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MINERAL PHOSPHATES, MYCORRHIZAE AND PHOSPHATE SOLUBILIZING BACTERIA IN RELATION TO GARLIC PLANT BEHAVIOR

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ABSTRACT

The effects of mineral phosphates, at rates of 0, 25, 50, 75 and 100% from the recommended superphosphate dose, mycorrhiza and phosphate solubilizing bacteria (phosphateine) on garlic behavior were studied during two successive growing seasons.

Plant height, fifth leaf length and width, bulb diameter, bulb, leaves, false stems, roots fresh weight, neck length and diameter and bulbing ratio positively responded to 50, 75 and 100% from the recommended P-dose, as 100% proved to be the best. Mycorrhizae and phosphateine showed similar positive effect.

Mineral phosphates, mycorrhizae and phosphateine increased P and K content in plant leaves. IAA, GA3, and Cytokinins also responded positively to the above mentioned treatments.

All studied treatments augmented bulbs yield, oil percentage in bulbs and reduced weight loss and emaciation percentage during storage.

The interaction between mineral phosphates on one side and mycorrhizae and phosphateine on the other side was studied.

INTRODUCTION

Garlic is a shallow-rooting crop, as it had some of the lowest-values of root length (Brewster,1997). This plant property is particularly important where the diffusion rate to individual roots limits the overall nutrient uptake rate. In soil, this diffusion barrier is normally important for phosphate (Baldwin,1995).

Phosphorus is one of the major essential macronutrients for biological growth and development

Helda and Reynaldo(1999). In spite of the considerable addition of phosphorus to soil, the amount of its available forms is usually low. The available phosphorus in the added fertilizer is rapidly transformed to tri calcium phosphate, thus, become unavailable for plants (Darweesh, 2002).

Thus, it is important to find out a way to increase available phosphorus in the soil. The most recommended ways are using phosphate solubilizing bacteria and mycorrhizae. Although several phosphate solubilizing bacteria occur in soil, usually their numbers are not high enough to compete with other bacteria commonly established in the rizosphere. Therefore, inoculation of plants by a target microorganism at much higher concentration than that normally found in the soil is necessary to take advantage of the property of phosphate solubilization for plant yield enhancement.

A complicating factor in our understanding of the response of garlic to soil phosphate is the possibility that the roots are infected with simbiotic micorrhizal fungi. It has been demonstrated that garlic so infected grow well than non-infected garlic (Hayman and Mosse, 1991). The ratio of surface to volume of the root plus micorrhizal system greatly exceeds that of the non-infected roots and the effect of infection on phosphate response is most simply explained in terms of diffusion to a larger absorbing surface (Sanders and Tinker, 1991).

The possibility of using some microbial treatments to facilitate the absorption of phosphates, in combination with mineral phosphates, by garlic is the aim of this study.

MATERIALS AND METHODS

These field trials were carried out in 2002/2003 and 2003/2004 seasons at the Experimental Farm of the Faculty of Agriculture, Minufiya University, using Chinees cultivar "Sun East" to study the effect of different mineral phosphates levels in combination with Vascular Mycorrhizal Fungi (VMF) and phosphateine (phosphate solubilizing bacteria) on plant growth, chemical constituents and bulbs yield. Weight loss in bulbs and emaciation during storage were also studied.

The experiments included 15 treatments which were five levels of mineral phosphates, i.e. 0, 25, 50, 75 and 100% from the recommended superphosphate dose which it is 300 Kg/fed. The microbial treatments were control, mycorrhizae and phosphateine.

A split-plot system in complete randomized blocks design with four replicates was used. The main plots were occupied by superphosphate levels while microbial treatments were distributed as sub-plots.

Each sub-plot contained four rows, 4 m. long and 0.70 m. width. Superphosphate levels were added onto the fields, one week prior cloves planting and mixed into the soil by a rake.

Cloves were planted on 1^{st} and 4^{th} October 2003 and 2004, respectively, on rows as spacing between plants within row was 15 cm. At 20 days from planting, microbial treatments were applied.

The VMF inoculum was applied at a rate of 4690 spores per 50 cm in the furrows and lightly covered with soil from the furrow through or during the day of planting. The VMF inoculum was added in furrows consisted of soil, root fragments and spores.

Phosphateine, commercial name in Egypt was taken from General Organization of Agriculture Equalization Fund, Ministry of Agriculture. It contains live cells of efficient bacteria strain (*Bacillus megaterium*) for dissolving phosphate in cultivated soil.

Phosphate solubilizing bacteria was added at the rate of 2 L/fed. The inoculum was putting besides planting cloves. The normal practices of growing garlic plants were followed.

At 119 days from planting, five plant samples, were undertaken from the two middle rows as plant height, fifth leaf length and width, fresh and dry weights of leaves, false stems, bulbs and roots, neck length and diameter, bulb diameter and bulbing ratio were determined.

N, P and K In leaves of garlic were determined using the methods of Bremner and Mulvaney (1982), Olsen and Sommers (1982) and Jackson (1972), respecting the order. The utilization quotient of N, P and K was calculated according to the equation of Loneragan and Asher (1967),

$$\textbf{Nutrient utilization quotient} = \frac{1}{N \chi D.\ wt}$$

Where N: nutrient concentration D. wt.: leaves dry weight

Samples were undertaken from the fifth leaf, the most physiological active leaf to determine GA, IAA, Cytokinin and ABA were determined using the method of Rademacher (1978).

At proper maturity stage of bulbs, 180 days after planting, bulbs in every plot were harvested and the average of bulb weight, number of cloves/bulb and total bulbs yield (Kg/fed.) were recorded.

Volatile oils in peeled cloves were determined according to Farag (1986) method.

