.06 & 2.91 cm) as compared with the analogous ones grown in loamy sandy soil (3.24 & 3.10 cm). On the other side, seedlings grown in sandy soil gave intermediate number of roots as compared with aforementioned two tested soil types (3.16 & 3.03 cm) in the first and second seasons, respectively. Generally, the differences in number of roots between the three tested soil types were statistically significant.

As for the effect of soil treatments on number of roots per seedling. **Table (4)** demonstrates that seedlings grown in sterilized or unsterilized soil (control) gave comparatively and similarly the lowest number of roots. On the other hand, sterilized soil enriched with mycorrhizal inoculation with ***Glomus australe*** or ***Glomus macrocarpum*** gave comparatively higher number of roots per seedling. However, ***Glomus macrocarpum*** surpassed ***Glomus australe*** in exerting more stimulative effect on roots development. Moreover, fertilizing sterilized soil inoculated with mycorrhizae fungi; particularly

Glomus macrocarpum produced the maximum positive effect on number of roots especially in 1998 season.

Furthermore, number of roots per seedling of Sour orange rootstock responded remarkably to the interaction between soil type and soil treatments (**Table, 5**). Generally, Sour orange seedlings grown in sterilized or unsterilized calcareous soil produced the lowest number of roots. On the other hand, seedlings grown in loamy sandy soil inoculated with ***Glomus macrocarpum*** and fertilized with rock-phosphate (1g/pot) succeeded in producing the most enhancing effect on number of roots followed descendling by those grown in sandy soil inoculated with the previously mentioned mycorrhizae species and fertilized with rock-phosphate and the analogous ones grown in loamy sandy, inoculated with ***Glomus australe*** and fertilized with rock-phosphate. Other tested combinations took intermediate positions between the previously two mentioned categories.

Table (3): Specific effect of soil type on some growth parameters of Sour orange rootstock seedlings (1998 & 1999 seasons).

Soil type	Stem length (cm)		Stem diameter (cm)		No. of lateral shoots/seedling		No. of leaves/seedling		Root length (cm)		No. of roots/seedling	
	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Calcareous	11.79 C	11.99 C	0.26 C	0.29 C	1.60 C	1.67 C	9.38 C	8.77 C	18.71 C	18.29 C	3.06 C	2.91 C
Sandy	13.54 B	13.77 B	0.29 B	0.32 B	1.71 B	1.78 B	10.56 B	9.88 B	20.79 B	20.41 B	3.16 B	3.03 B
Loamy sandy	15.53 A	15.76 A	0.31 A	0.35 A	1.89 A	1.96 A	11.78 A	11.11 A	22.88 A	22.57 A	3.24 A	3.10 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

Table (4): Specific effect of mycorrhizal inoculation and rock phosphate fertilization on some growth parameters of Sour orange rootstock seedlings (1998 & 1999 seasons).

Treatments	Stem length (cm)		Stem diameter (cm)		No. of lateral shoots/seedling		No. of leaves/seedling		Root length (cm)		No. of roots/seedling	
S.S + VAM + (P)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Control	12.56 E	12.77 E	0.23 D	0.26 D	1.15 D	1.22 D	8.33 D	7.66 D	17.22 E	16.83 E	2.10 E	1.95 D
S.S + ----- + -----	12.63 E	12.86 E	0.23 D	0.26 D	1.18 D	1.26 D	8.44 D	7.88 D	17.42 E	17.09 E	2.10 E	2.00 D
S.S + G.a + -----	13.83 D	14.04 D	0.28 C	0.32 C	1.85 C	1.92 C	10.67 C	10.00 C	19.93 D	19.60 D	3.33 D	3.18 C
S.S + G.m + -----	14.01 C	14.26 C	0.28 C	0.32 C	1.90 C	1.96 C	11.00 C	10.33 C	21.88 C	21.47 C	3.57 C	3.44 B
S.S + G.a + P	14.23 B	14.44 B	0.33 B	0.36 B	2.10 B	2.16 B	12.22 B	11.56 B	23.06 B	22.69 B	3.65 B	3.72 A
S.S + G.m + P	14.47 A	14.69 A	0.34 A	0.39 A	2.23 A	2.31 A	12.78 A	12.11 A	25.26 A	24.86 A	3.96 A	3.80 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

where:

S.S.= Sterilized soil
G.a = *Glomus australe*
VAM = Vesicular Arbuscular Mycorrhizae
G.m = *Glomus macrocarpum*
P= rock phosphate [$Ca_3(PO_4)_2$]

Table (5): Effect of interaction between soil type, mycorrhizal inoculation and rock phosphate fertilization on some growth parameters of Sour orange rootstock seedlings (1998 & 1999 seasons).

Soil type	Treatments S.S + VAM + (P)	Stem length (cm) (1998)	Stem length (cm) (1999)	Stem diameter (cm) (1998)	Stem diameter (cm) (1999)	No. of lateral shoots/seedling (1998)	No. of lateral shoots/seedling (1999)	No. of leaves/ seedling (1998)	No. of leaves/ seedling (1999)	Root length (cm) (1998)	Root length (cm) (1999)	No. of roots/seedling (1998)	No. of roots/seedling (1999)
Calcareous	Control	10.73 K	10.90 L	0.20 G	0.22 G	1.06 I	1.13 I	7.00 J	6.33 J	15.20 K	14.80 K	2.06 G	1.93 H
	S.S + ----- + ----	10.80 K	10.97 L	0.20 G	0.22 G	1.10 I	1.16 HI	7.33 J	7.00 IJ	15.47 K	15.13 K	2.06 G	1.96 H
	S.S + G.a + ----	12.00 J	12.23 K	0.27 EF	0.30 EF	1.70 F	1.76 F	9.66 H	9.00 H	17.87 I	17.47 I	3.13 F	2.97 G
	S.S + G.m + ----	12.17 J	12.43 J	0.27 EF	0.30 EF	1.76 EF	1.83 EF	10.00 GH	9.33 GH	19.77 G	19.33 GH	3.36 E	3.20 F
	S.S + G.a + P	12.40 I	12.60 IJ	0.30 CDE	0.33 CDE	1.96 C	2.03 CD	11.00 EFG	10.33 F	20.93 F	20.47 F	3.83 B	3.70 BC
	S.S + G.m + P	12.63 H	12.83 H	0.32 BCDE	0.35 BCDE	2.03 C	2.13 C	11.33 DEF	10.67 EF	23.00 D	22.57 D	3.90 B	3.70 BC
Sandy	Control	12.53 HI	12.73 HI	0.23 FG	0.27 FG	1.13 HI	1.20 HI	8.33 I	7.66 I	17.23 J	16.83 J	2.06 G	1.93 H
	S.S + ----- + ----	12.60 H	12.87 H	0.23 FG	0.27 FG	1.16 H	1.26 GH	8.33 I	7.66 I	17.40 J	17.10 IJ	2.06 G	1.96 H
	S.S + G.a + ----	13.73 G	13.93 G	0.28 DEF	0.32 DEF	1.83 DE	1.90 E	10.67 FG	10.00 FG	19.93 G	19.63 G	3.33 E	3.20 F
	S.S + G.m + ----	13.90 G	14.13 F	0.28 DEF	0.32 DEF	1.86 D	1.93 DE	11.00 EFG	10.33 F	21.87 E	21.43 E	3.70 C	3.60 CD
	S.S + G.a + P	14.13 F	14.37 E	0.33 BCD	0.37 BCD	2.06 C	2.13 C	12.39 CD	11.67 CD	23.07 D	22.57 D	3.86 B	3.73 BC
	S.S + G.m + P	14.37 E	14.60 D	0.37 AB	0.40 AB	2.23 B	2.30 B	12.67 BC	12.00 BC	25.27 B	24.87 B	3.93 B	3.80 AB
Loamy sandy	Control	14.40 E	14.67 D	0.27 EF	0.30 EF	1.26 G	1.33 G	9.66 H	9.00 H	19.23 H	18.87 H	2.16 G	2.00 H
	S.S + ----- + ----	14.50 E	14.73 D	0.27 EF	0.30 EF	1.30 G	1.36 G	9.66 H	9.00 H	19.40 H	19.00 H	2.16 G	2.16 H
	S.S + G.a + ----	15.77 D	15.97 C	0.30 CDE	0.33 CDE	2.03 C	2.10 C	11.67 CDEF	11.00 DEF	22.00 E	21.70 E	3.53 D	3.40 E
	S.S + G.m + ----	16.16 C	16.20 B	0.30 CDE	0.33 CDE	2.06 C	2.13 C	12.00 CDE	11.33 CDE	24.00 C	23.60 C	3.66 C	3.53 DE
	S.S + G.a + P	16.17 B	16.37 B	0.35 ABC	0.38 ABC	2.26 B	2.33 B	13.33 B	12.67 B	25.17 B	25.00 B	3.86 B	3.73 BC
	S.S + G.m + P	16.40 A	16.63 A	0.40 A	0.43 A	2.43 A	2.50 A	14.33 A	13.67 A	27.50 A	27.50 A	4.06 A	3.99 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

where: S.S.= Sterilized soil; VAM = Vesicular Arbuscular Mycorrhizae; P= rock phosphate [$Ca_3(PO_4)_2$]
G.a = *Glomus australe*; G.m. = *Glomus macrocarpum*

4.2. Rangpur lime rootstock

4.2.1. Seedling growth parameters

Growth response of Rangpur lime rootstock seedlings to soil type namely calcareous, sandy and loamy sandy soils and soil treatments, *i.e.* soil sterilization, supported with soil inoculation with mycorrhizal fungi (***Glomus australe*** and ***Glomus macrocarpum***), besides soil sterilization provided with soil inoculation with mycorrhizae species and enriched with rock-phosphate fertilization (1g/pot) as well as the interaction between soil type and soil treatments during 1998 and 1999 seasons is presented in **Tables (6, 7 and 8)**.

4.2.1.1. Stem length

Table (6) shows that Rangpur lime rootstock seedlings grown in loamy sandy soil produced taller plants (20.96 & 21.46 cm) as compared with the analogous ones grown in calcareous soil (17.16 & 17.67 cm) in 1998 and 1999 seasons, respectively. On the other hand, seedlings grown in sandy soil gave plants intermediate in their length (19.04 & 19.59 cm) as compared with the aforementioned two tested soil types in the first and second seasons, respectively. Generally, the differences in stem length between the three tested soil types were significant from the statistical standpoint.

As for the effect of soil treatments, **Table (7)** demonstrates that Rangpur lime seedlings grown in sterilized or unsterilized soil 'control' gave comparatively and similarly the shortest plants. On the other side, supplementing soil, inoculated with ***Glomus macrocarpum*** fungi produced longer plants as compared with the corresponding ones inoculated with ***Glomus australe*** particularly in the first season. Moreover, fertilizing seedlings grown in sterilized soil, inoculated with mycorrhizae fungi with rock- phosphate induced high stimulative effect on seedlings height.

Furthermore, the interaction between soil type and soil treatments exerted a pronounced effect on Rangpur lime seedling height **(Table, 8)**. It is quite evident that all combinations of loamy sandy soil produced statistically higher values of stem length in both seasons as compared with the analogous ones of calcareous and sandy soils. Generally, Rangpur lime seedlings grown in loamy sandy soil, inoculated with either one of tested mycorrhizae species and fertilized with tested rate of rock-phosphate gave comparatively the tallest plants. On the contrary, the interactions of calcareous soil showed to be the least effective combinations in exerting stimulative effect on stem length, particularly those grown in sterilized or unsterilized soil. On the other hand, the combinations of sandy soil produced inbetween values in this concern.

4.2.1.2. Stem diameter

Table (6) shows that Rangpur lime rootstock seedlings grown in loamy sandy soil had thicker stems (0.33 & 0.35 cm) as compared with the analogous ones grown in calcareous soil (0.28 & 0.29 cm) in 1998 and 1999 seasons, respectively. On the other hand, seedlings grown in sandy soil gave plants intermediate in their diameter (0.31 & 0.32 cm) as compared with aforementioned two tested soil types in the first and second seasons, respectively. Generally, the differences in stem diameter between the three tested soil types were significant from the statistical standpoint.

As for the effect of soil treatments, **Table (7)** demonstrates that seedlings grown in sterilized and unsterilized soil "control" gave comparatively and similarly the thinnest plants. On the other hand, supplementing sterilized soil, inoculated with mycorrhizae fungi produced enhancing effect on stem diameter. However, the differences between the two tested mycorrhizae species in this respect were lacking from the statistical standpoint. Furthermore, supporting sterilized and inoculated soil with mycorrhizae fungi with rock-phosphate fertilization succeeded in exerting the most stimulative effect on stem diameter. Anyhow, fertilizing sterilized soil, with rock-phosphate, particularly those inoculated with ***Glomus macrocarpum*** fungus surpassed the corresponding ones inoculated with ***Glomus australe*** fungus in producing the thickest stems.

Additionally, stem diameter of Rangpur lime rootstock responded remarkably to the interaction between soil type and soil treatments **(Table, 8)**. Generally, Rangpur lime seedlings grown in loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate proved to be the most effective treatment in enhancing stem diameter followed descendingly by those grown in sandy soil inoculated with the previously mentioned mycorrhizae species and fertilized with rock- phosphate and the analogous ones grown in loamy sandy soil, inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate. On the contrary, Rangpur lime seedlings grown in sterilized or unsterilized calcareous soil produced the least positive effect on stem diameter in both seasons. Other tested combinations took intermediate positions between the previously two mentioned categories.

4.2.1.3. No. of lateral shoots/seedling

Table (6) reveals that Rangpur lime seedlings grown in loamy sandy soil were more capable to shoot than the corresponding ones grown in the two tested soil types. On the contrary, calcareous soil exerted a depressive effect on Rangpur lime seedling shooting in both seasons of study. Besides, seedlings grown in sandy soil gave comparatively intermediate number of shoots in 1998 and 1999 seasons.

On the other hand, **Table (7)** shows that unsterilized soil "control" or sterilized one failed to add comparatively stimulate effect on plant shooting. Meanwhile, inoculating the sterilized soil with mycorrhizae fungi succeeded in enhancing seedling shooting. Anyhow, ***Glomus macrocarpum*** fungi surpassed ***Glomus australe*** in exerting the stimulative effect on number of shoots per seedling. Besides, fertilizing sterilized and inoculated soil with mycorrhizae fungi particularly ***Glomus macrocarpum*** with rock-phosphate produced the most positive effect on seedling shooting in both seasons of study.

In addition, the interaction between soil type and soil treatments showed a pronounced effect on number of lateral shoots per seedling in 1998 and 1999 seasons (**Table, 8**). Briefly, seedlings grown in sterilized loamy sandy soil, fertilized with rock-phosphate and inoculated with ***Glomus macrocarpum*** fungus produced comparatively the highest number of shoots, followed descendingly by the analogous ones, grown in loamy sandy soil, inoculated with ***Glomus australe*** fungus and those grown in sterilized sandy soil, fertilized with rock-phosphate and inoculated with ***Glomus macrocarpum*** fungus. On the contrary, Rangpur lime seedlings grown in unsterilized or sterilized calcareous or sandy soil gave the lowest values in this respect. Other tested combinations gave inbetween values in this concern.

4.2.1.4. No. of leaves/seedling

It is clear from **Table (6)** that in 1998 and 1999 seasons, Rangpur lime seedlings grown in loamy sandy soil produced significantly higher number of leaves (14.78 & 15.78) whether they compared with the analogous ones grown in calcareous soil (12.56 & 1356) or in sandy soil (13.78 & 14.78) in the first and second seasons, respectively. The differences regarding number of leaves produced by specific seedling between the three tested soils were obviously significant.

In addition, **Table (7)** shows the specific effect of soil treatments on number of produced leaves per seedling. It is quite clear that soil inoculation with mycorrhizae fungi significantly increased number of produced leaves per seedling as compared with those grown in unsterilized or sterilized soil deficient of mycorrhizal inoculation. In this respect, ***Glomus macrocarpum*** fungus produced similar data to the corresponding one ***Glomus australe*** fungus in exerting positive effect on number of produced leaves per seedling. Besides, enriching sterilized soil, inoculated with mycorrhizae fungi particularly ***Glomus macrocarpum*** with rock-phosphate fertilization induced the highest stimulative effect on number of leaves per seedling. Generally, the differences between the tested soil treatments were pronounced to reach the significance level.

Furthermore, **Table (8)** demonstrates that when soil type interacted with the tested soil treatments, they produced a remarkable effect on number of produced leaves/seedling. Shortly, Rangpur lime seedlings grown in unsterilized soil "control" or sterilized calcareous soil and those grown in unsterilized soil "control" or sterilized sandy soil produced comparatively the lowest number of leaves. Moreover, supplementing sterilized soil in general and loamy sandy soil in particular with mycorrhizal inoculation especially ***Glomus macrocarpum*** fungus greatly enhanced number of produced leaves per seedling. Besides, supporting, sterilized loamy sandy soil, inoculated with mycorrhizae fungi, particularly ***Glomus macrocarpum*** fungus exerted the most stimulative effect in this respect. Briefly, Rangpur lime seedlings grown in sterilized loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate (1g/pot) produced comparatively the highest number of leaves (17.33 & 18.33) followed descendingly by the analogous ones grown in the same soil type (sterilized loamy sandy) and fertilized with the same rate of rock-phosphate, but inoculated with ***Glomus australe*** fungus (16.33 & 17.33) and seedlings grown in sterilized sandy soil, inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate (16.33 & 17.33) in 1998 and 1999 seasons, respectively. Other interactions had intermediate values in this concern.

4.2.1.5. Root length

It is obvious from **Table (6)** that Rangpur lime seedlings grown in loamy sandy soil produced comparatively longer roots (24.88 & 24.52 cm) as compared with the corresponding ones, grown in calcareous soil (20.77 & 20.54 cm) and sandy soil (22.79 & 22.47 cm) in 1998 and 1999 seasons, respectively. Generally, the specific effect of soil type on root length was remarkable, hence the differences between the three tested soil types in this respect was significant at 5% level.

Moreover, **Table (7)** reveals that inoculating sterilized soil with mycorrhizae fungi encouraged Rangpur lime seedlings to produce longer roots than those uninoculated soil. Anyhow, ***Glomus macrocarpum*** fungus showed to be more effective in enhancing root growth as compared with the analogous fungus "***Glomus australe***". Besides, supporting sterilized soil inoculated with mycorrhizae fungi with rock-phosphate fertilization exerted the highest positive effect on root growth. Also, ***Glomus macrocarpum*** fungus proved to be superior in this respect than its corresponding ***Glomus australe*** fungus. Anyhow, the differences between tested soil treatments were pronounced to reach significance level at 5% level.

Furthermore, the interaction between soil type and soil treatments induced an obvious effect on root growth in 1998 and 1999 seasons (**Table, 8**). Briefly, Rangpur lime seedlings grown in unsterilized or sterilized calcareous soil, followed ascendingly by those grown in unsterilized or sterilized sandy soil produced comparatively the shortest roots. Besides, inoculating the soil with mycorrhizae fungi particularly ***Glomus macrocarpum*** fungus enhanced root growth especially those seedlings grown in loamy sandy soil, followed descendingly by those grown in sandy soil and finally calcareous soil. In addition, enriching sterilized soil, inoculated with mycorrhizae fungi particularly ***Glomus macrocarpum*** fungus and secondly those inoculated with ***Glomus australe***. Besides, Rangpur lime grown in sterilized soil, fertilized with rock-phosphate and inoculated with ***Glomus macrocarpum*** fungus gave comparatively longer roots. Other tested combinations produced inbetween values in this respect.

4.2.1.6. No. of roots/seedling

Table (6) reveals that Rangpur lime seedlings grown in loamy sandy and sandy soils produced not only similar number of roots but also higher number of produced roots per seedling as compared with the corresponding ones grown in calcareous soil from the statistical standpoint. Generally, seedlings grown in loamy sandy soil recorded 3.44 & 3.43 roots per seedling, besides the analogous ones grown in sandy soil produced 3.38 & 3.41 roots per seedling against 3.25 & 3.27 roots produced per each seedling grown in calcareous soil in 1998 and 1999 seasons, respectively.

Furthermore, **Table (7)** demonstrates that the lowest number of produced roots per each seedling was observed with those seedlings grown in sterilized or unsterilized soil "control". On the other hand, inoculating the sterilized soil with mycorrhizae fungi produced significant positive effect on number of produced roots per seedling. Anyhow, ***Glomus macrocarpum*** fungus surpassed its corresponding ***Glomus australe*** in exerting more positive effect in this respect. Finally, supplementing sterilized soil, inoculated with mycorrhizae fungi (particularly, ***Glomus macrocarpum*** fungus) with rock-phosphate fertilization greatly enhanced the development of lateral roots per seedling.

Additionally, the interaction between soil type and soil treatments produced a remarkable effect on number of produced roots per seedling (**Table, 8**). The lowest values of number of produced roots per seedling were recorded with seedlings grown in sterilized and unsterilized calcareous soil and sterilized and unsterilized sandy soil. On the contrary, Rangpur lime seedlings grown in sterilized loamy sandy soil, inoculated with ***Glomus***

macrocarpum fungus and fertilized with rock-phosphate (1g/pot) recorded statistically the highest number of produced roots per seedling, followed descendingly by those grown in sterilized loamy sandy soil, inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate and the corresponding ones, grown in sterilized sandy or calcareous soil, inoculated with ***Glomus macrocarpum*** or ***Glomus australe*** fungus and fertilized with rock-phosphate (1g/pot). Other tested combinations of the three tested soil types showed inbetween values in this respect.

Table (6): Specific effect of soil type on some growth parameters of Rangpur lime rootstock seedlings (1998 & 1999 seasons).

