Available online: www.notulaebotanicae.ro
Print ISSN 0255-965X; Electronic 1842-4309
Not Bot Horti Agrobo, 2014, 42(1):138-142

AcademicPres

Notulae Botanicae Horti Agrobotanici Cluj-Napoca

Effect of Zinc and *Glomus intraradices* on Control of *Pythium deliense*, Plant Growth Parameters and Nutrient Concentrations of Cucumber

Zeliha KÜÇÜKYUMUK[1]*, Hülya ÖZGÖNEN[2], İbrahim ERDAL[1], Figen ERASLAN[1]

[1]*Department of Soil Science and Plant Nutrition, Agricultural Faculty, Suleyman Demirel University, 32260, Isparta, Turkey; zelihakucukyumuk@sdu.edu.tr (*corresponding author)*
[2]*Department of Plant Protection, Agricultural Faculty, Suleyman Demirel University, 32260, Isparta, Turkey*

Abstract

Three levels of zinc fertilization (0, 5, 10 mg/kg) and an arbuscular mycorrhizal (AM) fungus *Glomus intraradices* were tested for their potential to control *Pythium deliense* on inoculated cucumber seedlings. Plant Zn, N, P, K, Mg, Ca, Fe, Mn, Cu contents, dry and fresh weights of plant and roots and disease severity were determined in the study. Resistance to Pythium rot was determined with the application of mycorrhiza with increasing doses of zinc. Zinc and mycorrhizal fungus applications had significant effects on plant nutrition except for K and Cu. While the highest N and P concentrations were noted under Zn_0 conditions, the values obtained under Zn_1 and Zn_2 conditions showed differences depending on *G. intraradices* and *P. deliense* treatments. Leaf Ca concentration reached up to highest level with $Zn_2GI_0Pd_1$ treatment and the lowest Ca content was recorded under GI_0Pd_0 for all Zn applications. Lower level of zinc together with $GIPd_0$ applications resulted in the highest leaf Mg concentration. The highest micronutrient concentrations were analysed on cucumber plants grown under Zn deficient conditions without GI but with *P. deliense.* Plant dry weight, root fresh and root dry weights were higher in cucumber plants challenged with AM fungus and *P. deliense* under zinc applied conditions. It was observed that certain rates of zinc and mycorrhiza based-treatments had positive effects on disease factors by suppressing Pythium rot and can be used for biological control.

Keywords: cucumber, *Glomus sp*., mycorrhiza, *Pythium sp*., zinc

Introduction

Pythium rot disease caused by *Pythium deliense* is one of the important diseases causing seedling losses after planting in vegetable crops. To solve this problem the use of zinc and mycorrhiza comes up.

Plant mineral nutrition level effects on the degree of disease factors. Especially, the micro nutrients decrease pathogen cell penetration and infection by affecting the cell wall rigidity and also the structural integrity of membranes as well as by their direct toxic effects to the pathogen (Marschner, 1995). Plants zinc nutrition and application of zinc with mycorrhiza had positive effects against diseases. Pythium seedling rot (*Pythium* sp.) is the most important diseases in vegetable seedlings.

Arbuscular mycorrhizal (AM) fungi were reported to be effective in controlling plant diseases (Agrios, 1997). Mycorrhizae are able to increase nutrient uptake in plants and to affect their development and were found to be effective against many fungal diseases (Marschner and Dell, 1994).

The disease severity reducing effects induced by mycorrhiza were reported in various pathosystems such as peanut - *Sclerotium rolfsii*, eggplant - *Verticillium dahlie*, tomato - *Phytophthora nicotianae* var. *parasitica*, pea-*Rhizoctonia solani*, tomato - *Fusarium oxysporum* f. sp. *lycopersici and F. oxysporum* f. sp. *radicis-lycopersici*, and pepper - *Phytophthora capsici* (Krishna and Bagyaraj, 1983; Caron *et al*., 1986; Matsubara *et al*., 1995; Trotta *et al*., 1996; Karagiannidis *et al*., 2002; Akküprü and Demir, 2006; Özgönen and Erkılıç, 2007).

