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Implication of using silver nano-particles and mycorrhizae symbiosis on growth, yield and quality of artichoke plants

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Abstract

A field experiments were carried out at the experimental Farm of the Faculty of Agriculture, Moshtohor, Benha university, Qalubiya Governorate, Egypt during the two successive seasons of 2010/2011 and 2011/2012, to study the response of artichoke plant to chemical phosphorus fertilizers (calcium super phosphate, 15.5 % soluble P_2O_5); or natural phosphorus fertilizer (rock phosphate, 27% insoluble P_2O_5 as source of P) only or with inoculation by Vesicular Arbuscular Mycorrhizas (VAM) (*Glomus mosseae*) and study their effects on the growth, yield and its components as well as flower head quality of globe artichoke (*Cynara scolymus* L.) cv. Fransawy, Which was treated with anti-fungal stumps or nano-silver.

Results showed that using RP + VAM, enhanced plant growth, increased yield and improved head quality than the control (SP +AF). Also, inoculating with VAM gave good results than untreated in the case of using RP. Also, pre-planting with NS gave good results (in most cases) in terms of vigor growth, higher yield and head quality as compared with AF. Therefore, using RP + VAM + NS gave the highest values of growth parameters and increased early and total yield with the best head quality as compared with all other used treatments. This increase in yield as a result of using this particular treatment reached 20.3 and 18.6 % as an average in both seasons for total yield per plant and per feddan, respectively, as compared with plants supplied with SP + AF (control).

Keywords: Globe artichoke, Vesicular Arbuscular Mycorrhizae (VAM), Nano-silver (NS), Anti-fungai (AF), Rock phosphate (RP), Calcium super phosphate (SP).

Introduction

In slightly alkaline soils such as Egyptian soils phosphorus (P) is considered a limiting factor for crop production due to P fixation in these soils upon addition in soluble forms such as superphosphate (El-Katkat, 1992). Using mycorrhiza in Egyptian soils proved positive in increasing crop production, by increasing nutrient absorption especially P, particularly with perennial crops like artichokes (Ezz El-Din *et al*., 2010). It is worthy to mention that the results recorded from using mycorrhiza with rock phosphate (insoluble P) were similar to those attained with superphosphate treatments (soluble P) (Bolan, 1991, Hammond and Leon, 1992 and Smith and Read, 1997), subsequently using combination of rock phosphate and mycorrhiza could be practical and promoted.

Artichokes seedling is usually treated with fungicides which reduce growth and activity of mycorrhiza (Rai, 2006). Finding a new technique to shield seedling from soil disease and in the same time encourage mycorrhiza growth is of practical implication. Nanotechnology could be the answer, treating artichokes seedling with nano-silver before planting proved useful in protecting seedling treated with mycorrhiza (*Glomus mosseae*) form disease and in the same time not affecting mycorrhiza activity because this species was not sensitive to nano-silver. (Abbasian *et al*., 2012).

Globe artichoke (*Cynara scolymus*, L) is considered an important vegetable crop in Egypt due to its special nutritive and medical values. Also, it gained a highly exportable importance to the European markets. The immature flower bud (head) is the edible part which includes the fleshy receptacle and fleshy tender basis of bracts. It is, really, good source of inulin, fibers and minerals (Ryder *et al*., 1983). In addition, the edible flower bud and other artichoke plant extracts are rich in polyphenols and have high levels of antioxidant activity (Liorach *et al*., 2002).

Vesicular Arbuscular Mycorrhizae (VAM) are the main group of mycorrhiza fungi which improve plant growth through different mechanisms such as phosphate solubilization and enhancement of water / nutrients absorption (Rai, 2006).

This ability of mycorrhiza is mainly attributed to its hyphae. Hyphae are external root shaped organs which penetrate into soil pores and cracks, and make higher soil volume available to plant to be used as the source of water and nutrients (Wiedenhoeft, 2006). Different experiments have reported the improvement of plant growth, yield and nutrients uptake as the function of mycorrhizal inoculation (Ardakani *et al*., 2011).

