Research Journal of Agriculture and Biological Sciences, 2(6): 503-508, 2006

Effects of VA Mycorrhizal Inoculation on Growth, Yield and Nutrient Content of Cantaloupe and Cucumber under Different Water Regimes

[1]Ahmed A. M. Abdelhafez and [2]Rihan A. Abdel-Monsief

[1]Unit of Biofertilizers, Department of Microbiology, Faculty of Agriculture, Ain Shams University
[2]Central Laboratory for Agricultural Climate, Agriculture Research Center, Giza, Egypt.

Abstract: Cantaloupe and cucumber seedlings were transplanted into polyethylene bags (10 kg capacity) contained sandy soil amended with 15.5mg P_2O_5/kg soil as super phosphate or rock phosphate. Rock phosphate treated plants were inoculated with a mixed inoculum of VA mycorrhizal fungi. Seedlings of both plants were grown in plastic house under three level of water regime, i.e. 70, 85 and 100% of the soil water holding capacity. Developed plants were sampled after 30, 60 and 90 days from transplantation. Percentages of root infection along with the area of 4^{th} leaf, plant total dry weight and shoot NPK contents were also recorded at each interval. The total yield and NPK content of fruits were recorded at harvest. Data of this study showed that VA mycorrhizal development was gradually increased with time. Increase of VA mycorrhizal development was more obvious with 85 and 100% water regime and little increase was detected with 70% at 90 days compared with 60 days interval. Superphosphate-amended plants (Control) showed growth, NPK content and yield performance positively correlated with increased water regimes. No considerable differences, however, were observed between mycorrhizal-treated plants grown with 85 and those with 100% water regime. Generally, growth, NPK content and yield were higher in mycorrhizal plants grown under the 85% water regime than those of the superphosphate-amended plants grown with 100% water regime.

Key words: water regime, VA mycorrhizae, water uptake, growth, yield, NPK content, nutrient uptake, cantaloupe, cucumber

INTRODUCTION

Water availability is known to limit crop production in many parts the world. Therefore, there has been an intense interest in studying plant water stress interactions in arid and semi-arid environments. Vesicular-arbuscular mycorrhizae (VAM) are type of fungi that interact with numerous plant species and produce vesicles and arbuscules in root tissue along with extraordinary hyphae in the soil[6]. These hyphae represent an extension for that improve the exploratory ability of the roots and increase the attainment of ions which are slow diffusing ions though the soil[2]. VA mycorrhizal fungi are also capable of dissolving weakly soluble soil minerals by releasing acids[10] or increasing CO_2 partial pressure[9]. Therefore, they have the ability to enhance host plant uptake of relatively immobile nutrients particularly P and Zn[17]. In addition, mycorrhizal hyphae can provide access to insoluble nutrient sources through enzyme activity or some physical or chemical modification of the rhizosphere[7]. Other studies also showed that VA mycorrhizal fungi could alleviate drought stress in their host plants via the direct uptake and transfer of water and nutrients through the fungal hyphae to the host plants[6].

Although most of the work done with VA mycorrhizal fungi has concentrated on their effects in plant nutrition, there is now increasing interest also in drought resistance of mycorrhizal plants. In the present study, the effects of mycorrhizal colonization on growth, yield and NPK contents of cantaloupe and cucumber under different levels of water regime were evaluated by comparing growth, yield and NPK content of VAM-treated plant were compared with those untreated plants.

MATERIALS AND METHODS

Soil: A sandy soil sample, enough for experimentation, was collected, mixed, and then passed through a 2mm sieve in order to give a uniform plant growth medium. Soil samples were mechanically analyzed according to the method described by[13]. The electrical conductivity (EC) was measured in saturated soil paste according to the method described by[8].Soluble anions, cations and soil pH were determined in saturated soil paste according to the method described by[15]. Data of soil physical and chemical analysis are given in Table 1.

Corresponding Author: Ahmed A.M. Abdelhafez, Unit of Biofertilizers, Department of Microbiology, Faculty of Agriculture, Ain Shams University, Egypt. E-mail: aabdelhafez@yahoo.com

Table 1: Physicochemical analysis of the used soil.