Zinc has direct effect on fungal growth and secondary metabolism and indirect effects on host susceptibility (Duffy, 2009). Zinc-sufficient plants have been found to be more tolerant to root infection by Fusarium wilt than Zn-deficient plants (Marschner, 1995; Streeter *et al*., 2001). This probably results from the fungitoxicity of Zn and the role of Zn in stabilizing the membranes of root cells (Marschner, 1995).

In view of the role of zinc in both generation and detoxification of oxygen radicals and hydrogen peroxide, plant resistance was reported to be markedly influenced by mineral nutrition during host plant-pathogen interactions (Marschner, 1995).

The resistance of plants to diseases is closely related to the nutrition levels. The deficiency of mineral elements influences the growth of the plant and can cause disease (Cai *et al*., 2007).

There are some reports on zinc effect in controlling plant disease. In fact, *Fusarium solani* and *Rhizoctania solani* were reduced by increasing soil concentrations of zinc from 0 to 1.6 mg/kg (Siddiqui *et al*., 2002). The potential of zinc in reducing disease severity has been signalled in various fungal diseases as is the case of Charcoal rot disease of maize caused by *Macrophomina phaseolina*, potato powdery scab, *Mycosphaeralla pinodes* and *Phoma medicaginis* in bean, *Rhizoctania* root rot of cowpea, alfalfa root rot, corn smut, Fusarium root rot of wheat (Braithwaite *et al*., 1994; Kostandi *et al*., 1997; Pareek and Pareek, 1999; Davidson and Ramsey, 2000; Grewal, 2001; Kalim *et al*., 2003; Khoshgoftarmanesh *et al*., 2010).

In a previous study, zinc and mycorrhiza were successfully used for the control of Phytophthora Blight of pepper. In fact, *Phytophothora capsici* infection and disease severity were reduced by individual or combined applications of Zn and AM fungus. These treatments also led to an increase in plant yield and nutrient concentration (Küçükyumuk *et al*., 2013).

This study aimed to determine the effects of zinc and *mycorrhiza* on control of *Pythium deliense,* plant yield and mineral nutrient uptakes on cucumber plants.

Materials and methods

Cucumber (*Cucumis sativus* L.) cv. Silyon F1 was used as plant material. *Glomus intraradices* (GI) used as mycorrhizal inoculant produced on maize (*Zea mays* L.) (Harley and Smith, 1983). *Pythium deliense* (Pd) was isolated from naturally infected cucumber plants which showed post-emergence damping-off symptoms on corn meal agar (CMA) at 25 °C for 7 days. The soil mixture including soil: sand: pumice (1:1:1; v: v: v) was sterilized at 121 °C and 1 KPa two times for 1 hour. Plants were grown for 9 weeks in pots under greenhouse conditions with inoculation of *G. intraradices* at 1000 spores 10 g^{-1} soil and Zn fertilization was applied at three rates (0, 5 and 10 mg Zn kg^{-1} soil as $ZnSO_4$). *P. deliense* was inoculated 4 weeks after planting. For inoculation, Pd was cultured on CMA at 25 °C for 7 days and then cultures were added sterile distilled water and incubated at 4 °C for 30 min to induce zoospore release. Later, 10 ml at the concentration of 10^6 zoospore ml^{-1} were applied to each pot. In the experiment, there were 12 treatments in total with 8 replicates, giving a total of 96 pots in a completely randomized block design. The experimental soil was loam having pH 7.8 (1:2.5 water); $CaCO_3$ 17%; organic matter 1.5% (Jackson, 1973); 0.5 M $NaHCO_3^-$ extractable P 30 kg ha^{-1}; NH_4OAC-exchangeable K 550 kg ha^{-1} (Olsen *et al*., 1954; Knudsen *et al*., 1982); DTPA-extractable Zn 0.7 mg kg^{-1}(Lindsay and Norvell, 1978). As basal fertilization, 200, 120 and 150 mg kg^{-1} N, P and K was given to the pots as NH_4NO_3 and KH_2PO_4, respectively. For Zn fertilization, a stock solution was prepared using as $ZnSO_4.7H_2O$ given to the soil and mixed together with other fertilizers.

