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The Impact of Arbuscular Mycorrhizal Fungi Applications and NPK Fertilization ratios on some Morphological and Physiological Traits of *Swieteina mahogany* seedlings

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Abstract

A potfactorial experiment was carried out to investigate the effect of plants inoculation by four levels from arbuscular mycorrhizal (AM) fungi spores (zero, 150, 300 and 450±10 spores plant $^{-1}$) with six NPK fertilizer ratios (0:0:0, 0:10:5, 5:10:5, 10:5:5, 5:5:5 and 5:0:5) on the growth traits of *Swieteina mahogany* seedlings under sandy soil conditions. The inoculums of AM fungi were used as mixed spores for one genus with three species *Glomus mosseae*, *G. etunicatum* and *G. clarum*. The results were shown that the high values in all plant growth parameters and NPK plant uptake in biomass were recorded at plant treated with NPK at ratio 10:05:05 in the presence of 450 AM spores plant^{1}. Also the high level of plant chlorophyll a; chlorophyll b and carotenoids were observed at plants treated with 300 AM spores plant^{-1} at NPK ratio10:05:05. The AM spore's numbers were increased at NPK fertilization ratio 0:10:05 at all levels of inoculation. While the AM root colonization% was increased by increasing in both addition of nitrogen and phosphorus fertilization. The combination between AM fungi and NPK fertilization had better growth effect on increased NPK plant uptake when comparison between other treatments. The positive effects of plant inoculation only by AM fungi were helped *S. mahagoni* to absorb more nutrients from soil more than plants free from AM treatment.

Key Words: Woody trees, AM fungi, Bio-fertilization, Mahogany, NPK fertilization ratios

Introduction

Swietenia mahagoni (L.) Jacq. is a large, deciduous and economically important timber tree (rated among the top 12 timber woods in the world) native to the west Indies which is commonly known as Mahogany (**Mayur *et al*., 2011**). It has a heavy, extremely strong, stable and decay resistant trunk. Its wood is used for making decorative veneers, shipbuilding, fine boat interiors and fine jewelry **(Ali *et al*., 2011; Amira and Suloma, 2013**). Mahogany has various types of medicinal values like antimalarial and antidiarrhoeal effects. The plant extracts have been accounted to possess antibacterial and antifungal activities (**Munoz *et al*., 2000; Majid *et al*., 2004**; **Anup *el al*., 2007**). Mycorrhiza is a symbiotic association between a group of soil fungi called arbuscular mycorrhizal (AM) fungi and plants. Mycorrhizal associations have been intensively studied over the past several decades and increased understanding of the important role of this symbiosis in the function and performance of plants in nursery **(Barnhill, 1981)**. The successful association between plants and AM fungi constitutes a strategy to improve the nutritional status of both associates and reduces the use of fertilizers specially phosphorus nutrition **(Almagrabi and Abdelmoneim, 2012).** Mycorrhizal symbioses facilitate plant uptake of nutrient resources and water (**Allen, 1991; Newsham *et al*., 1995; Zobel *et al.,* 1997).** Most studies have investigated P, but mycorrhizal have been implicated in the uptake of most essential nutrients. Plants colonized by AM fungi have increase the ability to absorb nutrients like P, N, K, Ca and Mg which results in better survival under stressed conditions (**Auge and Stodola, 1990**). Arbuscular mycorrhizal fungi species are decrease in agro-ecosystems comparing to natural ecosystems. Because the frequently of agricultural fertilization and irrigation are reduce more AM spores than un-intensive managed agricultural soils **(Höflich and Metz 1997).** The fertilization is one of the most critical components of producing high-quality nursery stock. Plants require adequate quantities of mineral nutrients in the proper balance for basic physiological processes, such as photosynthesis, and to promote rapid growth and development (**Douglass** and **Thomas, 2009**). N-P_2O_5-K_2O (sometimes abbreviated to N-P-K) requirements without over applying any of these nutrients is possible by blending various types of fertilizer to give the correct NPK ratio. This allows applying the correct rate of a particular mixed fertilizer **(Rory *et al*., 2009). Gill *et al.,* (2011)** concluded that we can use a complete fertilizer contain Nitrogen, Phosphorus and Potassium for trees and shrubs with a ratio of either 3:1:1, 3:1:2 or 3:1:3 to supply a plant for macro elements. **Kujawski and Ryan (2011)** showed that the N-P-K ratios of 4-1-1, 3-1-1 or 3-1-2 were generally recommended for feeding established woody plants. The present study was aimed to determine the impact of the plant inoculation by

some species of indigenous AM fungi in 4 levels with 6 NPK fertilization ratios on some of morphological and physiological traits of *Swieteina mahagani* seedlings under sandy soil conditions.

Materials and Methods

The experiment was carried out at El-Kassasin Horticultural Research Station, Ismailia, during two successive seasons of 2012 /2013 and 2013/2014.

-Plant materials:

In mid of March 2012 and 2013 seasons , one year old transplants were brought from the Horticultural Research Institute nurseries. The seedlings were averaged at 30 cm in height and 0 .35 cm in diameter (5 cm above ground). Seedlings were grown in poly ethyeln bags (40 cm in diameter and 45 cm in height). Each bag contains about 20 kg.of sandy soil**.**

-Physical and Chemical Properties of Soil:

The nitrogen, organic carbon, pH and Electrical conductivity were determined according to **Page (1982).** The cations and anions were determined in the soil extract according to **Richards (1954)** Table(1).

Table 1. Physical and chemical properties of soil samples before fertilizer application practices.