Soil type	Stem length (cm)		Stem diameter (cm)		No. of lateral shoots/seedling		No. of leaves/seedling		Root length (cm)		No. of roots/seedling	
	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Calcareous	17.16 C	17.67 C	0.28 C	0.29 C	1.80 C	1.81 C	12.56 C	13.56 C	20.77 C	20.54 C	3.25 B	3.27 B
Sandy	19.04 B	19.59 B	0.31 B	0.32 B	1.91 B	1.92 B	13.78 B	14.78 B	22.79 B	22.47 B	3.38 A	3.41 A
Loamy sandy	20.96 A	21.46 A	0.33 A	0.35 A	2.09 A	2.10 A	14.78 A	15.78 A	24.88 A	24.52 A	3.44 A	3.43 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

Table (7): Specific effect of mycorrhizal inoculation and rock phosphate fertilization on some growth parameters of Rangpur lime rootstock seedlings (1998 & 1999 seasons).

Treatments	Stem length (cm)		Stem diameter (cm)		No. of lateral shoots/seedling		No. of leaves/seedling		Root length (cm)		No. of roots/seedling	
S.S + VAM + (P)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Control	17.92 D	18.42 C	0.25 D	0.26 D	1.34 E	1.36 E	11.56 D	12.67 D	19.26 E	19.10 E	2.30 E	2.33 E
S.S + ------- + -------	18.00 D	18.51 C	0.25 D	0.27 D	1.38 E	1.35 E	11.67 D	12.67 D	19.46 E	19.17 E	2.34 E	2.35 E
S.S + G.a + -------	19.09 C	19.59 B	0.30 C	0.32 C	2.04 D	2.05 D	13.67 C	14.67 C	21.98 D	21.79 D	3.52 D	3.50 D
S.S + G.m + -------	19.41 B	19.91 B	0.30 C	0.32 C	2.11 C	2.13 C	14.00 C	15.00 C	23.89 C	23.66 C	3.77 C	3.75 C
S.S + G.a + P	19.82 A	20.43 A	0.35 B	0.36 B	2.30 B	2.30 B	15.22 B	16.11 B	25.06 B	24.79 B	4.06 B	4.08 B
S.S + G.m + P	20.07 A	20.58 A	0.38 A	0.39 A	2.44 A	2.46 A	16.11 A	17.11 A	27.26 A	26.57 A	4.17 A	4.20 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

where:

S.S.= Sterilized soil
VAM = Vesicular Arbuscular Mycorrhizae
P= rock phosphate [$Ca_3(PO_4)_2$]
G.a = *Glomus australe*
G.m. = *Glomus macrocarpum*

Table (8): Effect of interaction between soil type, mycorrhizal inoculation and rock phosphate fertilization on some grow parameters of Rangpur lime rootstock seedlings (1998 & 1999 seasons).

Soil type	Treatments S.S + VAM + (P)	Stem length (cm)		Stem diameter (cm)		No. of lateral shoots/seedling		No. of leaves/ seedling		Root length (cm)		No. of roots/seedling	
		(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Calcareous	Control	16.10 I	16.60 I	0.22 G	0.24 J	1.23 H	1.27 I	10.33 I	11.67 I	17.30 K	17.10 L	2.20 I	2.27 H
	S.S + ----- + ----	16.17 I	16.70 I	0.22 G	0.24 J	1.30 GH	1.27 I	10.67 I	11.67 I	17.57 K	17.23 L	2.27 HI	2.27 H
	S.S + G.a + ----	17.37 H	17.87 H	0.29 EF	0.30 H	1.87 E	1.87 F	12.67 G	13.67 G	20.00 I	19.80 J	3.33 G	3.30 F
	S.S + G.m + ----	17.53 GH	18.03 GH	0.29 EF	0.31 GH	2.00 D	2.03 E	13.00 FG	14.00 FG	21.80 G	21.60 H	3.57 EF	3.57 E
	S.S + G.a + P	17.77 GH	18.27 GH	0.32 CDE	0.33 EF	2.17 C	2.13 D	14.00 DE	14.67 EF	22.93 F	22.73 G	4.03 BC	4.07 B
	S.S + G.m + P	18.00 G	18.53 G	0.34 BCDE	0.35 D	2.27 C	2.30 C	14.67 CD	15.67 CD	25.00 D	24.80 E	4.10 B	4.17 B
Sandy	Control	17.90 G	18.40 GH	0.26 FG	0.27 I	1.33 G	1.37 H	11.67 H	12.67 H	19.23 J	19.10 K	2.33 HI	2.37 GH
	S.S + ----- + ----	17.97 G	18.47 GH	0.26 FG	0.27 I	1.37 G	1.37 H	11.67 H	12.67 H	19.40 J	19.17 K	2.37 H	2.40 G
	S.S + G.a + ----	19.10 F	19.60 F	0.31 DEF	0.33 FG	2.03 D	2.03 E	13.67 EF	14.67 EF	21.93 G	21.73 H	3.53 F	3.57 E
	S.S + G.m + ----	19.37 EF	19.87 EF	0.31 DEF	0.33 FG	2.07 D	2.07 DE	14.00 DE	15.00 DE	23.87 E	23.67 F	3.90 CD	3.93 C
	S.S + G.a + P	19.83 DE	20.67 D	0.36 BCD	0.37 C	2.27 C	2.27 C	15.33 C	16.33 C	25.07 D	24.77 E	4.07 B	4.07 B
	S.S + G.m + P	20.07 D	20.57 D	0.39 AB	0.41 B	2.43 B	2.43 B	16.33 B	17.33 B	27.27 B	26.37 C	4.13 AB	4.13 B
Loamy sandy	Control	19.77 DE	20.27 DE	0.29 EF	0.30 H	1.47 F	1.47 G	12.67 G	13.67 G	21.23 H	21.10 I	2.37 H	2.37 GH
	S.S + ----- + ----	19.87 DE	20.37 DE	0.29 EF	0.30 H	1.50 F	1.43 GH	12.67 G	13.67 G	21.40 H	21.10 I	2.40 H	2.40 G
	S.S + G.a + ----	20.80 C	21.30 C	0.32 CDE	0.34 DEF	2.23 C	2.27 C	14.67 CD	15.67 CD	24.00 E	23.83 F	3.70 E	3.63 E
	S.S + G.m + ----	21.33 B	21.83 BC	0.32 CDE	0.35 DE	2.27 C	2.30 C	15.00 C	16.00 C	26.00 C	25.70 D	3.87 D	3.77 D
	S.S + G.a + P	21.87 A	22.37 AB	0.37 ABC	0.39 B	2.47 B	2.50 B	16.33 B	17.33 B	27.17 B	26.87 B	4.07 B	4.13 B
	S.S + G.m + P	22.13 A	22.63 A	0.42 A	0.44 A	2.63 A	2.67 A	17.33 A	18.33 A	29.50 A	28.53 A	4.27 A	4.30 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

where: S.S.= Sterilized soil; VAM = Vesicular Arbuscular Mycorrhizae; P= rock phosphate [$Ca_3(PO_4)_2$]
G.a = *Glomus australe*; G.m. = *Glomus macrocarpum*

4.3. Volkamer lemon rootstock

4.3.1. Seedling growth parameters

The response of Volkamer lemon rootstock seedlings growth to soil type namely calcareous, sandy and loamy sandy soil and soil treatments, *i.e.* soil sterilization, supported with mycorrhizae fungi (***Glomus australe*** and ***Glomus macrocarpum***), besides soil sterilization provided with soil inoculation with mycorrhizae species and enriched with rock-phosphate fertilization (1 g/pot) as well as the interaction between soil type and soil treatments during 1998 and 1999 seasons is presented in **Tables (9, 10 & 11).**

4.3.1.1. Stem length

Table (9) reveals that Volkamer lemon rootstock seedlings grown in loamy sandy soil were the tallest plants (20.22 & 19.74 cm) as compared with the analogous ones grown in calcareous soil (18.02 & 17.78 cm) in 1998 and 1999 seasons, respectively. On the other hand, seedlings grown in sandy soil were intermediate in their length (19.16 & 18.79 cm) as compared with those grown in the aforementioned two tested soil types in the first and second seasons, respectively. Generally, the differences in stem length between the three tested soil types were significant from the statistical standpoint.

As for the effect of soil treatments, **Table (10)** demonstrates that Volkamer lemon rootstock seedlings grown in sterilized or unsterilized soil 'control' gave comparatively and similarly the shortest plants. On the other side, supplementing sterilized soil with mycorrhizal inoculation with ***Glomus australe*** fungus resulted in taller plants as compared with the corresponding ones inoculated with ***Glomus macrocarpum*** fungus particularly in the first season. Moreover, fertilizing Volkamer lemon seedlings grown in sterilized soil, inoculated with ***Glomus macrocarpum*** fungus with rock-phosphate induced high stimulative effect on seedling height as compared with the analogous ones inoculated with ***Glomus australe*** fungus.

Furthermore, the interaction between soil type and soil treatments exerted a pronounced effect on Volkamer lemon seedling height **(Table, 11)**. It is quite evident that most combinations of loamy sandy soil produced statistically higher values of stem length in both seasons as compared with the analogous of calcareous and sandy soils. Generally, Volkamer lemon seedlings grown in loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate gave comparatively the longest plants followed descendingly by the analogous ones in the sandy soil. On the contrary, the interactions of calcareous soil showed to be the least effective combinations in exerting stimulative effect on stem length, particularly those grown in sterilized or unsterilized soil "control". On the other hand, the combinations of sandy soil produced inbetween values in this concern.

4.3.1.2. Stem diameter

It is quite evident from **Table (9)** that Volkamer lemon rootstock seedlings grown in calcareous soil had the thinnest stems (0.38 & 0.40 cm) as compared with the analogous ones grown in loamy sandy soil (0.44 & 0.46 cm) in 1998 and 1999 seasons, respectively. On the other hand, seedlings grown in sandy soil had stems intermediate in their diameter (0.41 & 0.44 cm) as compared with those grown in the aforementioned two tested soil types in the first and second seasons, respectively. Generally, the differences in stem diameter between the three tested soil types were pronounced to be significant.

As for the effect of soil treatments, **Table (10)** demonstrates that Volkamer lemon rootstock seedlings grown in sterilized and unsterilized soil had comparatively and similarly the thinnest stems. On the other hand, supplementing the sterilized soil, inoculated with mycorrhizae fungi produced enhancing effect on stem diameter. However, the differences between the two tested mycorrhizae species in this respect were lacking from the statistical standpoint. Furthermore, supporting sterilized soil, inoculated with mycorrhizae fungi with rock-phosphate fertilization succeeded in exerting the most stimulative effect on stem diameter. Anyhow, fertilizing sterilized and inoculated soil with rock-phosphate particularly with ***Glomus macrocarpum*** fungus surpassed the corresponding ones inoculated with ***Glomus australe*** fungus in producing the thickest stems.

Additionally, stem diameter of Volkamer lemon rootstock responded remarkably to the interaction between soil type and soil treatments **(Table, 11)**. Generally, Volkamer lemon seedlings grown in loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate proved to be the most effective treatment in enhancing stem diameter, followed descendingly by those grown in sandy soil inoculated with the previously mentioned mycorrhizae species and fertilized with rock-phosphate and the analogous ones grown in loamy sandy soil, inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate. On the contrary, Volkamer lemon seedlings grown in sterilized or unsterilized calcareous soil produced the least positive effect on stem diameter in both seasons. Other tested combinations took an intermediate positions between the previously two mentioned categories.

4.3.1.3. No. of lateral shoots/seedling

It is clear from **Table (9)** that Volkamer lemon rootstock seedlings grown in loamy sandy soil had significantly higher number of lateral shoots (3.18 & 4.61 cm) as compared with the analogous ones grown in calcareous soil (2.90 & 4.10 cm) in 1998 and 1999 seasons, respectively.. On the other hand, seedlings grown in sandy soil gave plants intermediate in their number of lateral shoots per seedling (3.01 & 4.31 cm) as compared with the aforementioned two tested soil types in the first and second seasons, respectively. Generally, the differences in number of lateral shoots per seedling between the three tested soil types were significant.

As for the effect of soil treatments **(Table, 10)** demonstrates that Volkamer lemon rootstock seedlings grown in sterilized or unsterilized soil gave comparatively and similarly the lowest number of developed shoots per seedling. On the other hand, supplementing the sterilized soil, inoculated with ***Glomus macrocarpum*** fungus resulted in significant increase in number of lateral shoots as compared with the analogous ones inoculated with ***Glomus australe***. Furthermore, enriching sterilized soil, inoculated with ***Glomus macrocarpum*** fungus with rock-phosphate fertilization succeeded in exerting the most stimulative effect on number of lateral shoots per seedling as compared with the analogous ones inoculated with ***Glomus australe*** fungus.

Additionally, number of lateral shoots per seedling of Volkamer lemon rootstock responded remarkably to the interaction between soil type and soil treatments **(Table, 11)**. Generally, Volkamer lemon seedlings grown in loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate proved to be the most effective treatment in enhancing the development of developed shoots on seedling, followed descendingly by the analogous ones inoculated with ***Glomus australe*** fungus or those grown in sandy soil inoculated with ***Glomus macrocarpum*** and fertilized with rock-phosphate. On the contrary, Volkamer lemon seedlings grown in sterilized or unsterilized calcareous soil produced the least positive effect on number of developed shoots per seedling in both seasons. Other tested combinations took intermediate positions between the previously two mentioned categories.

4.3.1.4. No. of leaves/seedling

It is quite clear form **Table (9)** that in 1998 and 1999 seasons, seedlings grown in calcareous soil produced the lowest number of leaves (22.94 & 24.56) against (26.67 & 28.33) for those grown in loamy sandy soil in the first and second seasons, respectively. Besides, Volkamer lemon seedlings grown in sandy soil produced comparatively intermediate values (25.00 & 26.67) in 1998 and 1999 seasons, respectively. However, the differences in number of produced leaves per seedling between the three tested soil types were obvious to reach the significance level.

On the other hand, **Table (10)** reveals that Volkamer lemon seedlings grown in sterilized or unsterilized soil produced similarly the lowest number of leaves in both seasons of study. Besides, enriching the sterilized soil with mycorrhizal inoculation significantly increased the number of produced leaves per seedling. The two tested mycorrhizae species exerted statistically similar positive effect on number of produced leaves per seedling. Supporting sterilized soil, inoculated with mycorrhizae fungi (particularly, ***Glomus macrocarpum*** fungus), with rock-phosphate fertilization produced the most enhancing effect on number of produced leaves per seedling.

As for the effect of interaction between soil type and soil treatments on number of produced leaves per seedling (**Table, 11**) reveals that Volkamer lemon seedlings grown in sterilized or unsterilized calcareous soils produced statistically the lowest number of leaves per seedling in both seasons. On the contrary, the highest number of produced leaves per seedling was observed with Volkamer lemon seedlings grown in sterilized loamy sandy soil, inoculated particularly with ***Glomus macrocarpum*** fungus followed descendingly by those grown in loamy sandy soil, inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate (1g/pot) and those grown in sterilized sandy soil, inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate. Other studied combinations of the three soil types recorded inbetween values in this respect.

4.3.1.5. Root length

It is clear from **Table (9)** that in both seasons, Volkamer lemon seedlings grown in loamy sandy soil produced comparatively the longest roots (32.22 & 31.90 cm) against (28.11 & 27.90 cm) for the roots of seedlings grown in calcareous soil in 1998 and 1999 season, respectively. Besides, Volkamer lemon seedlings grown in sandy soil produced roots moderate in their length (30.13 & 29.90 cm) in the first and second seasons, respectively. However, the differences in root length between the three tested soil types were remarkable to reach the significance at 5% level.

Furthermore, **Table (10)** demonstrates that in both seasons, Volkamer lemon seedlings grown in sterilized or unsterilized soil "control" produced similarly and statistically the lowest values of root length. Moreover, inoculating sterilized soil with mycorrhizae fungi, particularly ***Glomus macrocarpum*** fungus produced significantly higher stimualtive effect on root growth. Besides, supplementing sterilized soil, inoculated with mycorrhizae fungi particularly with ***Glomus macrocarpum*** fungus with rock-phosphate induced the most enhancing positive effect on root development. Generally, differences between all tested treatments in this concern were obvious to be significant.

Additionally, the interaction between soil type and soil treatments exerted a pronounced effect on root length of Volkamer lemon seedlings (**Table, 11**). Briefly, Volkamer lemon seedlings grown in sterilized or unsterilized calcareous soil produced statistically the shortest roots, followed ascendingly by the analogous ones grown in sterilized or unsterilized sandy soil. On the contrary, the longest roots were produced by Volkamer lemon seedlings grown in sterilized loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate (1g/pot), followed descendingly by the corresponding ones grown in sterilized loamy sandy soil, inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate and Volkamer lemon seedlings grown in sterilized sandy soil, inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate. Other tested combinations induced inbetween values in this respect.

4.3.1.6. Number of roots/seedling

It is quite clear from **Table (9)** that in both seasons, Volkamer lemon whether grown in sandy or loamy sandy soil had statistically similar and higher number of roots as compared with the analogous ones grown in calcareous soil. In other words, Volkamer lemon seedlings grown in loamy sandy soil produced 3.64 & 3.73 roots per seedling and those grown in sandy soil gave 3.59 & 3.70 roots per seedling against 3.45 & 3.55 roots per seedling for those grown in calcareous soil in 1998 and 1999 seasons, respectively.

On the other hand, **Table (10)** indicates that Volkamer lemon seedlings grown in sterilized or unsterilized soil produced statistically similarly and the lowest number of roots per seedling. Besides, enriching sterilized soil with mycorrhizal inoculation exerted significant positive effect on number of developed roots per seedling. Anyhow, soil inoculation with ***Glomus macrocarpum*** fungus surpassed the corresponding one ***Glomus australe*** fungus in enhancing the development of lateral roots. In addition, fertilizing sterilized soil, inoculated with mycorrhizae fungi (particularly, ***Glomus macrocarpum*** fungus) induced the highest positive effect on the development of lateral roots.

Additionally, the interaction between soil type and soil treatments induced a remarkable effect on root development on Volkamer lemon seedling (**Table, 11**). Shortly, Volkamer lemon seedlings grown in sterilized and unsterilized calcareous or sandy soil produced similarly the lowest number of roots per seedling from the statistical standpoint. On the contrary, Volkamer lemon seedlings grown in sterilized loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate, followed descendingly by those grown in sterilized loamy sandy soil, inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate and the analogous ones grown in sterilized sandy soil, inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate produced the highest number of roots per seedling. Other tested combinations of the three studied soil types recorded inbetween values in this respect.

Conclusively, Sour orange, Rangpur lime and Volkamer lemon seedlings grown in loamy sandy soil recorded the highest values of the studied seedling growth parameters expressed as stem length, stem diameter, number of developed leaves, root length and number of produced roots. On the contrary, seedling growth parameters of the previously three tested rootstocks showed the lowest values when the seedlings were grown in calcareous soil. Furthermore, inoculating sterilized soil with mycorrhizae fungi particularly, ***Glomus macrocarpum*** fungus induced the most stimulative effect on the previously mentioned seedling growth parameters. Also, supplementing sterilized soil inoculated with mycorrhizae fungi especially ***Glomus macrocarpum*** fungus with rock-phosphate fertilization exerted high significant stimulative effect on the studied seedling growth parameters. Generally, the longest and thickest stems and the highest number of produced leaves and roots per seedling as well as the longest roots were observed on seedlings of the three studied rootstocks grown in sterilized loamy sandy soil inoculated with mycorrhizae fungi firstly with ***Glomus macrocarpum*** and secondly with ***Glomus australe*** fungus and fertilized with rock-phosphate (1g/pot), followed descendingly by those grown in sterilized sandy soil, inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate.

4.2. Seedling dry weight parameters

Seedling dry weight parameters expressed as root dry weight, top dry weight, total seedling dry weight and top : root ratio of Sour orange, Rangpur lime and Volkamer lemon seedling in response to soil type namely calcareous, sandy and loamy sandy soil and soil treatments with mycorrhizal inoculation and rock-phosphate fertilization as well as their combinations during 1998 and 1999 seasons is presented in **Tables (12-20)**.

Table (9): Specific effect of soil type on some growth parameters of Volkamer lemon rootstock seedlings (1998 & 1999 seasons).

Soil type	Stem length (cm)		Stem diameter (cm)		No. of lateral shoots/seedling		No. of leaves/seedling		Root length (cm)		No. of roots/seedling	
	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Calcareous	18.02 C	17.78 C	0.38 C	0.40 C	2.90 C	4.10 C	22.94 C	24.56 C	28.11 C	27.90 C	3.45 B	3.55 B
Sandy	19.16 B	18.79 B	0.41 B	0.44 B	3.01 B	4.31 B	25.00 B	26.67 B	30.13 B	29.90 B	3.59 A	3.70 A
Loamy sandy	20.22 A	19.74 A	0.44 A	0.46 A	3.18 A	4.61 A	26.67 A	28.33 A	32.22 A	31.90 A	3.64 A	3.73 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

Table (10): Specific effect of mycorrhizal inoculation and rock phosphate fertilization on some growth parameters of Volkamer lemon rootstock seedlings (1998 & 1999 seasons).

Treatments	Stem length (cm)		Stem diameter (cm)		No. of lateral shoots/seedling		No. of leaves/seedling		Root length (cm)		No. of roots/seedling	
S.S + VAM + (P)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Control	16.50 E	16.36 D	0.36 D	0.38 D	2.44 F	3.37 E	15.56 D	16.67 D	21.14 F	21.10 E	2.50 E	2.63 E
S.S + ----- + -----	16.46 E	16.30 D	0.36 D	0.38 D	2.48 E	3.38 E	15.67 D	16.67 D	21.43 E	21.16 E	2.55 E	2.64 E
S.S + G.a + -----	18.68 C	18.13 C	0.41 C	0.42 C	3.14 D	4.38 D	27.33 C	29.33 C	31.98 D	31.79 D	3.72 D	3.82 D
S.S + G.m + ----	18.32 D	18.19 C	0.41 C	0.43 C	3.21 C	4.80 C	28.00 C	30.00 C	33.89 C	33.66 C	3.97 C	4.04 C
S.S + G.a + P	21.26 B	20.72 B	0.45 B	0.47 B	3.40 B	4.96 B	30.44 B	32.22 B	35.11 B	34.79 B	4.25 B	4.36 B
S.S + G.m + P	23.58 A	22.93 A	0.48 A	0.51 A	3.53 A	5.13 A	32.22 A	34.22 A	37.34 A	36.58 A	4.37 A	4.46 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

where:

S.S.= Sterilized soil; VAM = Vesicular Arbuscular Mycorrhizae; P= rock phosphate [$Ca_3(PO_4)_2$]

G.a = *Glomus australe*; G.m. = *Glomus macrocarpum*

Table (11): Effect of interaction between soil type, mycorrhizal inoculation and rock phosphate fertilization on some growth parameters of Volkamer lemon rootstock seedlings ((1998) & (1999) seasons).