Plant samples were harvested 9 weeks after planting and the fresh weight of the above ground part of the plants was recorded. At first, samples were washed thoroughly with tap water and distilled water then they were kept at 65 ± 5 °C until stable weights reached. Finally, dry weights of plants were measured. After this, samples were grounded for nutrient analysis. In order to determine P, K, Ca, Mg, Fe, Zn and Mn concentrations, 0.4 g of grounded samples were wet digested at 180 °C for 15 min in microwave (CEM Mars X-press) and digestives were filled up with 50 ml with pure water. Phosphorus concentrations were determined by vanadate-molybdate colorimetric method. Zinc, K, Ca, Mg, Fe and Mn concentrations were determined using atomic absorption spectrophotometer as described by Kacar and İnal (2008). For fresh and dry weight measurement, shoots were separated from roots. The roots were washed with tap water and washed roots were left on two layers of filter paper to remove excess water. The roots in each treatment were weighed to determine fresh weight and then dried at 65°C to determine dry weight.

Disease severity was determined using 0-4 scale where 0 = healthy plant; 1 = 1-25% diseased of whole plant; 2 = 26-50% diseased plant; 3 = 51-75% diseased plant; 4 = 76-100% diseased plant (Zhang *et al.,* 1996). Disease severity and index values were calculated from scale values. In addition, the impact ratios were calculated according to the Abbot formula. Differences between treatments were analyzed by multiple comparison tests LSD (P = 0.01) using variance analyses to the results.

Results and discussion

Effect of zinc and *G. intraradices* on the dry weight of the above ground plant part was given in Tab. 1. As shown in this table, this parameter varied significantly depending on the treatments tested. Comparing to control conditions ($Zn_0GI_0Pd_0$) (1.49 g) dry weight of plants increased with zinc applications. The dry weight of plants inoculated with *P. deliense* was 0.64 g. Cucumber plants inoculated with *P. deliense* and treated with zinc and *G. intraradices* showed the highest records of dry weight (3.8 g).

Tab. 1. The effect of different zinc rates and *Glomus intraradices* applications above ground part of plant dry weight and root fresh and dry weight in cucumber

Applications		Plant dry weight (g)	Root fresh weight (g)	Root dry weight (g)
Zn_0	GI_0Pd_0	1.49 d	0.65 c	0.07 b
	GI_0Pd_1	0.64 e	0.13 d	0.03 c
	GI_1Pd_0	1.75 cd	0.85 bc	0.10 b
	GI_1Pd_1	1.76 cd	0.86 bc	0.08 b
Zn_1	GI_0Pd_0	1.66 cd	0.75 bc	0.08 b
	GI_0Pd_1	2.56 b	1.17 bc	0.09 b
	GI_1Pd_0	1.79 cd	0.87 bc	0.09 b
	GI_1Pd_1	3.8 a	1.68 a	0.17 a
Zn_2	GI_0Pd_0	2.06 c	0.87 bc	0.09 b
	GI_0Pd_1	3.15 b	1.27 ab	0.15 a
	GI_1Pd_0	2.11 c	0.87 bc	0.09 b
	GI_1Pd_1	3.8 a	1.70 a	0.17 a

For each column, means followed by the same letter are not significantly different according to LSD test (P = 0.05)

Effects of zinc and *G. intraradices* on cucumber root fresh and dry weights were given in Tab. 1. The results obtained revealed that the root fresh and dry weights varied significantly depending on the factors tested. In fact, results of fresh and dry weight of roots had a similar trend. Cucumber plants inoculated with *P. deliense* showed the lowest root fresh (0.13 g) and dry weights (0.03 g). Those inoculated with the pathogen and treated with zinc and *G. intraradices* presented the highest root fresh (1.7 g) and dry weights (0.17 g).

Effect of pathogen, zinc concentrations and *G. intraradices* on Zn contents in cucumber plants were given in Tab. 2. In fact, plants inoculated with *P. deliense* and treated with Zinc rates and *G. intraradices* showed significant variation in their zinc contents. This parameter was 42 mg kg^{-1} in control conditions, 46 mg kg^{-1} with Zn_1 application and 53 mg kg^{-1} with Zn_2 application.

According to control conditions, plant zinc content increased with the application of *G. intraradices*. As shown in Tab. 2, plants inoculated with *P. deliense* (73 mg kg^{-1}) had the highest zinc concentrations. Zn_2 application (53 mg kg^{-1}) had higher zinc concentrations compared to Zn_1 (46 mg kg^{-1}) applications.