Nanosilver is a new classes of material with remarkably different physiochemical and biological characteristics such antimicrobial activity (Choi *et al*., 2009) has shown to have antibacterial, antifungal and antiviral effects (Nomiya *et al.*, 2004; Sondi and Salopek-Sondi, 2004) and can reduce the damages and the lost caused by these diseases (Russell & Hugo, 1994). The nanosilver products make broad claims about the power of their nanosilver ingredients, such as: "eliminates 99% of bacteria" renders material "permanently antimicrobial and antifungal", "kills approximately 650 kinds of harmful germs and viruses" and "kills bacteria in a short time as 30 min" and it was 2-5 times faster than other forms of silver (Emtiazi *et al.*, 2009).

Nanosilver is a solution containing nanosilver and used for its antimicrobial effects (Choi *et al*., 2009).

Global Artichoke can benefit from antimicrobial effect of nanosilver before culture in the field. No published research was found regarding the effect of nanosilver on production efficiency of global artichoke grown in the field.

The aim of this subject is to do a comparison within using inorganic phosphorus calcium super phosphate as chemical fertilizer and Rock phosphate as (natural fertilizer) only or with inoculation by Vesicular Arbuscular Mycorrhizas (VAM) and study their effects on the growth, yield and it's some physical and chemical properties of artichoke plants Which was treated with anti-fungal stumps or nano-silver.

Material and methods

A field experiments were carried out at the experimental Farm of the Faculty of Agriculture, Moshtohor, Benha university, Qalubiya Governorate, Egypt during the two successive seasons of 2010/2011 and 2011/2012, to study the response of artichoke plant to chemical phosphorus fertilizers (calcium super phosphate, 15.5 % soluble P_2O_5); or natural phosphorus fertilizer (rock phosphate, 27% insoluble P_2O_5 as a source of P) only or with inoculation by Vesicular Arbuscular Mycorrhizas (VAM) and the effect of that on the vegetative growth, yield and its components as well as flower head quality of globe artichoke (*Cynara scolymus L.*) cv. Fransawy, Which was treated with anti-fungal stumps or nano-silver.

Mycorrhiza (*Glomus mosseae*) were prepared by the Biofertilizer Unite, Faculty of Agriculture, Ain Shams University, Egypt. (500 ml/fed.) was added one month after transplanting.

Nanosilver (< 50 nm, 50 mg/L, Tahmasbi *et al*., 2011) was provided by Nanotech Egypt for Photoelectronics, Bahgat group, 6 October region, Giza Governorate.

Random soil samples were collected from the experimental soil at the depth of 0-30 cm before planting for the physical and chemical properties of soil according to methods described by Jackson (1969). Data of physical and chemical analysis are shown in Table 1.

Table 1. Physical and chemical analyses of the experimental soil before transplanting

Soil texture				pH	EC	O.M	$CaCO_3$	Soil available macronutrients (mg kg^{-1})		
Sand (%)	Silt (%)	Clay (%)	Texture		(dS m^{-1})	(%)	(%)	N	P	K
24.4	24.6	51	Clay loam	7.9	2.16	1.41	1.53	22.5	9.1	120

Old crowns (taken from the previous plants) was used as a plant material for propagation and were planted on middle of August during the two seasons of study (2009/2010 and 2010/2011). This experiment was set out in a complete randomized blocks design with three replicates in both seasons of study. Each experimental plot included four ridges, 1 m width and 4.0 m length with an area of 16 m^2 from which, three ridges were planted and one was left without planting as a guard one between plots. The old crowns were planted at a distance of 1 m apart on one side.

The usual cultural procedures of globe artichoke growing including fertilization which was done using 250 kg ammonium sulphate (20.6 % N), 64 kg P_2O_5 (calcium superphosphate; 15.5 % soluble P_2O_5 or Rock phosphate; 27 % insoluble P_2O_5) and 100 kg potassium sulphate (48 % K_2O) /fed. were added in three equal doses after 2, 3 and 4 monthes from planting.

Rock phosphate was obtained from Abu Zaabal fertilizer and chemical Co., Egypt.