Soil type	Treatments S.S + VAM + (P)	Stem length (cm) (1998)	Stem length (cm) (1999)	Stem diameter (cm) (1998)	Stem diameter (cm) (1999)	No. of lateral shoots/seedling (1998)	No. of lateral shoots/seedling (1999)	No. of leaves/ seedling (1998)	No. of leaves/ seedling (1999)	Root length (cm) (1998)	Root length (cm) (1999)	No. of roots/seedling (1998)	No. of roots/seedling (1999)
Calcareous	Control	15.43 K	15.30 K	0.32 G	0.34 H	2.33 I	3.27 I	14.33 I	15.67 I	18.97 L	19.10 L	2.40 I	2.57 I
	S.S + ----- + ----	15.33 K	15.27 K	0.32 G	0.34 H	2.40 HI	3.27 I	14.67 I	15.67 I	19.50 K	19.23 L	2.47 I	2.57 I
	S.S + G.a + ----	17.57 H	17.10 I	0.39 EF	0.39 FGH	2.97 F	3.87 G	25.33 G	27.33 G	30.00 H	29.80 I	3.53 G	3.67 G
	S.S + G.m + ----	17.07 HI	17.17 I	0.39 EF	0.41 FGH	3.10 E	5.03 C	26.00 FG	28.00 FG	31.80 G	31.60 H	3.77 EF	3.83 F
	S.S + G.a + P	20.23 E	19.80 F	0.42 CDE	0.45 CDEF	3.27 D	5.13 C	28.00 DE	29.33 EF	33.10 F	32.73 G	4.23 BC	4.30 CD
	S.S + G.m + P	22.47 C	22.03 C	0.44 BCDE	0.46 BCDE	3.37 C	4.50 E	29.33 CD	31.33 CD	35.27 D	34.80 E	4.33 AB	4.37 BC
Sandy	Control	16.60 IJ	16.50 J	0.36 FG	0.38 GH	2.43 H	3.40 H	15.67 HI	16.67 HI	21.23 J	21.10 K	2.53 HI	2.67 HI
	S.S + ----- + ----	16.50 J	16.40 J	0.36 FG	0.38 GH	2.47 H	3.47 H	15.67 HI	16.67 HI	21.40 J	21.17 K	2.60 H	2.67 HI
	S.S + G.a + ----	18.70 G	18.20 H	0.41 DEF	0.43 DEFG	3.13 E	5.03 C	27.33 EF	29.33 EF	31.93 G	31.73 H	3.73 F	3.87 F
	S.S + G.m + ----	18.30 G	18.20 H	0.41 DEF	0.44 CDEFG	3.17 E	5.07 C	28.00 DE	30.00 DE	33.87 E	33.67 F	4.10 CD	4.23 D
	S.S + G.a + P	21.27 D	20.80 E	0.46 BCD	0.48 BCD	3.37 C	4.67 E	30.67 C	32.67 C	35.07 D	34.77 E	4.27 B	4.37 BC
	S.S + G.m + P	23.57 B	22.67 B	0.49 AB	0.51 AB	3.53 B	5.30 D	32.67 B	34.67 B	37.27 B	36.40 C	4.33 AB	4.43 B
Loamy sandy	Control	17.47 H	17.27 I	0.39 EF	0.41 EFG	2.57 G	3.47 H	16.67 H	17.67 H	23.23 I	23.10 J	2.57 H	2.67 HI
	S.S + ----- + ----	17.53 H	17.27 I	0.39 EF	0.41 EFG	2.60 G	3.43 H	16.67 H	17.67 H	23.40 I	23.07 J	2.60 H	2.70 H
	S.S + G.a + ----	19.77 EF	19.10 G	0.42 CDE	0.45 CDEF	3.33 CD	4.27 F	29.33 CD	31.33 CD	34.00 E	33.83 F	3.90 E	3.93 F
	S.S + G.m + ----	19.60 F	19.20 G	0.42 CDE	0.44 CDEF	3.37 C	4.30 F	30.00 C	32.00 C	36.00 C	35.70 D	4.07 D	4.07 E
	S.S + G.a + P	22.27 C	21.57 D	0.47 ABC	0.44 ABC	3.57 B	5.27 B	32.67 B	34.67 B	37.17 B	36.87 B	4.27 B	4.43 B
	S.S + G.m + P	24.70 A	24.10 A	0.52 A	0.54 A	3.70 A	5.43 A	34.67 A	36.67 A	39.50 A	38.53 A	4.47 A	4.60 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

where: S.S.= Sterilized soil; VAM = Vesicular Arbuscular Mycorrhizae; P= rock phosphate [$Ca_3(PO_4)_2$]
G.a = *Glomus australe*; G.m. = *Glomus macrocarpum*

4.2.1 Sour orange rootstock

The response of Sour orange rootstock seedling growth (dry weight parameters) to soil type namely, calcareous, sandy and loamy sandy soils and soil treatments, *i.e.* soil sterilization, supported with soil inoculation with mycorrhizae fungi (***Glomus australe*** or ***Glomus macrocarpum***), besides soil sterilization provided with soil inoculation with mycorrhizae species, enriched with rock-phosphate fertilization (1g/pot) as well as the interaction between soil type and soil treatments during 1998 and 1999 seasons is presented in **Tables (12, 13 and 14).**

4.2.1.1. Root dry weight

Table (12) shows that Sour orange rootstock seedlings grown in loamy sandy soil were significantly heavier in root dry weight (1.80 & 1.78 g) as compared with the analogous ones grown in calcareous soil (1.50 & 1.46 g) in 1998 and 1999 seasons, respectively. On the other hand, seedlings grown in sandy soil gave plants intermediate in their root dry weight (1.71 & 1.66 g) as compared with the aforementioned two tested soil types in the first and second seasons, respectively. Generally, the differences in root dry weight between the three tested soil types were significant from the statistical standpoint.

As for the effect of soil treatments on root dry weight **(Table, 13)** demonstrates that seedlings grown in sterilized or unsterilized soil "control" gave comparatively and similarly the lowest values of root dry weight. On the other hand, supplementing sterilized soil with mycorrhizal inoculation produced enhancing effect on root dry weight. However, the differences between the two tested mycorrhizae species in this respect were so small to reach significance level. Furthermore, supporting sterilized soil, inoculated with mycorrhizae fungi with rock-phosphate fertilization succeeded in exerting the highest stimulative effect on root dry weight. Anyhow, inoculating sterilized and rock-phosphate fertilized soil with ***Glomus macrocarpum*** fungus surpassed the corresponding ones inoculated with ***Glomus australe*** fungus in producing the highest significant increase in root dry weight.

Additionally, root dry weight of Sour orange rootstock seedlings responded remarkably to the interaction between soil type and soil treatments (**Table, 14**). Generally, Sour orange seedlings grown in loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate proved to be the most effective treatment in increasing root dry weight, followed descendingly by those grown in sandy soil inoculated with the previously mentioned mycorrhizae species and fertilized with rock-phosphate and the analogous ones grown in loamy sandy soil, inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate. On the contrary, Sour orange seedlings grown in sterilized or unsterilized calcareous soil produced the least positive effect on root dry weight in both seasons. Other tested combinations took intermediate positions between the previously two mentioned categories.

4.2.1.2. Top dry weight

It is obvious from **Table (12)** that in both seasons, Sour orange rootstock seedlings grown in calcareous soil had significantly the lowest top dry weight (2.60 & 2.48 g) as compared with the corresponding ones grown in loamy sandy soil (2.90 & 2.71 g) in 1998 and 1999 seasons, respectively. On the other hand, seedlings grown in sandy soil gave plants intermediate in their top dry weight (2.81 & 2.63 g) as compared with the aforementioned two tested soil types in the first and second seasons, respectively. Generally, the differences in top dry weight between the three tested soil types were obvious to reach the significance level.

As for the effect of soil treatments on top dry weight **(Table, 13)** demonstrates that Sour orange seedlings grown in sterilized or unsterilized soil "control" gave comparatively and similarly the lowest values of top dry weight. On the other hand, supplementing sterilized soil with mycorrhizal inoculation fungi produced positive effect on top dry weight. However, the differences between the two tested mycorrhizae species in this respect were so small to reach significance level. Furthermore, supporting sterilized soil inoculated with mycorrhizae fungi with rock-phosphate fertilization succeeded in exerting the most stimulative effect on top dry weight. Anyhow, inoculating sterilized soil, with ***Glomus macrocarpum*** fungus surpassed the corresponding ones inoculated with ***Glomus australe*** fungus in producing the high significant increase in top dry weight.

Furthermore, top dry weight of Sour orange rootstock responded remarkably to the interaction between soil type and soil treatments (**Table, 14**). Generally, Sour orange seedlings grown in loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate proved to be the most effective treatment in improving top dry weight, followed descendingly by those grown in sandy soil inoculated with the previously mentioned mycorrhizae species and fertilized with rock-phosphate and the analogous ones grown in loamy sandy soil, inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate. On the contrary, Sour orange seedlings grown in sterilized or unsterilized calcareous soil produced the least positive effect on top dry weight in both seasons. Other tested combinations took intermediate positions between the previously two mentioned categories.

4.2.1.3. Total seedling dry weight (g)

It is quite evident from **Table (12)** that in both seasons, Sour orange rootstock seedlings grown in sandy soil gave plants intermediate in their total seedling dry weight (4.52 & 4.29 g). Besides, growing Sour orange rootstock seedlings in loamy sandy soil caused high significant increase in total seedling dry weight (4.70 & 4.49 g), whereas the analogous ones grown in calcareous soil showed the lowest significant increase in total seedling dry weight (4.10 & 3.94 g) in the first and second seasons, respectively. Generally, the differences in total seedling dry weight between the three tested soil types were more pronounced and significant.

As for the effect of soil treatments on total seedling dry weight, **Table (13)** demonstrates that seedlings grown in sterilized or unsterilized soil gave comparatively and similarly the lowest total seedling dry weight. On the other side, supplementing sterilized soil with mycorrhizal inoculation produced enhancing effect on total seedling dry weight. However, the differences between the two tested mycorrhizae species in this respect were lacking from the statistical standpoint. Furthermore, supplementing sterilized soil inoculated with mycorrhizae fungi with rock-phosphate fertilization succeeded in exerting the most stimulative effect on total seedling dry weight. Anyhow, inoculating sterilized soil, fertilized with ***Glomus macrocarpum*** fungus surpassed the corresponding ones inoculated with ***Glomus australe*** fungus in producing higher significant increase in total seedling dry weight.

Additionally, total seedling dry weight of Sour orange rootstock responded remarkably to the interaction between soil type and soil treatments **(Table, 14).** Sour orange seedlings grown in sterilized or unsterilized calcareous soil showed the least positive response regarding total seedling dry weight in both seasons. On the other hand, Sour orange seedlings grown in loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate proved to be the most effective treatment in enhancing total seedling dry weight, followed descendingly by those grown in sandy soil inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate and the analogous ones grown in loamy sandy soil, inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate. On the other hand, other tested combinations took intermediate positions between the previously two mentioned categories.

4.2.1.4. Top / root ratio

Table (12) shows that Sour orange rootstock seedlings grown in calcareous soil recorded the highest values of top : root ratio (1.83 & 1.80) followed descendingly by those grown in sandy soil (1.70 & 1.64) and loamy sandy soil (1.67 & 1.59) in 1998 and 1999 seasons, respectively. However, the differences in top : root ratio between calcareous soil on one hand and sandy and loamy sandy soil on the other one were significant whereas the differences in top : root ratio between sandy and loamy sandy soil were significant in the side of sandy soil in second season (1999), only.

Furthermore, **Table (13)** demonstrates that Sour orange seedlings grown in sterilized or unsterilized soil recorded the highest ratio of top : root as compared with other tested soil treatments. On the contrary, sterilized soil inoculated with mycorrhizae fungi particularly ***Glomus macrocarpum*** fungus recorded the lowest values of top : root ratio. The decrease in top : root ratio as a result of the previously mentioned treatments attributed to the fact that these tested treatments, *i.e.* soil inoculation with mycorrhizae fungi or rock-phosphate fertilization induced more stimulative effect on root growth than on top growth.

Table (12): Specific effect of soil type on some dry weight parameters of Sour orange rootstock seedlings (1998 & 1999 seasons).

Soil type	Root dry weight (g)		Top dry weight (g)		Total seedling dry weight (g)		Top/root ratio	
	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Calcareous	1.50 C	1.46 C	2.60 C	2.48 C	4.10 C	3.94 C	1.83 A	1.80 A
Sandy	1.71 B	1.66 B	2.81 B	2.63 B	4.52 B	4.29 B	1.70 B	1.64 B
Loamy sandy	1.80 A	1.78 A	2.90 A	2.71 A	4.70 A	4.49 A	1.67 C	1.59 B

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

Table (13): Specific effect of mycorrhizal inoculation and rock phosphate fertilization on some dry weight parameters of Sour orange rootstock seedlings (1998 & 1999 seasons).

Treatment	Root dry weight (g)		Top dry weight (g)		Total seedling dry weight (g)		Top/root ratio	
S.S + VAM + (P)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Control	0.98 D	0.97 D	2.08 D	1.94 D	3.06 D	2.91 D	2.13 A	2.02 A
S.S + ----- + -----	1.03 D	1.00 D	2.13 D	1.97 D	3.16 D	2.97 D	2.08 B	1.99 A
S.S + G.a + -----	1.90 C	1.84 C	3.00 C	2.82 C	4.90 C	4.66 C	1.58 C	1.53 B
S.S + G.m + -----	1.87 C	1.82 C	2.97 C	2.83 C	4.84 C	4.65 C	1.59 C	1.56 B
S.S + G.a + P	2.01 B	1.96 B	3.11 B	2.96 B	5.12 B	4.92 B	1.55 C	1.51 BC
S.S + G.m + P	2.22 A	2.16 A	3.32 A	3.12 A	5.54 A	5.28 A	1.49 D	1.44 C

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

where:

S.S.= Sterilized soil
G.a = *Glomus australe*
VAM = Vesicular Arbuscular Mycorrhizae
G.m. = *Glomus macrocarpum*
P= rock phosphate [$Ca_3(PO_4)_2$]

Table (14): Effect of interaction between soil type. mycorrhizal inoculation and rock phosphate fertilization on some d[cut off] weight parameters and mycorrhizal dependency ratio of Sour orange rootstock seedlings (1998 & 1999 seasons)

Soil type	Treatments S.S + VAM + (P)	Root dry weight (g) (1998)	Root dry weight (g) (1999)	Top dry weight (g) (1998)	Top dry weight (g) (1999)	Total dry weight (g) (1998)	Total dry weight (g) (1999)	Top/root ratio (1998)	Top/root ratio (1999)	MDR (1998)	MDR (1999)
Calcareous	Control	0.83 I	0.80 I	1.93 I	1.80 I	2.76 I	2.60 I	2.32 A	2.26 A	---	---
	S.S + ----- + ----	0.87 I	0.87 I	1.96 I	1.90 HI	2.83 I	2.77 I	2.27 A	2.19 A	---	---
	S.S + G.a + ----	1.73 G	1.66 FG	2.83 G	2.70 FG	4.56 G	4.36 FG	1.63 D	1.62 C	1.65	1.68
	S.S + G.m + ----	1.70 G	1.63 G	2.80 G	2.66 G	4.50 G	4.29 G	1.64 D	1.62 C	1.63	1.56
	S.S + G.a + P	1.80 FG	1.76 EF	2.90 FG	2.80 EFG	4.70 FG	4.56 EF	1.61 DE	1.58 CD	1.70	1.75
	S.S + G.m + P	2.06 C	2.03 CD	3.16 C	3.03 BC	5.22 C	5.06 BC	1.53 EFGH	1.49 CDE	1.89	1.95
Sandy	Control	1.03 H	1.03 H	2.13 H	2.00 H	3.16 H	3.03 H	2.06 B	1.94 B	---	---
	S.S + ----- + ----	1.10 H	1.06 H	2.20 H	2.03 H	3.30 H	3.09 H	2.00 BC	1.92 B	---	---
	S.S + G.a + ----	1.93 DE	1.86 E	3.03 DF	2.83 DEF	4.96 DE	4.69 DE	1.56 DEFG	1.52 CDE	1.56	1.55
	S.S + G.m + ----	1.90 EF	1.83 E	3.00 EF	2.83 DEF	4.90 EF	4.66 E	1.58 DEF	1.54 CDE	1.55	1.54
	S.S + G.a + P	2.03 CD	2.00 D	3.13 CD	2.96 CD	5.16 CD	4.96 C	1.54 EFGH	1.48 CDE	1.63	1.64
	S.S + G.m + P	2.26 AB	2.20 AB	3.36 AB	3.13 AB	5.62 AB	5.33 A	1.48 GH	1.42 E	1.78	1.72
Loamy sandy	Control	1.10 H	1.10 H	2.20 H	2.03 H	3.30 H	3.13 H	2.00 BC	1.84 B	---	---
	S.S + ----- + ----	1.13 H	1.06 H	2.23 H	2.00 H	3.36 H	3.06 H	1.97 C	1.87 B	---	---
	S.S + G.a + ----	2.03 CD	2.00 D	3.13 CD	2.93 CDE	5.16 CD	4.93 CD	1.54 EFGH	1.46 DE	1.56	1.58
	S.S + G.m + ----	2.03 CD	2.00 D	3.13 CD	3.00 BC	5.16 CD	5.00 C	1.54 EFGH	1.50 CDE	1.56	1.60
	S.S + G.a + P	2.20 B	2.13 BC	3.30 B	3.13 AB	5.50 B	5.26 AB	1.50 FGH	1.46 DE	1.67	1.68
	S.S + G.m + P	2.33 A	2.26 A	3.43 A	3.20 A	5.76 A	5.46 A	1.47 H	1.41 E	1.75	1.74

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

where: S.S.= Sterilized soil; VAM = Vesicular Arbuscular Mycorrhizae; P= rock phosphate [$Ca_3(PO_4)_2$]
G.a = *Glomus australe*; G.m. = *Glomus macrocarpum*; MDR = Mycorrhizal dependency ratio

On the other hand, **Table (14)** reveals that Sour orange seedlings grown in sterilized or unsterilized calcareous soil, followed descendingly by those grown in sterilized or unsterilized sandy and loamy sandy soil had the highest ratios of top : root. On the contrary, most of tested soil types combinations particularly those of loamy sandy soil, inoculated with mycorrhizae fungi and fertilized with rock-phosphate recorded the lowest values of top : root ratio.

4.2.1.5. Mycorrhizal Dependency ratio (MDR)

Mycorrhizal dependency ratio is defined as the degree to which a plant is dependent on the mycorrhizal conditions to produce its maximum growth or yield at a given level of soil fertility (**Gerdeman, 1975**). Mycorrhizal dependency ratio can also be defined numerically by expressing the dry weight of mycorrhizal plant as a ratio of the dry weight of non-mycorrhizal plant. However, Sour orange seedlings grown in sterilized calcareous soil inoculated with ***Glomus australe*** fungus recorded 1.65 & 1.68 mycorrhizal dependency ratio against 1.63 & 1.56 MDR for those grown in calcareous soil and inoculated with ***Glomus macrocarpum*** fungus. Moreover, the addition of rock-phosphate to sterilized calcareous soil, inoculated with ***Glomus macrocarpum*** fungus raised the MDR (1.89 & 1.95) against 1.70 & 1.75 MDR for those grown in sterilized calcareous soil inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate in 1998 and 1999 seasons, respectively. Also, MDR of sterilized sandy soil, inoculated with ***Glomus australe*** fungus scored 1.56 & 1.55 whereas, the analogous one inoculated with ***Glomus macrocarpum*** fungus recorded 1.55 and 1.54 MDR for the first and second seasons, respectively. Besides, the enrichment of sterilized sandy soil, inoculated with ***Glomus macrocarpum*** fungus with rock-phosphate greatly enhanced MDR to recorded 1.78 & 1.72 against 1.63 & 1.64 MDR for the corresponding ones grown in sterilized sandy soil, fertilized with rock-phosphate and inoculated with ***Glomus australe*** fungus in 1998 and 1999 seasons, respectively. Finally, MDR of Sour orange seedlings grown in sterilized loamy sandy soil, inoculated with ***Glomus australe*** fungus recorded (1.56 & 1.58) against 1.56 & 1.60 for those inoculated with ***Glomus macrocarpum*** fungus in the first and second seasons, respectively. Moreover, supplementing, sterilized loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus with rock-phosphate fertilization enhanced MDR (1.75 & 1.74), as compared with the analogous ones inoculated with ***Glomus australe*** fungus (1.67 & 1.68) MDR in 1998 and 1999 seasons, respectively.

4.2.2 Rangpur lime rootstock

The response of Rangpur lime rootstock seedlings growth (dry weight parameters) to soil type namely, calcareous, sandy and loamy sandy soil and soil treatments, *i.e.* soil sterilization, supported with mycorrhizae inoculation with fungi (***Glomus australe*** and ***Glomus macrocarpum***), besides, soil sterilization provided with soil inoculation with mycorrhizae species and enriched with rock-phosphate fertilization (1g/pot) as well as the interaction between soil type and soil treatments during 1998 and 1999 seasons is presented in **Tables (15, 16 and 17)**.