As indicated in Tab. 2, copper concentrations did not vary significantly on different zinc rates and mycorrhizal applications tested. Plant contents ranged between 30 and 56 mg kg^{-1}.

Iron (Fe) and manganese (Mn) contents varied significantly depending on inoculation with pathogen, zinc rates and mycorrhizal applications. With zinc application, plants inoculated with *P. deliense* showed increased iron concentrations as compared to control (153 mg kg^{-1}) plants. *P. deliense* inoculated plants had the highest (314 mg kg^{-1}) iron concentrations. Mn concentrations shown in Tab. 2 were also significantly different depending on treatments tested. This parameter varied from 443 mg kg^{-1} in control plants whereas with zinc application, plant Mn concentrations were 483 and 488 mg kg^{-1} and they were in the same statistical group.

Tab. 2. The effect of different zinc rates and *Glomus intraradices* applications on Zn, Fe, Mn and Cu concentrations in cucumber plants

Applications		Zn (mg/kg)	Fe(mg/kg)	Mn (mg/kg)	Cu (mg/kg)
Zn_0	GI_0Pd_0	42 b*	153 b	443 ab	34 a
	GI_0Pd_1	73 a	314 a	534 ab	56 a
	GI_1Pd_0	40b	155 b	400 b	30 a
	GI_1Pd_1	43 b	195 ab	529 ab	34 a
Zn_1	GI_0Pd_0	46 b	164 b	483 ab	34 a
	GI_0Pd_1	50 ab	200 ab	492 ab	35 a
	GI_1Pd_0	47 ab	211 ab	500 ab	34 a
	GI_1Pd_1	50 ab	184 b	547 ab	36 a
Zn_2	GI_0Pd_0	53 ab	155 b	488 ab	34 a
	GI_0Pd_1	56 ab	186 b	575 a	35 a
	GI_1Pd_0	55 ab	190 b	548 ab	30 a
	GI_1Pd_1	55 ab	201 ab	605 a	32 a

*For each column, means followed by the same letter are not significantly different according to LSD test (P = 0.05)

Tab. 3 indicates that nitrogen and phosphorus concentrations of plants were significantly affected by the treatments tested while for potassium concentrations, no significant effect of different zinc doses and *G. intraradices* applications was recorded. Compared to control conditions, nitrogen concentrations were not affected by zinc sulphate applications. Nitrogen concentrations of host plants decreased according to control conditions. Plants inoculated with *P. deliense* and treated with Zn_2 applications showed the lowest nitrogen (4.21%) concentrations whereas their treatment with the mycorrhizal fungi led to highest nitrogen (4.65%) content.

Tab. 3. The effect of different zinc rates and *Glomus intraradices* applications on N, P and K concentrations

Applications		N (%)	P (%)	K (%)
Zn_0	GI_0Pd_0	4.34 bc*	0.43 b	5.0 a
	GI_0Pd_1	4.31 bc	0.89 a	5.5 a
	GI_1Pd_0	4.65 a	0.42 b	5.3 a
	GI_1Pd_1	4.54 ab	0.54 ab	5.1 a
Zn_1	GI_0Pd_0	4.31 bc	0.21 b	5.9 a
	GI_0Pd_1	4.37 abc	0.38 b	5.2 a
	GI_1Pd_0	4.49 abc	0.57 ab	5.1 a
	GI_1Pd_1	4.23 c	0.38 b	5.4 a
Zn_2	GI_0Pd_0	4.49 abc	0.39 b	6.0 a
	GI_0Pd_1	4.21 c	0.59 ab	5.2 a
	GI_1Pd_0	4.46 abc	0.50 ab	5.2 a
	GI_1Pd_1	4.47 abc	0.36 b	5.5 a

*For each column, means followed by the same letter are not significantly different according to LSD test (P = 0.05)

Tab. 4. The effect of different zinc rates and *Glomus intraradices* applications on Ca and Mg concentrations