For storage studies, samples of cured plants, i.e. 3 kg from each sub-plot was put in a palm crates and stored at normal room temperature for 20 weeks. Bulbs of each treatment were weighed at two weeks intervals, then the cumulative weight loss percentage was recorded.

At the 14, 16, 18 and 20 weeks in storage emaciation (empty cloves) was recorded based on visual examination.

Data were statistically analyzed according to Snedecor and Cochran (1980). The differences between treatment means were tested using L.S.D multiple range test.

RESULTS AND DISCUSION

1- Growth of garlic plants

Plant growth was evaluated as plant height, fifth leaf length and width, leaves, false stems, roots bulb fresh and dry weights (Table 1, 2 and 3), as well as neck length and diameter in addition to bulb diameter and bulbing ratio (Table 4).

1.1. Effect of mineral phosphates

Addition of mineral phosphates at 50, 75 and 100 % from the recommended dose gave superior records in all studied growth parameters compared to the control or 25% from the recommended dose. In this connection, the dose of 100% proved, in general, to be the best one .

Phosphorus was frequently reported to promote root growth and consequently may enhances nutrients absorption (Fontes, 1984), that finally could increase plant growth. Furthermore, phosphorus may affect photosynthesis and carbohydrates formation and translocation (Govind *et al.*,1989), thereby, it could increase plant organs dry weight as well as bulbs growth.

Another interpretation could be done as phosphorus stimulates plant metabolism (El-Shamma *et al.*, 2000), factor that positively reflected on plant growth.

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Furthermore, phosphates regulates many enzymatic processes, the phosphorylation of adenosine di-phosphate (ADP) to adenosine tri-phosphate (ATP), also phosphate acts as an activator of some enzymes, leading to enhancement of the metabolism processes and formation of new cells, consequently increasing the vegetative growth (Darweesh, 2002).

Results of Ghazi (2002) on garlic and Darweesh (2002) on tomato go along with the obtained ones, as they reported an increase in plant vegetative growth due to superphosphate addition. Another confirmation was reported by El-Melegy (2001), Ashok *et al.*, (2003),and Groot *et al.*,(2003) on tomato where superphosphate showed superior effect on plant growth.

1.2. Effect of phosphates solubilizing bacteria and micorrhizal treatments

Both micorrhizae and phosphateine significantly increased all studied growth parameters compared to the control (Tables 1,2,3). It is worthy mentioned that significant differences were generally noticed between the above mentioned treatments, although phosphateine was generally more effective. These results were insistently observed in both growing seasons.

Growth increases of micorrhizal inoculated plants may be a result of increasing photosynthesis intensity. The relation between micorrhizae and photosynthesis was also reported by Koch *et al.*, (1997) and El-Melegy (2001). Higher photosynthesis in micorrhizal plants has been also found by Johnson (1983) and Brown and Bethenfalvay (1987).

Further interpretation could be done as micorrhizae inoculation treatment caused a change in the endogenous levels of plant growth hormones, especially cytokinins. Druge and Schonbeck (1992) drawn similar conclusion.

Obtained results are in conformity with those of Ghazi (2002) on garlic, Darweesh (2002) on tomato and Mehmet and Kaydan. (2004) on beans.

As for the improving effect of phosphate solubilizing bacteria on plant growth, it could suggest that plant inoculation improved soil fertility and plant growth by releasing P-element. This interpretation was also done by Helda and Reynaldo (1999) and Mansour *et al.*, (2002) working on globe artichoke and Midan (2006) on pepper. Further interpretation could be done, as phosphate solubilizing bacteria release growth hormones as IAA, GA and cytokinins, which stimulate plant growth and dry matter accumulation. Similar conclusion was previously drawn by Darweesh (2002).

1.3. Effect of mineral phosphates and microbial treatments interactions

It is obviously clear that mineral phosphates at 50, 75 and 100% from the recommended P dose as interacted with mycorrhizae and solubilizing bacteria gave superior records in all studied growth indicators, although the highest phosphate dose, as interacted factor, caused the best results in both seasons (Tables 1,2.3). In this connection, plants received neither mineral phosphates nor microbial treatments showed the least growth parameter values. Ghazi (2002) confirmed our obtained results as he reported that garlic growth increased as soil-P level increased for micorrhizal inoculated plants.

An explanation could be done as adding mineral phosphates encouraged micorrhizal root colonization. Ghazi (2002), working on garlic, came to similar conclusion.

In confirmity with obtained results, Darweesh (2002) and Hewedy *et al.*, 2003) reported on beans that, combination between seed inoculation with phosphorein and 75% or 50% of the recommended-P dose significantly promoted plant dry weight and number of leaves per plant.

2- Bulbing ratio

2.1. Effect of mineral phosphates

Application of superphosphate at 75% and 100% from the recommended P-dose exhibited superior values of bulbing ratio comparing to the control, although that of 75% proved to be the best (Table 4). The dose of 25% and 50% in the first season and 25% in the second one gave the lowest values of this growth parameter.

Increasing bulbing ratio at the highest phosphate dose owe much to increasing bulb growth (Leonardo *et al.*, 2004).

2.2. Effect of phosphates solubilizing bacteria and micorrhizal treatments

Both microbial treatments increased, in general, bulbing ratio (Table 4) indicating the positive effect of increasing available phosphates on bulb growth. Similar conclusion was previously drawn by **Leonardo *et al.*, (2004).**

2.3. Effect of mineral phosphates and microbial treatments interaction

The highest value of bulbing ratio was generally noticed due to the application of 75% and 100% from the recommended P- dose as interacted with phosphateine treatment (Table 4). Again, results could be easily explained as increasing available P level increased bulbs growth and consequently enhanced bulbing ratio.

Plants had received no mineral phosphates, or received its lowest level, in interaction with no microbial inoculation showed, in general, the lowest bulbing ratio (Table 4). Results could be explained on the above mentioned base as the omission of phosphates depressed bulbs growth, that negatively reflected on bulbing ratio.

