Journal of Applied Botany and Food Quality 82, 179 - 182 (2009)

[1] Vegetable Research Department, National Research Center, Dokki, Cairo, Egypt
[2] Botany Department, National Research Center, Dokki, Cairo, Egypt
[3] Institute for Horticultural Sciences, Humboldt University of Berlin, Germany

Hormonal changes, growth and yield of tomato plants in response to chemical and bio-fertilization application in sandy soils

W.A. El-Tohamy[1], H.M. El-Abagy[1], N.H.M. El-Greadly[2], N. Gruda[3]

(Received May 4, 2008)

Summary

The response of tomato plants to chemical and bio-fertilization under sandy soil conditions was investigated. The experiments were conducted in Nubaria region, Egypt. Tomato plants were treated with Microbein or a mixture of Phosphorine and Biogein as bio-fertilizers under different rates of the recommended nitrogen and phosphorus fertilization (100% of N and P, 75% of N and P and 50% of N and P). In addition, plants of three treatments received only the rates of chemical fertilizers and were not treated with the bio-fertilizers. Vegetative growth measurements, yield, hormonal changes in leaves, and N, P and K contents of leaves were recorded to study the effects of these treatments. The results showed that bio-fertilization significantly increased the vegetative growth of tomato plants (including plant height, number of branches, number of leaves and the fresh weight of plants) and yield compared to non-treated plants. Growth and yield of tomato plants was negatively affected by the low chemical fertilization treatments especially at 50% of N and P while bio-fertilization enhanced growth and productivity under such conditions. Tomato plants which were treated with a mixture of Phosphorine and Biogein had higher growth and yield than plants treated with Microbein. Bio-fertilization resulted in higher N, P and K contents of leaves and higher indole acetic acid (IAA), Gibberellins (GA3) and Cytokinins. The possible effects of the treatments are discussed.

Introduction

Tomato is one of the most important vegetables grown in Egypt. The production of vegetables with minimum chemical residues and avoiding environmental pollution requires minimizing the use of chemicals during the production process including minimizing the use of chemical fertilizers. However, new-reclaimed lands in the desert in Egypt are characterized with poor soil fertility that requires the addition of high levels of chemical fertilizers. Using bio-fertilizers may help reducing the amounts of chemical fertilizers added to the soil and improve tomato production under sandy soil conditions (AMER et al., 2003). Bio-fertilizers application resulted in improvement of growth and yield of different vegetable crops, as for instance, pepper (ABDALLA et al., 2001), garlic (ALI et al., 2001) and cucumber (EL-SANAFAWI, 2006). The positive effects of bio-fertilizers on growth and productivity of plants could be attributed to the effect of different strain groups of microorganisms such as nitrogen fixers, nutrients mobilizing group which improve the availability of metals and increase the levels of extractable N, P, K, Fe, Zn and Mn as stated by EL-KARAMANY et al. (2000). This may help minimizing the amounts of chemical fertilizers and improve their application efficiency and subsequently avoiding environmental pollution by the access of these chemicals. The present study was designed to explore the various responses of tomato plants to different applications of bio-fertilizers under different levels of chemical fertilizers and to study these effects under sandy soil condition in the new-reclaimed lands.

Material and methods

The experiments were carried out under sandy soil conditions at the experimental station of the National Research Center in Nubaria region (Egypt) during two successive seasons of 2006 and 2007. Physical and chemical properties of the soil are presented in Tab. 1. Tomato (*Lycopersicon esculentum* L.) seedlings 'Super strain B' were transplanted on the 10th of April. Seedlings were transplanted on ridges of 70 cm width with a spacing of 30 cm in the row. Soil preparations before transplanting were followed according to the recommendations of the Ministry of Agriculture, Egypt. The treatments included three levels of chemical fertilizers: 100, 75 and 50% of the recommended dose of both nitrogen and phosphorus fertilizers (100% of both N and P were calculated as 0.1 kg m^{-2} of ammonium sulfate and of superphosphate respectively). Potassium was kept at 100% of the recommended dose for all treatments.

The bio-fertilization treatments included:

- Microbein at a rate of 1 g 2.5 g^{-1} seeds. Microbein functions as biodenitrogen fixer, nutrient mobilizer and growth promoter and it is composed of a selected group of micro-organisms (YAKOUT and GREISH, 2001), such as *Bacillus* sp., *Azospirillum* sp. and *Pseudomonas* sp.
- A mixture of Phosphorine (a set of P-dissolving bacteria including *Bacillus* sp.) and Biogein (contains N-fixing bacteria including *Azotobacter* sp.) at a rate of 1g 2.5 g^{-1} seeds of each. All bio-fertilizers used in this study are produced under supervision of the Ministry of Agriculture in Egypt.

Tab. 1: Physical and chemical properties of the experimental soil.

Physical properties						
Sand (%)	Clay (%)	Silt (%)	Texture		Field capacity %	Wilting point %
90.08	9.26	0.66	Sandy		16.57	5.25
Chemical analysis						
pH	Ca	Mg	Na	K	HCO_3	Cl
			mequivalent/L			
8.2	7.02	0.527	0.982	0.31	1.3	0.566

Both chemical and bio-fertilization treatments were applied as follows.

1- 100% of N and P + Microbein
2- 75% of N and P + Microbein
3- 50% of N and P + Microbein
4- 100% of N and P + Phosphorine+Biogein
5- 75% of N and P + Phosphorine+Biogein
6- 50% of N and P + Phosphorine+Biogein
7- 100% of N and P (without bio-fertilization).
8- 75% of N and P (without bio-fertilization).
9- 50% of N and P (without bio-fertilization).