Treatments

1. Calcium superphosphate + Anti-fungi * (Control)
2. Calcium superphosphate + Nano-silver
3. Rock phosphate + Anti-fungi *
4. Rock phosphate + Nano-silver
5. Rock phosphate + Mycorrhaiza
6. Rock phosphate + Mycorrhaiza + Anti-fungi *
7. Rock phosphate + Mycorrhaiza + Nano-silver

* Anti-fungi mixture (fungicides) i.e. Reyzolex plus Topsen plus Redomil at 3:2:1.5 g/l for each of them, respectively for 30 min.

Data recorded

1 -Vegetative growth characters.

Vegetative growth aspects of globe artichoke plants were measured at the beginning of blooming stage (120 days after planting). Representative sample of five plants from each experimental plot was taken for measuring the vegetative growth aspects as follows:-

1. Plant height was measured from the soil surface to the tip of the largest linear blade in plant.
2. Number of leaves were calculated as the average num-ber of green leaves per plant.
3. Leaf area. The samples of five plants were taken from each plot and the average leaf area was determined using a digital leaf area meter (L1-300 portable area meter produced by L1-COR, Lincoln, Nebraska, USA).
4. At the end of harvesting number of offshoots /plant was accounted.

2- Early and total yield.

The early yield was calculated from the start of harvest (after 4 month from transplanting)until the end of February and total yield was up to the end of May (end of the production season of artichoke), were evaluated for each plot in both seasons of the study as follows:

1. Early yield per fed.
2. Total yield per fed.
3. Total yield per plant

3- Head quality.

3-1- Physical head characters.

Five heads from each plot were randomly taken at every harvest period (early – late) in both seasons of study for measuring the physical head characters of globe artichoke expressed as follows:

1. Head height. (It was measured by calipers)
2. Head diameter. (It was measured by calipers)
3. Average head fresh weight.
4. Average edible part fresh weight.

3-2- Chemical constituents of heads.

Samples of heads edible part were taken at the beginning and the end of harvesting season and dried in an electric oven to constant weight at 70 ^{O}C. Inulin concentration was determined according to Winton and Winton, 1958, while the fibers were determined according to A.O.A.C., (1990).

Statistical analysis:

Statistical analysis was performed using the SPSS package program version 15.0 (SPSS Inc., Chicago, III, USA). Data were analyzed by one-way analysis of variance (ANOVA), followed by Duncan's multiple range post-hoc test. Differences were considered significant at $P<0.05$.

Results and Discussion

1- Vegetative growth.

Data in Table 2 show that treating with Nano-silver (NS) enhancing plant growth parameters specially leave area/plant comparing to Anti-fungai (AF) treatment in the addition of Rock phosphate (RP) or Calcium superphosphate (SP) in both seasons.

Also, the combination treatment of (RP + VAM + NS) significantly increased the number of offshoots and leave area per plant comparing with the combination treatment of (RP +VAM + AF) and control treatment in both season.

It could be indicated that VAM did not affected by treating stumps by NS, but showed enhancing effect on plant growth comparing to treating with AF compounds as antifungal treatment.

From the previous, it could be concluded that the combination treatment (RP + VAM + NS) improve the production of offshoot which used in the propagation. Arbuscular symbiosis can improve a soil structure and protect host plants against the detrimental effects caused by the drought stress, which happens after the harvest season (Schreiner *et al*., 1997).

The superiority of Nano-silver than Anti-fungal especially in the case of using rock phosphate and inoculation with Mycorrhaiza (*Glomus mosseae*) due to this species was not sensitive to nanosilver. (Abbasian *et al*., 2012).

Nanosilver has shown to have antibacterial, antifungal and antiviral effects (Nomiya *et al.*, 2004; Sondi & Salopek- Sondi, 2004).

The application of fungicide damages external hyphae of mycorrhiza and prevents root colonization; reducing water and nutrient uptake, photosynthesis and plant growth (Kung'u *et al*., 2008).

2- Early and total yield.

Data presented in Table 3 indicate that there were no significant differences between using NS or AF components at the addition of SP or RP treatments only in both seasons.

Also, the treatment which received RP with AF or NS gave the lowest values of yield with significant difference comparing with other treatments in both seasons.

The treatments which received SP gave a significant difference on yield and its components comparing with treatments of RP in the addition of NS or AF without inoculation of Mycorrhizae (VAM) in both seasons.

On the other hand, the enhancing effect of VAM inoculation was regarded on yield and its components in the treatment of RP without significant differences with the control (SP and AF) treatment.