Applications		Ca (%)	Mg (%)
Zn_0	GI_0Pd_0	4.9 c*	5.8 abcd
	GI_0Pd_1	5.3 bc	5.9 abcd
	GI_1Pd_0	4.9 c	5.6 cd
	GI_1Pd_1	5.4 a	6.0 abc
Zn_1	GI_0Pd_0	5.0 c	5.8 abcd
	GI_0Pd_1	5.9 abc	5.5 d
	GI_1Pd_0	5.5 bc	6.2 a
	GI_1Pd_1	6.4 ab	6.1 ab
Zn_2	GI_0Pd_0	5.0 c	5.9 abcd
	GI_0Pd_1	6.3 ab	5.7 bcd
	GI_1Pd_0	6.2 ab	6.1 ab
	GI_1Pd_1	6.8 a	6.1 ab

*For each column, means followed by the same letter are not significantly different according to LSD test (P = 0.05)

Tab. 5. The effects of disease severity of Pythium deliense on applications of mycorrhiza and zinc

Applications	Disease index
Zn_1+ Pd	2
Zn_2+ Pd	2
Zn_1+ Gi + Pd	2
Zn_2+ Gi +Pd	1
Pd +Gi	1
Pd	4
Control (-)	-

Tab. 6. Root colonization rates of mycorrhiza applications (%)

Applications	Root colonization rates (%)
G. intraradices (Gi)	71.3 a*
Zn_1 + Gi	70.2 a
Zn_2 + Gi	72.8 a
Pd +Gi	62.6 b

*Means followed by the same letter are not significantly different according to LSD test (P = 0.05)

Cucumber plants inoculated with *P. deliense* and untreated with zinc rates nor with *G. intraradices* exhibited the highest (0.89%) Phosphorus content but this parameter decreased to 0.43% on the uninoculated and untreated control plants, to 0.21% and 0.39% on uninoculated plants treated with Zn_1 and Zn_2 applications, respectively. In absence of pathogen inoculation, plants treated with Zn_1 and mycorrhiza showed a P content of about 0.57%. This parameter decreased to 0.38% and 0.36% on cucumber plants inoculated with *P. deliense* and treated with mycorrhiza and Zn_1 and Zn_2 applications, respectively (Tab. 3).

The Potassium concentrations in cucumber plants did not vary significantly depending on zinc and mycorrhizal fungi applications.

Calcium (Ca) and Magnesium (Mg) concentrations of cucumber plants varied significantly according to zinc doses and mycorrhizal treatments tested (Tab. 4). With zinc fertilization only, plant calcium concentrations (5.0%) were significantly similar to untreated control (4.9%). When combined treatments with zinc (Zn_1 and Zn_2) and mycorrhiza, plant Ca concentrations increased to 6.4% and 6.8%, respectively. Mycorrhiza based-treatments led to increased Ca concentrations.

Magnesium concentrations also varied depending on the applications tested.

Disease index results affected by mycorrhiza, pathogen inoculation and zinc rates were given in Tab. 5. This parameter ranged between 1.0 and 4.0. Disease index values were decreased by zinc and mycorrhiza based-treatments. Plants inoculated with *P. deliense* had the highest disease scale (4). Different zinc doses tested and mycorrhiza had protected cucumber plants from Pythium rot disease as compared to the control. Both of zinc doses showed typical damping off symptoms of *P. deliense* and got 2-scale value in cucumber plants untreated with *G. intraradices*. However, for plants treated with Zn_1 and Zn_2 together with mycorrhiza, disease scale was 2 and 1, respectively.

Root colonization

Root colonization results were given in Tab. 6. Colonization of cucumber roots ranged between 62.6 % and 72.8%. Plants treated with *G. intraradices* and Zn_1 or Zn_2 applications showed root colonization ranging between 70.2 and 72.8%. The lowest records (62.6%) were noted on cucumber plants inoculated with pathogen and challenged with AM fungi. Although mycorrhiza colonization decreased due to pathogen application, it was found to be successful in reducing disease severity.

The results recorded from this study indicated that mineral element concentrations in diseased inoculated plants were higher than the other plants. Some compounds such fitoalexins, fenols, flavonoids and oxins were reported to be effective in inducing disease resistance. These compounds were produced due to plant nutrient amounts and collected in the infection area (Uçgun and Gezgin, 2013).