Chemical properties										
Macronutrients (mg/kg)				**Cations (meq/l):**				**Anions (meq/l):**		
Available N	Available P	Available K	OM %	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	$HCO_3^{-} + CO_3^{2-}$	SO_4^{2-}
7.1	2.1	13.4	0.01	5.7	2.6	7.0	0.8	7.6	2.8	5.6
Physical properties										
Particle sie distribution				Textural class				*EC dSm^{-1}		pH
Sand (%)	Silt (%)	Clay (%)		Sanady soil				1.6		7.08
87.13	7.24	5.63								
*Average (3 soil samples) EC = Electric conductivity										
Soluble cations and anion meq/L(in1:1exracat)										

-Preparation of mycorrhizal inoculums:

The AM fungi were used in this study as a mixed culture from species of *Glomus mosseae* (60%), *G. etunicatum* (13%) and *G. clarum* (27%) supplied from microbiology Lab. Faculty of Agriculture, Suez Canal University, Ismailia, Egypt. The spores of arbuscular mycorrhizal fungi were identified depending on the spore morphological characters such as shape, arrangement, size, germination, surface texture, color and wall layers according to **Trappe and Molina (1986)**; **Morton and Benny (1990) and Walker (1992).** The three AM fungi species were multiplied under onion plant root in sterilized soil. After 40 days of growth, plant shoots were removed and the substrate containing hyphae, spores and root was air dried and used as the inoculums. The inoculums were calculated based on number of spores present in 1g of dry roots (150 spore's g^{-1}). The inoculums prepared in three levels Low (150 spores $plant^{-1}$), medium (300 spores $plant^{-1}$) and High (450 spores $plant^{-1}$) from dry roots culture in addition to the fourth level which included 1g autoclaved dry root as a check treatment (zero spores g^{-1}).

-Fertilizer ratios:

The appropriate amount of fertilizers for plant age and stage of the growth was identified by **Van de Werken (1984**) and **Watkins (1998)**. Six fertilizer ratios were used as 00:00:00,00:10:5,05:10:05, 0:05:05,05:05:05 and 05:00:05 from NPK. The Fertilizers were divided into 20 doses per 10 months depend on a mount of doses per seedling and they were add to plant every 2 weaks (Tabel 2).

Table 2. Different quantities of mixed fertilizer (ratios) used for preparation of 100g mixed fertilizer

NPK Ratio	**Ammonium nitrate 33.5% N (g)**	**Phosphoric acid 55% P_2O_5 (g)**	**Potassium sulphate 50% K_2O (g)**	**EC (dSm^{-1})**	**pH**	**Total amount of NPK mixed fertilizer (g)**	**Cost by EGP**
00 : 00: 00	**0.0**	**0.00**	**0.0**	**-**	**-**	**-**	**0.00**
00 : 10: 05	**0.0**	**9.75**	**10**	**0.70**	**4.46**	**19.75**	**0.40**
10 : 05: 05	**30**	**4.78**	**10**	**1.4**	**6.46**	**44.78**	**0.60**
05: 10: 05	**15**	**9.75**	**10**	**1.32**	**5.65**	**34.75**	**0.20**
05: 05 :0 5	**15**	**4.78**	**10**	**1.10**	**5.75**	**39.78**	**0.20**
05: 00 : 05	**15**	**0.00**	**10**	**0.96**	**4.62**	**25.00**	**0.20**

-Seedlings irrigation:

It was determining the amount of irrigation water based on field capacity of the soil. Each seedling was irrigated two times weekly in summer and one time weekly in winter using 2000 ml water per seedling.

-Experimental design:

A factorial pot experiment was designed in six NPK fertilizer ratios (0:0:0, 0:10:5, 5:10:5, 10:5:5, 5:5:5 and 5:0:5) with four levels of AM fungi spores (zero, 150, 300 and 450±10 spores plant^{-1}). The experiment was laid in completely randomized design with. Means compared using Duncan Test at 5% level according to **Snedecor and Cochran (1967).**

-Following data were recorded:

Vegtative growth was determied as height increment; diameter increment% of stem at a height 5cm; Fresh and dry weight of tree portions (landolt and Kandeler, 1987) and dry weight/fresh weight according to Martha *et al.*, 1997.

The nitrogen content in dried leaves of plant samples was determined by Kjeldahl, and phosphorus concentration was determined by the molybdate blue ascorbic acid method**.** The Potassium was determined according to the procedure described by **Mazumdar** and **Majumder (2003)**. Also Cd, Ni and Pb were measured by Atomic Absorption Spectrophotometer **(Page, 1982)**. In addation to estmated Chlorophyll a, b and carotenoids content in the fresh leaves.

The seedling quality index was used to measure the performance of seedlings that calculated according to **Dickson *et al*., (1960)** as following:

$$\text{Quality index} = \frac{\text{total biomass}(g)}{\text{heigh}(cm)/\text{stem diameter}(mm) + \text{shoot biomass}(g)/\text{root biomass}(g)}$$

-Estimated AM fungi root colonization% and spores densities

The plant roots were separated, washed and stored in the storage vial with formalineacetic acidealcohol (FAA) solution until staining according to the methodology described by Phillips and Hayman, (1970). The presence of an AM fungi infection was determined visually by clearing washed roots in 10% KOH and staining the preparation with 0.05% (vol/vol) trypan blue in lactophenol as described by Koske and Gemma (1989). The stained roots placed on the glass slides for microscopic observations under 100×magnifications (Leica DM550Q, USA). The calculation of AM fungi colonization was estimated for each sample by examination about one hundred pieces of roots (1 cm long), and expressed as the following formula. The AM fungi spore's densities were calculated according to Schenck, (1982).

$$\text{AM fungi colonization (\%)} = \frac{\text{Number of mycorrhizal root pieces}}{\text{Total number of observed root pieces}} \times 100\%$$

Results:

In regard to height increment% of seedlings, data presented in **Table (3)** show that, the fertilization ratio at 10:05:05 with 300 spores/plant of AM fungi were gave the height increment% (100.13% and 120.28%) in the first and second season respectively. Also the same treatment was gave highest diameter increment% value (64.61% and 164.61%) on both season respectively. On the other hand, the fertilization ratio at 10:05:05 with 450 spores/plant from AM fungi were recorded the heaviest mean value on fresh weight of plant leaves (40.33 and 34.13g/plant) in first and second season respectively **Table (4)**. Moreover, the same treatment was gave the highest mean value on fresh weight of stem (88.06 and 80.27g/plant) and higher mean value on fresh weight of root (35.8 and 29.73 g/plant) on first season and second season, respectively.

Data presented in **Table (5)** indicate that, fertilization ratio at 10:05:05 with 450 spores/plant of AM fungi was gave the highest mean value for dry weight of leaves (12.73 and 8.06 g/plant) for both seasons respectively. Also that was gave the same result for highest values dry weight of stems (63.16 and, 62.17g/plant) and higher mean value of dry weight of plant root (20.00 and 15.33g/plant) for first season and second season respectively.

