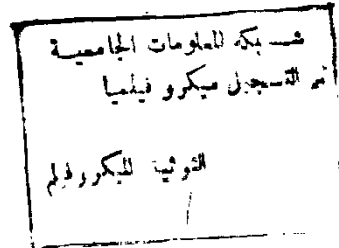


INTERACTION BETWEEN VESICULAR ARBUSCULAR
MYCORRHIZAS AND *RHIZOBIUM LEGUMINOSARUM*

BY

CLAIR NAIM FARES



A thesis submitted in Partial Fullfilment
of
the requirements for the degree of

DOCTOR OF PHILOSOPHY

in



44813

632.4
C. IV

Agricultural Sciences
(Agric. Microbiology)

Department of Agric. Microbiology
Faculty of Agriculture
Ain Shams University

1992



Approval sheet

INTERACTION BETWEEN VESICULAR ARBUSCULAR
MYCORRHIZAS AND *RHIZOBIUM LEGUMINOSARUM*

BY

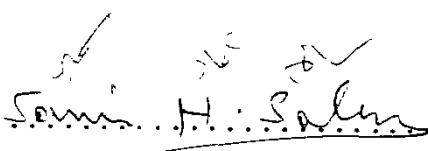
CLAIR NAIM FARES

B.Sc. in Agric. Microbiology, Fac. of Agric., Ain Shams Univ., 1980

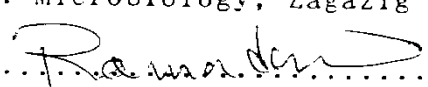
M.Sc. in Agric. Microbiology, Fac. of Agric., Ain Shams Univ., 1986

تمت المذاكرة والمناقشة

This thesis for Ph.D. degree has been approved by:

Prof. Dr. S.H. Salem 

Prof. of Agric. Microbiology, Zagazig Univ.

Prof. Dr. E.M. Ramadan 

Prof. of Agric. Microbiology, Ain Shams Univ.

Prof. Dr. Y.Z. Ishac  (Supervisor)

Prof. of Agric. Microbiology, Ain Shams Univ.

Date of Exmination /8/1992



INTERACTION BETWEEN VESICULAR ARBUSCULAR
MYCORRHIZAS AND *RHIZOBIUM LEGUMINOSARUM*

By

CLAIR NAIM FARES

B.Sc. in Agric of microbiology, Ain Shams Univ., 1980

M.Sc. in Agric of Microbiology, Ain Shams Univ., 1986

Under the supervision of :

Prof. Dr. Y.Z. Ishac

Prof. of Agric. Microbiology, Fac. Agric.,
Ain Shams Univ.

Prof. Dr. M.A.El-Borollosy

Prof of Agric. Microbiology, Fac. Agric., Ain
Shams Univ.

Dr. M.E.El-Demerdash

Ass.Prof.of Agric. Microbiology., Fac. Agric,
Ain Shams Univ.

ABSTRACT

This study was carried out to evaluate the effect of inoculation with different imported and local strains of *R. leguminosarum* biovar *viceae* and/or VA mycorrhizas on growth,

nodulation and chemical contents of two genotypes of faba bean and lentil grown on two types of soil and amended with two forms of phosphate.

The obtained results revealed that the imported strain *R. leguminosarum* USDA-102 F 84- faba bean genotype 402 and the local strain *R. leguminosarum* ARC-202L-lentil genotype 370 proved to be the most effective symbiotic systems when used in combination with VAM. These combination produced significant improvements in plant growth, nodulation, nitrogen and phosphorus contents and mycorrhizal root infection of both plants.

It was also observed that the clay-loam soil supported better growth, nodulation, chemical contents and mycorrhizal development compared with calcareous soil.

However, no significant differences were observed between the effects of super-or rockphosphate application with single or dual inoculation treatments in the two types of soil.

To evaluate the nodulation and mycorrhizal status of faba bean and lentil plants grown under conditions of bad drainage, a preliminary survey was carried out in two governorate at upper Egypt, i.e. El-Minia and Assuit. Representative samples were taken from a well drained soil to be

used as a control. Data showed that bad drainage adversely affected the number of nodules and number of mycorrhizal spores to greater extent than mycorrhizal infection. No correlation was generally observed between the number of mycorrhizal spores and mycorrhizal root infection.

The effect of soil moisture content, inoculation with the most effective *R. leguminosarum* strains and/or VAM and soil types on the growth, nodulation, N & P contents, mycorrhizal root infection and number of mycorrhizal spores was studied in a pot experiment. The recorded results showed that moisture content representing 60% of soil WHC gave the highest growth, nodulation, N & P contents and mycorrhizal root infection of faba bean and lentil plants. Increasing or decreasing soil moisture content above or under this level resulted in decreasing growth parameters and mycorrhizal infection of both hosts. The level of reduction in the measured parameters with increasing moisture content to 90% of WHC was more pronounced than that observed with 30% moisture content.