When the results were evaluated, zinc and mycorrhiza applications increased plant dry weight. While plant zinc concentrations increased with zinc applications, phosphorus concentrations decreased. Mycorrhiza applications increased plant nitrogen and phosphorus concentrations. Similar results were determined by the other researchers (Kumar *et al*., 1998; Çığşar *et al*., 2000; Özcan and Taban, 2000; Tüfenkçi *et al*., 2005; Küçükyumuk *et al*., 2013) that zinc and mycorrhiza applications increased plant yield.

As a result, zinc and mycorrhiza had positive effects by controlling Pythium rot disease of cucumber seedlings and could, thus, be used for integrated control of this disease. Pythium seedling rot disease is harmful in nursery circuit for all vegetable crops. Results obtained in the cucumber-*Pythium* pathosystem could be extended to other vegetables. Joint application of Zinc rates with *G. intraradices* might be considered as a new approach in the struggle for Pythium seedling rot disease. Present study showed that the combination of *G. intraradices* and zinc concentration reduced disease severity under pot conditions.

Conclusion

It can be concluded that improving Zn nutrition and application of mycorrhizal fungus to cucumber seedlings will be an environmentally safe approach in controlling Pythium rot disease.

Acknowledgement

This study was financially supported by the TÜBİTAK (The Scientific and Technological Research Council of Turkey), Project No. 112O025.

References

Agrios GN (1997). Plant pathology, 4th ed. Academic Press, San Diego.

Akköprü A, Demir S (2006). Biological control of Fusarium wilts in tomato caused by *Fusarium oxysporum* f. sp. *lycopersici* by AMF *Glomus intraradices* and some rhizobacteria. J Phytopathol 153:544-550.

Braithwaite M, Falloon RE, Genet RA, Wallace AR, Fletcher JD, Braam, WF (1994). Control of powdery scab of patatoes with chemical seed tuber treatments. New Zeal J Crop Hort. 22: 121-128.

Cai J, Huang B, Chen J, Ji Q (2007). Effects of mineral elements on growth and resistance to Phytophthora blight of pepper. Jiangsu J Agric Sci 23:46-49.

Caron M, Fortin JA, Richard J (1986). Effect of *Glomus intraradices* on infection by *Fusarium oxysporum* f. sp. *radicis-lycopersici* tomatoes over a 12-week period. Can J Bot 64:552-556.

Çığşar S, Sarı N, Ortaş İ (2000). Hıyarda Vesiküler-Arbüsküler Mikorizanın Bitki Büyümesi ve Besin Maddeleri Alımı Üzerine Etkileri. Türk J Agric For 24:571-578.

Davidson JA, Ramsey MD (2000). Pea yield decline syndrome in South Australia: The role of diseases and impact of agronomic practices. Aust J Agr Res 51:347-354.

Duffy B (2009). *Zinc and Plant Disease*. Mineral Nutrition and Plant Disease. In: Mineral Nutrition and Plant Disease. The American Phytopathotological Society St. Paul, pp. 155-175. Minnesota, USA.

Grewal HS (2001). Zinc influences nodulation, disease severity, leaf drop and herbage yield of alfalfa cultivars. Plant and Soil 234:47-59.

Harley JL, Smith SE (1983). Mycorrhizal wheat under moisture stress condition. Indian J. Symbiosis. Academic Press, London.

Jackson ML (1973). Soil Chemical Analysis, Advanced Course: 2nd. ed., Publ. by the author, Dept. Soil Science, Univ. Wisc., Madison, Wisconsin, 895 pp.

Kacar B, İnal A (2008). Plant Analysis. Nobel, 1241 Ankara, Turkey.

Kalim S, Luthra YP, Gandhi SK (2003). Role of zinc and manganese in resistance of cowpea root rot. J Plant Dis Prot 110:235-243.

Karagiannidis N, Bletsos F, Stavropoulosi N (2002). Effect of Verticillium wilt (*Verticillium dahliae* Kleb.) and mycorrhizae (*Glomus mosseae*) on root colonization, growth and nutrient uptake in tomato and eggplant seedlings. Scientia Horticulturae 94:145-156.

Khoshgoftarmanesh A, Kabiri S, Shariatmadari HB, Sharifnabi B, Schulin R (2010). Zinc nutrition effect on the tolerance of wheat genotypes to Fusarium root rot disease in a solution culture experiment. Soil Sci Plant Nutr 56:234-243.