Physical analysis		Chemical analysis			
Sand	94.5%	pH	7.4		
Clay	3.5%	EC	0.4 Mmohs/Cm		
Silt	2.0%	Cations	meq/L	Anion	meq/L
Soil texture:	Sandy	Ca^{++}	1.0	CO_3^{-2}	--
Field capacity	13.0%	Mg^{++}	1.0	HCO_3^-	2.1
Saturation	26.0%	Na^+	1.5	Cl^-	1.4
$CaCO_3$	1.1%	K^+	0.4	SO_4^{-2}	0.4

Plant Seeds: Cantaloupe (*Cucumis melo* L. cv. *Vicar* F1 hyprid) and cucumber (*Cucumis sativus* L. cv. *Bitostar*) seeds were obtained form El-Bosaily Protected Cultivation Experimental Farm, Agricultural Research Center, Rossetta, Behaira Governorate, Egypt.

VAM inoculum: A mixed inoculum consisted of 3 VA mycorrhizal fungi, i.e. *Glomus etunicatum, Glomus intraradices* and *Glomus monosporum* along with VAM-infected maize root segments were used in this study. The inoculum was provided through cooperative program between the Unit of Biofertilizers (Faculty of Agriculture Ain Shams University) and the CLAC.

Phosphate Fertilizers: Superphosphate (15.5% P_2O_5) and rock phosphate (32% P_2O_5) were purchased from Al-Ahram Company for Natural fertilizers, Giza, Egypt.

Experimental techniques: The experiment was carried out in a plastic house covered with 200 micron-thick polyethylene film at the Central Laboratory for Agricultural Climate (CLAC), Agriculture Research Center, Giza. 30cm diameter plastic bags were filled with 10 kg soil amended with 15.5mg P_2O_5/kg sand soil as super phosphate or rock phosphate (equivalent to 100Kg superphosphate / Fedan). Two-week old healthy seedlings of cantaloupe or cucumber were transplanted at a rate of one transplant/bag. Prior to transplantation, rock phosphate-amended soil was inoculated with the mixed VAM inoculum at a rate of 250 spores plus 2 g maize VAM-infected root segments / bag. Bags were then divided into 3 groups to be subjected for different water regimes, being 70, 85 and 100% of soil water holding capacity (WHC). Ten replicates were made for each treatment. Developed plants were kept under the above mentioned water regimes by adjusting bag weight up to the desired level throughout the experimental period (90 days). Samples of shoots and roots were collected after 30, 60 and 90 days of transplantation to monitor the effects of VAM colonization on growth, yield and NPK content of both host plants.

Parameters measured:

Growth and Yield Parameters: The following parameters were determined; (a) plant height (cm/plant), (b) number of leaves/plant, (c) total yield (g/plant), (d) area of the 4th leaf (cm^2, using a digital leaf area meter L1-300 portable area meter, L1-COR, Lincoln, Nebraska, USA), and (e) dry weight of shoot and root after oven drying at 70°C until reaching constant weight. Total yield of each host along with NPK content of fruits were also recorded

Root Infection and Spore Numbers of Vam: The percentages of root infection with VAM in cantaloupe and cucumber were estimated by the method described by Phillips and Hayman[12] Mycorrhizal spores were extracted by wet-sieving and decanting technique as described Gerdemann and Nicolson[5].

Chemical Analyses: Total nitrogen, phosphate and potassium contents of shoots and roots of cantaloupe or cucumber plants were determined by the method described by Jackson[8].

RESULTS AND DISCUSSIONS

Effect of Water Regime on VA Mycorrhizal Development: Results showed that increasing water regime for both cantaloupe and cucumber from 85 to 100% water did not increase spore number nor infection percentage of VA mycorrhizae. Mycorrhizal spore count and infection percentage in cantaloupe roots reached their highest level (1240 and 96% respectively) after 90 days of transplantation at 85% water regime. In cucumber plants, spore count and infection level also reached their maxima (1600 and 95% respectively) at the same interval and regime (see Table 2). Reid and Bowen[14] considered that changes in soil water potential may have little impact on absorption processes by mycorrhizal and non-mycorrhizal roots. Other studies showed that water stress had no effect on VAM infection levels of *Glomus clarum*, *Glomus monosporum* and

Table 2: Mycorrhizal spore count and infection level (%) in cantaloupe and cucumber plants as affected by different water regime.

Plant	Treament	Water regime	Days of transplantation 30 No Spores	30 % infection	60 No Spores	60 % infection	90 No Spores	90 % infection
		70	-	-	-	-	-	-
	Control	85	-	-	-	-	-	-
	(S.Ph)[1]	100	-	-	-	-	-	-
		70	170.4	20.3	230.7	50.3	440.0	59.3
Cantaloupe	VAM[2] +	85	189.3	32.1	470.3	73.4	1240.7	95.7
	R. Ph.[3]	100	180.1	34.3	460.7	74.5	1103.7	96.4
		70	150.0	21.6	430.0	60.9	750.6	75.0
Cucumbor	VAM[2] +	85	190.3	30.3	530.3	73.0	1600	95.0
	R. Ph.[3]	100	188.3	35.8	473.3	71.2	936.3	85.3

[1]: Super Phosphate
[2] :VAM: Vesicular Arbuscular Mycorrhizae
[3]: RPh: Rock phosphate fertilizer.