4.2.2.1. Root dry weight

Table (15) reveals that Rangpur lime rootstock seedlings grown in loamy sandy soil showed highly significant increase in root dry weight (2.06 & 1.92 g) as compared with the analogous ones grown in calcareous soil (1.70 & 1.63 g) in 1998 and 1999 seasons, respectively. On the other hand, seedlings grown in sandy soil gave plants intermediate in their root dry weight (1.91 & 1.83 g) as compared with the aforementioned two tested soil types in the first and second seasons, respectively. Generally, the differences in root dry weight between the three tested soil types were more remarkable to be significant.

As for the effect of soil treatments, **Table (16)** demonstrates that seedlings grown in sterilized or unsterilized soil gave comparatively and similarly the lowest significant values of root dry weight. On the other side, supplementing sterilized soil with mycorrhizal inoculation produced enhancing effect on root dry weight. However, the differences between the two tested mycorrhizae species in this respect were lacking from the statistical standpoint. Furthermore, supporting sterilized soil, inoculated with mycorrhizae fungi with rock-phosphate fertilization succeeded in exerting the most stimulative effect on root dry weight. Anyhow, inoculating sterilized soil, fertilized with rock-phosphate with ***Glomus macrocarpum*** fungus surpassed the corresponding ones inoculated with ***Glomus australe*** fungus in root dry weight.

Additionally, root dry weight of Rangpur lime rootstock seedlings responded remarkably to the interaction between soil type and soil treatments (**Table, 17**). Generally, Rangpur lime seedlings grown in loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate proved to be the most effective treatment in enhancing root dry weight, followed descendingly by those grown in sandy soil inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate. On the contrary, Rangpur lime seedling grown in sterilized or unsterilized calcareous soil produced the least positive effect on root dry weight in both seasons. Other tested combinations took intermediate positions between the previously two mentioned categories.

4.2.2.2. Top dry weight

It is obvious from **Table (15)** that in both seasons, Rangpur lime rootstock seedlings grown in calcareous soil produced significantly the lowest values of top dry weight (2.91 & 3.01 g) as compared with the analogous ones grown in loamy sandy soil (3.20 & 3.38 g) in 1998 and 1999 seasons, respectively. On the other hand, seedlings grown in sandy soil gave plants intermediate in their top dry weight (3.11 & 3.28 g) as compared with the aforementioned two tested soil types in the first and second seasons, respectively. Generally, the differences in top dry weight between the three tested soil types were obvious to reach the significance level.

As for the effect of soil treatments on top dry weight **(Table, 16)** demonstrates that seedlings grown in sterilized or unsterilized soil gave comparatively and similarly the lowest values of top dry weight. On the other hand, supplementing sterilized soil with mycorrhizal inoculation produced positive effect on top dry weight. However, the differences between the two tested mycorrhizae species in this respect were so small to reach the significance level. Furthermore, supporting sterilized soil inoculated with mycorrhizae fungi with rock-phosphate fertilization succeeded in exerting the most stimulative effect on top dry weight. Anyhow, inoculating sterilized soil, with ***Glomus macrocarpum*** fungus surpassed the corresponding ones inoculated with ***Glomus australe*** fungus in producing the highest significant increase in top dry weight.

Furthermore, top dry weight of Rangpur lime rootstock seedlings responded remarkably to the interaction between soil type and soil treatments (**Table, 17**). Generally, Rangpur lime seedlings grown in loamy sandy soil and seedlings grown in sandy soil inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate proved to be the most effective treatments in having the highest values of top dry weight, followed descendingly by those grown in loamy sandy soil inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate. On the contrary, Rangpur lime seedlings grown in sterilized or unsterilized calcareous soil produced the least positive effect on top dry weight in both seasons. Other tested combinations took an intermediate positions between the previously two mentioned categories.

4.2.2.3. Total seedling dry weight (g)

It is quite evident from **Table (15)** that in both seasons, Rangpur lime rootstock seedlings grown in sandy soil gave plants intermediate in their total seedling dry weight (5.02 & 5.14 g). Besides, growing Rangpur lime rootstock seedlings in loamy sandy soil caused high significant increase in total seedling dry weight (5.26 & 5.30 g), whereas the analogous ones grown in calcareous soil showed the lowest significant increase in total seedling dry weight (4.61 & 4.64 g). Generally, the differences in total seedling dry weight between the three tested soil types were more pronounced and significant.

As for the effect of soil treatments on total seedling dry weight, **Table (16)** demonstrates that seedlings grown in sterilized or unsterilized soil gave comparatively and similarly the lowest total seedling dry weight. On the other hand, supplementing sterilized soil with mycorrhizal inoculation produced enhancing effect on total seedling dry weight. However, the differences between the two tested mycorrhizae species in this respect were so small to reach significance level. Furthermore, supporting sterilized soil with rock-phosphate fertilization succeeded in exerting the most stimulative effect on total seedling dry weight. Anyhow, inoculating sterilized soil, fertilized with ***Glomus macrocarpum*** fungus surpassed the corresponding ones inoculated with ***Glomus australe*** fungus in producing higher significant increase in total seedling dry weight.

Additionally, total seedling dry weight of Rangpur lime rootstock responded remarkably to the interaction between soil type and soil treatments **(Table, 17).** Rangpur lime seedlings grown in sterilized or unsterilized calcareous soil produced the least positive effect on total seedling dry weight in both seasons. On the other hand, Rangpur lime seedlings grown in loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate proved to be the most effective treatment in enhancing total seedling dry weight followed descendingly by seedlings grown in sandy soil inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate. On the other hand, other tested combinations produced inbetween values in this respect.

4.2.2.4. Top / root ratio

Table (15) shows that Rangpur lime rootstock seedlings grown in calcareous soil recorded the highest values of top : root ratio (1.79 & 1.95) followed descendingly by those grown in sandy soil (1.67 & 1.86) and loamy sandy soil (1.64 & 1.83) in 1998 and 1999 seasons, respectively. However, the differences in top : root ratio between calcareous soil on one hand and sandy and loamy sandy soil on the other one were significant, whereas the differences in top : root ratio between sandy and loamy sandy soil were significant in the side of sandy soil in the first season (1998), only.

Furthermore, **Table (16)** demonstrates that Rangpur lime seedlings grown in sterilized or unsterilized soil recorded the highest ratio of top : root as compared with other tested soil treatments. On the contrary, sterilized soil inoculated with mycorrhizae fungi particularly ***Glomus macrocarpum*** fungus recorded the lowest values of top : root ratio. The decrease in top : root ratio as a result of the previously mentioned treatments attributed to the fact that these tested treatments, *i.e.* soil inoculation with mycorrhizae fungi or rock-phosphate fertilization induced greater stimulative effect on root growth rather than top growth.

On the other hand, **Table (17)** reveals that Rangpur lime seedlings grown in unsterilized calcareous soil, followed descendingly by sterilized soil had the highest ratios of top : root. On the contrary, most of tested soil types combinations particularly those of loamy sandy soil, inoculated with mycorrhizae fungi and fertilized with rock-phosphate recorded the lowest values of top : root ratio.

4.2.2.5. Mycorrhizal Dependency ratio (MDR)

Table (17) shows that Rangpur lime seedlings grown in sterilized calcareous soil inoculated with ***Glomus australe*** fungus recorded 1.54 & 1.55 mycorrhizal dependency ratio against 1.52 & 1.54 MDR for those grown in calcareous soil and inoculated with ***Glomus macrocarpum*** fungus. Moreover, supporting the sterilized calcareous soil, inoculated with ***Glomus macrocarpum*** fungus with rock-phosphate fertilization raised the MDR to be 1.73 & 1.73 against 1.61 & 1.63 for those grown in sterilized calcareous soil inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate in 1998 and 1999 seasons, respectively. Furthermore, MDR of sterilized sandy soil, inoculated with ***Glomus australe*** fungus scored 1.49 & 1.52, whereas, the analogous one inoculated with ***Glomus macrocarpum*** fungus recorded 1.47 and 1.52 MDR for the first and second seasons, respectively. Besides, the addition of rock-phosphate to sterilized sandy soil, inoculated with ***Glomus macrocarpum*** fungus greatly increased MDR to reach 1.67 & 1.71 against 1.54 & 1.61 MDR for the corresponding ones grown in sterilized sandy soil, fertilized with rock-phosphate and inoculated with ***Glomus australe*** fungus in the first and second seasons, respectively. Finally, MDR of Rangpur lime seedlings grown in sterilized loamy sandy soil, inoculated with ***Glomus australe*** fungus recorded 1.54 & 1.49 MDR against 1.54 & 1.50 MDR for those inoculated with ***Glomus macrocarpum*** fungus in 1998 and 1999 seasons, respectively. Moreover, enriching sterilized loamy sandy soil inoculated with ***Glomus macrocarpum*** fungus with rock-phosphate fertilization enhanced MDR (1.71 & 1.65) as compared with the analogous ones inoculated with ***Glomus australe*** fungus (1.63 & 1.59 MDR) in 1998 and 1999 seasons, respectively.

Table (15): Specific effect of soil type on some dry weight parameters of Rangpur lime rootstock seedlings (1998 & 1999 seasons).

Soil type	Root dry weight (g)		Top dry weight (g)		Total seedling dry weight (g)		Top/root ratio	
	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Calcareous	1.70 C	1.63 C	2.91 C	3.01 C	4.61 C	4.64 C	1.79 A	1.95 A
Sandy	1.91 B	1.83 B	3.11 B	3.28 B	5.02 B	5.14 B	1.67 B	1.86 B
Loamy sandy	2.06 A	1.92 A	3.20 A	3.38 A	5.26 A	5.30 A	1.64 C	1.83 B

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

Table (16): Specific effect of mycorrhizal inoculation and rock phosphate fertilization on some dry weight parameters of Rangpur lime rootstock seedlings (1998 & 1999 seasons).

Treatments S.S + VAM + (P)	Root dry weight (g)		Top dry weight (g)		Total seedling dry weight (g)		Top/root ratio	
	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Control	1.18 D	1.08 D	2.40 D	2.52 D	3.58 D	3.60 D	2.03 A	2.33 A
S.S + ------ + -------	1.23 D	1.13 D	2.42 D	2.54 D	3.65 D	3.67 D	1.97 B	2.26 A
S.S + G.a + -------	2.10 C	2.01 C	3.30 C	3.46 C	5.40 C	5.47 C	1.57 C	1.72 B
S.S + G.m + -------	2.07 C	2.03 C	3.27 C	3.44 C	5.34 C	5.47 C	1.58 C	1.69 BC
S.S + G.a + P	2.21 B	2.18 B	3.44 B	3.62 B	5.65 B	5.80 B	1.56 C	1.65 BC
S.S + G.m + P	2.42 A	2.33 A	3.61 A	3.77 A	6.03 A	6.10 A	1.49 D	1.62 C

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

where:

S.S.= Sterilized soil   VAM = Vesicular Arbuscular Mycorrhizae   P= rock phosphate **[$Ca_3(PO_4)_2$]**

G.a = *Glomus australe*   . G.m. = *Glomus macrocarpum*

Table (17): Effect of interaction between soil type, mycorrhizal inoculation and rock phosphate fertilization on some dry weigh parameters and mycorrhizal dependency ratio of Rangpur lime rootstock seedlings (1998 & 1999 seasons).

Soil type	Treatments S.S + VAM + (P)	Root dry weight (g) (1998)	Root dry weight (g) (1999)	Top dry weight (g) (1998)	Top dry weight (g) (1999)	Total dry weight (g) (1998)	Total dry weight (g) (1999)	Top/root ratio (1998)	Top/root ratio (1999)	MDR (1998)	MDR (1999)
Calcareous	Control	1.03 I	0.93 G	2.27 E	2.37 H	3.30 H	3.30 G	2.20 A	2.54 A	---	---
	S.S + ----- + ----	1.07 I	1.00 G	2.27 E	2.37 H	3.34 H	3.37 G	2.13 A	2.38 B	---	---
	S.S + G.a + ----	1.93 G	1.87 E	3.13 C	3.23 F	5.06 EF	5.10 E	1.62 DE	1.73 D	1.54	1.55
	S.S + G.m + ----	1.90 G	1.87 E	3.10 C	3.20 F	5.00 F	5.07 E	1.63 DE	1.72 D	1.52	1.54
	S.S + G.a + P	2.00 FG	1.97 DE	3.30 B	3.40 E	5.30 DE	5.37 D	1.65 D	1.73 D	1.61	1.63
	S.S + G.m + P	2.27 C	2.17 BC	3.43 B	3.53 CDE	5.70 C	5.70 BC	1.52 FGH	1.63 D	1.73	1.73
Sandy	Control	1.23 H	1.13 F	2.43 D	2.53 G	3.66 G	3.67 F	1.97 B	2.24 BC	---	---
	S.S + ----- + ----	1.30 H	1.17 F	2.50 D	2.60 G	3.80 G	3.77 F	1.93 BC	2.24 BC	---	---
	S.S + G.a + ----	2.13 DE	2.03 CD	3.33 B	3.53 CDE	5.46 D	5.57 CD	1.56 EFG	1.74 D	1.49	1.52
	S.S + G.m + ----	2.10 EF	2.07 CD	3.30 B	3.50 DE	5.40 D	5.57 CD	1.57 DEF	1.70 D	1.47	1.52
	S.S + G.a + P	2.23 CD	2.23 B	3.43 B	3.67 BC	5.66 C	5.90 B	1.54 FGH	1.64 D	1.54	1.61
	S.S + G.m + P	2.47 AB	2.40 A	3.67 A	3.87 A	6.14 AB	6.27 A	1.49 GH	1.61 D	1.67	1.71
Loamy sandy	Control	1.30 H	1.20 F	2.50 D	2.67 G	3.80 G	3.87 F	1.92 BC	2.22 BC	---	---
	S.S + ----- + ----	1.33 H	1.23 F	2.50 D	2.67 G	3.83 G	3.90 F	1.88 C	2.17 C	---	---
	S.S + G.a + ----	2.23 CD	2.13 BC	3.43 B	3.63 CD	5.66 C	5.76 BC	1.54 FGH	1.70 D	1.54	1.49
	S.S + G.m + ----	2.23 CD	2.17 BC	3.43 B	3.63 CD	5.66 C	5.80 BC	1.54 FGH	1.68 D	1.54	1.50
	S.S + G.a + P	2.40 B	2.37 A	3.60 A	3.80 AB	6.00 B	6.17 A	1.50 FGH	1.61 D	1.63	1.59
	S.S + G.m + P	2.53 A	2.43 A	3.73 A	3.93 A	6.26 A	6.36 A	1.48 H	1.62 D	1.71	1.65

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

where: S.S.= Sterilized soil; VAM = Vesicular Arbuscular Mycorrhizae; P= rock phosphate [$Ca_3(PO_4)_2$]
Ga. = *Glomus australe*; G.m. = *Glomus macrocarpum*; MDR = Mycorrhizal dependency ratio

4.2.3. Volkamer lemon rootstock

The response of Volkamer lemon rootstock seedling growth (dry weight parameters) to soil type namely, calcareous, sandy and loamy sandy soil and soil treatments, *i.e.* soil sterilization, supported with soil inoculation with mycorrhizae fungi (***Glomus australe*** and ***Glomus macrocarpum***), besides, soil sterilization provided with soil inoculation with mycorrhizae species and enriched with rock-phosphate fertilization (1g/pot) as well as the interaction between soil type and soil treatments during 1998 and 1999 seasons is presented in **Tables (18, 19 and 20)**.

4.2.3.1. Root dry weight

Table (18) reveals that Volkamer lemon rootstock seedlings grown in loamy sandy soil showed high significant increase in root dry weight (2.50 & 2.32 g) as compared with the analogous ones grown in calcareous soil (2.20 & 2.02 g). in 1998 and 1999 seasons, respectively. On the other hand, seedlings grown in sandy soil gave plants intermediate in their root dry weight (2.41 & 2.23 g) as compared with those grown in the aforementioned two tested soil types in the first and second seasons, respectively. Generally, the differences in root dry weight between the three tested soil types were clear to be significant.

As for the effect of soil treatments, **Table (19)** demonstrates that seedlings grown in sterilized or unsterilized soil gave comparatively and similarly the lowest values of root dry weight. On the other side, supplementing sterilized soil with mycorrhizal inoculation produced enhancing effect on root dry weight. However, the differences between the two tested mycorrhizae species in this respect were lacking from the statistical standpoint. Furthermore, supporting sterilized soil, inoculated with mycorrhizae fungi with rock-phosphate fertilization succeeded in exerting the most stimulative effect on root dry weight. Anyhow, inoculating sterilized soil, fertilized with rock-phosphate with ***Glomus macrocarpum*** fungus surpassed the analogous ones inoculated with ***Glomus australe*** fungus in increasing root dry weight.

Additionally, root dry weight of Volkamer lemon rootstock seedlings responded remarkably to the interaction between soil type and soil treatments (**Table, 20**). Generally, Volkamer lemon seedlings grown in loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate proved to be the most effective treatment in enhancing root dry weight, followed descendingly by those grown in sandy soil, inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate and those grown in loamy sandy soil, inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate. On the other hand, Volkamer lemon seedlings grown in sterilized or unsterilized calcareous soil produced the least positive effect on root dry weight in both seasons. Other tested combinations gave an intermediate values in this concern.

4.2.3.2. Top dry weight

It is clear from **Table (18)** that in both seasons, Volkamer lemon seedlings grown in calcareous soil had the lowest values of top dry weight (4.11 & 4.01 g) as compared with the analogous ones grown in loamy sandy soil (4.39 & 4.38 g). On the other hand, seedlings grown in sandy soil gave plants intermediate in their top dry weight (4.31 & 4.28 g) as compared with those grown in the aforementioned two tested soil types in the first and second seasons, respectively. Generally, the differences in top dry weight between the three tested soil types were significant from the statistical standpoint.

As for the effect of soil treatments, **Table (19)** demonstrates that Volkamer lemon seedlings grown in sterilized or unsterilized soil gave comparatively and similarly the lowest increase in top dry weight. On the other hand, supplementing sterilized soil with mycorrhizal inoculation produced enhancing effect on top dry weight. However, the differences between the two tested mycorrhizae species in this respect were so small to reach the significance level. Furthermore, supporting sterilized soil, inoculated with mycorrhizae fungi with rock-phosphate fertilization succeeded in exerting the most stimulative effect on top dry weight. Generally, inoculating sterilized soil, fertilized with rock-phosphate with ***Glomus macrocarpum*** fungus surpassed the corresponding ones inoculated with ***Glomus australe*** fungus in producing higher top dry weight in both seasons.

Furthermore, the interaction between soil type and soil treatments exerted a pronounced effect on Volkamer lemon top dry weight (**Table, 20**). It is quite evident that Volkamer lemon seedlings grown in loamy sandy soil inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate gave comparatively the most positive effect on top dry weight, followed descendingly by seedlings grown in sterilized sandy soil and inoculated with ***Glomus macrocarpum*** fungus, fertilized with rock-phosphate and the corresponding ones inoculated with ***Glomus australe*** fungus in loamy sandy soil. On the contrary, Volkamer lemon seedlings grown in sterilized or unsterilized calcareous soil produced the least positive effect on top dry weight in both seasons. Other tested combinations took an intermediate positions between the previously two mentioned categories.

4.2.3.3. Total seedling dry weight

Table (18) shows that Volkamer lemon rootstock seedlings grown in sandy soil gave intermediate values of seedlings dry weight (6.72 & 6.51 g) between those grown in loamy sandy soil (6.89 & 6.70 g) and the lowest total seedling dry weight for those grown in calcareous soil (6.31 & 6.03 g) in the first and second seasons, respectively. Generally, the differences in total dry weight between the three tested soil types were more pronounced to be significant.

As for the effect of soil treatments, **Table (19)** demonstrates that Volkamer lemon seedlings grown in sterilized or unsterilized soil gave comparatively and similarly the lowest increase in total dry weight. On the other side, supplementing sterilized soil with mycorrhizal inoculation produced enhancing effect on total seedling dry weight. However, the differences between the two tested mycorrhizae species in this respect were so small to reach significance level. Furthermore, supporting sterilized soil, inoculated with mycorrhizae fungi with rock-phosphate fertilization succeeded in exerting the most stimulative effect on total seedling dry weight. Generally, inoculating sterilized soil, fertilized with rock-phosphate with ***Glomus macrocarpum*** fungus surpassed the corresponding ones inoculated with ***Glomus australe*** fungus in producing higher total dry weight in both seasons.

Additionally, total seedling dry weight of Volkamer lemon rootstock responded remarkably to the interaction between soil type and soil treatments **(Table, 20).** Volkamer lemon seedlings grown in loamy sandy and sandy soil inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate and those grown in loamy sandy soil inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate gave comparatively the most positive effect on total seedling dry weight. On the other hand, seedlings grown in sterilized or unsterilized calcareous soil produced the least positive effect on total seedling dry weight in both seasons. Other tested combinations took intermediate position between the previously two mentioned categories.

4.2.3.4. Top / root ratio

Table (18) shows that Volkamer lemon rootstock seedlings grown in calcareous soil recorded the highest values of top : root ratio (1.92 & 2.05), followed descendingly by those grown in sandy soil (1.82 & 1.96) and loamy sandy soil (1.79 & 1.94) in 1998 and 1999 seasons, respectively. However, the differences in top : root ratio between calcareous soil on one hand and sandy and loamy sandy soil on the other one were significant, whereas the differences in top : root ratio between sandy and loamy sandy soil were significant in the side of sandy soil in the first season (1998), only.

Furthermore, **Table (19)** demonstrates that Volkamer lemon seedlings grown in sterilized or unsterilized soil recorded the highest ratio of top : root as compared with other tested soil treatments. On the contrary, sterilized soil inoculated with mycorrhizae fungi particularly ***Glomus macrocarpum*** fungus recorded the lowest values of top : root ratio. The decrease in top : root ratio as a result of the previously mentioned treatments may be due to the fact that these studied treatments, *i.e.* soil inoculation with mycorrhizae fungi or rock-phosphate fertilization induced more enriching effect on root growth rather than top growth.