The mineral contents in dried leaves were presented in **Table (6)**. The plants were treated with fertilizer ratio10:05:05 in the presence of AM fungi (450 spores/plant) recorded that, the highest **Nitrogen%** value 2.46 % and 2.29% in first season and second season, respectively. Also the same treatment gave the highest phosphorus% (0.29 and 0.67) and Potassium**%** value (0.89% and 0.97%) during the two seasons, respectively**.**

The high level mean of Chlorophyll (a) values (2.18 and 2.25 mg/g FW) were recorded from NPK ratio 10:05:05 in the presence of AM fungi by 300 spores/plant for first and second season **Table (7)**. The same treatment was gave highest values for Chlorophyll (b) (0.67 and 0.68mg/ g FW) and Carotenoids (2.78 and 3.04 mg/ g FW) during two seasons, respectively.

Data presented in **Table (8)** show the values for quality index stem of *S. mahagoni* seedling during the two seasons. The large mean value in the first season 12.73 was recorded at NPK ratio 10:05:05 with AM level of inoculation at 300 spores/plant and 17.32 at same NPK ratio but with 450 spores/ plant from AM on second season.

The effects of different fertilization ratios on AM fungi spore formation (100g/soil) on *S. mahagoni* were illustrated in **Fig.(1).** The number of AM fungi spores were increased at fertilizer ratio 00:10:05 with

all AM fungi inoculation levels. The maximum number of AM fungi spores (80 spores100g/soil) was observed in plant treatment with 450 spores/plant followed by 300 spores/plant, and then 150 spores/plant (55 and 45 spores/100g soil respectively). On contrast the lowest numbers of AM fungi spores were recorded in two NPK ratios 0:0:0 and 05:0:05 at all AM fungi inoculation levels which free from any additional of phosphorus fertilizer. Also the maximum root colonization% was recorded at NPK ratio 10:05:05 in all plant infection levels by AM fungi (80%,55% and 49% at 450, 300 and 150 spores $100g^{-1}$ respectively).The AM colonization% was increased by increasing in nitrogen fertilization rate in the presence of phosphorus fertilization. The photomicrograph for AM fungi structures in *S. mahagoni* roots was illustrated in **Fig. (2),** which was proved the evidence for activity of the AM fungi inside the roots of treated plants by different levels of mycorrhizal fungi.

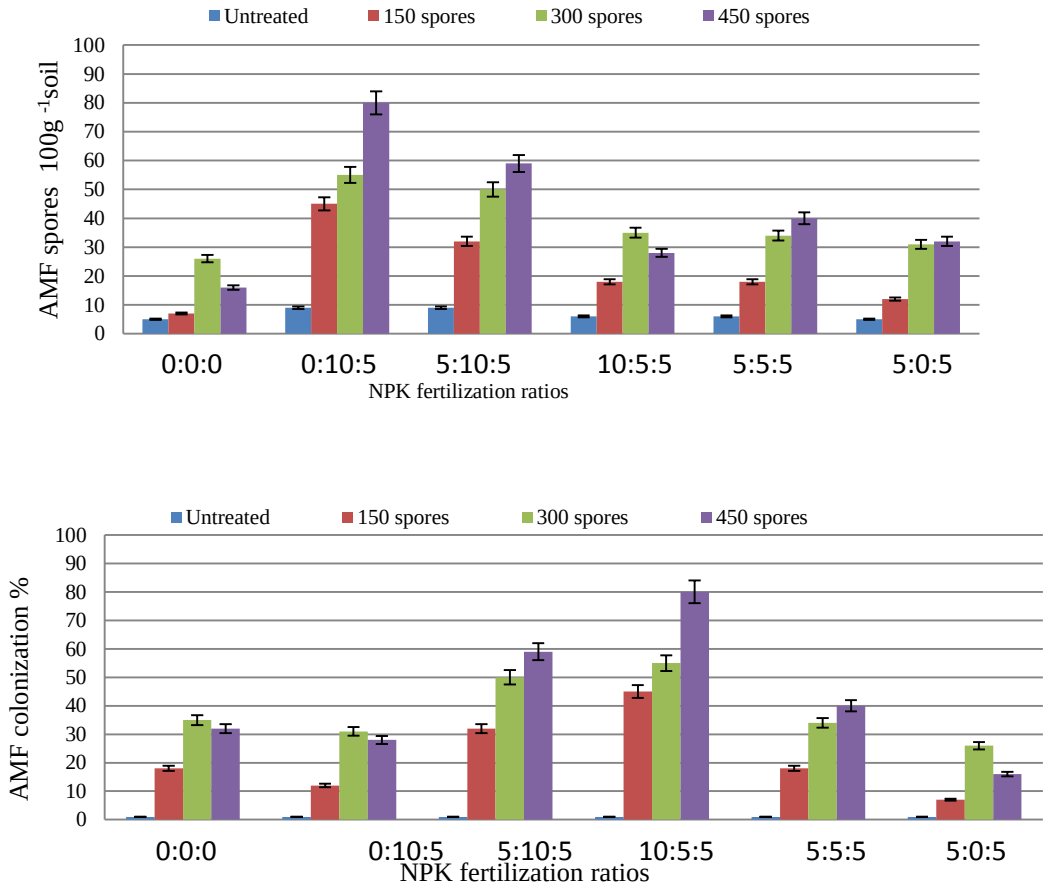

Fig. (1): The effects of different NPK fertilization ratios on arbuscular mycorrhizal (AM) fungi spores and AM fungi root colonization% on *Swietenia mahagoni*

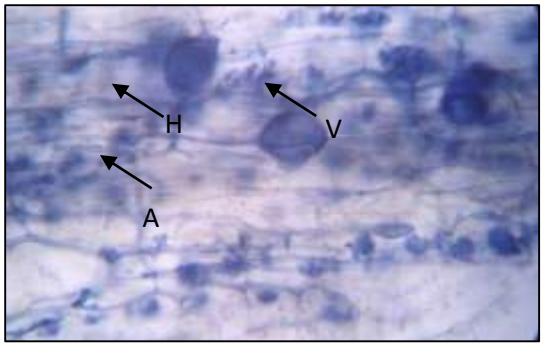

Fig. (2): Photomicrograph for arbuscular mycorrhizal fungi (AMF) structures in *Swietenia mahagoni* roots after clearing and staining (200×). A: Mature arbusculer, H: Internal hayphae and V: Typical vesicle