Table 3: Plant height (H, cm/plant), number of leaves (LN), leaf area (LA, cm^2), and total dry weight (TDW, g/plant) in cantaloupe and cucumber plants as affected by mycorrhizal inoculation and water regime.

Plant	Treat-ment	Water regime	30 H	30 *LN*	30 LA	30 TDW	60 H	60 *LN*	60 LA	60 TDW	90 H	90 *LN*	90 LA	90 TDW
Cantaloupe	Control	70	40.1	7.0	24.1	12.7	95.3	20.2	43.1	20.3	140.1	28.8	76.3	30.9
	(S.Ph)[1]	85	50.2	8.2	27.2	14.2	101.6	21.3	48.4	24.3	161.5	32.3	81.4	35.1
		100	68.5	9.5	38.3	18.6	118.3	26.6	65.3	32.8	170.2	38.2	95.3	51.5
	VAM[2]	70	54.3	7.2	29.2	16.1	110.6	20.7	50.7	30.3	154.2	30.1	83.2	37.5
	+	85	69.4	11.5	54.1	19.3	128.3	27.3	79.4	41.0	193.6	44.7	110.3	64.6
	R.Ph.[3]	100	71.3	13.0	44.6	21.3	130.4	29.1	81.3	42.9	191.4	45.1	101.2	61.4
Cucumbor	Control	70	35.5	7.1	29.2	5.8	96.1	22.0	50.2	18.4	150.2	30.1	81.3	28.0
	(S.Ph)[1]	85	41.2	8.0	31.3	7.1	102.4	23.1	54.5	19.2	169.1	34.1	85.5	29.1
		100	59.7	9.9	43.1	14.3	119.7	27.9	70.1	27.2	179.3	40.3	101.0	35.1
	VAM[2]	70	50.1	7.0	33.2	9.7	110.3	22.3	54.3	23.4	163.1	33.1	85.3	32.3
	+	85	70.1	12.5	59.2	14.4	130.2	28.3	85.3	29.1	197.2	45.0	116.7	42.6
	R.Ph.[3]	100	75.4	13.3	49.2	13.7	135.6	29.1	80.1	29.1	195.5	46.0	106.1	40.1

[1]: Super Phosphate
[2]: VAM: Vesicular Arbuscular Mycorrhizae
[3]: RPh: Rock phosphate fertilizer.

Acaulospora sp., whereas spore production from most inocula was reduced by water-stress[16].

Growth Parameters: Increasing water supplementation for super phosphate amended plants had positive effect on all plant growth parameters which reached their highest level after 90 days of transplantation at 100% water regime. In contrast, all growth parameters of VA mycorrhiza-cantaloupe and cucumber plants reached their maxima after 90 days of transplantation but with 85% water regime. All Growth parameters of VAM-treated plants were generally increased by 10-25% with 85% water regime than untreated (control) plants grown with 100% water regime (Table 3). Thus mycorrhizal inoculation seems to increase plant growth. Under these conditions, VA mycorrhizal inoculation of the seedlings of *Vangueria infausta*, Kalahari tree, increased the dry mass and mineral acquisition, particularly P, Ca and N[3]. Mycorrhizae-treated *Drendrocalamus asper* plants were also significantly taller than their respective control

Table 4: Nitrogen (N), phosphorus (P), and potassium (K) content (%) in whole plants of cantaloupe and cucumber as affected by mycorrhizal inoculation and water regime.

