MANSOURA JOURNAL OF BIOLOGY
Official Journal of Faculty of Science, Mansoura University, Egypt
E-mail: scimag@mans.edu.eg ISSN: 2974-492X

Arbuscular mycorrhizal fungi: Diversity and soil fertility in Egypt

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Received:7/2/2025
Accepted:2/3/2025

Abstract : Many soils in the tropics are fragile and prone to degradation. Some characteristics of tropical soils put severe constraints on food production. proposed a fertility capability soil classification that identifies the major attributes that constrain plant production. These constraints include soil moisture stress, low nutrient capital, erosion risks, low pH with aluminium (Al) toxicity, high phosphorus (P) fixation, low levels of soil organic matter, and a loss of soil biodiversity. This study addressed the physico-chemical features of soil where *Reichardia tingitana* is growing which favored sandy soil. In addition, the effect of mycorrhizal colonization on growth parameters of *Lupins* were assessed. Our findings demonstrated that colonization of lupinus with AM fungi significantly increased growth parameters than non-mycorrhizal plants.

Keywords: Mycorrhizal fungi, Soil fertility, toxicity, Lupinus, colnization.

1.Introduction

It is proved that use of chemical fertilizers crop production for fulfillment of food requirements and other pesticides are causing tremendous harm to the environment by pollution and contamination in water and soil and human are suffering by many means, especially their health has been affected[1].Therefore, the need to increase production of crops, to preserve soil fertility and to protect the environment from detrimental, agronomic techniques has brought about a revision of productive systems in agriculture. Recently, the employment of beneficial microorganisms has gained popularity [2].

The arbuscular mycorrhizal (AM) association has received attention as part of an increasingly popular paradigm that considers an active and diverse soil biological community as essential for increasing the sustainability of agricultural systems. The ability of AM fungi to enhance host-plant uptake of relatively immobile nutrients, in particular P, and several micronutrients, has been the most recognized beneficial effect of mycorrhiza./Rhizosphere interactions occur between AM fungi and other soil micro-organisms with effects on plant nutrient balances, such as nitrogen-fixing bacteria and plant growth-promoting rhizobacteria [3].

AM colonization may furthermore protect plants against pathogens. AM fungi interact with heavy metals/micronutrients. They can restore the equilibrium of nutrient uptake that is misbalanced by heavy metals [4]. AM fungi can alleviate Al toxicity. AM fungi improve water relations, especially under nutrient limitation. The extra- radical hyphae of AM fungi contribute to soil aggregation and structural stability. Therefore, mycorrhizas are multi- functional in (agro) ecosystems potentially improving physical soil quality (through the external hyphae), chemical soil quality (through enhanced nutrient uptake), and biological soil quality (through the soil food web) [5].

2. Materials and methods

2.1. Plant collection

The plant materials used in this study included *R. tingitana* collected from two different habitats, coastal desert (along the Deltaic Mediterranean coast of Egypt) and the inland desert (Eastern Desert of Egypt). During April-May 2022, the aerial parts of the this plant were washed with distilled water, air-dried at room temperature until complete dryness, ground, and finally deposited in polyethylene bags.

Fig. 1: Morphology of *Reichardia tingitana*.

2.2. Soil- analysis

Three soil samples were collected at 50 cm depth and pooled as a composite. Physicochemical properties of soil were estimated according to the Association of Official Agricultural Chemists (AOAC) [6]. Na^+, K^+, Ca^{++} and Mg^{++} were approached by a flame-photometer.

2.3. Evaluation of vesicular-arbuscular mycorrhizal inoculums

2.3.1. Extraction of AM spores

Spores of AM-fungi were collected from rhizosphere soil of selected plants by the wet sieving and decanting technique [6]. as follows:

Approximately 250 g of rhizosphere soil were suspended in l000 ml of tap water. Heavier particles were allowed to settle down for few seconds, then the liquid decanted through a fine sieve to remove large pieces of organic debris, the suspension pass through a set of sieves to retain spores. Spores were kept moist by storing at 40C, until used.

2.3.2. Multiplication of VAM inoculums

spores were inoculated in Sudan grass plants (stock plants) planted in sterilized plastic pots (30 cm in diameter) filled with sandy clay soil. The plants were watered when necessary. After three months of planting, the spores were extracted as described before. Inoculums from it can be used to establish a large number of stock for further experiments.

2.4. Planting and growth conditions

The sterilized seeds of lupins were allowed to germinate at four stages vegetative stage, flowering stages, fruiting stages and yield stages. Uniform germinating seedlings planted (4 seeds/pot) in plastic pots. Half of the pots received a mycorrhizal inoculum consisting of soil, spores and chopped roots of leek colonized by stock culture of the mycorrhizal fungi.