No	Contents	page
1.	INTRODUCTION	1
2.	REVIEW OF LITERATURE	2
2.1.	Rhizobia-legume association	2
2.2.	Factors affecting the response of leguminous plants to rhizobia inoculation	7
2.2.1.	Rhizobial strain	7
2.2.2.	The plant host	10
2.2.3.	Soil conditions :	
2.2.3.1.	Type of soil	12
2.2.3.2.	Mineral nutrient content	14
a.	Nitrogen	14
b.	Phosphorus	17
c.	Other nutrients	19
2.2.3.3.	Moisture content	22
2.2.3.4.	pH	25
2.2.3.5.	Salinity	26
2.3.	Vesicular-arbuscular mycorrhizal association .	28
2.3.1.	Effects of VAM on plant growth	29
2.3.1.1.	Nutritional effects	29
2.3.1.2.	Non-nutritinal effects	34
2.4.	The additive effects of VA mycorrhizas on <i>Rhizobium</i> legume symbiosis	36
2.4.1.	Plant growth	36
2.4.2.	Nutrients uptake	39
2.4.3.	Nodulation and N ₂ -fixation	42
2.4.4.	Water relations	44
3.	MATERIALS AND METHODS	49
3.1.	Materials	49
3.1.1.	Host genotypes	49
3.1.2.	Soil	50
3.1.3.	Fertilizers	50
a.	Nitrogen	50
b.	Phosphate	50
3.1.4.	Inoculants	51
a.	Rhizobia inoculants	51
b.	VA mycorrhizal inoculants	51
3.2.	Methods	52
3.2.1.	Experimental techniques	52

3.2.1.1.	Performance of Rhizobia-faba bean or lentil symbiosis as influenced by host genotype, soil type, P amendment and VA mycorrhizal infection	52
3.2.1.2.	A survey study reporting nodulation and VA mycorrhizal status of faba bean and lentil plants grown under conditions of bad drainage in upper Egypt	55
3.2.1.3.	Interacting effects of soil type and soil moisture on growth, nodulation, chemical contents and VA mycorrhizal infection of faba bean and lentil plants.....	56
3.2.2.	Soil measurements	58
3.2.3.	Plant measurements	59
3.2.3.1.	Total plant dry weight	59
3.2.3.2.	Number of nodules	59
3.2.3.3.	Dry weight of nodules	59
3.2.3.4.	Chemical contents	59
3.2.4.	Fungal measurements	59
3.2.4.1.	Spore production	59
3.2.4.2.	Mycorrhizal infection	60
3.2.5.	Statistical analyses	60
4.	RESULTS	61
4.1.	Performance of Rhizobia-faba bean or lentil symbiosis as influenced by host genotypes, soil type, P amendment and VA mycorrhizal infection.	
4.1.1.	Faba bean	61
4.1.1.1.	Plant dry weight	61
4.1.1.2.	Nodulation	65
a.	Number of nodules per plant	65
b.	Dry weight of nodules	67
4.1.1.3.	Nitrogen contents	67
4.1.1.4.	Phosphorus contents	69
4.1.1.5.	Mycorrhizal root infection	72
4.1.1.6.	Density of mycorrhizal spores ..	74

No	Page
4.1.2. Lentil	77
4.1.2.1. Plant dry weight	77
4.1.2.2. Nodulation	79
a. Number of nodules per plant	79
b. Dry weight of nodules	79
4.1.2.3. Nitrogen contents	82
4.1.2.4. Phosphorus contents	82
4.1.2.5. Mycorrhizal root infection	85
4.1.2.6. Density of mycorrhizal spores ..	87
4.2. A survey study reporting nodulation and VA mycorrhizal status of faba bean and lentil plants grown under conditions of bad drainage in two governrate at upper Egypt	89
4.2.1. Physical and chemical properties of the collected soil samples	89
4.2.2. Nodulation and VA mycorrhizal status ..	91
4.3. Interacting effects of soil type and soil moisture on growth, nodulation, chemical contents and VA mycorrhizal infection of faba bean and lentil plants	93
4.3.1. Plant dry weight	96
4.3.2. Nodulation	99
a. Number of nodules per plant.....	99
b. Dry weight of nodulation	102
4.3.3. Nitrogen contents	102
4.3.4. Phosphorus contents	107
4.3.5. Mycorrhizal root infection	107
4.3.6. Density of mycorrhizal spores	113
5. DISCUSSION	116
6. SUMMARY	127
7. REFERENCES	132
8. ARABIC SUMMARY	