Discussion

The maximum values in all plants parameters, mineral content and some wood properties were recorded in the plant treated with NPK at ratio 10:05:05 with AM fungi inoculation at rate 450 spores plant^{-1} .The results are in agreement with **Gaur *et al*., (2000)** who found increase in plant vegetative growth while inoculating with AM fungi with recommended dose of chemical fertilizers. **El-Khateeb *et al., (*2010)** also observed increase in height of *Chamedora elegans* by AM fungi and NPK. The above results explain the important role of AM fungi for NPK plant uptake and fixing nitrogen which had the most favorable effects on the plants metabolism, therefore enhancing the other growth parameters.

The percentage of nitrogen, phosphorus and potassium in *S. mahagoni* seedling were significantly increased in plants treated with AM fungi when compared to untreated plants. The maximum values of NPK % in plants biomass were found in the plants treated with NPK ratio 10:05:05 with 450 spores for AM fungi in two seasons. The similar results were reported on some plant species such as *Trifolium repense*; *Rosa multiflora* and *Solanum lycopersicum* by **Cartmill *et al.* (2008); Joner (2000); Deguchi *et al*., (2007); Al-Agely and Sylvia (2008) and Cavagnaro *et al.* (2009)**

The maximum amount of plant chlorophyll a; chlorophyll b and carotenoids were observed at plants treated with AM fungi by rate 300 spores plant^{-1} at 10:05:05 ratio on both seasons. This result was in agreement with **Mathur and Vyas (1995)** they found the amount of chlorophyll in mycorrhizal plants was higher than non mycorrhizal plants. That also agreement with **Manoharan *et al.*, (2008)** who found that the chlorophyll a, chlorophyll b, carotenoid, nitrogen, phosphorus and potassium content increased by plant inoculation with AM fungi. **Auge (2001**) found that the AM fungi symbiosis was increased the rate of photosynthesis, and so increase the rates of photosynthetic storage and export at the same time. Also, carotenoids carry out an essential function during photosynthesis in the complexes of chloroplasts from green organs. Therefore, the regulation of the biosynthesis of chlorophyll and carotenoid biosynthesis are associated in photosynthetic organs (**Woitsch and Römer, 2003; Joyard *et al*., 2009).**

The successful association between plants and AM fungi constitutes a strategy to improve the nutritional status of both associates and reduces the use of fertilizers specially phosphorus nutrition **(Almagrabi and Abdelmoneim, 2012**). Mycorrhizal symbioses facilitate plant uptake of nutrient resources and water **(Allen, 1991, Newsham *et al.*, 1995, Zobel *et al.*, 1997).** Most studies have investigated P, but mycorrhizas have been implicated in the uptake of most essential nutrients. Plants colonized by AM fungi have greater ability to absorb nutrients like P, N, K, Ca and Mg which results in better survival under stressed conditions **(Auge and Stodola, 1990)**. Arbuscular mycorrhizal fungi species are decrease in agro-ecosystems comparing to natural ecosystems. Because the frequently of agricultural fertilization and irrigation are reduce more AM fungi spores than un-intensive managed agricultural soils (**Höflich and Metz, 1997)**

The lowest numbers of AM fungi spores were recorded in two NPK ratios (0:0:0 and 5:0:5) with all AM fungi inoculation levels which free from any addition from phosphate fertilizer rate. This result was due to the availability of phosphorus (P) fertilization in the treated soil, which is a one of the most important factors affecting on sporulation of AM fungi and growth. This result was in agreement with **Hepper (1983**); **Douds and Schenck (1990)** and **Masanori**, *et al.,* (**2011**). While the nitrogen (N) addition it has a negative effect on AM fungi sporulation especially in NPK ratio 10:5:5, which was caused sharp decrease in AM fungi sporulation. This result was in agreement with **Johnson *et al.*, (2003**) who found that N enrichment generally decreases AM fungi structures, especially to spores and extra-radical hyphae. Also **Masanori *et al.*, (2011**) found the effect of nitrogen on the sporulation of AM fungi differed among species and that in some species nitrogen may suppress the sporulation. The maximum percent root colonization was recorded at NPK ratio 10:05:05 in all infection levels of AM fungi. The AM fungi colonization% was increased by increasing in nitrogen fertilization rate in the presence of phosphorus fertilization. This result may be due to the effect of nitrogen fertilization, which increasing N/P ratio in plant root tissues consequently increase the rate of AM fungi infection for the new root fragments **(Hepper, 1983 and Douds and Schenck, 1990).**

Recommendation:

It could be concluded that the addition of Endo-mycorrhizal fungi rates by 300 and 450 spores / plant to NPK fertilization increased the growth parameters of mahogany seedlings grown under sandy soil conditions

Table 3. Effects of interaction between fertilization ratios and inoculation by mycorrhizal fungi on height increment% and diameter increment% at 5 cm of *Swietenia mahagoni* seedlings during the two seasons (2012-2013) and (2013-2014)