Table 2. Effect of calcium super phosphate or rock phosphate only or with inoculation by Vesicular Arbuscular Mycorrhizas (VAM) on vegetative growth of globe artichoke which was treated with anti-fungai stumps or nano-silver, during 2010/2011 and 2011/2012 seasons.

Treatments	Plant height (cm)	No. of leaves /plant	No. of offshoots / plant	Leave area cm^2
First season 2010/2011				
Calcium superphosphate + Anti-fungai (Control)	87.3 AB	34.7 ABC	2.67 AB	515 C
Calcium superphosphate + Nano-silver	94.3 A	39.7 AB	3.03 AB	526 B
Rock phosphate + Anti-fungai	80.0 B	31.7 C	0.67 C	495 D
Rock phosphate + Nano-silver	84.3 AB	33.7 BC	2.33 B	516 C
Rock phosphate + Mycorrhaiza	87.0 AB	37.0 ABC	2.67 AB	531 AB
Rock phosphate + Mycorrhaiza + Anti-fungai	89.7 AB	33.3 BC	2.23 B	514 C
Rock phosphate + Mycorrhaiza + Nano-silver	95.0 A	41.0 A	3.33 A	536 A
Second season 2011/2012				
Calcium superphosphate + Anti-fungai (Control)	85.0 AB	36.0 AB	1.67 C	519 D
Calcium superphosphate + Nano-silver	93.3 AB	41.6 A	3.01 AB	532 C
Rock phosphate + Anti-fungai	82.6 B	30.0 B	1.33 C	492 E
Rock phosphate + Nano-silver	83.4 B	31.6 AB	1.67 C	518 D
Rock phosphate + Mycorrhaiza	87.3 AB	35.7 AB	2.33 ABC	535 B
Rock phosphate + Mycorrhaiza + Anti-fungai	91.0 AB	36.7 AB	2.01 BC	519 D
Rock phosphate + Mycorrhaiza + Nano-silver	96.0 A	42.3 A	3.33 A	540 A

Means of the same column followed by the same letter were not significantly differed due to Duncan MRT at 5%.

Table 3. Effect of calcium super phosphate or rock phosphate only or with inoculation by Vesicular Arbuscular Mycorrhizas (VAM) on early, total yield and its components of globe artichoke which was treated with anti-fungai stumps or nano-silver, during 2010/2011 and 2011/2012 seasons.

Treatments	Early yield (ton/fed)	Total yield (kg/plant)	Total yield (ton/fed)
First season 2010/2011			
Calcium superphosphate + Anti-fungai (Control)	2.342 BC	3.470 B	13.74 c
Calcium superphosphate + Nano-silver	3.273 AB	4.090 A	16.26 b
Rock phosphate + Anti-fungai	0.635 D	2.600 C	10.30 e
Rock phosphate + Nano-silver	1.193 CD	2.770 C	11.05 e
Rock phosphate + Mycorrhaiza	3.227 AB	3.380 B	13.42 c
Rock phosphate + Mycorrhaiza + Anti-fungai	2.950 AB	3.100 B	12.30 d
Rock phosphate + Mycorrhaiza + Nano-silver	4.195 A	4.360 A	17.36 a
Second season 2011/2012			
Calcium superphosphate + Anti-fungai (Control)	2.433 BC	4.150 A	16.56 c
Calcium superphosphate + Nano-silver	4.113 AB	4.470 A	17.68 b
Rock phosphate + Anti-fungai	0.549 D	2.600 C	10.34 f
Rock phosphate + Nano-silver	1.200 CD	2.860 C	11.24 e
Rock phosphate + Mycorrhaiza	3.740 AB	3.620 B	14.35 d
Rock phosphate + Mycorrhaiza + Anti-fungai	2.780 ABC	3.950 B	15.68 c
Rock phosphate + Mycorrhaiza + Nano-silver	4.392 A	4.770 A	19.01 a

Means of the same column followed by the same letter were not significantly differed due to Duncan MRT at 5%.

It could be observed that the combination treatments of NS or AF with RP and VAM gave the highest early yield comparing with other treatments in both seasons.