2.5. Measurements

The treatments used in this study were summarized as the following:

Clay	**-AMF**	**Control without mycorrhizal fungi**
	+AMF	**With mycorrhizal fungi**
sand	**-AMF**	**Control without mycorrhizal fungi**
	+AMF	**With mycorrhizal fungi**
2:1 clay: sand	**-AMF**	**Control without mycorrhizal fungi**
	+AMF	**With mycorrhizal fungi**
1:1 clay: sand	**-AMF**	**Control without mycorrhizal fungi**
	+AMF	**With mycorrhizal fungi**

Table 1. Physical-chemical properties of soil samples collected from the habitat of *R. tingitana*

Soil factor		**mean±SE Coastal**	**mean±SE Inland**
Sand (%)		98.5±0.33	81.81±2.88
Silt (%)		1.16±0.3	14.72±2.85
Clay (%)		0.34±0.04	3.47±0.24
Porosity (%)		33.68±0.77	38.99±0.3
WHC (%)		29.66±0.71	31.23±2.94
$CaCO_3$ (%)		1.33±0.33	24.5±2.25
OC (%)		0.22±0.06	0.13±0.03
pH		7.68±0.3	8.3±0.12
EC (mmhos cm^{-1})		0.17±0.06	0.18±0.05
Cl^- (%)		0.02±0.01	0.03±0
SO_4^{--} (%)		0.05±0.01	0.33±0.12
HCO_3^- (%)		0.18±0	0.22±0.03
TN	**mg/100 g dry soil**	27.05±2.15	0.02±0.01
TDP		4.2±0.55	0.33±0.04
Na^+		11.31±5	0.11±0.01
K^+		16.58±7.82	0.22±0.01
Ca^{++}		6.22±0.38	2.28±0.05
Mg^{++}		4.51±0.76	0.78 ±0.07

WHC: water holding capacity, OC: organic carbon, EC: electric conductivity, TN: total nitrogen, TDP: total dissolved phosphorus, SE: standard error.

3. Results

3.1. Soil properties

The physical and chemical properties of soil samples where *R. tingitana* is growing are displayed in **Table 1**. *R. tingitana* favored sandy soil with mean values of sand, silt and clay of 98.5, 1.16 and 0.34%, respectively in coastal habitat and 81.81, 14.72 and 3.47%, respectively in inland habitat . In addition, other physical features of soil, include soil porosity and water holding capacity of 33.86 and 29.66%, respectively in coastal habitat and 38.99 and 31.23%, respectively in inland habitat

Soil calcium carbonates have an average of 1.33% in coastal habitat and 24.5% in inland habitat , while organic carbon has a mean value of 0.22% in coastal habitat and 0.13% in inland habitat. The mean values of total nitrogen and total dissolved phosphorous are 27.05 and 4.2 mg g^{-1} dry soil, respectively in coastal habitat and 0.02 and 0.33 mg g^{-1} dry soil in inland habitat. The results of macroelements (Na^{+}, K^{+}, Ca^{++} and Mg^{++}) are displayed in **Table (1)**.

3.2. Growth parameters

Results of the effect of mycorrhizal colonization on growth parameters are presented in **Table (2)**. In general, all growth parameters were significantly increased in common bean plants colonized with mycorrhizal fungi

Table (2). Shoot height, root height parameters of mycorrhizal (+AMF) and non-mycorrhizal (−AMF) common bean plants in vegetative and flowering grown under different soil types.

Growth stage	Treatments		Shoot height (cm/plant)	Root height (cm/plant)
	Soil type Clay: sand ratio	AMF status		
Vegetative	Clay	−AMF	19	3.8
		+AMF	29	8.6
	Sand	−AMF	20	4.5
		+AMF	34	7.2
	1:1	−AMF	19	4.4
		+AMF	30.6	9.2
	2:1	−AMF	16.4	2.7
		+AMF	31	7.2
Flowering	Clay	−AMF	25	7.7
		+AMF	49	12.2
	Sand	−AMF	30.2	5.2
		+AMF	46	9.5
	1:1	−AMF	29	8.2
		+AMF	49.8	11.6
	2:1	−AMF	36.4	9.6
		+AMF	48.8	12.3

4. Discussion

Arbuscular mycorrhizal fungi are the most widespread root fungal symbiont and are associated with the vast majority of higher plants. AMF have been shown to improve soil structure [7]. and have a great importance due to their great capability to increase the plant growth and yield through efficient nutrient uptake [8]. In relation to plant growth and grain yield, our results clearly showed the beneficial effect of AM colonization on plant growth compared with non-mycorrhizal plants. It widely known that the AM fungi are the most important microbial symbioses for the majority of plants improving their nutrient content, growth, and productivity [9]. In this study, the results demonstrated that colonization of bean plants with AM fungi significantly increased growth parameters (number of leaves, shoot and root fresh and dry weights, shoot heights, and leave area), as compared to non-mycorrhizal plants that have NPK recommended fertilizers only particularly at 50% and 75% NPK concentration with mycorrhizal colonization than non-mycorrhizal plants.

Previous studies reported that, The effect of Arbuscular mycorrhizal (AM) fungi in the multiplication and growth of crop plant can demonstrate to be the most effective alternative to fertilizers for enhancing growth and biomass production. Arbuscular mycorrhizal fungi developed an external mycelium which is a bridge connecting the root with the surrounding soil [10]. Arbuscular mycorrhizal (AM) fungi are responsible for absorption of nutrients from the fungus to the roots and ultimately enhance plants growth and yield [11]. It leads to improvement in plant nutrients translocation, photosynthesis, and plant metabolism.

5. Conclusion

The current study addressed the habitat features (soil conditions) where *R. tingitana* is growing, as well as ,the effect of mycorrhizal colonization on growth. After broaden studies, The AM association has received attention as part of an increasingly popular paradigm that considers an active and diverse soil biological community as essential for increasing the sustainability of agricultural systems.

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