Knudsen D, Peterson GA, Pratt PF (1982). *Lithium, Sodium and Potassium*. In: 'Methods of Soil Analysis. Chemical and Microbiological Properties'. Agronomy no. 9, Part 2. 2nd edn (Ed. AL Page) pp. 225-246.

Kostandi SF, Soliman MF, Ghaly AA (1997). Smut disease and yield performance in corn (*Zea GIays* L.) as influenced by nitrapyrin, urea and zinc applications in coarse- textured soils. J. Agron. Crop Sci. 179:219-226.

Krishna KR, Bagyaraj DJ (1983). Interaction between *Glomus fasciculatum* and *Sclerotium rolfsii* in peanut. Can J Bot 61:2349-2351.

Kumar M, Yadav K, Thakur SK, Mandal K (1998). Effect of vasicular-arbuscular mycorrhizal fungi and *Rhizobium* inoculation on nodülation, root colonization, nitrogen fixation and yield to chick-pea. J Indian Soc Soil Sci 46:375-378.

Küçükyumuk Z, Özgönen H, Erdal İ (2013). Influence of zinc and mycorrhizal fungus *Glomus intraradices* on plant yield, nutrient concentrations and control of Phytophthora blight of pepper. J Food Agric Environ 11:807-812.

Lindsay WL, Norvell WA (1978). Development of a DTPA soil test for zinc, iron, manganese and copper. Soil Sci Soc Am J 42:421-428.

Marschner H, Dell B (1994). Nutrient uptake in mycorrhizal symbiosis. Plant and Soil 159: 89-102.

Marschner H (1995). Mineral Nutrition of Higher Plants, 2nd edn. AcadeGIic Press, London, United Kingdom.

Matsubara Y, Tamura H, Harada T (1995). Growth enhancement and Verticillium wilt control by vesicular-arbuscular mycorrhizal fungus inoculation in eggplant. J Jpn Soc Hortic Sci 64:555-561.

Olsen SR, Cole V, Watanabe FS, Dean LA (1954). Estimations of Available Phosphorus in Soils by Extractions with Sodium Bicarbonate. U.S. Dept. Of Agric. Cric. 939-941.

Özcan H, Taban S (2000). VA-Mycorrhiza'nın alkalin ve asit toprakla yetiştirilen mısır bitkisinin gelişimi ile fosfor, çinko, demir, bakır ve mangan konsantrasyonları üzerine etkisi. Türk J Agric Tübitak 24:629-635.

Özgönen H, Erkılıç A (2007). Growth enhancement and Phytophthora blight (*Phytophthora capsici* Leonian) control by arbuscular mycorrhizal fungal inoculation in pepper. Crop Prot. 26:1682-1688.

Pareek S, Pareek S (1999). Effect of macro- and micro-nutrients on charcoal rot disease development of maize induced by *Macrophomina phaseolina*. Annals of Agriculture. Research 20:129-131.

Siddiqui IA, Shaukat SS, Hamid M (2002). Role of zinc in rhizobacteria-mediated suppression of root-infecting fungi and root-knot nematode. J. Phytopathol 150:569-575.

Streeter TC, Rengel Z, Neate SM, Graham RD (2001). Zinc fertilization increases tolerance to *Rhizoctonia solani* (AG 8) in *Medicago truncatula*. Plant and Soil 228:233-242.

Trotta A, Varese GC, Gnavi E, Fusconi A, Sampo S, Berta G (1996). Interactions between the soilborne root pathogen *Phytophthora nicotianae* var. *parasitica* and the arbuscular mycorrhizal fungus *Glomus mosseae* in tomato plants. Plant and Soil 185:199-209.

Tüfenkçi S, Sönmez F, Sensoy R (2005). Effects of arbuscular mycorrhiza fungus inoculation and phosphorous and nitrogen fertilizations on some plant growth parameters and nutrients content of chickpea. Bull Pure Appl Sci 24:71-80.

Uçgun K, Gezgin S (2013). Relationship between disease and macro nutrients www.marim.gov.tr. Date of Access: 30.07.2013.

Zhang W, Dick WA, Hoitink HAJ (1996). Compost-induced systematic acquired resistance in cucumber to Pythium root rot and anthracnose . Phytopathology 86:1066-1070.