On the other hand, **Table (20)** reveals that Volkamer lemon seedlings grown in unsterilized calcareous soil, followed descendingly by sterilized soil had the highest ratios of top : root. On the contrary, most of tested soil types combinations particularly those of loamy sandy soil, inoculated with mycorrhizae fungi and fertilized with rock-phosphate recorded the lowest values of top : root ratio.

Abstractly, Sour orange, Rangpur lime and Volkamer lemon seedlings grown in loamy sandy soil recorded the highest values of seedling dry weight parameters, *i.e.* root dry weight, top dry weight and total seedling dry weight. On the contrary, seedlings of the three studied citrus rootstocks grown in calcareous soil recorded the lowest values of seedling dry weight parameters. Sandy soil recorded inbetween values in this respect. Moreover, inoculating sterilized soil with mycorrhizae fungi particularly ***Glomus macrocarpum*** fungus enhanced the studied seedling dry weight parameters. Supplementing sterilized soil inoculated with mycorrhizae fungi especially ***Glomus macrocarpum*** fungus with rock-phosphate fertilization produced the highest values of the studied seedling dry weight parameters. Finally, Sour orange, Rangpur lime and Volkamer lemon seedlings grown in sterilized loamy sandy soil, inoculated with mycorrhizae fungi, firstly ***Glomus macrocarpum*** fungus and secondly ***Glomus australe*** fungus and fertilized with rock-phosphate gave comparatively the highest values of the studied seedling dry weight parameters.

4.2.2.5. Mycorrhizal Dependency ratio (MDR)

Table (20) demonstrated that Volkamer lemon seedlings grown in sterilized calcareous soil, inoculated with ***Glomus australe*** fungus recorded 1.35 & 1.38 mycorrhizal dependency ratio against 1.20 & 1.38 MDR for those grown in calcareous soil and inoculated with ***Glomus macrocarpum*** fungus. Moreover, supporting the sterilized calcareous soil, inoculated with ***Glomus macrocarpum*** fungus with rock-phosphate fertilization raised the MDR to be 1.48 & 1.51 against 1.40 & 1.44 for those grown in sterilized calcareous soil, inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate in 1998 and 1999 seasons, respectively. Furthermore, MDR for sterilized sandy soil, inoculated with ***Glomus australe*** fungus scored 1.43 & 1.37 MDR, whereas the analogous one inoculated with ***Glomus macrocarpum*** fungus recorded 1.32 and 1.37 MDR in the first and second seasons, respectively. Besides, the addition of rock-phosphate to sterilized sandy soil inoculated with ***Glomus macrocarpum*** fungus greatly increased MDR to reach 1.45 & 1.51 against 1.37 & 1.44 MDR for the corresponding ones grown in sterilized sandy soil, fertilized with rock-phosphate and inoculated with ***Glomus australe*** fungus in the first and second seasons, respectively. Finally, MDR for Volkamer lemon seedlings grown in sterilized loamy sandy soil, inoculated with ***Glomus australe*** fungus recorded 1.33 & 1.36 MDR against 1.34 & 1.37 MDR for those inoculated with ***Glomus macrocarpum*** fungus in 1998 and 1999 seasons, respectively. Moreover, enriching sterilized loamy sandy soil with rock-phosphate fertilization enhanced MDR (1.45 & 1.47) as compared with the analogous ones inoculated with ***Glomus australe*** fungus (1.39 & 1.44 MDR) in 1998 and 1999 seasons, respectively.

In this respect, **Helail *et al.* (1993)** studied the mycorrhizal dependency ratio of "Le Conte" pear transplants grown in soil inoculated with two species of mycorrhizal fungi. They found that transplants grown in ***Glomus macrocarpum*** inoculated soil showed (1.59 & 1.48 MDR), while those grown in ***Glomus australe*** inoculated soil gave (1.44 & 1.41 MDR) in both seasons. Also, **Helail and El-Deeb (1993)** mentioned that Rangpur lime seedlings grown in sterilized soils inoculated with ***Glomus macrocarpum*** fungus showed (1.66 & 1.65 MDR), while those grown in ***Glomus australe*** inoculated soil gave (1.47 & 1.50 MDR) in both seasons, respectively. In addition, **Helail and Awad (1993)** reported that Volkamer lemon seedlings grown in ***Glomus macrocarpum*** inoculated soil showed (1.34 & 1.37 MDR), while those grown in ***Glomus australe*** inoculated soil gave (1.29 & 1.37 MDR) in both seasons, respectively. Furthermore, **Helail (1993)** stated that mycorrhizal dependency ratio for avocado seedlings were (2.37 & 2.68 MDR) for ***Glomus fasciculatus*** fungus and (2.51 & 2.61 MDR) for ***Glomus australe***, in both seasons. Recently, **Helail and El-Kholey (1999)** mentioned that annona seedlings grown in sterilized soil, fertilized with different levels of rock-phosphate (0.25 , 0.50 and 1.00 g/pot) and inoculated with ***Glomus macrocarpum*** fungus gave higher mycorrhizal dependency ratio as compared with the analogous ones inoculated with ***Glomus australe*** fungus.

Briefly, Sour orange, Rangpur lime and Volkamer lemon seedlings grown in loamy sandy soil showed higher values of seedling dry weight parameters *i.e.* root dry weight, top dry weight and total seedling dry weight. On the contrary, the seedlings of the three tested citrus rootstocks grown in calcareous soil showed the lowest values of the previously mentioned seedling growth parameters. On the other hand, Sour orange, Rangpur lime and Volkamer lemon grown in sandy soil took an intermediate position between the aforementioned two soil types regarding the studied seedling dry weight parameters.

Furthermore, inoculating the sterilized soil with mycorrhizae fungi enhanced the studied seedling dry weight parameters of Sour orange, Rangpur lime and Volkamer lemon rootstocks. Generally, ***Glomus macrocarpum*** fungus surpassed the corresponding one ***Glomus australe*** fungus in exerting more stimulative effect on the studied seedling dry weight parameters of the three citrus rootstocks.

In addition, fertilizing, inoculated soil with mycorrhizae fungi particularly, those inoculated with ***Glomus macrocarpum*** fungus with rock-phosphate (1 g/pot) induced the highest positive effect on seedling dry weight parameters of Sour orange, Rangpur lime and Volkamer lemon rootstocks.

The role of mycorrhizae fungi in enhancing seedling growth may be explained by the fact that **(a)** vesicular arbuscular mycorrhizae may improve the growth of host plant through increasing the uptake of P, Zn and other nutrients, reducing the incidence of soil borne plant diseases and increasing tolerance to drought stress (**Maronek *et al.*, 1981b**), **(b)** Mycorrhizae fungi may be capable of producing growth regulating substances like auxins, cytokinins, gibberellin or B vitamins which can be transferred to the host plant (**Mac Daygal and Dufreneoy, 1944**) and **(c)** Mycorrhizae fungi may lead to marked increase in respiration which enhance the cation exchange and accumulation of the mineral elements (**Blackeman *et al.*, 1976**).

The obtained results of soil type, regarding seedling growth go in line with the findings of **Kutubidze and Kutubidze (1986), Laiger (1987), Assal *et al.* (1994)** and **Abou-Rawash *et al.* (1995).** Besides, the results of mycorrhizae in enhancing seedling growth are in harmony with the finding of **Onkarrayya *et al.* (1993), Santoso (1989), Gendiah *et al.* (1991), Jaizme *et al.* (1991), Nemec (1992), Vosukanen (1992), Helail (1993), Helail and El-Deeb (1993), Helail and Saad El-Din (1993), Helail *et al.* (1993), Farih *et al.* (1994) and Rapparini *et al.* (1994).** Moreover, the results of the response of seedling growth to the interaction between soil type and mycorrhizae fungi are in accordance with the reports of **Treeby (1992), Cheng-Yung Husiug *et al.* (1997) and Harvir-Kaur *et al.* (1998).** Furthermore, the improvement of seedling growth due to the interaction between mycorrhizal inoculation and phosphorus fertilization were reported earlier by **Timmer and Leyden (1978), Mahaney and Nemec (1979), Graham and Timmer (1985), Gendiah *et al.* (1991) and Jayachandran *et al.* (1992).** Finally, the enhancement of seedling growth due to the interaction between soil type, mycorrhizal inoculation and phosphorus fertilization is in agreement with the findings of **Graham and Syvertsen (1984), Cardoso *et al.* (1986), Abd El-Maksoud *et al.* (1988), Boutros *et al.* (1988), Gendiah *et al.* (1991) and Helail and El-Kholey (1999).**

Table (18): Specific effect of soil type on some dry weight parameters of Volkamer lemon rootstock seedlings (1998 & 1999 seasons).

Soil type	Root dry weight (g)		Top dry weight (g)		Total seedling dry weight (g)		Top/root ratio	
	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Calcareous	2.20 C	2.02 C	4.11 C	4.01 C	6.31 C	6.03 C	1.92 A	2.05 A
Sandy	2.41 B	2.23 B	4.31 B	4.28 B	6.72 B	6.51 B	1.82 B	1.96 B
Loamy sandy	2.50 A	2.32 A	4.39 A	4.38 A	6.89 A	6.70 A	1.79 C	1.94 B

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

Table (19): Specific effect of mycorrhizal inoculation and rock phosphate fertilization on some dry weight parameters of Volkamer lemon rootstock seedlings (1998 & 1999 seasons).

Treatments	Root dry weight (g)		Top dry weight (g)		Total seedling dry weight (g)		Top/root ratio	
S.S + VAM + (P)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Control	1.68 D	1.48 D	3.60 D	3.52 D	5.28 D	5.00 D	2.13 A	2.37 A
S.S + ----- + -----	1.73 D	1.53 D	3.62 D	3.54 D	5.35 D	5.07 D	2.09 B	2.32 A
S.S + G.a + -----	2.58 C	2.40 C	4.50 C	4.46 C	7.08 C	6.86 C	1.74 C	1.86 B
S.S + G.m + ----	2.57 C	2.43 C	4.48 C	4.44 C	7.05 C	6.87 C	1.74 C	1.82 B
S.S + G.a + P	2.71 B	2.58 B	4.63 B	4.62 B	7.34 B	7.20 B	1.71 C	1.78 BC
S.S + G.m + P	2.92 A	2.73 A	4.81 A	4.77 A	7.73 A	7.50 A	1.64 D	1.74 C

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

where:

S.S.= Sterilized soil
G.a = *Glomus australe*
VAM = Vesicular Arbuscular Mycorrhizae
G.m. = *Glomus macrocarpum*
P= rock phosphate [$Ca_3(PO_4)_2$]

4.3 Leaf mineral content

Table (20): Effect of interaction between soil type. mycorrhizal inoculation and rock phosphate fertilization on some dry weigh parameters and mycorrhizal dependency ratio of Volkamer lemon rootstock seedlings (1998 & 1999 seasons).

Soil type	Treatments S.S + VAM + (P)	Root dry weight (g) (1998)	Root dry weight (g) (1999)	Top dry weight (g) (1998)	Top dry weight (g) (1999)	Total dry weight (g) (1998)	Total dry weight (g) (1999)	Top/root ratio (1998)	Top/root ratio (1999)	MDR (1998)	MDR (1999)
Calcareous	Control	1.53 I	1.33 G	3.47 G	3.37 H	5.00 I	4.70 G	2.26 A	2.53 A	---	---
	S.S + ----- + ----	1.57 I	1.40 G	3.47 G	3.37 H	5.04 I	4.77 G	2.21 A	2.41 AB	---	---
	S.S + G.a + ----	2.43 G	2.23 E	4.33 E	4.23 F	6.76 FG	6.46 E	1.78 DE	1.90 D	1.35	1.38
	S.S + G.m + ----	2.40 G	2.27 E	4.30 E	4.20 F	6.70 G	6.47 E	1.79 D	1.86 DE	1.20	1.38
	S.S + G.a + P	2.50 FG	2.37 DE	4.50 D	4.40 E	7.00 EF	6.77 D	1.80 D	1.86 DE	1.40	1.44
	S.S + G.m + P	2.77 C	2.57 BC	4.63 CD	4.53 CDE	7.40 C	7.10 BC	1.68 FGH	1.77 DE	1.48	1.51
Sandy	Control	1.73 H	1.53 F	3.63 F	3.53 G	5.36 H	5.06 F	2.10 B	2.31 BC	---	---
	S.S + ----- + ----	1.80 H	1.57 F	3.70 F	3.60 G	5.50 H	5.17 F	2.06 BC	2.31 BC	---	---
	S.S + G.a + ----	2.63 DE	2.43 CD	4.53 D	4.53 CDE	7.16 CDE	6.96 CD	1.72 F	1.86 DE	1.43	1.37
	S.S + G.m + ----	2.60 EF	2.47 CD	4.50 D	4.50 DE	7.10 DE	6.97 CD	1.73 EF	1.83 DE	1.32	1.37
	S.S + G.a + P	2.73 CD	2.63 B	4.63 CD	4.67 BC	7.36 CD	7.30 B	1.70 FG	1.77 DE	1.37	1.44
	S.S + G.m + P	2.97 AB	2.80 A	4.87 AB	4.87 A	7.84 AB	7.67 A	1.64 GH	1.74 E	1.45	1.51
Loamy sandy	Control	1.80 H	1.60 F	3.70 F	3.67 G	5.50 H	5.27 F	2.06 BC	2.30 BC	---	---
	S.S + ----- + ----	1.83 H	1.63 F	3.70 F	3.67 G	5.53 H	5.30 F	2.02 C	2.25 C	---	---
	S.S + G.a + ----	2.70 DE	2.53 BC	4.63 CD	4.63 CD	7.33 CD	7.16 BC	1.72 F	1.83 DE	1.33	1.36
	S.S + G.m + ----	2.73 CD	2.57 BC	4.63 CD	4.63 CD	7.36 CD	7.20 BC	1.70 FG	1.81 DE	1.34	1.37
	S.S + G.a + P	2.90 B	2.77 A	4.77 BC	4.80 AB	7.67 B	7.57 A	1.64 GH	1.74 E	1.39	1.44
	S.S + G.m + P	3.03 A	2.83 A	4.93 A	4.93 A	7.96 A	7.76 A	1.63 H	1.74 E	1.45	1.47

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

where: S.S.= Sterilized soil; VAM = Vesicular Arbuscular Mycorrhizae; P= rock phosphate $[Ca_3(PO_4)_2]$

G.a = *Glomus australe*; G.m. = *Glomus macrocarpum*; MDR = Mycorrhizal dependency ratio

Furthermore, the interaction between soil type and soil

Additionally, the interaction between soil type and soil treatments, **Table (23)** demonstrates that seedlings grown in calcareous soil and loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus, fertilized with rock-phosphate had higher values of leaf phosphorus content, followed descendingly by the analogous ones inoculated with ***Glomus australe*** fungus fertilized with rock-phosphate in the same soil. On the other hand, the leaves of seedlings grown in sterilized or unsterilized sandy soil had the lowest phosphorus content. Other tested combinations gave plants with intermediate values of leaf phosphorus content.

4.3.1.3. Potassium

It is clear from **Table (21)** that in both seasons Sour orange seedlings grown in loamy sandy soil produced leaves rich in their potassium content (1.30 & 1.30%) as compared with the analogous ones grown in calcareous soil (1.22 & 1.21%) in 1998 and 1999 seasons, respectively. On the other side, seedlings grown in sandy soil gave plants intermediate in their leaf potassium content (1.26 & 1.25%) between the previously two soil types in both seasons of study. Generally, the differences between the three tested soil in leaf potassium content were more obvious to be significant.

As for the effect of soil treatments on leaf potassium content, **Table (22)** shows that growing Sour orange seedlings in sterilized or unsterilized soil induced the lowest values of leaf potassium content as compared with those grown in sterilized soil, inoculated with mycorrhizae species and fertilized with rock-phosphate. On the other hand, soil inoculated with ***Glomus australe*** fungus gave plants intermediate in their leaf potassium content.

Furthermore, the interaction between soil type and soil treatments **(Table, 23)** shows that all combination treatments of loamy sandy soil gave plants had the highest values of leaf potassium content as compared with all combinations of calcareous soil. On the contrary, all combinations of sandy soil gave plants intermediate in their leaf potassium content between the other two soil types. On the other hand, seedlings grown in loamy sandy soil inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate produced higher values of leaf potassium content than the analogous ones inoculated with ***Glomus australe*** fungus, fertilized with rock-phosphate. Moreover, growing Sour orange seedlings in sterilized or unsterilized calcareous soil induced the least positive effect on leaf potassium content. Other tested combinations took an intermediate position between the previously two mentioned categories.

4.3.1.4. Calcium

Table (21) demonstrates that Sour orange seedlings grown in calcareous soil produced leaves rich in their calcium content (1.63 & 1.53%) as compared with the analogous ones grown in sandy soil (1.57 & 1.51%) in the first and second seasons, respectively. On the other hand, seedlings grown in loamy sandy soil gave plants intermediate between the two soil types in their leaf calcium percent (1.58 & 1.51%) in 1998 and 1999 seasons, respectively.

As for the effect of soil treatments, **Table (22)** shows that Sour orange seedlings grown in sterilized soil, inoculated with ***Glomus macrocarpum*** fungus fertilized with rock-phosphate produced leaves rich in their calcium percent. On the other side, sterilized or unsterilized soil gave comparatively and similarly the lowest leaf calcium content. On the contrary, other treatments gave inbetween values in this respect.

Additionally, leaf calcium content of Sour orange seedling responded remarkably to the interaction between soil type and soil treatments **(Table, 23).** Generally, seedlings grown in calcareous soil, inoculated with ***Glomus macrocarpum*** fungus, fertilized with rock-phosphate or the analogous ones inoculated with ***Glomus australe*** fungus without fertilization produced the highest values of leaf calcium content. Other interactions gave intermediate effect in this sphere.

4.3.1.5. Magnesium

It is obvious from **Table (21)** that in 1998 and 1999 seasons, calcareous and sandy soils produced the least positive effect on leaf magnesium content (0.49 & 0.49%) and (0.50 & 0.50%) as compared with loamy sandy soil (0.53 & 0.53%) in the first and second seasons, respectively.

As for the effect of soil treatments on leaf magnesium content, **Table (22)** reveals that seedlings grown in sterilized or unsterilized soil had the lowest values of leaf magnesium content. Other tested combinations induced statistically similar positive effect on leaf magnesium content.

Furthermore, the interaction between soil type and soil treatments exerted a pronounced effect on leaf magnesium content. **Table (23)** reveals that all combinations of loamy sandy soil produced the most stimulative effect on leaf magnesium content as compared with the analogous ones of calcareous soil. On the other side, the interactions of sandy soil gave intermediate values between the previously two groups. Generally, seedlings grown in loamy sandy soil inoculated with

Glomus macrocarpum fungus, fertilized with rock-phosphate gave plants had the highest values of leaf magnesium content, followed descendingly by the analogous ones inoculated with ***Glomus macrocarpum*** and ***Glomus australe*** fungi and received no fertilization in the same soil. On the other hand, sterilized or unsterilized calcareous soil produced the least positive effect on leaf magnesium content. Other tested combinations gave inbetween values in this respect.

4.3.1.6. Iron

Table (24) shows that seedlings grown in loamy sandy soil had higher values of leaf iron content (140 & 142 ppm) as compared with the analogous ones grown in calcareous soil (125 & 128 ppm) in the first and second seasons, respectively. On the other hand, seedlings grown in sandy soil gave leaves intermediate in their iron content (133 & 136 ppm) between the two soil types in both seasons, respectively. Generally, the difference in leaf iron content between the three tested soil were significant from the statistical standpoint.

As for the effect of soil treatments, **Table (25)** shows that seedlings grown in sterilized, inoculated with ***Glomus macrocarpum*** fungus fertilized with rock-phosphate produced high values of leaf iron content, followed descendingly by those grown in sterilized soil inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate in both seasons. On the other hand, seedlings grown in sterilized or unsterilized soil gave the lowest values of leaf iron content.

Furthermore, the interaction between soil type and soil treatments demonstrates that most combinations of loamy sandy soil produced statistically higher values of leaf iron content in both seasons as compared with the analogous ones of calcareous and sandy soils **Table (26)**. Generally, Sour orange seedlings grown in loamy sandy soil, inoculated with mycorrhizae species, fertilized with rock-phosphate or without fertilization gave the most effective enhancing values of leaf iron content followed descendingly by those grown in loamy sandy soil inoculated with mycorrhizae fungi and received no rock-phosphate fertilization and those grown in sandy soil, inoculated with ***Glomus macrocarpum*** and fertilized with rock-phosphate. On the other hand, sterilized or unsterilized calcareous soil gave plants the lowest effect of leaf iron content. Other tested combinations took intermediate positions between the previously two mentioned categories.

4.3.1.7. Zinc

It is obvious from **Table (24)** that in 1998 and 1999 seasons, Sour orange rootstock seedlings grown in loamy sandy soil produced the highest values of leaf zinc content (48 & 48 ppm) as compared with the analogous ones grown in sandy soil (44 & 44 ppm). On the other hand, seedlings grown in calcareous soil had the lowest values of leaf zinc content (42 & 41 ppm) as compared with the aforementioned two tested soil types in the first and second seasons, respectively. Generally, the differences between the three tested soil types were significant from the statistical standpoint.

As for the effect of soil treatments, **Table (25)** shows that seedlings grown in sterilized or unsterilized soil gave comparatively and similarly the lowest values of leaf zinc content. On the other side, seedlings grown in sterilized soil, inoculated with mycorrhizae fungi fertilized with rock-phosphate or without fertilization produced similarly and highly significant effect on leaf zinc content.

Additionally, leaf zinc content of Sour orange rootstock seedlings responded remarkably to the interaction between soil type and soil treatments (**Table, 26**). Generally, growing Sour orange seedlings in sterilized loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus fertilized with rock-phosphate or without fertilization induced the most stimulative effect on leaf zinc content, followed descendingly by those grown in the same, sterilized soil, inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate. On the contrary, Sour orange seedlings grown in sterilized or unsterilized calcareous soil produced the least positive effect on leaf zinc content in both seasons. Other tested combinations took intermediate positions between the previously two mentioned categories.