The activity of mycorrhiza external hyphae is related to succinate dehydrogenase enzyme which improves plant photosynthesis and P uptake (Gyaneshwar *et al*., 2002 , Xiao *et al*., 2008).

Different experiments have reported the improvement of plant growth, yield and nutrients uptake as the function of mycorrhizal inoculation (Akond *et al*., 2008, Ardakani *et al*., 2011, Abbasian *et al*., 2012).

But the combination treatment of NS, RP and VAM gave the highest total yield per plant and feddan comparing with other treatments especially the treatment which received RP + VAM + AF, this trend was true in both seasons.

This result due to the fungicide inhibits mycorrhiza growth and development because of the activity of methyl 1, 2-benzimidazole carbamate which is a product of benomyl hydrolysis (Carr and

Hinkley, 1985). Moreover, application of benomyl damages external hyphae of mycorrhiza and prevents root colonization; reducing water and nutrient uptake, photosynthesis and plant growth (Dodd and Jeffries, 1989).

The enhancing effect of NS as antifungal comparing with antifungi compounds used in this experiments, hence the VAM specie used in this experiment was not sensitive to NS (Abbasian *et al*., 2012).

Although, there were no significant differences between the treatments of compination of (NS. VAM and RP) and (SP and NS) on early and total yield per plant and feddan, but the addition of (RP + VAM) decreases manufacturing costs for producing SP as artificial fertilizer.

3- Head quality.

Data in Tables 4 indicate that the combination treatment of (RP, VAM and NS) gave the highest physical quality traits (Head diameter and length in early and late yield) with significant deference comparing with the control (SP + AF) in both seasons. But the lowest records of physical quality properties observed in treating with RP and AF in both seasons.

Table 4. Effect of calcium super phosphate or rock phosphate only or with inoculation by Vesicular Arbuscular Mycorrhizas (VAM) on early and late heads characteristics of globe artichoke which was treated with anti-fungai stumps or nano-silver, during 2010/2011 and 2011/2012 seasons.

Treatments	Early yield		Late yield	
	Head diameter (cm)	Head length (cm)	Head diameter (cm)	Head length (cm)
First season 2010/2011				
Calcium superphosphate + Anti-fungai (Control)	7.57 BC	11.50 A	6.57 C	11.03 B
Calcium superphosphate + Nano-silver	8.60 AB	12.17 A	7.68 B	12.00 A
Rock phosphate + Anti-fungai	7.13 C	11.33 A	6.13 D	10.62 C
Rock phosphate + Nano-silver	7.67 BC	11.00 A	6.69 C	11.00 B
Rock phosphate + Mycorrhaiza	8.53 AB	12.17 A	7.57 B	12.03 A
Rock phosphate + Mycorrhaiza + Anti-fungai	8.00 ABC	11.67 A	6.82 C	11.13 B
Rock phosphate + Mycorrhaiza + Nano-silver	9.10 A	12.23 A	8.27 A	11.89 A
Second season 2011/2012				
Calcium superphosphate + Anti-fungai (Control)	7.63 BC	11.83 A	6.77 B	11.20 CD
Calcium superphosphate + Nano-silver	9.10 AB	12.00 A	7.03 A	12.03 AB
Rock phosphate + Anti-fungai	7.43 C	11.17 A	6.37 B	10.97 D
Rock phosphate + Nano-silver	7.83 BC	11.50 A	7.74 B	11.49 BC
Rock phosphate + Mycorrhaiza	8.83 ABC	12.03 A	7.76 A	11.85 AB
Rock phosphate + Mycorrhaiza + Anti-fungai	7.80 BC	12.00 A	6.80 B	11.80 AB
Rock phosphate + Mycorrhaiza + Nano-silver	9.00 A	12.43 A	7.87 A	11.83 A

Means of the same column followed by the same letter were not significantly differed due to Duncan MRT at 5%.

Data presented in Table 5 show that plants supplied with RP, VAM and NS, improved average edible part fresh weight than the control (SP with AF). This trend was true in both seasons. Data also show that treatments received RP with VAM only or with VAM and AF came in the second rank followed by those received RP with AF or NS with significant differences in average head fresh weight and average edible part as a general trend in both seasons.