LIST OF TABLES

No		Page
1.	Physical and chemical properties of soil samples collected from the field of Faculty of Agriculture, Ain Shams Univ. (site 1) and El-Nubaria (site 2)	52
2.	Total dry weight (g plant ⁻¹) of 2 genotypes of faba bean inoculated with 4 strains of <i>R. leguminosarum</i> biovar <i>viceae</i> alone or combined with VA mycorrhizas and grown on 2 types of soil amended with 2 forms of phosphate	54
3.	Number of nodules (plant ⁻¹) of 2 genotypes of faba bean inoculated with 4 strains of <i>R. leguminosarum</i> biovar <i>viceae</i> alone or combined with VA mycorrhizas and grown on 2 types of soil amended with 2 forms of phosphate.....	56
4.	Dry weight of nodules (mg plant ⁻¹) of 2 genotypes of faba bean inoculated with 4 strains of <i>R. leguminosarum</i> biovar <i>viceae</i> alone or combined with VA mycorrhizas and grown on 2 types of soil amended with 2 forms of phosphate	58
5.	Nitrogen contents (mg plant ⁻¹) of 2 genotypes of faba bean inoculated with 4 strains of <i>R. leguminosarum</i> biovar <i>viceae</i> alone or combined with VA mycorrhizas and grown on 2 types of soil amended with 2 forms of phosphate	70
6.	Phosphorus content (mg plant ⁻¹) of 2 genotypes of faba bean inoculated with 4 strains of <i>R. leguminosarum</i> biovar <i>viceae</i> alone or combined with VA mycorrhizas and grown on 2 types of soil amended with 2 forms of phosphate	71
7.	Mycorrhizal root infection (%) of 2 genotypes of faba bean inoculated with VA mycorrhizas alone or combined with different strains of <i>R. leguminosarum</i> biovar <i>viceae</i> and grown on 2 types of soil amended with 2 forms of phosphate	73

No		Page
8.	Number of mycorrhizal spores (kg soil ⁻¹) collected from around the roots of 2 genotypes of faba bean inoculated with VA mycorrhizas alone or combined with different strains of <i>R. leguminosarum</i> biovar <i>viceae</i> growth on 2 types of soil amended with 2 forms of phosphate	75
9.	Total dry weight (g plant ⁻¹) of 2 genotypes of lentil inoculated with 4 strains of <i>R. leguminosaum</i> biovar <i>viceae</i> alone or combined with VA mycorrhizas and grown on 2 types of soil amended with 2 forms of phosphate ..	78
10.	Number of nodules (plant ⁻¹) of 2 genotypes of lentil inoculated with 4 strains of <i>R. leguminosaum</i> biovar <i>viceae</i> alone or combined with VA mycorrhizas and grown on 2 types of soil amended with 2 forms of phosphate ..	80
11.	Dry weight of nodules (mg plant ⁻¹) of 2 genotypes of lentil inoculated with 4 strains of <i>R. leguminosaum</i> biovar <i>viceae</i> alone or combined with VA mycorrhizas and grown on 2 types of soil amended with 2 forms of phosphate	81
12.	Nitrogen contents (mg plant ⁻¹) of 2 genotypes of lentil inoculated with 4 strains of <i>R. leguminosaum</i> biovar <i>viceae</i> alone or combined with VA mycorrhizas and grown on 2 types of soil amended with 2 forms of phosphate ..	83
13.	Phosphorus contents (mg plant ⁻¹) of 2 genotypes of lentil inoculated with 4 strains of <i>R. leguminosaum</i> biovar <i>viceae</i> alone or combined with VA mycorrhizas and grown on 2 types of soil amended with 2 forms of phosphate.	84
14.	Mycorrhizal root infection (%) of 2 genotypes of lentil inoculated with VA mycorrhizas alone or combined with different strains of <i>R. leguminosarum</i> biovar <i>viceae</i> and grown on 2 types of soil amended with 2 forms of phosphate	86

No	Page
15.	88
16.	90
17.	92
18.	94
19.	97
20.	100
21.	103

No	Page
22. Intracting effects of soil type and soil moisture on nitrogen contents (mg N plant ⁻¹) of faba bean (<i>Vicia faba</i> cv. G402) and lentil (<i>Lens esculenta</i> cv. G 370) inoculated with <i>R. leguminosarum</i> USDA-102 F 84 and ARC-202 L, respectively and/or VA mycorrhizas	105
23. Intracting effects of soil type and soil moisture on phosphorus contents (mg P plant ⁻¹) of faba bean (<i>Vicia faba</i> cv. G402) and lentil (<i>Lens esculenta</i> cv. G 370) inoculated with <i>R. leguminosarum</i> USDA-102 F 84 and ARC-202 L, respectively and/or VA mycorrhizas	108
24. Intracting effects of soil type and soil moisture on mycorrhizal infection (%) of faba bean (<i>Vicia faba</i> cv. G402) and lentil (<i>Lens esculenta</i> cv. G 370) inoculated with <i>R. leguminosarum</i> USDA-102 F 84 and ARC-202 L, respectively and VA mycorrhizas	111
25. Intracting effects of soil type and soil moisture on number of mycorrhizal spores (kg ⁻¹ soil) of faba bean (<i>Vicia faba</i> cv. G402) and lentil (<i>Lens esculenta</i> cv. G 370) inoculated with <i>R. leguminosarum</i> USDA-102 F 84 and ARC-202 L, respectively and VA mycorrhizas	114