4.3.1.8. Manganese

Table (24) shows that Sour orange rootstock seedlings grown in sandy soil gave plants intermediate in their leaf manganese content (34 & 35 ppm), whereas loamy sandy soil produced the highest positive effect on leaf manganese content (35 & 37 ppm) and calcareous soil produced the least effect on leaf manganese content (33 & 34 ppm). Generally, the differences in leaf manganese content between the three tested soil types were significant from the statistical standpoint particularly in the second season.

As for the effect of soil treatments, **Table (25)** shows that seedlings grown in sterilized soil or unsterilized soil gave comparatively and similarly the lowest effect on leaf manganese content. On the other hand, sterilized soil, inoculated with

Glomus macrocarpum fungus fertilized with rock-phosphate produced high positive effect on leaf manganese content, followed descendingly by the analogous ones inoculated with ***Glomus australe*** fungus fertilized with rock-phosphate or those grown in sterilized soil, inoculated with ***Glomus macrocarpum*** fungus without fertilization and those grown in sterilized soil, inoculated with ***Glomus australe*** fungus.

Furthermore, leaf manganese content of Sour orange rootstock seedlings responded remarkably to the interaction between soil type and soil treatments **(Table, 26).** It is quite evident that seedlings grown in loamy sandy sterilized soil, inoculated with ***Glomus macrocarpum*** fungus fertilized with rock-phosphate produced positive effect on leaf manganese content, followed descendingly by those grown in the same soil inoculated with ***Glomus australe*** fungus fertilized with rock-phosphate or these inoculated with ***Glomus macrocarpum*** fungus without fertilization. On the contrary, Sour orange grown in sterilized or unsterilized calcareous soil produced the least positive effect on leaf manganese content. Finally, other tested combinations took intermediate positions between the previously two mentioned categories.

4.3.1.9. Copper:

It is clear from **Table (24)** that Sour orange seedlings grown in loamy sandy and sandy soils produced high values of leaf copper content (14 & 13 ppm), and (14 & 12 ppm) in 1998 and 1999 seasons, respectively, followed by calcareous soil (12 & 10 ppm) in their leaf copper content.

As for the effect of soil treatments, **Table (37)** demonstrates that seedlings grown in sterilized or unsterilized soil had the lowest leaf copper content. On the other hand, seedlings grown in sterilized soil, inoculated with ***Glomus macrocarpum*** fungus fertilized with rock-phosphate produced high positive effect of leaf copper content and those inoculated with ***Glomus australe*** fungus fertilized with rock-phosphate, besides, those inoculated with ***Glomus macrocarpum*** fungus and those inoculated with ***Glomus australe***.

Additionally, leaf copper content of Sour orange rootstock responded remarkably to the interaction between soil type and soil treatments **(Table, 26)**. Generally, seedlings grown in sterilized loamy sandy soil, inoculated with ***Glomus australe*** fungus, fertilized with rock-phosphate proved to be the most effective treatments in enhancing leaf copper content. On the other hand, seedlings grown in sterilized or unsterilized calcareous soil had the lowest values of leaf copper content. Other tested combinations took an intermediate positions between the previously two mentioned categories.

4.3.2. Rangpur lime rootstock

The response of leaf mineral content of Rangpur lime rootstock seedlings to soil type namely, calcareous, sandy and loamy sandy soil and soil treatments, *i.e.* soil sterilization, supported with soil inoculation with mycorrhizae fungi (***Glomus australe*** and ***Glomus macrocarpum***), besides, soil sterilization provided with soil inoculation with mycorrhizae species and enriched with rock-phosphate fertilization (1g/pot) as well as the interaction between soil type and soil treatments during 1998 and 1999 seasons is presented in **Tables (27 - 32)**.

Table (21): Specific effect of soil type on leaf mineral content (N, P, K, Ca and Mg) of Sour orange rootstock seedlings (1998 & 1999 seasons).

Soil type	Elements concentration in dried leaves (%)									
	N		P		K		Ca		Mg	
	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Calcareous	2.51 B	2.42 B	0.15 A	0.14 A	1.22 C	1.21 C	1.63 A	1.53 A	0.49 B	0.49 B
Sandy	2.54 B	2.48 A	0.13 B	0.13 B	1.26 B	1.25 B	1.57 B	1.51 A	0.50 B	0.50 B
Loamy sandy	2.61 A	2.51 A	0.14 B	0.13 B	1.30 A	1.30 A	1.58 AB	1.51 A	0.53 A	0.53 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

Table (22): Specific effect of soil type on leaf mineral content (N, P, K, Ca and Mg) of Sour orange rootstock seedlings (1998 & 1999 seasons).

Treatments	Elements concentration in dried leaves (%)									
	N		P		K		Ca		Mg	
S.S + VAM + (P)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Control	2.52 BC	2.45 AB	0.12 C	0.11 C	1.22 D	1.22 C	1.56 B	1.46 C	0.48 B	0.48 B
S.S + ----- + -----	2.50 C	2.43 B	0.12 C	0.11 C	1.23 C	1.23 C	1.56 B	1.50 C	0.47 B	0.47 B
S.S + G.a + -----	2.54 ABC	2.45 AB	0.14 B	0.13 B	1.26 B	1.26 B	1.62 AB	1.55 AB	0.53 A	0.52 A
S.S + G.m + -----	2.56 AB	2.48 AB	0.14 B	0.13 B	1.27 AB	1.27 AB	1.60 AB	1.50 C	0.53 A	0.53 A
S.S + G.a + P	2.60 A	2.51 A	0.16 A	0.16 A	1.30 A	1.28 A	1.57 AB	1.51 BC	0.54 A	0.53 A
S.S + G.m + P	2.60 A	2.50 A	0.17 A	0.16 A	1.30 A	1.28 A	1.65 A	1.56 A	0.54 A	0.53 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

where:

S.S.= Sterilized soil　　VAM = Vesicular Arbuscular Mycorrhizae　　P= rock phosphate **[$Ca_3(PO_4)_2$]**

G.a = *Glomus australe*　　G.m. = *Glomus macrocarpum*

Table (23): Effect of interaction between soil type, mycorrhizal inoculation and rock phosphate fertilization on leaf mineral content (N, P, K, Ca, and Mg) of Sour orange rootstock seedlings (1998 & 1999 seasons).

Soil type	Treatments	Elements concentration in dried leaves (%)									
		N		P		K		Ca		Mg	
	S.S + VAM + (P)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Calcareous	Control	2.43 C	2.37 C	0.13 EF	0.13 D	1.18 G	1.18 H	1.63 ABC	1.47 BC	0.45 G	0.45 H
	S.S + ----- + ----	2.43 C	2.37 C	0.13 EF	0.12 E	1.19 G	1.19 H	1.63 ABC	1.50 BC	0.44 H	0.44 I
	S.S + G.a + ----	2.50 BC	2.40 BC	0.15 BC	0.15 BC	1.23 E	1.23 FG	1.70 A	1.60 A	0.51 E	0.51 F
	S.S + G.m + ----	2.57 AB	2.47 ABC	0.16 AB	0.15 BC	1.24 E	1.24 F	1.63 ABC	1.50 BC	0.52 CDE	0.52 DEF
	S.S + G.a + P	2.57 AB	2.47 ABC	0.17 A	0.17 A	1.24 E	1.24 F	1.53 BCD	1.47 BC	0.53 CDE	0.53 CDE
	S.S + G.m + P	2.57 AB	2.47 ABC	0.17 A	0.17 A	1.24 E	1.23 F	1.70 A	1.60 A	0.53 CDE	0.53 CDE
Sandy	Control	2.53 BC	2.50 AB	0.12 F	0.11 F	1.21 F	1.21 G	1.50 CD	1.43 C	0.48 F	0.48 G
	S.S + ----- + ----	2.50 BC	2.47 ABC	0.12 F	0.11 F	1.23 E	1.23 FG	1.47 D	1.47 BC	0.47 F	0.47 G
	S.S + G.a + ----	2.57 AB	2.47 ABC	0.14 CD	0.13 D	1.28 D	1.28 DE	1.63 ABC	1.57 AB	0.53 CDE	0.53 CDE
	S.S + G.m + ----	2.53 BC	2.47 ABC	0.14 CD	0.13 D	1.28 D	1.27 E	1.57 ABCD	1.50 ABC	0.52 CDE	0.52 DEF
	S.S + G.a + P	2.57 AB	2.50 AB	0.16 AB	0.16 AB	1.28 D	1.28 DE	1.60 ABCD	1.53 ABC	0.53 CDE	0.53 CDE
	S.S + G.m + P	2.57 AB	2.50 AB	0.16 AB	0.15 BC	1.29 BCD	1.29 CDE	1.67 AB	1.57 AB	0.53 CDE	0.53 CDE
Loamy sandy	Control	2.60 AB	2.50 AB	0.12 EF	0.12 E	1.29 BCD	1.29 CDE	1.57 ABCD	1.50 ABC	0.51 DE	0.51 EF
	S.S + ----- + ----	2.57 AB	2.47 ABC	0.13 EF	0.12 E	1.29 CD	1.29 CDE	1.60 ABCD	1.53 ABC	0.52 CDE	0.52 DEF
	S.S + G.a + ----	2.57 AB	2.50 AB	0.14 CD	0.13 D	1.29 CD	1.29 CDE	1.53 BCD	1.50 ABC	0.55 AB	0.55 AB
	S.S + G.m + ----	2.60 AB	2.53 A	0.14 CDE	0.13 D	1.30 ABC	1.30 ABC	1.60 ABCD	1.50 ABC	0.55 AB	0.55 AB
	S.S + G.a + P	2.67 A	2.57 A	0.16 AB	0.16 AB	1.31 A	1.31 A	1.60 ABCD	1.53 ABC	0.55 AB	0.55 AB
	S.S + G.m + P	2.67 A	2.53 A	0.17 A	0.16 AB	1.31 AB	1.31 A	1.60 ABCD	1.53 ABC	0.56 A	0.56 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

where: S.S.= Sterilized soil; G.a = *Glomus australe*; VAM = Vesicular Arbuscular Mycorrhizae; G.m. = *Glomus macrocarpum*; P= rock phosphate $Ca_3(PO_4)_2$

Table (24): Specific effect of soil type on leaf Fe, Zn, Mn, and Cu content of Sour orange rootstock seedlings (1998 & 1999 seasons).

Soil type	Elements concentration in dried leaves (ppm)							
	Fe		Zn		Mn		Cu	
	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Calcareous	125 C	128 C	42 C	41 C	33 B	34 C	12 B	10 B
Sandy	133 B	136 B	44 B	44 B	34 B	35 B	14 A	12 A
Loamy sand	140 A	142 A	48 A	48 A	35 A	37 A	14 A	13 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

Table (25): Specific effect of mycorrhizal inoculation and rock phosphate fertilization on leaf Fe, Zn, Mn and Cu content of Sour orange rootstock seedlings (1998 & 1999 seasons).

Treatment	Elements concentration in dried leaves (ppm)							
	Fe		Zn		Mn		Cu	
S.S + VAM + (P)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Control	125 C	128 D	29 B	28 B	30 D	31 D	7 C	5 C
S.S + ----- + -----	125 C	128 D	29 B	29 B	30 D	31 D	7 C	5 C
S.S + G.a + -----	134 B	137 C	51 A	50 A	34 C	36 C	15 B	14 B
S.S + G.m + -----	135 B	138 C	54 A	53 A	36 B	37 B	17 A	15 AB
S.S + G.a + P	138 A	141 B	53 A	52 A	37 A	39 A	17 A	15 A
S.S + G.m + P	139 A	143 A	53 A	52 A	38 A	39 A	17 A	15 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

where:

S.S.= Sterilized soil
G.a = *Glomus australe*

VAM = Vesicular Arbuscular Mycorrhizae
G.m. = *Glomus macrocarpum*

P= rock phosphate [$Ca_3(PO_4)_2$]

4.3.2.1. Nitrogen

Table (26): Effect of interaction between soil type, mycorrhizal inoculation and rock phosphate fertilization on leaf Fe, Z Mn, and Cu content of Sour orange rootstock seedlings (1998 & 1999 seasons).

Soil type	Treatments S.S + VAM + (P)	Elements concentration in dried leaves (ppm)							
		Fe		Zn		Mn		Cu	
		(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Calcareous	Control	118H	120 H	25 F	24 G	30 E	32 E	6 G	4 H
	S.S + ----- + ----	117 H	120 H	25 F	25 FG	30 E	31 E	6 G	5 H
	S.S + G.a + ----	128 EFG	130 EFG	49 D	48 D	33 D	35 D	14 E	13 D
	S.S + G.m + ----	129 DEF	132 EF	51 BCD	50 BCD	35 CD	36 CD	14 E	13 D
	S.S + G.a + P	129 DEF	132 EF	50 CD	51 ABCD	35 CD	37 CD	15 DE	13 D
	S.S + G.m + P	130 DE	133 DE	50 CD	49 CD	35 CD	37 CD	15 E	13 D
Sandy	Control	126 FG	128 G	30 EF	29 EFG	30 E	31 E	7 FG	5 FG
	S.S + ----- + ----	126 FG	129 FG	29 EF	30 EF	30 E	32 E	7 FG	5 FG
	S.S + G.a + ----	135 C	138 C	51 BCD	50 BCD	33 D	35 D	16 CDE	14 CD
	S.S + G.m + ----	135 C	139 C	53 ABCD	52 ABCD	36 BCD	38 BC	18 ABC	17 A
	S.S + G.a + P	138 B	141 B	52 ABCD	51 ABCD	37 BC	39 BC	18 ABC	16 ABC
	S.S + G.m + P	139 B	142 B	53 ABCD	52 ABCD	38 B	39 BC	18 ABC	16 ABC
Loamy sandy	Control	132 D	134 D	34 E	33 E	30 E	31 E	8 F	7 EF
	S.S + ----- + ----	132 D	135 D	33 E	33 E	30 E	31 E	9 F	7 E
	S.S + G.a + ----	140 B	142 B	55 ABC	54 ABC	36 BCD	38 BC	16 BCDE	15 BCD
	S.S + G.m + ----	141 B	143 B	57 A	56 A	37 BC	39 BC	17 ABCD	15 BCD
	S.S + G.a + P	148 A	149 A	56 AB	55 AB	40 A	42 A	19 A	17 A
	S.S + G.m + P	148 A	151 A	57 A	56 A	40 A	42 A	18 ABC	16 ABC

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

where: S.S.= Sterilized soil VAM = Vesicular Arbuscular Mycorrhizae P= rock phosphate $Ca_3(PO_4)_2$
G.a = *Glomus australe* G.m. = *Glomus macrocarpum*

phosphate gave the highest percentage of leaf nitrogen, followed type and soil treatments **(Table, 29)**. It is quite evident that all combinations of loamy sandy soil produced statistically higher values of leaf phosphorus content in both seasons as compared with the analogous ones of calcareous and sandy soils. Generally, Rangpur lime seedlings grown in loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate proved to be the most effective treatment in enhancing leaf phosphorus content, followed descendingly by the analogous ones inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate. On the contrary, Rangpur lime seedlings grown in sterilized or unsterilized calcareous, sandy and loamy sandy soils and received no mycorrhizal inoculation or rock-phosphate fertilization produced the least positive effect on leaf phosphorus content in both seasons. Other tested combinations took an intermediate positions between the previously two mentioned categories.

4.3.2.3. Potassium

It is clear from **Table (27)** that Rangpur lime rootstock seedlings grown in loamy sandy soil gave plants high in their leaf potassium content (1.26 & 1.26%) as compared with those grown in calcareous soil (1.22 & 1.22%) in both seasons. On the other side, seedlings grown in sandy soil gave plants intermediate in their leaf potassium content (1.24 & 1.24%), in the first and second seasons, respectively. Generally, the differences in leaf potassium content between the three tested soil types were obvious to be significant.

As for the effect of soil treatments, **Table (28)** shows that Rangpur lime seedlings grown in sterilized or unsterilized soil gave comparatively and similarly the lowest values of leaf potassium content as compared with other tested treatments. On the other side, all soil treatments inoculated with mycorrhizae species without fertilization or with rock-phosphate fertilization proved to be the most effective treatments in enhancing leaf potassium content

Furthermore, the interaction between soil type and soil treatments exerted a pronounced effect on leaf potassium content of Rangpur lime seedling **(Table, 29).** It is quite evident that Rangpur lime seedlings grown in sterilized or unsterilized calcareous and sandy soils showed to be the least effective combinations in exerting stimulative effect on leaf potassium content as compared with those grown in sterilized or unsterilized loamy sandy inoculated with mycorrhizae fungi and fertilized with rock-phosphate. On the other side, the other tested combinations took and intermediate positions between the previously two mentioned categories.

4.3.2.4. Calcium

It is obvious from **Table (27)** that in 1998 and 1999 seasons Rangpur lime seedlings grown in calcareous soil showed higher percentage of leaf calcium content (1.74 & 1.66%), followed descendingly by those grown in loamy sandy soil (1.67 & 1.66%) and those grown in sandy soil (1.65 & 1.61%) in the first and second seasons, respectively.

As for the effect of soil treatments, **Table (28)** demonstrates that seedlings grown in sterilized or unsterilized soil gave comparatively and similarly the lowest values of leaf calcium content. On the other hand, all tested soil treatments implying mycorrhizal inoculation, whether fertilized or not with type and soil treatments **(Table, 29)**. It is quite evident that all combinations of loamy sandy soil produced statistically higher values of leaf phosphorus content in both seasons as compared with the analogous ones of calcareous and sandy soils. Generally, Rangpur lime seedlings grown in loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate proved to be the most effective treatment in enhancing leaf phosphorus content, followed descendingly by the analogous ones inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate. On the contrary, Rangpur lime seedlings grown in sterilized or unsterilized calcareous, sandy and loamy sandy soils and received no mycorrhizal inoculation or rock-phosphate fertilization produced the least positive effect on leaf phosphorus content in both seasons. Other tested combinations took an intermediate positions between the previously two mentioned categories.

4.3.2.3. Potassium

It is clear from **Table (27)** that Rangpur lime rootstock seedlings grown in loamy sandy soil gave plants high in their leaf potassium content (1.26 & 1.26%) as compared with those grown in calcareous soil (1.22 & 1.22%) in both seasons. On the other side, seedlings grown in sandy soil gave plants intermediate in their leaf potassium content (1.24 & 1.24%), in the first and second seasons, respectively. Generally, the differences in leaf potassium content between the three tested soil types were obvious to be significant.

As for the effect of soil treatments, **Table (28)** shows that Rangpur lime seedlings grown in sterilized or unsterilized soil gave comparatively and similarly the lowest values of leaf potassium content as compared with other tested treatments. On the other side, all soil treatments inoculated with mycorrhizae species without fertilization or with rock-phosphate fertilization proved to be the most effective treatments in enhancing leaf potassium content

Furthermore, the interaction between soil type and soil treatments exerted a pronounced effect on leaf potassium content of Rangpur lime seedling **(Table, 29).** It is quite evident that Rangpur lime seedlings grown in sterilized or unsterilized calcareous and sandy soils showed to be the least effective combinations in exerting stimulative effect on leaf potassium content as compared with those grown in sterilized or unsterilized loamy sandy inoculated with mycorrhizae fungi and fertilized with rock-phosphate. On the other side, the other tested combinations took and intermediate positions between the previously two mentioned categories.

4.3.2.4. Calcium

It is obvious from **Table (27)** that in 1998 and 1999 seasons Rangpur lime seedlings grown in calcareous soil showed higher percentage of leaf calcium content (1.74 & 1.66%), followed descendingly by those grown in loamy sandy soil (1.67 & 1.66%) and those grown in sandy soil (1.65 & 1.61%) in the first and second seasons, respectively.

As for the effect of soil treatments, **Table (28)** demonstrates that seedlings grown in sterilized or unsterilized soil gave comparatively and similarly the lowest values of leaf calcium content. On the other hand, all tested soil treatments implying mycorrhizal inoculation, whether fertilized or not with rock-phosphate or without fertilization proved to be the most effective treatments in enhancing leaf calcium content.

Additionally, leaf calcium content of Rangpur lime seedling responded remarkably to the interaction between soil type and soil treatments **(Table, 29).** Generally, Rangpur lime seedlings grown in calcareous, sandy and loamy sandy soil sterilized or unsterilized soil produced the least positive effect on leaf calcium content in both seasons. On the other side, the other tested treatments of the three soils had higher values of leaf calcium content.

4.3.2.5. Magnesium

It is clear from **Table (27)** that, in both seasons, Rangpur lime seedlings grown in sandy soil showed higher percentage of leaf magnesium content (0.50 & 0.51%) as compared with the analogous ones grown in calcareous soil (0.46 & 0.47%) in the first and second seasons, respectively. On the other hand, seedlings grown in sandy soil gave leaves intermediate in their magnesium content (0.48 & 0.48%) as compared with aforementioned two tested soil types in 1998 and 1999 seasons, respectively. Generally, the differences in leaf magnesium content between the three tested soil types were remarakable to be significant.

As for the effect of soil treatments on leaf magnesium content, **Table (28)** shows that seedlings grown in sterilized or unsterilized soil gave comparatively and similarly the lowest percent of leaf magnesium content. On the other side, all soil treatments inoculated with mycorrhizae fungi fertilized with rock-phosphate or without fertilization proved to be the most effective treatments in enhancing leaf magnesium content.

Furthermore, the interaction between soil type and soil treatments, **Table (29)** demonstrates that leaf magnesium content of Rangpur lime seedlings grown in sterilized loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus, fertilized with rock-phosphate or without fertilization produced the highest effective of leaf magnesium content, followed descendingly by seedlings grown in sterilized loamy sandy soil, inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate. On the other hand, Rangpur lime seedlings grown in sterilized or unsterilized calcareous soil produced the least positive effect on leaf magnesium content. Besides, other tested combinations took an intermediate positions between the previously two mentioned categories.