Data in Tables (6) indicate that the highest of inulin in edible parts was recorded by the treatments of (SP + NS) or (RP + NS + VAM) in both seasons with significant differences compared with other treatments in the early yield and recorded the lowest fiber content in the edible parts.

While, the highest fiber content was recorded in plants received RP and AF in both seasons with significant differences in comparing with other treatments in late yield only.

Treatments on head quality are connected with those effects on increasing vegetative growth plant growth (Table, 2). These results were in agreement with Ardakani *et al*. (2011), Nedorost and Pokluda (2012) and Abbasian *et al*. (2012).

Conclusion

Under such conditions it could be concluded that soil addition of Rock phosphate and inoculation with Vesicular Arbuscular Mycorrhizae (*Glomus mosseae*) during the growing season are recommended to increase the vegetative growth, early and total produced yield. Moreover, pre-planting treatment propagation material with Nano-silver is recommended to obtain the highest head flower yield of Globe artichoke with the best quality.

Table 5. Effect of calcium super phosphate or rock phosphate only or with inoculation by Vesicular Arbuscular Mycorrhizas (VAM) on early and late heads characteristics of globe artichoke which was treated with anti-fungai stumps or nano-silver, during 2010/2011 and 2011/2012 seasons.

Treatments	Early yield		Late yield	
	Average head fresh weight (g)	Average edible part fresh weight (g)	Average head fresh weight (g)	Average edible part fresh weight (g)
First season 2010/2011				
Calcium superphosphate + Anti-fungai (Control)	243.3 AB	59.0 B	238.3 A	45.5 D
Calcium superphosphate + Nano-silver	256.7 A	66.3 A	243.4 A	65.3 B
Rock phosphate + Anti-fungai	195.0 C	35.3 C	183.6 C	30.4 G
Rock phosphate + Nano-silver	199.0 BC	45.7 B	191.0 C	42.7 E
Rock phosphate + Mycorrhaiza	250.0 A	53.0 B	227.7 B	60.4 C
Rock phosphate + Mycorrhaiza + Anti-fungai	246.7 A	50.0 B	223.5 B	41.9 F
Rock phosphate + Mycorrhaiza + Nano-silver	276.7 A	73.3 A	251.5 A	70.6 A
Second season 2011/2012				
Calcium superphosphate + Anti-fungai (Control)	238.3 A	45.7 C	231.8 BC	43.6 D
Calcium superphosphate + Nano-silver	261.7 A	70.7 A	241.0 AB	69.4 B
Rock phosphate + Anti-fungai	190.6 B	35.3 D	182.9 D	29.6 E
Rock phosphate + Nano-silver	203.3 B	46.7 BC	190.0 D	44.3 D
Rock phosphate + Mycorrhaiza	246.7 A	60.0 B	228.3 C	59.2 C
Rock phosphate + Mycorrhaiza + Anti-fungai	241.7 A	51.7 BC	235.0 BC	44.4 D
Rock phosphate + Mycorrhaiza + Nano-silver	272.0 A	74.0 A	254.7 A	71.5 A

Means of the same column followed by the same letter were not significantly differed due to Duncan MRT at 5%.

Table 6. Effect of calcium super phosphate or rock phosphate only or with inoculation by Vesicular Arbuscular Mycorrhizas (VAM) on inulin and fiber of globe artichoke heads which was treated with anti-fungai stumps or nano-silver, during 2010/2011 and 2011/2012 seasons.