Spores/plant (B)	Untreated	150	300	450	Mean	Untreated	150	300	450	Mean
NPK Ratio(A)	1st year					2nd year				
	Height increment %									
Control	28.05 k	32.59 jk	33.31 jk	38.43 i-k	45.21 C	17.25 m	37.02 kl	58.98 g	24.27 i-m	34.38 F
0:10: 5	43.78 f-j	40.41 h-k	54.15 d-h	62.24 c-e	55.18 B	58.16 g	92.18 cd	57.83 g	54.79 g-i	65.74 D
5:10: 5	59.30 c-f	46.63 f-j	78.92 b	62.30 c-e	56.98AB	73.10 ef	63.44 fg	102.44 bc	81.29 de	84.53 B
10: 5: 5	66.91 b-d	50.24 e-i	100.13 a	77.68 b	63.26 A	52.35 g-j	108.33 ab	120.28 a	120.17 a	95.38 A
5: 5: 5	47.84 e-j	46.02 f-j	72.75 bc	57.57 c-g	58.1 AB	39.61 jk	74.44 ef	79.60 de	78.59 de	74.21 C
5: 0: 5	45.53 f-j	37.52 i-k	58.24 c-g	44.82 f-j	42.51 C	42.19 i-k	44.08 h-k	60.00 f	56.92 gh	55.70 E
Mean	42.24 D	48.56 C	66.25 A	57.17 B		47.11C	69.92B	86.93A	69.34B	
	Diameter increment %									
Control	18.39 g	26.54 ef	39.44 de	37.38 de	30.44 C	31.89 j	48.53 ij	51.98 i	60.64 i	48.26 E
0:10: 5	33.93 ef	26.19 fg	38.65 de	26.25 fg	31.26 C	60.96 i	114.20 ef	112.04 ef	128.75 c-e	103.98 C
5:10: 5	44.95 b-d	42.34 b-e	49.90 b	44.07 b-d	43.62 B	153.51 ab	92.2 gh	137.26 b-d	137.39 b-d	132.86 A
10: 5: 5	42.18 b-e	62.77 a	64.61 a	40.04 c-e	54.10 A	140.80 bc	121.59 d	164.61 a	150.29 ab	141.55 A
5: 5: 5	46.13 b-d	45.20 b-d	49.24 bc	22.35 g	40.73 B	88.76 h	116.53 ef	139.51 bc	113.31 ef	114.53 B
5: 0: 5	41.80 c-e	38.78 de	23.79 g	22.94 g	31.82 C	80.19 h	84.30 h	107.69 fg	85.83 h	89.50 D
Mean	37.33B	40.87 AB	44.27A	32.17C		94.53B	96.22B	116.99A	112.70A	

- Means in each column followed by the same letter are not significantly different ($P < 0.05$) as determined by Duncan's multiple range test
-Values are the means of three replications

Table 4. Effects of interaction between fertilization ratios and inoculation by mycorrhizal fungi on fresh weight (FW) of leaves, stem and root of *Swietenia mahagoni* seedlings during the two seasons (2012-2013) and **(2013-2014)**

Spores/plant	Untreated	150	300	450	Mean	untreated	150	300	450	Mean
NPK Ratio	1st year					2nd year				
	FW of Leaves (g/plant)									
Control	23.46 kl	26.20 i-l	27.13 h-k	27.86 h-k	26.16 D	18.13 j	20.53 ij	21.93 h-j	21.47 h-j	20.52 E
0:10: 5	23.00 l	29.60 e-i	29.13 f-j	33.00 c-g	28.68 C	17.40 j	23.73 g-i	23.67 g-i	25.13 d-h	22.48 C
5:10: 5	24.46 j-l	33.67 b-f	41.33 b-e	31.33 d-h	30.90 B	17.93 j	26.80 c-g	25.53 d-h	30.53 a-c	25.20 B
10: 5: 5	26.67 h-l	36.46 a-c	38.13 ab	40.33 a	35.40 A	23.00 g-i	32.13 ab	32.47 ab	34.13 a	30.53 A
5: 5: 5	26.53 i-l	29.67 e-i	33.40 b-f	35.60 a-d	31.30 A	20.60 ij	26.73 c-g	29.27 b-e	29.93 a-d	26.63 A
5: 0: 5	25.53 i-l	28.40 g-j	29.86 e-i	32.80 c-g	29.15 C	20.73 ij	24.27 f-i	27.33 c-g	28.73 b-f	25.26 D
Mean	24.94 C	30.66 D	30.63 AB	33.48 A		19.70C	25.7 B	26.97 AB	28.04 A	
	FW of Stem (g/plant)									
Control	36.93 m	36.40 m	48.33 ik	58.40 f	45.01 F	29.80 m	31.00 m	37.93 j-l	41.60 h-j	35.08 E
0:10: 5	43.06 l	48.00 k	62.06 e	66.13 d	54.81 D	33.80 m	35.00 k-m	48.33 g	59.73 de	44.22 D
5:10: 5	51.53 hij	56.40 fg	71.06 c	80.30 b	64.83 B	40.33 i-k	47.33 gh	64.33 d	72.40 b	56.1 B
10: 5: 5	48.93 i-k	62.26 e	77.20 b	88.06 a	69.12 A	46.76 gh	57.33 e	69.93 bc	80.27 a	63.57 A
5: 5: 5	48.26 jk	54.73 gh	68.13 cd	68.13 cd	59.81 C	44.73 g-i	55.40 ef	65.93 c	64.73 cd	57.7 B
5: 0: 5	40.26 l	52.93 h	52.40 h	51.93 hi	49.38 E	38.67 j-l	50.20 fg	50.47 fg	55.40 ef	48.68 C
Mean	44.83 D	51.78 C	63.20 B	68.83 A		39.02 D	46.04 C	56.15 B	62.35 A	
	FW of Root (g/plant)									
Control	20.36 h	24.86 fg	23.06 gh	25.46 e-g	23.44 D	16.53 i	17.93 g-i	17.73 g-j	19.33 f-i	17.88 D
0:10: 5	24.40 fg	24.67 fg	25.60 e-g	28.67 b-e	25.83 C	17.73 h-j	20.47 e-i	19.93 e-i	21.80 d-f	19.98 C
5:10: 5	26.26 d-g	28.53 b-e	30.10 bc	32.13 ab	29.27 B	18.37 g-i	21.80 d-f	22.40 d-f	27.00 a-c	22.39 B
10: 5: 5	30.67 bc	29.86 b-d	31.20 b	35.80 a	31.63 A	20.26 e-i	24.80 cd	28.80 ab	29.73 a	25.9 A
5: 5: 5	30.20 bc	27.07 c-f	32.06 ab	31.13 b	30.12 AB	20.66 e-h	23.00 de	26.20 bc	27.80 a-c	24.41 A
5: 0: 5	25.73 e-g	23.73 f-h	26.00 e-g	28.60 b-e	26.01 C	17.33ij	20.07 e-i	22.60 de	21.00 e-f	20.25 C
Mean	26.27 C	24.45 C	28.01 B	30.13 A		18.48 D	21.34 C	22.94 B	24.44 A	