4.3.2.6. Iron

It is clear from **Table (30)** that in both seasons, Rangpur lime seedlings grown in loamy sandy soil had higher values of leaf iron content (134 & 132 ppm) as compared with the analogous ones grown in calcareous soil (76 & 74 ppm). On the other hand, seedlings grown in sandy soil gave leaves intermediate in their iron content (106 & 105 ppm) as compared with the aforementioned two tested soil types in the first and second seasons, respectively. Generally, the differences in leaf iron content between the three tested soils were obvious to be significant.

As for the effect of soil treatments, **Table (31)** demonstrates that seedlings grown in sterilized or unsterilized soil gave the least values of leaf iron content. On the other side, supplementing sterilized soil with mycorrhizae inoculation with ***Glomus macrocarpum*** fungus produced higher percentage of leaf iron content, followed descendingly by seedlings grown in sterilized soil inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate, and seedlings grown in sterilized soil, inoculated with ***Glomus australe*** fungus, fertilized with rock-phosphate.

Furthermore, the interaction between soil type and soil treatments exerted a pronounced effect on leaf iron content of Rangpur lime seedling (**Table, 33**). It is quite evident that all combinations of loamy sandy soil produced leaves statistically high in their iron content in both seasons as compared with the analogous ones of calcareous and sandy soils. Generally, Rangpur lime seedlings grown in loamy sandy soil, inoculated with ***Glomus australe*** fungus gave high percentage of leaf iron content, followed descendingly by the analogous ones inoculated with ***Glomus macrocarpum*** fungus. On the contrary, Rangpur lime seedling grown in sterilized or unsterilized calcareous soil produced the least positive effect on leaf iron content in both seasons. Other tested combinations took an intermediate positions between the previously two mentioned categories.

4.3.2.7. Zinc

It is obvious from **Table (30)** that in 1998 and 1999 seasons, leaves of Rangpur lime seedlings grown in calcareous soil had the lowest values of zinc content (34 & 34 ppm) as compared with the analogous ones grown in loamy sandy soil (40 & 40 ppm) in 1998 and 1999 seasons, respectively. On the other hand, seedlings grown in sandy soil gave leaves intermediate in their zinc content (36 & 37 ppm) as compared with the aforementioned two tested soil types in the first and second seasons, respectively. Generally, the differences in leaf zinc content between the three tested soil were significant from the statistical standpoint.

As for the effect of soil treatments on leaf zinc content, **Table (31)** shows that seedlings grown in sterilized or unsterilized soil gave comparatively and similarly the lowest percent of leaf zinc content. On the other side, seedlings grown in sterilized soil, inoculated with ***Glomus macrocarpum*** fungus, fertilized or not with rock-phosphate produced significantly higher values of leaf zinc content. Furthermore, seedlings grown in sterilized soil, inoculated with ***Glomus australe*** fungus, fertilized with rock-phosphate gave plants intermediate in leaf zinc content as compared with the aforementioned two previously categories, followed descendingly by those grown in sterilized soil and inoculated with ***Glomus australe*** fungus without fertilization.

Additionally, leaf zinc content of Rangpur lime seedlings responded remarkably to the interaction between soil type and soil treatments (**Table, 32**). Generally, growing Rangpur lime seedlings in sterilized loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus, fertilized with rock-phosphate or without fertilization produced the most stimulative effect on leaf zinc content, followed descendingly by those grown in the same soil, sterilized soil, inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate. On the contrary, planting Rangpur lime seedlings in sterilized or unsterilized calcareous soil produced the least positive effect on leaf zinc content in both seasons. Other tested combinations took intermediate positions between the previously two mentioned categories.

4.3.2.8. Manganese

Table (30) shows that leaves of Rangpur lime seedlings grown in sandy soil had an intermediate values of manganese content (26 & 22 ppm), whereas those grown in loamy sandy soil produced the highest values of leaf manganese content (26 & 23 ppm), and calcareous soil produced the lowest leaf manganese content (22 & 21 ppm).

As for the effect of soil treatments on leaf manganese content, **Table (31)** demonstrates that seedlings grown in sterilized soil or unsterilized calcareous soil had comparatively and similarly the lowest leaf manganese content. On the other hand, all soil treatments, inoculated with mycorrhizae fungi, fertilized with or without rock-phosphate proved to be the superior treatments in enhancing leaf manganese content.

Rangpur lime seedlings responded remarkably to the interaction between soil type and soil treatments **(Table, 32).** It is quite evident that seedlings grown in loamy sandy sterilized soil, inoculated with ***Glomus macrocarpum*** fungus, fertilized with rock-phosphate or received no fertilization had the highest values of leaf manganese content. On the other hand, Rangpur lime seedlings grown in sterilized or unsterilized calcareous soil showed the least positive response regarding leaf manganese content. On the contrary, other tested combinations took intermediate positions between the previously two mentioned categories.

4.3.2.9. Copper

It is clear from **Table (30)** that Rangpur lime seedlings grown in loamy sandy soil had higher percentage of leaf copper content (12 & 11 ppm) as compared with the analogous ones grown in calcareous soil (9 & 9 ppm). On the other hand, seedlings grown in sandy soil showed intermediate values of leaf copper content (11 & 11 ppm) as compared with the aforementioned two tested soil types in the first and second seasons, respectively. Generally, the differences in leaf copper content between the three tested soil types were significant from the statistical standpoint.

As for the effect of soil treatments, **Table (31)** demonstrates that seedlings grown in sterilized or unsterilized soil had the lowest values of leaf copper content as compared with those grown in sterilized soil, inoculated with ***Glomus macrocarpum*** fungus, fertilized with rock-phosphate or without fertilization and the analogous ones inoculated with ***Glomus australe*** fungus without fertilized with rock-phosphate. On the contrary, sterilized soil, inoculated with ***Glomus australe*** fungus gave plants intermediate in their leaf copper content as compared with the aforementioned two group previously in the first and second seasons, respectively.

Furthermore, the interaction between soil type and soil treatments exerted a pronounced effect on Rangpur lime seedling **(Table, 32)**. It is quite evident that seedlings grown in sterilized loamy sandy soil, inoculated with ***Glomus australe*** fungus, fertilized with rock-phosphate or the analogous ones inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate proved to be the most effective combination in enhancing leaf copper content, followed descendingly by those grown in sandy soil inoculated with ***Glomus macrocarpum*** fungus. On the other side, seedlings grown in sterilized or unsterilized calcareous soil had the lowest values of leaf copper content. Other tested combinations took an intermediate positions between the previously two mentioned categories.

Table (27): Specific effect of soil type on leaf mineral content (N, P, K, Ca and Mg) of Rangpur lime rootstock seedlings (1998 & 1999 seasons).

Soil type	Elements concentration in dried leaves (%)									
	N		P		K		Ca		Mg	
	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Calcareous	2.33 C	2.27 C	0.13 B	0.14 B	1.22 C	1.22 C	1.74 A	1.66 A	0.46 C	0.47 C
Sandy	2.42 B	2.41 B	0.14 B	0.15 B	1.24 B	1.24 B	1.65 B	1.61 B	0.48 B	0.48 B
Loamy sandy	2.48 A	2.51 A	0.15 A	0.16 A	1.26 A	1.26 A	1.67 B	1.66 A	0.50 A	0.51 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

Table (28): Specific effect of soil treatments on leaf mineral content (N, P, K, Ca and Mg) of Rangpur lime rootstock seedlings (1998 & 1999 seasons).

Treatments S.S + VAM + (P)	Elements concentration in dried leaves (%)									
	N		P		K		Ca		Mg	
	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Control	2.25 C	2.24 C	0.11 C	0.11 C	1.18 B	1.18 B	1.53 B	1.50 B	0.45 B	0.45 B
S.S + ------ + -------	2.24 C	2.23 C	0.11 C	0.11 C	1.18 B	1.18 B	1.53 B	1.51 B	0.44 B	0.45 B
S.S + G.a + -------	2.43 B	2.43 B	0.15 B	0.16 B	1.26 A	1.26 A	1.77 A	1.72 A	0.50 A	0.50 A
S.S + G.m + -------	2.50 A	2.47 AB	0.15 B	0.16 B	1.27 A	1.27 A	1.76 A	1.72 A	0.50 A	0.50 A
S.S + G.a + P	2.54 A	2.50 A	0.16 A	0.17 A	1.27 A	1.27 A	1.76 A	1.70 A	0.50 A	0.50 A
S.S + G.m + P	2.50 A	2.51 A	0.16 A	0.18 A	1.27 A	1.27 A	1.77 A	1.71 A	0.50 A	0.51 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

where:

S.S.= Sterilized soil
G.a = *Glomus australe*

VAM = Vesicular Arbuscular Mycorrhizae
G.m. = *Glomus macrocarpum*

P= rock phosphate [$Ca_3(PO_4)_2$]

Table (29): Effect of interaction between soil type, mycorrhizal inoculation and rock phosphate fertilization on leaf minera content (N, P, K, Ca, and Mg) of Rangpur lime rootstock seedlings (1998 & 1999 seasons).

Soil type	Treatments	Elements concentration in dried leaves (%)									
		N		P		K		Ca		Mg	
	S.S + VAM + (P)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Calcareous	Control	2.16 D	2.10 F	0.10 C	0.10 G	1.17 H	1.17 H	1.56 B	1.50 B	0.42 F	0.42 F
	S.S + ----- + ----	2.13 D	2.06 F	0.10 C	0.10 G	1.17 H	1.17 H	1.60 B	1.53 B	0.40 G	0.42 F
	S.S + G.a + ----	2.30 C	2.23 E	0.14 B	0.14 F	1.24 F	1.24 F	1.83 A	1.73 A	0.48 D	0.49 C
	S.S + G.m + ----	2.43 B	2.36 D	0.14 B	0.15 DEF	1.25 EF	1.25 EF	1.80 A	1.73 A	0.49 C	0.49 C
	S.S + G.a + P	2.50 AB	2.43 CD	0.15 B	0.16 BCDE	1.25 EF	1.25 EF	1.83 A	1.73 A	0.50 B	0.50 B
	S.S + G.m + P	2.46 AB	2.43 CD	0.15 B	0.16 BCDE	1.25 DEF	1.25 EF	1.83 A	1.73 A	0.50 B	0.50 B
Sandy	Control	2.26 C	2.26 E	0.11 C	0.10 G	1.18 H	1.18 H	1.50 B	1.46 B	0.44 E	0.45 E
	S.S + ----- + ----	2.26 C	2.26 E	0.11 C	0.10 G	1.18 H	1.18 H	1.50 B	1.50 B	0.44 E	0.45 E
	S.S + G.a + ----	2.46 AB	2.46 BC	0.14 B	0.15 EF	1.26 CDE	1.26 CDE	1.73 A	1.66 A	0.50 B	0.51 AB
	S.S + G.m + ----	2.50 AB	2.50 ABC	0.15 B	0.16 CDEF	1.27 ABC	1.27 BCD	1.73 A	1.70 A	0.49 C	0.50 B
	S.S + G.a + P	2.56 A	2.50 ABC	0.16 B	0.17 ABC	1.27 BCD	1.27 BCD	1.73 A	1.66 A	0.49 C	0.50 B
	S.S + G.m + P	2.46 AB	2.50 ABC	0.15 B	0.18 AB	1.27 BCD	1.27 BCD	1.73 A	1.66 A	0.50 B	0.50 B
Loamy sandy	Control	2.33 C	2.36 D	0.12 C	0.11 G	1.20 G	1.20 G	1.53 B	1.53 B	0.48 D	0.48 D
	S.S + ----- + ----	2.33 C	2.36 D	0.12 C	0.11 G	1.20 G	1.20 G	1.50 B	1.50 B	0.49 C	0.49 CD
	S.S + G.a + ----	2.53 AB	2.60 A	0.16 B	0.17 ABC	1.29 A	1.29 A	1.76 A	1.76 A	0.52 A	0.52 A
	S.S + G.m + ----	2.56 A	2.56 AB	0.16 B	0.17 ABC	1.29 A	1.29 A	1.76 A	1.73 A	0.52 A	0.52 A
	S.S + G.a + P	2.56 A	2.56 AB	0.18 A	0.18 AB	1.29 AB	1.29 A	1.73 A	1.70 A	0.52 A	0.52 A
	S.S + G.m + P	2.56 A	2.60 A	0.18 A	0.19 A	1.28 ABC	1.28 ABC	1.76 A	1.73 A	0.52 A	0.52 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

where: S.S.= Sterilized soil; VAM = Vesicular Arbuscular Mycorrhizae; P= rock phosphate [$Ca_3(PO_4)_2$]
G.a = *Glomus australe*; G.m. = *Glomus macrocarpum*

Table (30): Specific effect of soil type on leaf Fe, Zn, Mn, and Cu content of Rangpur lime rootstock seedlings (1998 & 1999 seasons).

Soil type	Elements concentration in dried leaves (ppm)							
	Fe		Zn		Mn		Cu	
	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Calcareous	76 C	74 C	34 C	34 C	22 B	21 B	9 B	9 B
Sandy	106 B	105 B	36 B	37 B	26 A	22 A	12 A	11 A
Loamy sandy	134 A	132 A	40 A	40 A	26 A	23 A	12 A	11 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

Table (31): Specific effect of mycorrhizal inoculation and rock phosphate fertilization on leaf mineral content (Fe, Zn, Mn and Cu) of Rangpur lime rootstock seedlings (1998 & 1999 seasons).

Treatments	Elements concentration in dried leaves (ppm)							
	Fe		Zn		Mn		Cu	
S.S + VAM + (P)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Control	90 B	87 C	25 C	27 B	19 B	19 B	6 C	6 C
S.S + ------- + -------	92 B	86 C	25 C	27 B	19 B	19 B	6 C	6 C
S.S + G.a + -------	113 A	112 A	41 B	41 A	28 A	23 A	12 B	11 B
S.S + G.m + -------	114 A	113 A	44 A	43 A	28 A	23 A	13 A	13 A
S.S + G.a + P	111 B	112 A	43 A	42 A	28 A	24 A	14 A	13 A
S.S + G.m + P	112 AB	113 A	43 A	43 A	29 A	24 A	14 A	13 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

where:

S.S.= Sterilized soil

G.a = *Glomus australe*

VAM = Vesicular Arbuscular Mycorrhizae

G.m. = *Glomus macrocarpum*

P= rock phosphate [$Ca_3(PO_4)_2$]

Table (32): Effect of interaction between soil type, mycorrhizal inoculation and rock phosphate fertilization on leaf Fe, Mn, and Cu content of Rangpur lime rootstock seedlings (1998 & 1999 seasons).

Soil type	Treatments S.S + VAM + (P)	Elements concentration in dried leaves (ppm)							
		Fe		Zn		Mn		Cu	
		(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Calcareous	Control	55 I	53 G	23 G	23 F	16 I	17 F	5 H	5 G
	S.S + ----- + ----	58 I	53 G	23 G	24 F	16 I	18 F	5 H	5 G
	S.S + G.a + ----	84 H	84 F	39 E	38 D	25 G	22 BCD	11 F	10 E
	S.S + G.m + ----	88 G	85 F	41 CDE	40 CD	25 G	23 ABC	12 EF	12 C
	S.S + G.a + P	85 GH	85 F	40 DE	40 CD	25 G	23 ABC	12 EF	11 D
	S.S + G.m + P	86 GH	86 EF	40 DE	41 BCD	26 FG	23 ABC	12 EF	11 D
Sandy	Control	93 F	89 D	25 FGH	28 EF	20 H	19 DEF	6 G	6 G
	S.S + ----- + ----	95 F	88 DE	26 FG	27 EF	20 H	19 DEF	7 G	6 G
	S.S + G.a + ----	114 D	113 C	41 CDE	40 BCD	29 CDE	24 AB	13 CD	12 C
	S.S + G.m + ----	114 D	114 C	43 BC	42 ABCD	28 EF	23 ABC	15 A	14 A
	S.S + G.a + P	110 E	112 C	42 CD	41 BCD	29 CDE	24 AB	14 ABC	14 A
	S.S + G.m + P	112 DE	114 C	43 BC	42 ABCD	29 BCDE	24 AB	14 ABC	14 A
Loamy sandy	Control	122 C	120 B	28 F	30 E	21 H	20 CDE	7 G	7 F
	S.S + ----- + ----	124 C	119 B	28 F	29 E	21 H	20 CDE	7 G	7 F
	S.S + G.a + ----	142 A	138 A	45 AB	44 ABC	32 A	24 AB	13 CD	13 B
	S.S + G.m + ----	140 AB	140 A	47 A	46 A	32 A	25 A	14 ABC	13 B
	S.S + G.a + P	138 B	140 A	47 A	45 AB	31 ABCD	25 A	15 A	15 A
	S.S + G.m + P	138 B	138 A	47 A	46 A	32 A	24 AB	15 A	15 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

where: S.S.= Sterilized soil; VAM = Vesicular Arbuscular Mycorrhizae; P= rock phosphate [$Ca_3(PO_4)_2$]

G.a = *Glomus australe*; G.m. = *Glomus macrocarpum*

4.3.3. Volkamer lemon rootstock

The response of leaf mineral content of Volkamer lemon rootstock seedlings to soil type namely, calcareous, sandy and loamy sandy soil and soil treatments, *i.e.* soil sterilization, supported with soil inoculation with mycorrhizae fungi (***Glomus australe*** and ***Glomus macrocarpum***), besides, soil sterilization provided with soil inoculation with mycorrhizae species and enriched with rock-phosphate fertilization (1g/pot) as well as the interaction between soil type and soil treatments during 1998 and 1999 seasons is presented in **Tables (33 - 38)**.

4.3.3.1. Nitrogen

It is obvious from **Table (33)** that in 1998 and 1999 seasons, Volkamer lemon seedlings grown in loamy sandy soil had higher values of leaf nitrogen content (2.55 & 2.45%) as compared with the analogous ones grown in calcareous soil (2.42 & 2.32%). On the other hand, seedlings grown in sandy soil gave leaves intermediate in their leaf nitrogen content (2.52 & 2.42%) as compared with the aforementioned two tested soil types in the first and second seasons, respectively. Generally, the differences in leaf nitrogen content between the three tested soil types were significant from the statistical standpoint.

As for the effect of soil treatments, **Table (34)** shows that, seedlings grown in sterilized or unsterilized soil gave the lowest percent of leaf nitrogen content. On the other hand, supplementing sterilized soil with inoculation with ***Glomus macrocarpum*** fungus produced higher percentage of leaf nitrogen followed descendingly by those inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate, sterilized soil, inoculated with ***Glomus australe*** fungus fertilized with rock-phosphate in the least these treatments inoculated with ***Glomus australe*** fungus without fertilization in the first and second seasons.

Furthermore, the interaction between soil type and soil treatments exerted a pronounced effect on leaf nitrogen content of Volkamer lemon seedlings **(Table, 35).** It is quite evident that Volkamer lemon grown in loamy sandy soil inoculated with ***Glomus macrocarpum*** fungus fertilized with rock-phosphate gave plants higher percent of leaf nitrogen content, followed descendingly by those grown in sterilized sandy soil, and inoculated with ***Glomus macrocarpum*** fungus. On the other hand, sterilized soil or unsterilized soil grown in calcareous soil gave plants with the lowest values of leaf nitrogen content. Other tested combinations took intermediate positions between the previously two mentioned categories.

4.3.3.2. Phosphorus

Table (33) shows that Volkamer lemon rootstock seedlings grown in loamy sandy soil induced higher percentage of leaf phosphorus content (0.148 & 0.152%) as compared with the analogous ones grown in calcareous soil (0.120 & 0.126%) in the first and second seasons, respectively. On the other hand, seedlings grows in sandy soil gave plants intermediate between the two soil types in their leaf phosphate content (0.136 & 0.139%) in both seasons. Generally, the differences in leaf phosphorus content between the three tested soil types were significant from the statistical standpoint.

As for the effect of soil treatments, **Table (34)** demonstrates that seedlings grown in sterilized soil, inoculated with mycorrhizae species, fertilized with rock-phosphate proved to be the most effective treatments in enhancing leaf phosphorus content as compared with those grown in sterilized or unsterilized soil in both seasons. On the other hand, seedlings grown in sterilized soil, inoculated with mycorrhizae species without fertilization gave plants intermediate between the previously two mentioned in leaf phosphorus content.

Additionally, leaf phosphorus content of Volkamer lemon rootstock responded remarkably to the interaction between soil type and soil treatments **(Table, 35)**. Generally, seedlings grown in loamy sandy soil, inoculated with mycorrhizae species, fertilized with rock-phosphate produced higher values of leaf phosphorus content, followed descendingly by those grown in sandy soil inoculated with mycorrhizae species and fertilized with rock-phosphate or those grown in loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus without fertilization. On the other side, seedlings grown in sterilized or unsterilized calcareous soil produced the least positive effect on leaf phosphorus content. Other tested interactions were intermediate between the previously two groups.

4.3.3.3. Potassium

It is clear from **Table (33)** that Volkamer lemon rootstock seedlings grown in calcareous soil produced the lowest positive effect on leaf potassium content (1.21 & 1.20%) as compared with the analogous ones grown in loamy sandy soil (1.25 & 1.24%) in the first and second seasons, respectively. On the other side, seedlings grown in sandy soil gave plants intermediate between the two soil types in their leaf potassium content (1.23 & 1.22%) in both seasons, respectively. Generally, the differences in leaf potassium content between the three tested soil types were significant from the statistical standpoint.

As for the effect of soil treatments, **Table (34)** shows that seedlings grown in sterilized soil, inoculated with ***Glomus macrocarpum*** fungus fertilized with rock-phosphate or without fertilization gave leaves with higher values of leaf potassium content, followed descendingly by those grown in sterilized soil inoculated with ***Glomus australe*** fungus fertilized with rock-phosphate and those inoculated with ***Glomus australe*** fungus without fertilization. On the other side, sterilized or unsterilized soil produced the least positive effect in their leaf potassium.