3- Nitrogen, phosphorous and potassium content

3.1. Effect of mineral phosphates

Increasing the dose of applied phosphates was associated with a linear reduction in N% in plant leaves, although an increase in P and K contents was noticed (Table 5).Results could be explained as phosphates application increased the absorbing efficiency of plant roots (Darweesh, 2002).

Increasing P_2O_5 level was also reported by Abou El-Magd *et al.*(1998), El-Meleigy (2001) and Abou El-Khair (2004) to increase P and K contents in garlic leaves. The reduction of N% owe much to the dilution effect of increasing growth.

3.2.Effect of phosphates solubilizing bacteria and mycorrhizal treatments

A reduction in N content was noticed due to both mycorrhizae and phosphate solubilizing bacteria, treatments that increased P and K% in both seasons (Table 5)

Such results are in accordance with those of Abou El-Khair (2004) who found that phosphorein significantly increased P and K in garlic leaves.

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Table (5): Effect of mineral phosphates, Micorrhizae and phosphateine application on nitrogen, phosphorus and potassium contents in garlic leaves .

Superphosphate (% from the recommended -P dose)	Microbial treatments	N %	P %	K %	N %	P %	K %
			2003			2004	
0	Micorrhizae	2.80	0.237	2.078	3.48	0.277	2.710
	phosphateine	2.65	0.284	1.913	3.30	0.289	2.00
	Control	2.95	0.234	1.748	3.00	0.250	1.885
	Means	2.80	0.250	1.913	3.26	0.272	2.198
25	Micorrhizae	2.65	0.270	2.550	3.37	0.285	2.770
	phosphateine	2.50	0.310	2.400	3.36	0.295	2.900
	Control	2.95	0.249	1.830	3.05	0.288	1.890
	Means	2.70	0.276	2.260	3.26	0.289	2.520
50	Micorrhizae	2.38	0.382	2.775	3.63	0.295	2.910
	phosphateine	2.30	0.409	2.625	3.63	0.300	2.960
	Control	2.65	0.316	1.913	3.20	0.300	1.900
	Means	2.44	0.369	2.438	3.49	0.298	2.59
75	Micorrhizae	2.38	0.385	2.850	3.79	0.325	3.040
	phosphateine	2.30	0.437	2.700	4.18	0.372	3.260
	Control	2.50	0.317	1.995	3.25	0.300	1.990
	Means	3.39	0.379	2.515	3.74	0.332	2.763
100	Micorrhizae	2.30	0.385	2.850	3.99	0.342	3.130
	phosphateine	2.23	0.473	2.700	4.03	0.348	3.300
	Control	2.45	0.325	2.078	3.65	0.308	2.940
	Means	2.33	0.394	2.543	3.89	0.333	3.123
L.S.D at 0.05 level							
	Phosph :	2.31	N. S.	N. S.	2.31	N. S.	N. S.
	Microb :	1.42	0.04	N. S.	1.42	0.03	N. S.
	PxM :	N. S.	N. S.	N. S.	N. S.	N. S.	N. S.

Mycorrhizae was also reported by El-Meleigy (2001) to increase P and K contents in tomato plant leaves. The increase in soil phosphate by mycorrhizal inoculated plant roots could be attributed to extensive hyphae in the soil which absorb and translocate phosphate to roots. Again, the reduction of N in plant leaves could be explained as a result of the dilution effect.

3.3 Effect of mineral phosphates and microbial treatments interaction

Plants received no mineral phosphates and that received 25% from the recommended P-dose showed the highest N% when neither mycorrhizae nor phosphateine were applied. In other words, the absence of phosphorus or its application at low dose increased N%. Phosphorus was previously discussed to depress N absorption, thus the above mentioned result appeared logic.

Besides, 75 and 100% from the recommended P-dose were interacted with phosphateine to produce the highest value of P and K%. Again, phosphates was previously mentioned to encourage P and K contents in plant leaves.

4- Nitrogen, phosphorus and potassium utilization quotient

4.1. Effect of mineral phosphates

Mineral phosphates increased the utilization quotient of N, P and K by garlic plants in both seasons (Table 6). This result go along with those of Hewedy *et al.,* (2003), who noticed that phosphates application increased the efficiency of nutrients utilization by tomato plants.

4.2. Effect of phosphates solubilizing bacteria and mycorrhizal treatment:

Results in (Table 6) show that mycorrhizae and phosphateine enhanced the values of N, P and K utilization quotient. Results could be explained as the applied treatments increased the available phosphorus, thereby it could increased nutrients efficiency. Hewedy et al (2003) came to similar results working on beans.

4.3.Effect of mineral phosphates and microbial treatments interaction

The interaction of 100% from the recommended P dose with phosphatiene caused the highest utilization quotient of N, P and K, indicating the role of phosphates application in promoting nutrients efficiency.

Besides the lowest values of N, P and K utilization quotient being obtained in plants received neither mineral phosphates nor microbial treatments.

Table (6) : Effect of mineral phosphates , Micorrhizae and phosphateine application on nitrogen, phosphorus and potassium utilization quotient of garlic plants .