- Means in each column followed by the same letter are not significantly different ($P < 0.05$) as determined by Duncan's multiple range test
-Values are the means of three replications

Table 5. Effects of interaction between fertilization ratios and inoculation by mycorrhizal fungi on Dry weight (DW) of leaves, stem and root of *Swietenia mahagoni* seedlings during the two seasons (2012-2013) and (2013-2014)

Spores/plant	Untreated	150	300	450	Mean	Untreated	150	300	450	Mean
NPK Ratio	1st year					2nd year				
	DW of Leaves (g/plant)									
Control	10.67 ef	10.60 ef	10.13 f	11.26 c-e	10.66 D	5.47 ij	5.40 ji	5.07 j	5.80 g-i	5.43 C
0:10: 5	10.73 d-f	11.26 c-e	10.66 ef	11.80 a-d	11.12 CD	5.40 ij	6.07 e-i	5.67 e-i	6.60 c-f	5.93 B
5:10: 5	10.93 d-f	12.13 a-c	11.40 b-e	12.40 ab	11.71 AB	5.53h-j	6.73 c-e	5.80 c-e	7.20 a-c	6.32 B
10: 5: 5	11.33 b-e	12.66 a	12.06 a-c	12.73 a	12.20 A	7.07b-d	7.93 ab	7.13 ab	8.06 a	7.55 A
5: 5: 5	11.23 c-e	10.80 d-f	11.26 c-e	12.13 a-c	11.35 BC	5.73f-i	6.13 e-i	6.46 e-i	7.20 a-c	6.38 B
5: 0: 5	10.40 ef	10.73 d-f	10.93 d-f	10.96 d-f	10.75 D	5.83e-i	6.00 e-i	6.20 d-i	6.40 c-h	6.11 B
Mean	10.88 C	11.36 BC	11.07 B	11.88 A		5.84 C	6.37 B	6.05 AB	6.87 A	
	DW of Stem (g/plant)									
Control	28.16i	28.16i	35.00g-i	39.50 f-i	32.71 D	21.00 k	24.50 ik	27.33 ij	29.17 ij	25.50 E
0:10: 5	31.33ji	34.83g-i	44.33d-f	52.50 c-e	40.75 C	25.67 i-k	26.33 ij	35.67 gh	43.50 de	32.79 D
5:10: 5	37.83f-i	42.33e-g	54.50bc	62.66 ab	49.33AB	29.83 i	35.00 gh	47.17 cd	56.00 b	42.00 B
10: 5: 5	40.16f-h	46.00c-e	53.33c	63.16 a	50.66 A	37.17 f-h	41.50 ef	50.67 c	62.17 a	47.87 A
5: 5: 5	38.67f-i	44.33d-e	50.67c-e	49.50 c-e	45.79 A	34.67 h	39.50e-h	49.00 c	47.83 cd	42.75 B
5: 0: 5	33.16h-j	39.00f-i	38.66f-i	44.00 d-f	38.71 C	29.17 i	38.00 f-g	35.67 gh	39.00 e-h	35.46 C
Mean	34.88 D	39.11 C	46.08 B	51.88 A		29.58 D	34.13 C	40.91 B	46.27 A	
	DW of Root (g/plant)									
Control	13.13 ji	15.73 e-h	14.93 f-i	16.73 c-g	15.13 CD	8.27 l	9.13 j-l	9.30 i-l	11.20 b-e	9.48 D
0:10: 5	15.06 f-i	15.80 e-i	16.86 c-g	18.33 a-d	16.52 B	9.60 h-l	l1.13 e-j	11.53 e-h	12.80 b-e	11.27 C
5:10: 5	15.20 f-i	17.33 d-e	18.80 a-c	19.60 ab	17.83 A	10.00 g-l	11.67 d-g	12.73 b-e	14.60 ab	12.43 B
10: 5: 5	15.60 e-j	18.53 a-d	19.06 a-c	20.00 a	18.20 A	11.13 e-i	13.67 a-d	15.40 a	15.33 a	13.70 A
5: 5: 5	14.53 g-j	15.46 e-i	17.73 a-d	17.40 b-e	16.28 BC	10.20 g-l	11.13 e-i	12.53 c-f	14.00 a-c	11.96 BC
5: 0: 5	13.53 h-j	12.60 j	15.60 e-i	16.13 d-g	14.46 D	8.73 kl	9.60 h-l	10.53 f-k	10.20 g-l	9.77 D
Mean	14.51 C	15.91 B	17.17 A	18.03 A		9.66 D	11.05b C	12.01 A	13.02 B	

- Means in each column followed by the same letter are not significantly different ($P < 0.05$) as determined by Duncan's multiple range test

-Values are the means of three replications

Table 6. Effects of interaction between fertilization ratios and inoculation by endomycorrhizal fungi on nitrogen%,phosphorus% and Potassium % contents on leaves of *Swietenia mahagoni* seedlings during the two seasons (2012-2013) and(2013-2014)