LIST OF FIGURES

No		Page
1.	Adiagramatic representation of experimental design to evaluate the performance of Rhizobia - faba bean or lentil symbiosis as influenced by 4 interacting factors...	54
2.	A diagrammatic representation of the experimental design to study the interacting effects of soil moisture and VA mycorrhizas on Rhizobia-faba bean or lentil symbiosis in 2 types of soil.....	58
3.	Intrating effects of soil type and soil moisture on total dry weight (g plant ⁻¹) of faba bean (<i>Vicia faba</i> cv. G402) and lentil (<i>Lens esculenta</i> cv. G 370) inoculated with <i>R. leguminosarum</i> USDA-102 F 84 and ARC-202 L, respectively and/or VA mycorrhizas.....	98
4.	Intrating effects of soil type and soil moisture on number of nodules (plant ⁻¹) of faba bean (<i>Vicia faba</i> cv. G402) and lentil (<i>Lens esculenta</i> cv. G370) inoculated with <i>R.leguminosarum</i> USDA-102 F 84 and ARC-202 L, respectively and/or VA mycorrhizas.....	101
5.	Intrating effects of soil type and soil moisture on dry weight of nodules (mg plant ⁻¹) of faba bean (<i>Vicia faba</i> cv. G402) and lentil (<i>Lens esculenta</i> cv. G370) inoculated with <i>R.leguminosarum</i> USDA-102 F 84 and ARC-202 L, respectively and/or VA mycorrhizas	104
6.	Intrating effects of soil type and soil moisture on nitrogen contents (mg N plant ⁻¹) of faba bean (<i>Vicia faba</i> cv. G402) and lentil (<i>Lens esculenta</i> cv. G370) inoculated with <i>R.leguminosarum</i> USDA-102 F 84 and ARC-202 L, respectively and/or VA mycorrhizas	106
7.	Intrating effects of soil type and soil moisture on phosphorus contents (mg P plant ⁻¹) of faba bean (<i>Vicia faba</i> cv. G402) and lentil (<i>Lens esculenta</i> cv. G370) inoculated with <i>R.leguminosarum</i> USDA-102 F 84 and ARC-202 L, respectively and/or VA mycorrhizas	109
8.	Intrating effects of soil type and soil moisture on mycorrhizal infection (%) of faba bean (<i>Vicia faba</i> cv. G402) and lentil (<i>Lens esculenta</i> cv. G370) inoculated with <i>R.leguminosarum</i> USDA-102 F 84 and ARC-202 L, respectively and VA mycorrhizas	112
9.	Intrating effects of soil type and soil moisture on number of mycorrhizal spores (kg soil ⁻¹) of faba bean (<i>Vicia faba</i> cv. G402) and lentil (<i>Lens esculenta</i> cv. G370) inoculated with <i>R.leguminosarum</i> USDA-102 F 84 and ARC-202 L, respectively and VA mycorrhizas	115

ACKNOWLEDGEMENT

I wish to express my sincere appreciation and gratitude to Prof. Dr. Y.Z. Ishac, Prof. of Agric. Microbiology, Prof. Dr. M.A. El. Borollosy, Prof. of Agric. Microbiology and Dr. M.E. El-Demerdash, Ass. Prof. of Agric. Microbiology, Agric. Microbiology Department, Faculty of Agriculture, Ain Shams University for suggesting the problems, helpful guidance and keeping interest throughout the work, and thanks to Dr. M.I. Mostafa, Lecturer of Agric. Microbiology, Agric. Microbiology Department, Faculty of Agriculture, Ain Shams University, for performing the statistical analysis and his fruitful scientific discussion.

Special thanks are extended to Dr. J.S. Angle, Prof. of soil Microbiology, Department of Agronomy, Univ. of Maryland for providing rhizobia strains, articles relevant to the subject, and his fruitful Scientific discussion during his visit to Egypt in March 1992.

Thanks are also extended to all staff members and colleagues in Agric. Microbiology, Dept., unit of Biofertilizers, Ain Shams Univ. and Microbiology Dept., Agric. Research center for supplying the facilities and materials that made this work possible.