Superphosphate(% from the recommended -P dose)	Microbial treatments	N %	P %	K %	N %	P %	K %
			2003			2004	
0	Micorrhizae	0.028	0.324	0.035	0.033	0.375	0.039
	phosphateine	0.028	0.326	0.034	0.035	0.433	0.044
	Control	0.025	0.273	0.030	0.028	0.320	0.030
	Means	0.027	0.308	0.033	0.032	0.376	0.038
25	Micorrhizae	0.030	0.350	0.035	0.033	0.380	0.040
	phosphateine	0.033	0.387	0.041	0.034	0.440	0.045
	Control	0.028	0.324	0.032	0.030	0.350	0.035
	Means	0.030	0.354	0.036	0.032	0.390	0.040
50	Micorrhizae	0.035	0.433	0.044	0.035	0.430	0.042
	phosphateine	0.036	0.450	0.043	0.038	0.450	0.045
	Control	0.030	0.333	0.031	0.032	0.362	0.039
	Means	0.034	0.405	0.039	0.035	0.414	0.042
75	Micorrhizae	0.035	0.433	0.044	0.036	0.450	0.043
	phosphateine	0.038	0.450	0.045	0.038	0.460	0.045
	Control	0.030	0.345	0.032	0.033	0.387	0.041
	Means	0.034	0.409	0.040	0.036	0.432	0.043
100	Micorrhizae	0.038	0.460	0.046	0.042	0.490	0.048
	phosphateine	0.040	0.488	0.049	0.045	0.495	0.050
	Control	0.035	0.433	0.039	0.040	0.485	0.045
	Means	0.038	0.460	0.045	0.042	0.490	0.048
L.S.D at 0.05 level							
	Phosph :	N. S.	0.01	0.005	0.003	0.03	0.002
	Microb :	1.42	0.016	0.004	0.003	0.014	0.004
	PxM :	N. S.	0.035	N. S.	N. S.	0.031	N. S.

5- Endogenous phytohormones content

5.1. Effect of mineral phosphates

Mineral phosphates application seemed to generally increased IAA, GA_3 and cytokinins contents in plant leaves of garlic (Table 7). On the other hand, phosphates application showed, in general, a negative effect on ABA, although significances were absent. Such obtained results are in conformity with those of Dhillon (1978) and Darweesh (2002) who reported that phosphorus can change the cytokinin level.

5.2. Effect of phosphates solubilizing bacteria and micorrhizal treatments

It is evident from such data (Table 7) that both micorrhizae and phosphateine exerted a positive effect on IAA, GA_3, cytokinins and ABA, although phosphateine showed the best results regarding its effect on the first three ones (Table 7).

Results could be explained as soil microorganisms release some phytohormones such as IAA, GA_3 and cytokinins.This interpretation was previously done by Darweesh (2002). Another explanation was done by Beguiristain *et al.* (2005) as micorrhizae inoculation stimulates tryptophan, the precursor of IAA.

5.3. Effect of mineral phosphates and microbial treatments interaction

A glimpse on the data of (Table 7) would show clearly that phosphateine with 100% and 50% from the recommended superphosphate dose showed respectively the highest values of IAA and GA_3. Phosphateine with 50% phosphates exerted superior ABA record. The highest value of cytokinin being obtained due to 75% from the recommended phosphate dose when added to plants received no microbial treatment indicating the importance of phosphorus in IAA, GA_3 and cytokinin synthesis (Darweesh, 2002). The least value of IAA was noticed in plants received no mineral phosphates with both micorrhizae and phosphateine treatments. Besides, control plants received 25% and 50% from the recommended P dose exhibited the lowest GA_3 record. However, zero phosphates with micorrhizae and 25% P with phosphateine attained the least cytokinin values. As for ABA contents, plants received no microbial treatments showed inferior ABA values irrespective applied P dose, indicating the importance of microbial treatments in the synthesis of ABA (Darweesh, 2002).

6- Yield and yield components

6.1. Effect of mineral phosphates

All levels of applied phosphates seemed to affect, in a positive manner, all studied yield components, although the highest phosphate level achieved the highest records in both seasons (Table 8).

Phosphorus was reported to promote photosynthesis and metabolic activities within plant (Druge and Schonbeck, 1992 and Groot *et al.*, 2003), thus its positive effect on bulbs growth became logic.

Similar increases in clove yields of garlic was also noticed by Leonardo *et al.*, (2004) due to mineral phosphates application.

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6.2. Effect of phosphates solubilizing bacteria and micorrhizal treatments

It is evident from data in (Table 8) that both studied ways of improving available phosphorus have a positive effect on total bulbs yield, average bulb fresh weight and number of cloves/bulb, although phosphateine showed the highest record of total bulbs yield where increases reached 8.08 % in the first season and 9.00 % in the second one, compared to the control. Micorrhizae gave superior record of bulbs fresh weight and number of cloves/bulb, since increases reached 8.74 % and 34.29 %, respectively in the first season and 9.88 % and 38.89 % in the second one, comparing to control.

Results could be easily explained as both treatments enhanced photosynthesis and carbohydrate accumulation in the storage organs, factors that positively reflected on bulbs yield.

In conformity with this suggestion, Druge and Schonbeck (1992) evidenced that increasing phosphorus availability increased photosynthesis intensity and positively affected bulbs yield. The relation between mycorrhizae and photosynthesis was also mentioned by Koch *et al.*, (1997) who noted that garlic plants colonized by VAM showed higher rates of photosynthesis than uncolonized plants.

Similar increases in garlic yield due to mycorrhizae inoculation were also reported by Koch *et al.*, (1997), Al-Karaki (2002) and Sari *et al.*, (2002).

6.3. Effect of mineral phosphates and microbial treatments interaction

The interaction of 100% from the recommended P-dose with phosphateine attained the highest total bulbs yield in both seasons. Meanwhile, the same mineral phosphate dose showed superior values of average bulb fresh weight and number of cloves/bulb as interacted with mycorrhizae inoculation. Results may be explained as increasing phosphate level by mean of mineral phosphate addition or the application of phosphate solubilizing bacteria or mycorrhizae led to further promoting of photosynthesis and increasing carbohydrate accumulation (Koch *et al.*, 1997), factors that positively reflected on bulbs yield.