Spores/plant	untreated	150	300	450	Mean	Untreated	150	300	450	Mean
NPK Ratio	1st year					2nd year				
	Nitrogen %									
Control	0.89 o	0.96 n	1.01 n	1.26 l	1.03 F	0.95 i	1.14 hi	1.01 hi	1.20 f-i	1.08 E
0:10: 5	1.29 kl	1.30 j-l	1.36 j	1.46 i	1.35 E	1.10 g-i	1.16 f-i	1.22 f-i	1.59 c-e	1.27 D
5:10: 5	1.56 h	1.94 de	1.92 e	2.20 b	1.90 B	2.15 ab	1.39 d-g	2.20 a	2.03 ab	1.78 B
10: 5: 5	1.70 g	2.00 d	2.10 c	2.46 a	2.06 A	1.31 e-h	2.16 a	1.66 cd	2.29 a	2.01 A
5: 5: 5	1.26 i	1.53 h	1.84 f	2.09 c	1.68 C	1.19 f-i	2.00 ab	1.86 bc	1.63 cd	1.67 B
5: 0: 5	1.14 m	1.35 jk	1.84 f	1.99 d	1.58 D	1.45 d-f	1.11 g-i	2.04 ab	1.12 g-i	1.43 C
Mean	1.30 D	1.51 C	1.68 B	1.91 A		1.36 B	1.49 B	1.63 A	1.68 A	
	Phosphorus %									
Control	0.14 j	0.16 ij	0.16 ij	0.17 hi	0.15 E	0.16 k	0.19 jk	0.24 h-k	0.26 c-g	0.21 C
0:10: 5	0.17 hi	0.17 hi	0.18 f-h	0.18 f-h	0.17 D	0.17 k	0.22 i-k	0.27 e-j	0.35 g-j	0.25 AB
5:10: 5	0.22 d	0.22 d	0.22 d	0.24 c	0.22 B	0.22 i-k	0.29 e-i	0.39 e-j	0.61 ab	0.38 A
10: 5: 5	0.25 c	0.27 b	0.25 bc	0.29 a	0.26 A	0.22 i-k	0.35 c-e	0.62 ab	0.67 a	0.46 A
5: 5: 5	0.20 de	0.21 d	0.21 de	0.20 d-f	0.20 C	0.19 jk	0.32 d-h	0.38 ab	0.57 b	0.36 AB
5: 0: 5	0.19 e-h	0.19 g-i	0.19 g-i	0.19 e-h	0.18 D	0.19 jk	0.26 f-j	0.34 cd	0.41 c	0.30 AB
Mean	0.18 C	0.19 B	0.20 B	0.21 A		0.19 D	0.27 C	0.38 B	0.48 A	
	Potassium %									
Control	0.55 c-f	0.37 b-e	0.63 b-e	0.37 f	0.55 C	0.56 ij	0.56 j	0.59 h-j	0.60 h-j	0.58 F
0:10: 5	0.67 a-d	0.44 d-f	0.40 ij	0.71 a-c	0.58 AB	0.69 d-f	0.67 fg	0.73 c-e	0.75 c	0.72 B
5:10: 5	0.85 ab	0.76 a-c	0.40 ij	0.70 a-c	0.73 A	0.69 ef	0.74 cd	0.82 b	0.97 a	0.81 A
10: 5: 5	0.80 a-c	0.73 a-c	0.84 ab	0.89 a	0.75 A	0.61 hi	0.62 gh	0.73 c-e	0.97 a	0.68 C
5: 5: 5	0.60 b-f	0.66 a-c	0.73 ef	0.84 ab	0.69 AB	0.59 h-j	0.61 h	0.67 f	0.67 fg	0.64 D
5: 0: 5	0.64 a-e	0.72 a-d	0.74 a-c	0.65 b	0.69 AB	0.60 h-j	0.60 h-i	0.62 gh	0.62 h	0.61 E
Mean	0.59 B	0.68 AB	0.65 AB	0.73 A		0.62 E	0.63 C	0.69 B	0.73 A	

- Means in each column followed by the same letter are not significantly different ($P < 0.05$) as determined by Duncan's multiple range test
-Values are the means of three replications

Table 7. Effects of interaction between fertilization ratios and inoculation by endo mycorrhizal fungi on FW), chlorophyll b (mg/g FW), carotenoids (mg/g FW) content on leaves of *Swietenia mahagoni* seedling during two seasons (2013-2013) and (2013-2014)

Spores/plant	Untreated	150	300	450	Mean	Untreated	150	300	450	Mean
NPK Ratio	1st year					2nd year				
	chlorophyll a (mg/ g FW)									
Control	1.01 h	1.21 e-h	1.30 d-g	1.05 gh	1.23 C	0.80 i	1.32 g-i	1.66 c-h	0.94 ij	1.18 D
0:10: 5	1.32 d-g	1.33 d-f	1.36 c-f	1.31 d-g	1.39 B	1.26 hi	1.87 a-e	1.76 b-f	1.63 c-h	1.63 BC
5:10: 5	1.54 cd	1.44 c-e	1.87 ab	2.00 a	1.65 A	1.63 d-h	1.84 a-e	2.16 ab	1.68 c-h	1.77 AB
10: 5: 5	1.19 e-h	1.95 a	2.18 a	2.10 a	1.76 A	1.34 f-i	2.06 a-d	2.25 a	1.94 a-d	1.95 A
5: 5: 5	1.38 c-f	1.52 cd	1.37 c-f	2.07 a	1.62 A	0.98 ij	1.73 b-g	2.07 ab	1.98 a-d	1.69 B
5 : 0: 5	1.17 f-h	1.36 c-f	1.62 bc	1.85 ab	1.43 B	0.79 j	1.47 e-h	1.73 b-g	1.78 b-e	1.44 C
Mean	1.27 D	1.47 C	1.58 B	1.73 A		1.13 B	1.71 A	1.71 A	1.89 A	
	chlorophyll b (mg/ g FW)									
Control	0.60 ab	0.39 d-h	0.48 b-g	0.38 e-h	0.46 B	0.25 i	0.30 kl	0.32 j-l	0.31 kl	0.29 E
0:10: 5	0.43 c-h	0.50 b-f	0.35 gh	0.54 a-d	0.45 B	0.30 kl	0.41 g-i	0.38 h-k	0.44 g-i	0.38 D
5:10: 5	0.52 a-e	0.50 b-f	0.44 c-h	0.47 b-g	0.49 AB	0.38 h-k	0.59 b-d	0.63 a-c	0.46 e-h	0.52 B
10: 5: 5	0.45 b-g	0.57 a-c	0.67 a	0.51 a-e	0.49 A	0.64 ab	0.62 a-d	0.68 a	0.66 ab	0.65 A
5: 5: 5	0.30 h	0.50 b-f	0.49 b-g	0.50 b-f	0.45 B	0.55 c-e	0.64 a-c	0.48 e-g	0.45 f-i	0.53 B
5: 0: 5	0.43 c-h	0.36 f-h	0.49 b-g	0.43 c-h	0.43 B	0.54 d-f	0.42 g-i	0.40 g-i	0.37 i-k	0.43 C
Mean	0.45 A	0.47 A	0.48 A	0.47 A		0.45 C	0.48 AB	0.50 A	0.45 BC	
	Carotenoids (mg/ g FW)									
Control	2.25 c-f	2.09 e-h	2.07 f-h	2.21 c-g	2.05 C	1 .99 g	2.13 e-g	2.31 c-g	2.05 fg	2.12 C
0:10: 5	2.09 e-h	2.19 c-h	2.09 e-h	2.43 bc	2.10 AB	2.18 d-g	2.53 b-e	2.63 a-d	2.45 c-g	2.45 AB
5:10: 5	2.39 b-d	2.56 ab	2.02 f-h	1.94 gh	2.20 ABC	2.37 c-g	2.94 ab	2.11 e-g	2.52 b-f	2.48 A
10: 5: 5	2.58 ab	2.31 b-f	2.78 a	2.12 d-h	2.33 A	2.45 c-g	2.68 a-c	3.04 a	2.46 c-f	2.66 A
5: 5: 5	1.92 h	2.22 c-g	2.03 f-h	2.21 c-g	2.23 ABC	2.32 c-g	2.10 e-g	2.30 c-g	2.24 c-f	2.24 BC
5: 0: 5	2.15 c-h	2.19 c-h	2.06 f-h	2.38 b-e	2.16 BC	2.11 e-g	2.18 d-g	2.06 e-g	2.16 e-g	2.12 C
Mean	2.12 B	2.20 AB	2.17 B	2.22 A		2.23A	2.43A	2.41A	2.31A	