Furthermore, the interaction between soil type and soil treatments in **Table (35)** shows that seedlings grown in loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus fertilized with rock-phosphate had higher percent of leaf potassium content followed descendingly by those grown in the same soil inoculated with ***Glomus macrocarpum*** fungus without fertilization and sterilized soil inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphorus. On the other side, sterilized or unsterilized calcareous soil produced the lowest effect of leaf potassium content. Other tested combinations occupied inbetween positions.

4.3.3.4. Calcium

It is obvious from **Table (33)** that in 1998 and 1999 seasons Volkamer lemon seedlings grown in the three soil types (calcareous, sandy and loamy sandy) had similar values of leaf calcium content (1.74 & 1.74%), (1.70 & 1.70%) and (1.71 & 1.70%), respectively. Generally, there were insignificant differences between soil types.

As for the effect of soil treatments, **Table (34)** demonstrates that seedlings grown in sterilized or unsterilized soil gave comparatively and similarly the lowest positive effect on leaf calcium content. On the other hand, all soil treatments inoculated with mycorrhizae species, fertilized with rock-phosphate or without rock-phosphate fertilization proved equally to be the most effective treatments in enhancing leaf calcium content.

Additionally, leaf calcium content of Volkamer lemon rootstock seedlings responded remarkably to the interaction between soil type and soil treatments **(Table, 35).** Generally, Volkamer lemon seedlings grown in calcareous, sandy and loamy sandy soil sterilized or unsterilized soil produced the least positive effect on leaf calcium content in both seasons. On the other side, the other treatments of the three soils had similar values of leaf calcium content.

4.3.3.5. Magnesium

Table (33) shows that Volkamer lemon seedlings grown in loamy sandy soil produced higher percentage of leaf magnesium content (0.47 & 0.49%) as compared with the analogous ones grown in calcareous soil (0.43 & 0.45%) in the first and second seasons, respectively. On the other side, seedlings grown in sandy soil gave plants intermediate in their leaf magnesium content (0.45 & 0.46%) between the previously two soil types. Generally, the differences in leaf magnesium content between the three tested soil types were significant from the statistical standpoint.

As for the effect of soil treatments, **Table (34)** demonstrates that sterilized or unsterilized soil produced the lowest positive effect on leaf magnesium content. On the other hand, other treatments produced higher values of leaf magnesium content. Generally, soil inoculation with mycorrhizae fungi gave highly positive effect on leaf magnesium content.

Furthermore, the interaction between soil type and soil treatments, **Table (35)** shows that seedlings grown in sterilized loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus, fertilized with rock-phosphate had higher values of leaf magnesium content, followed descendingly by those grown in the same soil, inoculated with ***Glomus macrocarpum*** fungus without fertilization. On the other side, seedlings grown in sterilized or unsterilized calcareous soil produced the least positive effect on leaf magnesium content. Other tested interactions were inbetween the two previously two mentioned categories.

4.3.3.6. Iron

Table (36) shows that seedlings grown in loamy sandy soil had higher values of leaf iron content (128 & 130 ppm) as compared with the analogous ones grown in calcareous soil (70 & 72 ppm) in the first and second seasons, respectively. On the other hand, seedlings grown in sandy soil gave leaves intermediate in their iron content between the previously two soil types (102 & 104 ppm) in both seasons, respectively. Generally, the difference in leaf iron content between the three tested soil were significant from the statistical standpoint.

As for the effect of soil treatments, **Table (37)** shows that seedlings grown in sterilized soil, inoculated with ***Glomus macrocarpum*** fungus fertilized with rock-phosphate or without fertilization produced high values of leaf iron content, followed descendingly by those grown in sterilized soil inoculated with ***Glomus australe*** fungus fertilized with rock-phosphate or without fertilization. On the other hand, seedling grown in sterilized or unsterilized gave the least values of leaf iron content.

Furthermore, the interaction between soil type and soil treatments in **Table (38)** demonstrates that all combinations of loamy sandy soil produced statistically higher values of leaf iron content in both seasons as compared with the analogous ones of calcareous and sandy soils. Generally, Volkamer lemon seedlings grown in loamy sandy soil, inoculated with mycorrhizae species, fertilized with rock-phosphate or without fertilization gave the most enhancing effect on leaf iron content followed descendingly by sterilized or unsterilized loamy sandy soil. On the other hand, sterilized or unsterilized calcareous soil gave the lowest values of leaf iron content. Other tested combinations took an intermediate positions between the previously two mentioned categories.

4.3.3.7. Zinc

It is obvious from **Table (36)** that in 1998 and 1999 seasons, Volkamer lemon rootstock seedlings grown in calcareous soil produced the lowest values of leaf zinc content (30 & 30 ppm) as compared with the analogous ones grown in loamy sandy soil (36 & 36 ppm). On the other hand, seedlings grown in sandy soil gave plants intermediate in their leaf zinc content (32 & 33 ppm) as compared with the aforementioned two tested soil types in the first and second seasons, respectively. Generally, the differences between the three tested soil types were significant from the statistical standpoint.

As for the effect of soil treatments, **Table (37)** shows that seedlings grown in sterilized or unsterilized soil gave comparatively and similarly the lowest values of leaf zinc content. On the other side, seedlings grown in sterilized loamy sandy soil, inoculated with ***Glomus macrocarpum*** and ***Glomus australe*** fungi fertilized with rock-phosphate or without fertilization produced highly positive effect on leaf zinc content.

Additionally, leaf zinc content of Volkamer lemon rootstock seedlings responded remarkably to the interaction between soil type and soil treatments (**Table, 38**). Generally, Volkamer lemon seedlings grown in sterilized loamy sandy soil, inoculated with ***Glomus macrocarpum*** fungus fertilized with rock-phosphate or without fertilization gave exerted the most stimulative effect on leaf zinc content, followed descendingly by those grown in the same sterilized soil, inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate. On the contrary, Volkamer lemon seedlings grown in sterilized or unsterilized calcareous soil produced the least positive effect on leaf zinc content in both seasons. Other tested combinations took an intermediate positions between the previously two mentioned categories.

4.3.3.8. Manganese

Table (36) shows that Volkamer lemon rootstock seedlings grown in sandy soil gave leaves intermediate in their manganese content (22 & 19 ppm) between loamy sandy soil which produced the highest values of leaf manganese content (24 & 21 ppm), and calcareous soil which scored the lowest values of leaf manganese content (19 & 18 ppm). Generally, the differences in leaf manganese content between the three tested soil types were significant from the statistical standpoint particularly in 1998 season.

As for the effect of soil treatments, **Table (37)** shows that seedlings grown in sterilized soil or unsterilized soil gave comparatively and similarly the lowest values of leaf manganese content. On the other hand, sterilized soil, inoculated with ***Glomus macrocarpum*** fungus fertilized with rock-phosphate induced high positive effect on leaf manganese content, followed descendingly by the analogous ones inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate or those grown in sterilized soil, inoculated with ***Glomus macrocarpum*** fungus without fertilization and those grown in sterilized soil, inoculated with ***Glomus australe*** fungus.

Furthermore, leaf manganese content of Volkamer lemon rootstock seedlings responded remarkably to the interaction between soil types and soil treatments **(Table, 38).** It is quite evident that seedlings grown in loamy sandy sterilized soil, inoculated with ***Glomus macrocarpum*** fungus and fertilized with rock-phosphate induced the most enhancing effect on leaf manganese content, followed descendingly by those grown in the same soil inoculated with ***Glomus australe*** fungus fertilized with rock-phosphate or those inoculated with ***Glomus macrocarpum*** fungus without rock-phosphate fertilization. On the contrary, Volkamer lemon grown in sterilized or unsterilized calcareous soil produced the least positive effect on leaf manganese content. Finally, other tested combinations took an intermediate positions between the previously two mentioned categories.

4.3.3.9. Copper

It is clear from **Table (36)** that Volkamer lemon rootstock seedlings grown in loamy sandy and sandy soils scored similarly high values of leaf copper content (10 & 11 ppm) and (10 & 11 ppm), respectively, followed by calcareous soil (8 & 9 ppm) in 1998 and 1999 seasons, respectively.

As for the effect of soil treatments, **Table (37)** demonstrates that seedlings grown in sterilized or unsterilized soil gave the lowest values of leaf copper content. On the other hand, seedlings grown in sterilized soil, inoculated with ***Glomus macrocarpum*** fungus fertilized with rock-phosphate produced high positive effect on leaf copper content followed descendingly by those inoculated with ***Glomus australe*** fungus and fertilized with rock-phosphate, those inoculated with ***Glomus macrocarpum*** fungus and those inoculated with ***Glomus australe*** fungus.

Additionally, leaf copper content of Volkamer lemon rootstock responded remarkably to the interaction between soil type and soil treatments **(Table, 38)**. Generally, seedlings grown in sterilized loamy sandy soil, inoculated with mycorrhizae species and fertilized with rock-phosphate proved to be the most effective treatments in enhancing leaf copper content. On the other hand, seedlings grown in sterilized or unsterilized calcareous soil had the lowest values of leaf copper content. Other tested combinations took an intermediate positions between the previously two mentioned categories.

Shortly, Sour orange, Rangpur lime and Volkamer lemon seedlings grown in loamy sandy soil had the highest values of leaf N, P, K, Mg, Fe, Zn, Mn and Cu. On the other hand, the three citrus rootstocks grown in calcareous soil gave higher values of leaf Ca content. Moreover, seedlings of the three citrus rootstocks grown in sandy soil occupied inbetween position in this concern.

Moreover, inoculating the sterilized soil with mycorrhizae fungi increased leaf content of N, P, K, Ca, Mg, Fe, Mn and Cu. ***Glomus macrocarpum*** fungus induced more stimulating effect on leaf mineral content than the analogous one ***Glomus australe*** fungus.

Additionally, rock-phosphate fertilization of mycorrhizal inoculated soil, particularly those inoculated with ***Glomus macrocarpum*** fungus gave the highest values of leaf mineral content of the three citrus rootstocks.

The obtained results regarding the effect of soil type on leaf mineral content are in harmony with the findings of **Hamze and Wacquant (1984), Assal *et al.* (1994), Sagee *et al.* (1994) and Abou-Rawash *et al.* (1995).** In addition, the obtained results of mycorrhizae fungi, regarding the enhancement effect on leaf mineral content are emphasized by the findings of **Menge *et al.* (1982), Cardoso *et al.* (1986), Shen (1990), Gardiner and Christensen (1991), Helail (1993), Helail and El-Deeb (1993), Helail and Saad El-Din (1993), Helail *et al.* (1993) and Farih *et al.* (1994).** Besides, the obtained results concerning the response of leaf mineral content to the interaction between soil type and mycorrhizae fungi are in accordance with the reports of **Treeby (1992) and Harvir-Kaur *et al.* (1978).** Furthermore, the improvement of leaf mineral content due to the interaction between mycorrhizal inoculation and phosphorus fertilization were reported earlier by **Timmer and Leyden (1978), Mahaney and Nemec (1979), Graham and Timmer (1985), Gendiah *et al.* (1991), Fonseca *et al.* (1994) and Rocha *et al.* (1995).**

Finally, the enhancement of leaf mineral content due to the interaction between soil type, mycorrhizal inoculation and phosphorus fertilization is in agreement with the findings of **Graham and Syvertsen (1984), Cardoso *et al.* (1986), Abd El-Maksoud *et al.* (1988), Boutros *et al.* (1988) and Helail and El-Kholey (1999).**

Table (33): Specific effect of soil type on leaf mineral content (N, P, K, Ca and Mg) of Volkamer lemon rootstock seedlings (1998 & 1999 seasons).

Soil type	Elements concentration in dried leaves (%)									
	N		P		K		Ca		Mg	
	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Calcareous	2.42 B	2.32 C	0.120 C	0.126 C	1.21 C	1.20 C	1.74 A	1.74 A	0.43 C	0.45 C
Sandy	2.52 A	2.42 B	0.136 B	0.139 B	1.23 B	1.22 B	1.70 A	1.70 A	0.45 B	0.46 B
Loamy sandy	2.55 A	2.45 A	0.148 A	0.152 A	1.25 A	1.24 A	1.71 A	1.70 A	0.47 A	0.49 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

Table (34): Specific effect of soil type on leaf mineral content (N, P, K, Ca and Mg) of Volkamer lemon rootstock seedlings (1998 & 1999 seasons).

Treatments S.S + VAM + (P)	Elements concentration in dried leaves (%)									
	N		P		K		Ca		Mg	
	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Control	2.33 D	2.24 C	0.104 C	0.108 C	1.18 C	1.17 D	1.55 B	1.53 B	0.418 B	0.42 B
S.S + ----- + -----	2.32 D	2.23 C	0.108 C	0.112 C	1.18 C	1.17 D	1.54 B	1.55 B	0.415 B	0.43 B
S.S + G.a + -----	2.54 C	2.44 B	0.136 B	0.141 B	1.25 B	1.24 C	1.78 A	1.78 A	0.466 A	0.48 A
S.S + G.m + -----	2.62 A	2.52 A	0.144 B	0.148 B	1.26 AB	1.26 A	1.78 A	1.80 A	0.467 A	0.48 A
S.S + G.a + P	2.56 BC	2.46 B	0.156 A	0.161 A	1.26 AB	1.25 BC	1.82 A	1.81 A	0.472 A	0.48 A
S.S + G.m + P	2.60 AB	2.25 A	0.160 A	0.164 A	1.29 A	1.29 AB	1.83 A	1.81 A	0.475 A	0.48 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

where:

S.S.= Sterilized soil VAM = Vesicular Arbuscular Mycorrhizae P= rock phosphate [$Ca_3(PO_4)_2$]

G.a = *Glomus australe* G.m. = *Glomus macrocarpum*

Table (35): Effect of interaction between soil type, mycorrhizal inoculation and rock phosphate fertilization on leaf mineral content (N, P, K, Ca, and Mg) of Volkamer lemon rootstock seedlings ((1998) & (1999) seasons).

Soil type	Treatments S.S + VAM + (P)	N (1998)	N (1999)	P (1998)	P (1999)	K (1998)	K (1999)	Ca (1998)	Ca (1999)	Mg (1998)	Mg (1999)
Calcareous	Control	2.23 H	2.17 H	0.09 G	0.10 FG	1.16 H	1.16 G	1.60 B	1.60 BC	0.39 G	0.40 F
	S.S + ----- + ----	2.23 H	2.13 H	0.10 FG	0.10 FG	1.16 H	1.16 G	1.60 B	1.63 B	0.38 G	0.40 F
	S.S + G.a + ----	2.47 EF	2.37 CD	0.12 DE	0.12 DE	1.23 E	1.22 E	1.80 A	1.77 A	0.45 E	0.47 CD
	S.S + G.m + ----	2.60 BC	2.50 B	0.13 CD	0.14 CD	1.24 DE	1.23 DE	1.77 A	1.83 A	0.46 DE	0.47 CD
	S.S + G.a + P	2.50 DE	2.40 C	0.14 BC	0.15 BC	1.24 DE	1.23 DE	1.83 A	1.83 A	0.47 BC	0.48 BC
	S.S + G.m + P	2.50 DE	2.40 C	0.14 BC	0.15 BC	1.25 D	1.22 E	1.87 A	1.80 A	0.47 BC	0.48 BC
Sandy	Control	2.37 G	2.27 FG	0.11 EF	0.11 EFG	1.18 G	1.16 G	1.53 B	1.50 C	0.41 F	0.42 E
	S.S + ----- + ----	2.33 G	2.23 G	0.11 EF	0.11 EFG	1.18 G	1.17 FG	1.50 B	1.50 C	0.41 F	0.43 E
	S.S + G.a + ----	2.57 CD	2.47 B	0.14 BC	0.15 BC	1.26 CD	1.25 CD	1.77 A	1.80 A	0.47 BC	0.48 BC
	S.S + G.m + ----	2.67 AB	2.57 A	0.15 B	0.15 BC	1.27 BC	1.27 AB	1.80 A	1.80 A	0.46 CD	0.48 BC
	S.S + G.a + P	2.60 BC	2.50 B	0.15 B	0.16 B	1.27 BC	1.25 CD	1.83 A	1.80 A	0.46 CD	0.48 BC
	S.S + G.m + P	2.60 BC	2.50 B	0.15 B	0.16 B	1.27 BC	1.26 BC	1.80 A	1.80 A	0.47 BC	0.48 BC
Loamy sandy	Control	2.40 FG	2.30 EF	0.11 EF	0.12 DEF	1.21 F	1.19 F	1.53 B	1.50 C	0.45 E	0.48 BC
	S.S + ----- + ----	2.40 FG	2.33 DE	0.12 DE	0.12 DEF	1.20 F	1.19 F	1.53 B	1.53 BC	0.46 CDE	0.47 CD
	S.S + G.a + ----	2.60 BC	2.50 B	0.15 B	0.15 BC	1.28 AB	1.26 BC	1.80 A	1.80 A	0.48 AB	0.49 AB
	S.S + G.m + ----	2.60 BC	2.50 B	0.16 B	0.16 B	1.28 AB	1.28 A	1.80 A	1.77 A	0.48 AB	0.50 A
	S.S + G.a + P	2.60 BC	2.50 B	0.17 A	0.18 A	1.28 AB	1.27 AB	1.80 A	1.80 A	0.48 AB	0.49 AB
	S.S + G.m + P	2.70 A	2.60 A	0.18 A	0.19 A	1.29 A	1.28 A	1.83 A	1.83 A	0.49 A	0.50 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

where: S.S.= Sterilized soil; VAM = Vesicular Arbuscular Mycorrhizae; P= rock phosphate $[Ca_3(PO_4)_2]$

G.a = *Glomus australe*; G.m . = *Glomus macrocarpum*

Table (36): Specific effect of soil type on leaf Fe, Zn, Mn, and Cu content of Volkamer lemon rootstock seedlings (1998 & 1999 seasons).

Soil type	Elements concentration in dried leaves (ppm)							
	Fe		Zn		Mn		Cu	
	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Calcareous	70 C	72 C	30 C	30 C	19 C	18 C	8 B	9 B
Sandy	102 B	104 B	32 B	33 B	22 B	19 B	10 A	11 A
Loamy sandy	128 A	130 A	36 A	36 A	24 A	21 A	10 A	11 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

Table (37): Specific effect of mycorrhizal inoculation and rock phosphate fertilization on leaf Fe, Zn, Mn and Cu content of Volkamer lemon rootstock seedlings (1998 & 1999 seasons).

Treatments	Elements concentration in dried leaves (ppm)							
	Fe		Zn		Mn		Cu	
S.S + VAM + (P)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Control	87 C	88 C	23 C	25 B	16 C	17 B	6 C	6 C
S.S + ----- + -----	88 C	89 C	23 C	25 B	16 C	17 B	6 C	6 C
S.S + G.a + -----	105 B	107 B	36 A	35 A	23 B	21 A	10 B	12 B
S.S + G.m + -----	108 A	109 A	39 A	37 A	24 A	21 A	11 A	13 A
S.S + G.a + P	106 B	110 A	38 A	37 A	24 A	21 A	11 A	13 A
S.S + G.m + P	108 A	110 A	38 A	38 A	26 A	21 A	12 A	13 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

where:

S.S.= Sterilized soil

G.a = *Glomus australe*

VAM = Vesicular Arbuscular Mycorrhizae

G.m. = *Glomus macrocarpum*

P= rock phosphate [$Ca_3(PO_4)_2$]

Table (38): Effect of interaction between soil type, mycorrhizal inoculation and rock phosphate fertilization on leaf Fe, Zn, Mn, and Cu content of Volkamer lemon rootstock seedlings (1998 & 1999 seasons).

Soil type	Treatments S.S + VAM + (P)	Elements concentration in dried leaves (ppm)							
		Fe		Zn		Mn		Cu	
		(1998)	(1999)	(1998)	(1999)	(1998)	(1999)	(1998)	(1999)
Calcareous	Control	52 I	54 G	20 F	22 F	15 J	16 H	5 G	5 E
	S.S + ----- + ----	53 I	54 G	21 F	22 F	14 J	16 H	5 G	5 E
	S.S + G.a + ----	78 H	79 F	34 D	31 D	21 F	19 CDE	9 DE	11 BC
	S.S + G.m + ----	82 G	83 E	36 CD	34 CD	22 DE	20 BC	9 DE	12 B
	S.S + G.a + P	78 GH	81 EF	35 CD	35 BCD	21 F	20 AB	9 DE	11 BC
	S.S + G.m + P	79 GH	82 EF	35 CD	35 BCD	22 DE	21 AB	10 CD	12 B
Sandy	Control	91 F	93 D	22 EF	26 EF	16 I	17 FGH	6 F	6 DE
	S.S + ----- + ----	92 F	94 D	23 EF	25 EF	17 HI	17 FGH	6 F	6 DE
	S.S + G.a + ----	104 E	108 C	36 CD	35 BCD	22 DE	21 AB	10 CD	12 B
	S.S + G.m + ----	109 CD	110 C	38 BC	37 BC	23 CD	20 ABC	12 AB	13 AB
	S.S + G.a + P	106 DE	112 C	37 BCD	36 BCD	24 CD	21 AB	12 AB	14 A
	S.S + G.m + P	111 C	111 C	38 BC	37 BC	27 B	21 AB	12 AB	14 A
Loamy sandy	Control	117 B	119 B	25 E	27 E	18 GH	18 DEF	6 F	6 DE
	S.S + ----- + ----	119 B	118 B	25 E	27 E	18 GH	18 DEF	6 F	7 D
	S.S + G.a + ----	134 A	135 A	40 AB	39 ABC	26 B	22 A	11 BC	12 B
	S.S + G.m + ----	133 A	135 A	42 A	41 A	27 B	22 A	12 AB	13 AB
	S.S + G.a + P	133 A	137 A	42 A	40 AB	27 B	22 A	12 AB	14 A
	S.S + G.m + P	134 A	137 A	42 A	41 A	30 A	22 A	13 A	14 A

Means within each column, followed by the same letter(s) are not significantly different at 5% level.

where: S.S.= Sterilized soil VAM = Vesicular Arbuscular Mycorrhizae P= rock phosphate [$Ca_3(PO_4)_2$]
G.a = *Glomus australe* G.m. = *Glomus macrocarpum*