7- Oil percentage in cloves

7.1. Effect of mineral phosphates

An increase in oil percentage in garlic cloves was noticed due to phosphate application at 50, 75 and 100% from the recommended P-dose, as the later two doses exhibited the best results in both seasons (Fig. 1).

Similar increases in volatile oils in garlic bulbs were also reported by Abou El-Khair (2004) due to P application, as the highest P dose showed the highest oil percentage.

7.2.Effect of phosphates solubilizing bacteria and micorrhizal treatments

Both ways of facilitating phosphorus seemed to increase oil percentage in cloves as the increases, respectively, reached 100 % and 186.67 % due to micorrhizae and phosphateine solubilizing bacteria compared to the control (Fig. 1).

The role of micorrhizae in increasing oil in garlic cloves may be explained as this treatment increased phosphorus availability. The relation between phosphorus and volatile oils was mentioned by Abou El-Khair (2004).

7.3. Effect of mineral phosphates and microbial treatments interaction

Mineral phosphates at 75% and 100% from the recommended P-dose was interacted with phosphateine to cause the highest oil percentage (fig. 1). The least oil percentage being obtained in plants received no mineral phosphates or that received 25% from the recommended P- dose when no microbial treatments were applied.

Results could be easily explained as increasing phosphate level through mineral addition or phosphateine enhanced oil synthesis as previously discussed (Abou El-Khair, 2004).

8- Weight loss during storage

8.1. Effect of mineral phosphates:

It is evident from data in (Table 9) that mineral phosphates application linearly reduced weight loss during storage, as the lowest loss was noticed due to the highest phosphate dose. This result was true in both growing seasons. Phosphates application reduced water content of bulbs, thereby it could reduce weight loss. Increasing water in garlic bulbs was also noticed by Abou El-Khair (2004) to increase water loss through evaporation and dry matter loss through respiration.

Obtained results are in accordance with those of El-Sheekh (1997), who reported that the highest level of P_2O_5 gave the lowest total weight loss percentage of onion bulbs compared to the other levels of phosphorus.

It is note worthy to mention here that weight loss increased with increasing storage period as the highest weight loss was noticed 20 weeks of storage. This result was confirmed by those of Abou El-Khair (2004).

8.2. Effect of phosphates solubilizing bacteria and micorrhizal treatments

Both ways of facilitating phosphorus absorption for garlic plants seemed to reduce weight loss of bulbs during storage as the least value was recorded due to phosphateine (Table 9). This result appeared true in both seasons. Again, phosphorus reduced water in bulbs and increased dry matter, thus the reduction of weight loss is reasonable.

8.3. Effect of mineral phosphates and microbial treatments interaction

At all assessing dates, plants received neither mineral phosphates nor microbial treatments showed, in general, the highest value of weight loss in bulbs during storage in both seasons (Table 9). However, the lowest weight loss was noticed in plants received 100% from the recommended P-dose in addition to phosphateine, indicating the role of phosphorus in reducing weight loss.

9- Emaciation percentage during storage

The emaciation percentage was assessed at the late weeks of storage, i.e the 14,16,18 and 20 weeks.

9.1. Effect of mineral phosphates

It is clearly evident that superphosphate application significantly reduced the emaciation percentage in stored garlic bulbs at both seasons (Fig. 2).

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In this connection, the highest emaciation percentage being obtained in control plants, as the least emaciation values were noticed due to the application of 100% from the recommended mineral phosphates dose. It is worthy mentioned that emaciation in garlic bulbs started at the 14^{th} weeks, then it linearly increased up to the 20^{th} week.

These results matched well with those of Abou El-Khair (2004) working on garlic.

9.2. Effect of phosphates solubilizing bacteria and micorrhizal treatments

Both microbial treatments seemed to reduce, in general, the emaciation percentage at all tested times of all both seasons (Fig. 2). Results may be explained as treatments increased the cloves swelling, thus emaciation appeared relatively small. Another interpretation could be done as both solubilizing bacteria and mycorrhizae increased phosphorus availability factor that reduced emaciation percentage.The role of phosphorus in reducing emaciation was noticed by Abou El-Khair (2004).

9.3. Effect of mineral phosphates and microbial treatments interaction:

Plants received 75% and 100% from the recommended P-dose, in combination with mycorrhizae or phosphateine showed the lowest emaciation percentage (Fig. 2). The highest emaciation percentage was noticed in plants received neither mineral phosphates nor microbial treatments. These results were generally observed in all tested storage dates.

Results could be explained, again, on the base of phosphorus role in reducing emaciation percentage.

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تأثر الفوسفات المعدني والميكروهيزا والبكتيريا الميسرة للفسفور علي نبات الثوم

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أجريت تجربة حقلية خلال موسمين ٢٠٠٣، ٢٠٠٤ بمزرعة كلية الزراعة – جامعة المنوفية بالستخدام صنف الثوم الصيني Sun East لدراسة تأثير استخدام الفوسفات المعدني بمعدل (صفر، ٢٥، ٥٠، ٧٥، ١٠٠%) من الكميات الموصي بها واستخدام الفوسفاتين (بكتيريا ميسرة للفسفور) وكذا الميكروهيزا علي النمو النباتي، المحتوي الكيماوي، محصول الأبصال، والفقد في وزن الأبصال وكذا التفريع أثناء التخزين.

أوضحت النتائج أن استخدام الفوسفات المعدني بمعدل ٥٠، ٧٥، ١٠٠% من الكميات الموصي بها وكذا ساتخدام الميكروهيزا والفوسفاتين كان لهم تأثير معنوياً علي طول النبات، طول وعرض الورقة الخامسة للنبات، قطر البصلة، الوزن الطازج والجاف للأبصال والأوراق والسيقان والجذور، طول وقطر العنق وكذا معدل التبصيل.