Treatments	Early yield		Late yield	
	Inuline %	Fiber contents (mg/g DW)	Inuline %	Fiber contents (mg/g DW)
First season 2010/2011				
Calcium superphosphate + Anti-fungai (Control)	1.63 B	4.48 ABC	1.40 AB	6.00 CD
Calcium superphosphate + Nano-silver	1.81 A	4.42 BC	1.42 AB	5.82 D
Rock phosphate + Anti-fungai	1.47 C	4.60 A	1.32 BC	8.27 A
Rock phosphate + Nano-silver	1.52 BC	4.57 AB	1.34 BC	7.30 B
Rock phosphate + Mycorrhaiza	1.58 BC	4.50 ABC	1.38 AB	5.90 CD
Rock phosphate + Mycorrhaiza + Anti-fungai	1.65 B	4.53 ABC	1.24 C	6.10 C
Rock phosphate + Mycorrhaiza + Nano-silver	1.88 A	4.38 C	1.50 A	5.83 D
Second season 2011/2012				
Calcium superphosphate + Anti-fungai (Control)	1.62 C	4.50 BC	1.32 BC	6.03 C
Calcium superphosphate + Nano-silver	1.83 AB	4.49 BC	1.43 AB	5.80 C
Rock phosphate + Anti-fungai	1.53 C	4.69 A	1.26 C	8.20 A
Rock phosphate + Nano-silver	1.57 C	4.57 ABC	1.34 ABC	7.38 B
Rock phosphate + Mycorrhaiza	1.59 C	4.58 AB	1.34 ABC	5.93 C
Rock phosphate + Mycorrhaiza + Anti-fungai	1.68 BC	4.50 BC	1.27 C	6.19 C
Rock phosphate + Mycorrhaiza + Nano-silver	1.90 A	4.42 C	1.49 A	5.85 C

Means of the same column followed by the same letter were not significantly differed due to Duncan MRT at 5%.

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أثر إستخدام جزيئات الفضة المتناهي الصغر وفطر الميكورهيزا على النمو والمحصول والجودة لنباتات الخرشوف

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أجريت تجربة حقلية في مزرعة الخضر بكلية الزراعة بمشتهر ، جامعة بنها ، محافظة القليوبيه، مصر خلال الموسمين 2011/2010 ، 2012/2011 على التوالي، لدراسة استجابة نباتات الخرشوف للتسميد الكيميائى بسوبر فوسفات الكالسيوم (15.5 % P_2O_5) أو المصدر الطبيعي للفوسفور (الصخر الفوسفاتى 27 ٪ P_2O_5) مع التلقيح بفطر الميكورهيزا (*Glomus mosseae*) ، ودراسة آثارها على النمو والمحصول و مكوناته وكذلك جودة النورة الزهرية (الجزء المأكول) لنبات الخرشوف (*Cynara scolymus* L.) الصنف الفرنساوى والتي تم معاملة تقاويها بالمضادات الفطرية أو جزيئات الفضة المتناهية الصغر.

وأظهرت النتائج أن استخدام صخر الفوسفات مع الميكورهيزا قد أدى إلى تحسن نمو النباتات و زيادة المحصول كما تحسنت جودة الجزء المأكول (النورة الزهرية) وذلك مقارنة بمعاملة الكنترول والتى أخذت نباتاتها سوبر فوسفات وعوملت تقاويها بالمضادات الفطرية. أيضا وجد أن تلقيح جذور النباتات بفطر الميكورهيزا قد أعطى نتائج جيدة مقارنة بعدم إستخدامه وذلك فى حالة المعاملة بصخر الفوسفات. كما وجد أن معاملة التقاوى بجزيئات الفضة المتناهية الصغر قبل الزراعة قد أعطت نتائج جيدة (في معظم الحالات) من حيث قوة النمو، وارتفاع المحصول وجودة النورات (الجزء المأكول) بالمقارنة مع معاملة التقاوى قبل الزراعة بالمبيدات الفطرية.

علاوة على ذلك فقد وجد أن التسميد بصخر الفوسفات مع التلقيح بفطر الميكورهيزا وإستخدام تقاوى معاملة بجزيئات الفضة المتناهية الصغر قد أعطى أعلى القيم وأدى إلى زيادة النمو و المحصول المبكر والكلي مع الحصول على أفضل نوعية للجزء المأكول وذلك مقارنة بجميع معاملات التجربة. وقد وصلت هذه الزيادة في المحصول نتيجة استخدام هذا المعاملة خاصة إلى 20.3 ، 18.6 % كمتوسط في كلا الموسمين للمحصول الكلي للنبات و الفدان على الترتيب وذلك مقارنة بمعاملة الكنترول (سوبر فوسفات + المضادات الفطرية).

<u>الكلمات الدالة</u>: نبات الخرشوف، فطر الميكوهيزا، جزيئات الفضة المتناهية الصفر ،المضادات الفطرية ، صخر الفوسفات ، السوبر فوسفات