Plant	Treatment	Water regime	Days of transplantation								
			30			60			90		
			N	P	K	N	P	K	N	P	K
Cantaloupe	Control (S.Ph)[1]	70	4.8	0.96	5.34	5.11	1.021	5.69	4.8	0.997	4.92
		85	5.6	1.14	5.55	5.62	1.083	6.24	5.4	1.04	5.37
		100	7.61	1.30	6.41	8.24	1.34	6.96	7.66	1.198	6.70
	VAM[2] + R.Ph.[3]	70	6.41	1.18	5.39	6.0	1.22	6.0	5.85	1.120	5.70
		85	7.49	1.33	6.55	8.59	1.40	7.94	8.47	1.215	7.75
		100	8.21	1.39	6.80	8.80	1.497	8.16	8.36	1.214	7.70
Cucumbor	Control (S.Ph)[1]	70	4.41	0.758	4.44	5.1	0.801	4.69	4	0.789	3.92
		85	4.81	0.819	4.55	5.41	0.843	5.14	4.7	0.82	4.39
		100	6.5	1.099	5.41	6.83	1.121	5.99	5.4	1.078	5.72
	VAM[2] + R.Ph.[3]	70	5.04	0.975	4.39	5.65	1.001	5.01	5	0.90	4.72
		85	6.71	1.109	5.56	8.51	1.274	6.96	7.2	1.105	6.76
		100	7.2	1.174	5.81	8.73	1.289	7.11	6.9	1.093	6.74

[1]: Super Phosphate
[2]: VAM: Vesicular Arbuscular Mycorrhizae
[3]: RPh: Rock phosphate fertilizer.

plants. Shoot P content and dry weight of both shoots and roots were all significantly higher in VA mycorrhizal plantlet than control ones[18]. The dry weight of tomato plants inoculated with the mycorrhizal fungus *Glumos fasciculatus* plus *Azotobacter* was also greater (62%) than un-inoculated plants[1].

NPK content: Nitrogen, phosphorus and potassium percentages reached their maxima after 60 days of transplantation with 100% water regime in control or VA mycorrhizae-infected plants. However, both VAM host plants showed increases of 7-28% in N-P-K content over untreated plants at the same level of water regime. VAM-inoculated cantaloupe plants contained 8.8% N, 1.497% P, and 8.16% K, while the control plants showed 8.24%, 1.34% and 6.96% for N, P and K content respectively. On the other hand, VA mycorrhizae-inoculated cucumber plants showed 8.73%, 1.289% and 7.11% for N, P, and K content, while the control plants contained 6.83% N, 1.121% P and 5.99% K content (see Table 4). These findings are supported by other reports showing that acquisition of mineral nutrient, particularly P, N and K, was enhanced in host plants infected with mycorrhizae, and the most reported mineral was P[11]. Other data on pepper infected with mycorrhizal fungus *Glomus intraradices* showed that P, dry matter content, sucrose and total sugar increased by 12-47%[4].

Yield and NPK Contents of Fruits: VAM-infected cantaloupe gave the maximum yield of 1.44 kg fruit/plant at 85% water regime, while control plants produced only1.0 kg fruit/plant at 100% water regime. Thus, mycorrhizal-cantaloupe plants produced 44% higher yield than those amended with super phosphate even under lower water regime (Table 5). NPK contents of VAM-cantaloupe plants were greated by 10, 5 and 7%, respectively, than those un-inoculated plants. In cucumber, control plants showed maximum yield of 2.9 kg fruit/plant at 100% water regime while VAM plants gave their maximum yield (4.1 kg fruit/plant) at 85% water regime. NPK contents of VA mycorrhizae-cucumber plants were 7.8, 28 and 7% higher than control plants (Table 5). Similar studies, carried out in pots,

Table 5: Total yield (kg/plant) and N, P, and K content (%), in cantaloupe and cucumber fruits as affected by mycorrhizal inoculation and water regime.

Plant	Treatment	Water regime	Total yield kg/plant	NPK content		
				N	P	K
Cantaloupe	Control	70	0.45	3.7	0.40	4.0
	(S.Ph)[1]	85	0.60	3.9	0.47	4.9
		100	1.0	4.8	0.82	5.6
	VAM[2]	70	0.75	4.5	0.85	5.3
	+	85	1.44	5.3	0.86	6.0
	R.Ph.[3]	100	1.41	5.0	0.81	6.0
Cucumbor	Control	70	1.5	2.8	0.21	3.5
	(S.Ph)[1]	85	2.1	2.93	0.29	3.8
		100	2.9	3.99	0.41	4.4
	VAM[2]	70	2.0	3.5	0.38	4.0
	+	85	4.1	4.3	0.50	4.7
	R.Ph.[3]	100	4.0	4.0	0.49	4.6

[1]: Super Phosphate
[2]: VAM: Vesicular Arbuscular Mycorrhizae
[3]: RPh: Rock phosphate fertilizer.

showed that mycorrhizal inoculation in low-P soil increased P concentrations in tissues, plant weights, and fruit yields of some vegetable crops compared to un-inoculated plant. Field experiments showed that total fruit yields and final shoot fresh weights were also higher when plants were inoculated before transplantation[19].