كما أوضحت التجارب أيضاً التأثير المعنوي لاستخدام الفوسفات المعدني، الميكروهيزا والفوسفاتين لزيادة محتوي الأوراق من النيتروجين والفوسفور والبوتاسيوم وكذا الهرمونات الداخلية للنبات مثل الأندول أستيك أسيد، الجبريلين، والسيتوكينين.

كما أظهرت المعاملات المستخدمة أيضاً تأثيراً معنوياً واضحاً علي المحصول ونسبة الزيت في الأبصال. أنقصت المعاملات من الفقد في الوزن والتفريع للفصوص أثناء التخزين. نوقشت كثير من التفاعلات بين العاملين تحت الدراسة.

Table (1) : Effect of mineral phosphates, Micorrhize and phoshpateine application on plant height, fifth leaf length and width of garlic plants.

Superphosphate	% from the recommended-P dose						% from the recommended-P dose					
Microbial treatments	**0**	**25**	**55**	**75**	**100**	**Means**	**0**	**25**	**50**	**75**	**100**	**Mean**
	2003					**Plant height (cm)**					**2004**	
Micorrhizae	65.44	70.44	72.11	70.44	71.54	69.99	67.44	72.43	74.58	73.23	73.87	72.31
phosphateine	68.78	73.78	68.40	69.52	70.23	70.14	70.94	76.12	72.80	71.57	74.70	73.23
Control	62.88	68.64	68.33	68.78	68.94	67.51	64.56	68.72	69.94	70.57	72.27	69.21
Means	65.70	70.95	69.61	69.58	70.24		67.65	72.42	72.44	71.79	73.61	
L.S.D at 0.05 level	Phosph :	1.42	Microb:	0.75	PxM:	1.68	Phosph:	0.62	Microb:	0.29	PxM:	0.64
						Fifth leaf length (cm)						
Micorrhizae	47.72	48.00	50.19	53.27	55.22	50.88	48.92	48.39	49.33	50.27	50.28	49.44
phosphateine	46.28	46.00	48.83	50.94	53.72	49.15	49.28	49.46	50.28	50.47	51.25	50.15
Control	43.83	44.90	46.77	48.75	50.49	50.55	46.19	46.96	47.20	48.65	49.37	47.67
Means	45.94	46.30	54.59	50.99	53.14		48.13	48.27	48.94	49.79	50.30	
L.S.D at 0.05 level	Phosph:	0.39	Microb :	0.44	PxM :	N. S.	Phosph:	0.35	Microb:	0.34	PxM:	0.77
						Fifth leaf width (cm)						
Micorrhizae	2.50	2.86	2.94	2.95	2.97	2.84	2.85	2.96	3.07	3.23	3.30	3.08
phosphateine	2.58	2.70	2.90	2.90	2.96	2.81	2.88	2.88	2.98	3.00	3.07	2.96
Control	1.96	1.96	1.97	2.00	2.00	1.98	1.85	1.93	1.98	2.17	2.37	2.06
Means	2.35	2.51	2.60	2.62	2.64		2.53	2.59	2.68	2.80	2.91	
L.S.D at 0.05 level	Phosph:	0.05	Microb:	0.04	PxM:	0.10	Phosph:	0.08	Microb:	0.07	PxM:	NS

Table (2) : Effect of mineral phosphates, Micorrhize and phoshpateine application on leaves and false stems fresh and dry weights of garlic plants.

Superphosphate	**% from the recommended-P dose**						**% from the recommended-P dose**					
Microbial treatments	**0**	**25**	**55**	**75**	**100**	**Means**	**0**	**25**	**50**	**75**	**100**	**Mean**
				2003		**Leaves fresh weight (gm/plant)**				**2004**		
Micorrhizae	41.00	41.72	45.05	45.08	45.79	43.73	42.17	42.75	45.40	42.13	43.47	43.18
phosphateine	41.03	42.38	44.40	43.52	44.04	43.07	42.03	43.62	43.50	43.20	44.23	43.32
Control	37.27	38.03	41.83	42.08	43.78	40.59	38.53	38.47	42.38	42.81	43.00	41.04
Means	39.77	40.71	43.76	43.56	44.54		40.91	41.61	43.76	42.71	43.57	
L.S.D at 0.05 level	Phosph:	0.35	Microb:	0.32	PxM:	0.72	Phosph:	N. S.	Microb:	N. S.	PxM:	N. S.
						Leaves dry weight (gm/plant)						
Micorrhizae	3.12	3.15	5.44	5.09	5.56	4.47	3.19	3.91	5.56	5.18	5.35	4.64
phosphateine	4.28	4.77	5.88	5.68	5.95	5.31	4.50	4.36	5.95	5.67	5.77	5.25
Control	2.61	2.72	4.14	4.27	7.74	3.69	2.42	2.29	4.25	4.27	5.00	3.64
Means	3.34	3.55	5.15	5.01	5.42		3.37	3.52	5.25	5.04	5.37	
L.S.D at 0.05 level	Phosph:	0.097	Microb:	0.08	PxM:	0.17	Phosph:	0.21	Microb:	0.10	PxM:	0.21
						False stems fresh weight (gm/plant)						
Micorrhizae	8.32	8.54	8.89	9.37	9.67	8.96	7.10	7.23	8.88	9.07	9.50	8.36
phosphateine	8.51	8.66	8.85	8.98	9.46	8.89	7.47	7.65	8.78	9.42	9.18	8.50
Control	6.13	6.33	6.89	7.46	7.82	6.93	5.32	5.55	6.22	7.23	7.75	6.41
Means	7.65	7.84	8.21	8.60	8.98		6.63	6.81	7.96	8.57	8.81	
L.S.D at 0.05 level	Phosph: ::	0.31	Microb:	0.15	PxM:	0.34	Phosph:	0.14	Microb:	0.15	PxM:	0.35
						False stems dry weight (gm/plant)						
Micorrhizae	0.82	0.83	0.96	1.15	1.22	0.99	0.62	0.66	0.98	1.05	1.10	0.88
phosphateine	0.82	0.95	0.97	1.15	1.22	1.02	0.63	0.75	0.98	1.11	1.13	0.92
Control	0.65	0.65	0.77	0.88	0.98	0.79	0.60	0.64	0.73	0.89	0.97	0.77
Means	0.76	0.81	0.90	1.06	1.14		0.62	0.68	0.89	1.02	1.07	
L.S.D at 0.05 level	Phosph:	0.02	Microb:	0.01	PxM:	0.03	Phosph:	0.01	Microb:	0.02	PxM:	0.04