-Means in each column followed by the same letter are not significantly different ($P < 0.05$) as determined by Duncan's multiple range test

-Values are the means of three replications

Table 8. Effects of interaction between fertilization ratios and inoculation by mycorrhizal fungi on quality index of *Swietenia mahagoni* seedlings during two seasons the two seasons (2012-2013) and (2013-2014).

Spores/plant	Untreated	150	300	450	Mean	Untreated	150	300	450	Mean
NPK Ratio	1st year					2nd year				
	Quality index									
0:0:0	10.66 ef	10.60 ef	10.13 f	11.26 c-e	10.67 D	9.52 j	10.10 ij	10.57 h-j	12.60 f-i	10.70 C
0:10: 5	10.73 d-f	11.26 c-e	10.66 ef	11.80 a-d	11.11 CD	10.92 h-j	12.77 e-h	13.09 d-h	14.68 b-f	12.87 B
5:10: 5	10.93 d-f	12.13 a-c	11.40 b-e	12.40 ab	11.71 AB	10.76 h-j	12.72 e-h	13.58 c-g	15.96 a-c	13.36 AB
10: 5: 5	11.33 d-f	12.06 a-c	12.66 a	12.73 a	12.20 A	12.69 e-i	15.19 a-e	17.32 a	16.4 ab	15.29 A
5: 5: 5	11.23 c-e	10.80 d-f	11.26 c-e	12.13 a-c	11.35 BC	11.42 g-j	12.67 e-h	13.76 c-g	15.38 a-d	13.31 B
5 : 0: 5	10.40 ef	10.73 d-f	10.93 d-f	10.96 d-f	10.75 CD	9.77 j	10.67 h-j	11.61 g-j	11.19 g-j	10.81 C
Mean	10.88 C	11.07 BC	11.36 B	11.88 A		10.85 C	12.35 B	13.32 AB	14.37 A	

-Means in each column followed by the same letter are not significantly different ($P < 0.05$) as determined by Duncan's multiple range test
-Values are the means of three replications

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تاثير التطبيقات بفطريات الميكوريزا الشجريه و نسب من تسميد NPK علي بعض الصفات المورفولوجية و الفسيولوجيه لشتلات الماهوجني

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الملخص:

نفذت تجربه عامليه لبحث تأثير التلقيح بأربعه مستويات من فطريات الميكوريزا الشجريه (٠، ١٥٠، ٣٠٠، ٤٥٠±١٠ جرثومه/النبات) فى وجود ستة نسب تسميديه من NPK (٠:٠:٠، ٥:١٠:٠، ٥:١٠:٥، ١٠:٥:٥، ٥:٥:٥، ٥:٠:٥) على صفات نمو شتلات الماهوجني *Swietenia mahagoni* تحت ظروف التربه الرمليه. وكان لقاح الميكوريزا المستخدم فى صوره خليط من جراثيم لثلاثه انواع تتبع جنس فطرى واحد وهم *Glomus mosseae* ، *G.etunicatum* ، *G. clarum* . ادت المعاملة بالنسبة السمادية والميكوهيزا الي زيادة ارفاع الشتلات وقطر الساق وكلك الاوزان الازجة والجافة لكل من الاوراق والساق والجذور خاصة مع النسبة السمادية ١٠:٥:٥ و٤٥٠جرثومة/للنبات من الميكورهيزامن NPK.وكذلك حصل علي اقصى قيمه مسجله للكلوروفيل أ، كلوروفيل ب والكاروتينيات لوحظت فى النباتات المعامله بفطريات الميكوريزا بمقدار ٣٠٠جرثومه/نبات عند نسبه سماديه ١٠:٥:٥ . كما ازدادت اعداد جراثيم الميكوريزا المتكونه عند استخدام النسبه السماديه ٥:١٠:٠فى جميع مستويات التلقيح بالميكوريزا. بينما ازدادت نسبة التوطيد الفطرى على جذور النباتات بزيادة كلاً من التسميد النتروجينى والفسفورى. كما أظهرت النتائج ان الخلط بين فطريات الميكوريزا والتسميد بواسطه NPK كان له تأثير جيد على زيادة أمتصاص النبات للتسميد بالمقارنه بالمعاملات الاخرى. ويرجع التاثير الايجابى لتلقيح النباتات بفطريات الميكوريزا الى مساعده نبات *S .mahagoni* فى إمتصاص المزيد من المواد المغذيه من التربه اكثر من النباتات الخاليه من المعامله بالميكوريزا.

التوصيه:

–إضافة الميكورهيزا بمعدل ٤٥٠ جرثومة لكل أو السماد الكيماوي NPK يؤدي إلي زيادة معدل نمو شتلات الماهوجني المنزرعة تحت ظروف الأراضي الرملية