Conclusion: The sum of the above results showed that inoculation with VA mycorrhizae may increase the efficiency of the plant water uptake, resulting in gaining higher plant growth at the same or less water regime of super phosphate amended plants. VAM colonization is also capable of increasing the nutrient content, which was reflected in higher NPK content of the shoots, roots and fruits of both hosts. Most importantly, VAM inoculation increased the total plant yield of fruits receiving 85% water regime which was much higher than those control plants even though receiving 100% water regime.

ACKNOWLEDGEMENTS

The authors would like to thank Prof. Dr. Magdi I. Mostafa Ismail and Prof. Dr. Shawky Selim for giving their valuable time.

REFERENCES

1. Bagyaraj, D.J. and J.A. Menge., 1978. Interaction between a VA Mycorrhiza and *Azotobacter* and their effects on rhizosphere microflora and plant growth. New Phytol. 80:567-573.
2. Barea, J.M., 1991. Vesicular-arbuscular mycorrhizae as modifiers of soil fertility. Adv. in Soil Science 15:1-40.
3. Bohrer, G., V. Kagan-Zur, N. Roth-Beierano, D. Ward, G. Beck and E. Bonifacio., 2003. Effects of different Kalahari-desert VA mycorrhizal communities on mineral acquisition and depletion from the soil by host plants. Journal of Arid Environment. 55:193-208.
4. Demir, Semra., 2004. Influence of arbuscular mycorrhiza on some physiological growth parameters of pepper. Turk J. Biol.28:85-90
5. Gerdemann, J.W. and T.H. Nicolson., 1963. Spores of mycorrhizal *Endogone* species extracted from soil by wet sieving and decanting. Transactions of the British Mycological Society 46:235-244
6. Harley, J.L. and S.E. Smith., 1983. Mycorrhizal Symbiosis. New York, USA: Academic Press.

7. Hetrick, B.A.D., 1989. Acquisition of phosphorus by VA mycorrhizal fungi and the growth responses of their host plants. pp: 205-226. In: L. Boddy, R. Marchant, and D.J. Reid (eds.), Nitrogen, Phosphorus, and Sulphur utilization by fungi. Cambridge University Press, New York, NY, USA.
8. Jackson, M.L., 1958. Soil chemistry analysis. Prentice-Hall, Englewood Cliffs, USA..
9. Knight, W.G., M.F. Allen, J.J. Jurinak, and L.M. Dudley., 1989. Elevated carbon dioxide and solution P in soil with vesicular-arbuscular mycorrhizal western wheatgrass. Soil Science Society of America Journal 53:1075-1082.
10. Leyval, C. and J. Berthelin., 1989. Interactions between *Laccaria laccata*, *Agrobacterium radiobacter* and beech roots: influence on P, K, Mg and Fe mobilization from mineral and plant growth. Plant and Soil 117:103-110.
11. Marschner, H. and B. Dell., 1994. Nutrient uptake in mycorrhizal symbiosis. Plant and Soil. 159:89-102.
12. Phillips, J.M. and D.S. Hayman., 1970. Improved procedures for clearing roots and staining parasitic and vesicular-arbuscular mycorrhizal fungi for rapid assessment of infection. Transactions of the British Mycological Society 55:158-161.
13. Piper, C.S., 1950. Soil and Plant analysis. Interscience Publisher, New York.
14. Reid, C.P.P. and G.D. Bowen., 1979. Effect of water stress on phosphorus uptake by mycorrhizas of *Pinus radiata*. New Phytol. 83:103-107
15. Richards, L.A., 1954. Diagnosis and improvement of saline and alkaline soils. U.S. Department of Agriculture (USDA), Handbook no. 60.
16. Simpson, D. and M.J. Daft., 1990. Interactions between water-stress and different mycorrhizal inocula on plant growth and mycorrhizal development in maize and sorghum. Plant and Soil. 122(2): 79-186
17. Thompson, J.P., 1987. Decline of vesicular-arbuscular mycorrhizas in long fallow disorder of field crops and its expression in phosphorus deficiency in sunflower. Aust. J. Agric. Res. 38: 847-867.
18. Verma, R.K. and I.D. Arya., 1998. Effect of arbuscular mycorrhizal fungal isolates and organic manure on growth and mycorrhization of micropropagated *Dendrocalamus asper plantlets* and on spore production in their rhizosphere. Mycorrhiza 8:113-116.
19. Waterer,D.R. and R.R. Coltman., 1989. Response of mycorrhizal bell peppers to inoculation timing, phosphorus, and water stress. Hort. Science, 24 (4): 688-690.