Table (4) : Effect of mineral phosphates , Micorrhizae and phosphateine application on neck length and diameter, bulb diameter and bulbing ratio of garlic plants .

Superphosphate / Microbial treatments	% from the recommended-P dose						% from the recommended-P dose					
	0	**25**	**55**	**75**	**100**	**Means**	**0**	**25**	**50**	**75**	**100**	**Mean**
			2003			**Neck length (cm)**				**2004**		
Micorrhizae	7.33	7.67	9.00	8.00	8.33	8.07	8.00	9.00	10.00	9.00	9.00	9.00
phosphateine	7.00	7.67	9.67	8.33	8.67	8.27	8.00	9.00	11.00	9.00	9.00	9.20
Control	5.00	6.55	7.18	7.00	7.48	6.64	6.00	7.00	8.00	8.00	7.00	7.40
Means	6.44	7.29	8.62	7.78	8.16		7.33	8.33	9.67	8.67	8.67	
L.S.D at 0.05 level	Phosph:	0.95	Microb:	0.48	PxM:	N. S.	Phosph:	0.63	Microb:	0.76	PxM:	N. S.
						Neck diameter (cm)						
Micorrhizae	1.13	1.47	1.97	1.77	1.93	1.65	2.15	2.50	3.00	2.80	2.90	2.67
phosphateine	1.13	1.57	2.36	1.77	2.13	1.79	2.15	2.50	4.00	2.85	2.95	2.89
Control	1.07	1.13	1.57	1.53	1.73	1.41	2.00	2.20	2.50	2.50	2.70	2.38
Means	1.11	1.39	1.97	1.69	1.93		2.10	2.40	3.17	2.72	2.85	
L.S.D at 0.05 level	Phosph:	0.08	Microb:	0.07	PxM:	0.16	Phosph:	0.48	Microb:	0.25	PxM:	NS
						Bulb diameter (cm)						
Micorrhizae	1.80	1.90	3.17	2.94	2.98	2.56	1.70	1.87	2.90	2.88	2.87	2.44
phosphateine	1.80	1.83	3.30	3.00	3.13	2.61	1.70	1.83	2.87	2.90	2.90	2.44
Control	1.40	1.43	2.40	2.50	2.40	2.03	1.30	1.33	2.10	2.17	2.27	1.83
Means	1.67	1.72	2.96	2.81	2.84		1.57	1.68	2.62	2.65	2.68	
L.S.D at 0.05 level	Phosph:	0.16	Microb:	0.05	PxM:	0.12	Phosph:	0.12	Microb:	0.07	PxM:	0.15
						Bulbing ratio (cm)						
Micorrhizae	1.59	1.36	1.59	1.63	1.57	1.55	0.62	0.66	0.98	1.05	1.10	0.88
phosphateine	1.59	1.22	1.10	1.67	1.65	1.45	0.63	0.75	0.98	1.11	1.13	0.92
Control	1.40	1.19	1.60	1.67	1.41	1.45	0.60	0.64	0.73	0.89	0.97	0.77
Means	1.53	1.26	1.43	1.66	1.54		0.62	0.68	0.89	1.02	1.07	
L.S.D at 0.05 level	Phosph:	N. S.	Microb:	N. S.	PxM:	N. S.	Phosph:	0.03	Microb:	0.03	PxM:	0.08

Table (3): effect of mineral phosphates , Micorrhizae and phosphateine application on roots and bulbs fresh and dry weights of garlic plants .

Superphosphate / Microbial treatments	% from the recommended-P dose						% from the recommended-P dose					
	0	**25**	**55**	**75**	**100**	**Means**	**0**	**25**	**50**	**75**	**100**	**Mean**
		2003				**Neck length (cm)**				**2004**		
Micorrhizae	7.33	7.67	9.00	8.00	8.33	8.07	8.00	9.00	10.00	9.00	9.00	9.00
phosphateine	7.00	7.67	9.67	8.33	8.67	8.27	8.00	9.00	11.00	9.00	9.00	9.20
Control	5.00	6.55	7.18	7.00	7.48	6.64	6.00	7.00	8.00	8.00	7.00	7.40
Means	6.44	7.29	8.62	7.78	8.16		7.33	8.33	9.67	8.67	8.67	
L.S.D at 0.05 level	Phosph:	0.95	Microb:	0.48	PxM:	N. S.	Phosph:	0.63	Microb:	0.76	PxM:	N. S.
						Neck diameter (cm)						
Micorrhizae	1.13	1.47	1.97	1.77	1.93	1.65	2.15	2.50	3.00	2.80	2.90	2.67
phosphateine	1.13	1.57	2.36	1.77	2.13	1.79	2.15	2.50	4.00	2.85	2.95	2.89
Control	1.07	1.13	1.57	1.53	1.73	1.41	2.00	2.20	2.50	2.50	2.70	2.38
Means	1.11	1.39	1.97	1.69	1.93		2.10	2.40	3.17	2.72	2.85	
L.S.D at 0.05 level	Phosph:	0.08	Microb:	0.07	PxM:	0.16	Phosph:	0.48	Microb:	0.25	PxM:	NS
						Bulb diameter (cm)						
Micorrhizae	1.80	1.90	3.17	2.94	2.98	2.56	1.70	1.87	2.90	2.88	2.87	2.44
phosphateine	1.80	1.83	3.30	3.00	3.13	2.61	1.70	1.83	2.87	2.90	2.90	2.44
Control	1.40	1.43	2.40	2.50	2.40	2.03	1.30	1.33	2.10	2.17	2.27	1.83
Means	1.67	1.72	2.96	2.81	2.84		1.57	1.68	2.62	2.65	2.68	
L.S.D at 0.05 level	Phosph:	0.16	Microb:	0.05	PxM:	0.12	Phosph:	0.12	Microb:	0.07	PxM:	0.15
						Bulbing ratio (cm)						
Micorrhizae	1.59	1.36	1.59	1.63	1.57	1.55	0.62	0.66	0.98	1.05	1.10	0.88
phosphateine	1.59	1.22	1.10	1.67	1.65	1.45	0.63	0.75	0.98	1.11	1.13	0.92
Control	1.40	1.19	1.60	1.67	1.41	1.45	0.60	0.64	0.73	0.89	0.97	0.77
Means	1.53	1.26	1.43	1.66	1.54		0.62	0.68	0.89	1.02	1.07	
L.S.D at 0.05 level	Phosph:	N. S.	Microb:	N. S.	PxM:	N. S.	Phosph:	0.03	Microb:	0.03	PxM:	0.08

Table (7) : Effect of mineral phosphates , Micorrhizae and phosphateine application on some phytohormones content in garlic leaves .

Superphosphate / Microbial treatments	% from the recommended-P dose						% from the recommended-P dose					
	0 %	**25 %**	**50 %**	**75 %**	**100 %**	**Mean**	**0 %**	**25 %**	**50 %**	**75 %**	**100 %**	**Mean**
	IAA (mg/100g)						**GA_3 (mg/100g)**					
Micorrhizae	120.48	123.33	119.07	123.30	123.10	121.86	62.60	63.07	62.47	63.43	62.07	62.73
phosphateine	120.57	125.50	123.83	121.77	124.97	123.33	61.97	64.57	65.00	62.77	61.83	63.23
Control	121.43	123.77	123.03	122.36	123.01	122.72	61.87	59.83	60.30	64.07	61.27	61.47
Means	120.83	124.20	121.98	122.48	123.69		62.15	62.49	62.59	63.42	61.72	
L.S.D at 0.05 level	Phosph:	N. S.	Microb:	N. S.	PxM:	N. S.	Phosph:	N. S.	Microb:	1.22	PxM:	N. S.
	Cytokinin (mg/100g)						**ABA (mg/100g)**					
Micorrhizae	179.67	187.43	183.34	184.33	181.70	183.29	14.50	13.70	14.14	12.53	12.33	13.44
phosphateine	189.13	179.67	182.30	184.63	180.00	181.35	12.87	12.40	15.00	11.77	12.90	12.99
Control	206.37	216.77	221.80	269.10	240.13	230.83	7.00	7.53	6.67	6.87	8.61	7.34
Means	188.72	194.62	195.81	212.69	200.61		11.46	11.21	11.94	10.39	11.28	
L.S.D at 0.05 level	Phosph:	3.53	Microb:	2.96	PxM:	6.62	Phosph:	1.01	Microb:	0.84	PxM:	1.87

Table (8) : Effect of mineral phosphates , Micorrhizae and phosphateine application on number of cloves / bulb, weight of bulb (gm) and total bulbs yield (kg / fed.) of garlic plants .

Superphosphate / Microbial treatments	% from the recommended-P dose						% from the recommended-P dose					
	0	**25**	**50**	**75**	**100**	**Mean**	**0**	**25**	**50**	**75**	**100**	**Mean**
			2003		**Number of cloves / bulb**			**2004**				
Micorrhizae	18	18	18	20	20	18	15	16	18	25	26	20
phosphateine	15	16	16	16	17	16	12	16	16	26	28	19
Control	13	13	14	15	15	14	10	12	14	18	18	14
Means	15	15	16	17	17		12	14	16	23	24	
L.S.D at 0.05 level	Phosph:	N. S.	Microb:	1.45	PxM:	N. S.	Phosph:	1.38	Micorr:	0.84	PxM:	1.88
	Weight of bulb (gm / bulb)											
Micorrhizae	48.89	84.40	86.73	90.67	91.32	80.40	51.60	89.10	91.80	95.20	100.00	85.54
phosphateine	42.51	80.70	83.90	85.42	89.48	76.42	45.90	83.80	85.50	88.50	95.50	79.84
Control	41.00	77.42	81.10	84.17	86.00	73.94	41.30	82.72	84.17	86.32	94.72	77.85
Means	44.13	80.87	83.91	86.75	88.93		46.27	85.21	87.16	90.01	96.74	
L.S.D at 0.05 level	Phosph:	3.53	Microb:	1.74	PxM:	N. S.	Phosph:	11.71	Microb:	N. S.	PxM:	N. S.
	Total yield (kg / fed)											
Micorrhizae	4300	5300	6400	7500	7580	6216	4350	5370	6450	7550	7600	6264
phosphateine	4400	5400	6500	7550	7600	6290	4450	5470	6550	7600	7650	6344
Control	4000	5000	6000	7000	7100	5820	4000	5000	6000	7000	7100	5820
Means	4233	5233	6300	7350	7426		4266	5280	6333	7383	7383	
L.S.D at 0.05 level	Phosph:	0.62	Microb:	0.36	PxM:	N. S.	Phosph:	N. S.	Microb:	0.41	PxM:	N. S.