The following measurements were recorded:
Plant parameters and yield: (plant height, number of leaves, number of branches and plant fresh weight) were recorded 60 days after transplanting. The total number of fruits and the total yield were recorded at the end of the experiment.
Chemical measurements: Nitrogen and potassium contents of plant leaves were recorded according to FAO (1980), and phosphorus content according to TROUG and MEYER (1939).
Endogenous phytohormones: Samples for determination of endogenous hormones including indole acetic acid (IAA), gibberellins (GA3) and total cytokinins were taken in fresh shoots. Identification and determination of acidic hormones (IAA and GA3) were carried out by gas liquid chromatography (GLC). Samples were extracted according to the method adopted by BADR et al. (1971). Cytokinins fractions were extracted as previously mentioned for the acidic hormones and were detected by HPLC.

Statistical analysis

Nine treatments were arranged as a completely randomized block design of two factors (chemical fertilization and bio-fertilization) with four replicates. Analysis of variance was calculated according to SNEDECOR and COCHRAN (1967). Least Significant Difference (L.S.D.) at 5% was used to compare between means.

Results and discussion

Effects of chemical and bio-fertilization treatments on vegetative growth and yield of tomato plants

The results showed that chemical and bio-fertilization treatments significantly increased vegetative growth including plant height, number of branches, number of leaves and fresh weight of plants in both seasons (Tab. 2). However, the interaction between chemical

Tab. 2: Effects of chemical and bio-fertilization treatments on vegetative growth and yield of tomato plants. Analysis of variance refers to 1st or 2nd season. Least Significant Difference (L.S.D.) at 5% was used to compare means within each column.

	Treatments	Plant height (cm)	Number of branches	Number of leaves	Number of fruits/plant	Plant fresh weight (g)	Total yield (kg m^{-2})
				1st season			
100% NP	Microbein	47.3	4.25	45.3	44.0	101.0	9.44
	Biogein+Phosphorine	47.8	5.00	57.25	50.2	108.4	12.25
	Without biofertilizers	47.0	3.25	34.5	33.3	81.72	6.70
75% NP	Microbein	42.3	4.00	35.25	37.8	79.8	8.31
	Biogein+Phosphorine	42.8	4.3	44.75	43.5	91.9	8.66
	Without biofertilizers	38.7	2.25	31.5	36.0	68.7	6.01
50% NP	Microbein	39.5	3.25	32.2	31.7	75.15	6.63
	Biogein+Phosphorine	39.8	3.29	36.25	39.5	79.52	7.22
	Without biofertilizers	34.0	2.24	30.0	22.00	61.17	4.60
L.S.D. at 5%	(Biofertilization)	1.71	0.34	2.45	0.6	4.37	0.16
	(Chemical fertilization)	1.71	0.34	2.45	0.6	4.37	0.16
	(Interaction)	N.S.	N.S.	4.25	0.9	N.S.	0.28
				2nd season			
100% NP	Microbein	45.2	4.6	43.4	40.2	92.3	8.68
	Biogein+Phosphorine	45.6	4.08	52.2	48.2	104.7	11.76
	Without biofertilizers	44.2	3.08	32.7	31.2	77.9	6.41
75% NP	Microbein	39.1	3.72	32.1	35.1	74.2	7.73
	Biogein+Phosphorine	39.3	3.95	41.6	40.4	85.5	8.05
	Without biofertilizers	37.6	2.18	30.5	29.1	66.6	5.83
50% NP	Microbein	37.5	3.05	31.1	29.8	70.6	6.23
	Biogein+Phosphorine	38.4	3.15	33.8	38.3	77.1	7.01
	Without biofertilizers	32.8	2.16	28.8	21.1	58.7	4.41
L.S.D. at 5%	(Biofertilization)	1.63	0.32	2.32	0.53	4.11	0.16
	(Chemical fertilization)	1.63	0.32	2.32	0.53	4.11	0.16
	(Interaction)	N.S.	N.S.	4.01	0.91	N.S.	0.27

and bio-fertilization was not significant for plant height, number of branches and fresh weight of plants. The combination of Biogein and Phosphorine had the best results on tomato growth and yield under all chemical fertilization levels. The combinations of chemical and bio-fertilization resulted in the highest plant growth and productivity in contrast to chemical fertilization alone.

These results are in agreement with the results found by AMER et al. (2003) who indicated that the bio-fertilization improved tomato productivity under sandy soil conditions. The mixture between Biogein and Phosphorine gave higher effects. This may be due to the fact that it contains different beneficial microbial strains, which can help fixing nitrogen and make the nutrients available to the plants. As indicated by EL-KARAMANY et al. (2000), the positive effects of bio-fertilizers on growth and productivity of plants could be attributed to the effect of different strain groups of microorganisms including nitrogen fixers, nutrients mobilizing group which improve the availability of metals and increase the levels of extractable N, P, K, Fe, Zn and Mn. The results indicated that bio-fertilization can compensate some of the chemical fertilizers added to the soil which positively improved tomato growth and productivity.

Effects of chemical and bio-fertilization treatments on chemical composition of leaves

Nitrogen, phosphorus and potassium content of leaves were significantly increased by all chemical and bio-fertilization treatments. However, a combination of chemical and bio-fertilization treatments had higher results than the chemical fertilization alone (Tab. 3). The interactions were also significant between chemical and bio-fertilization except for the phosphorus content in the first season. Decreasing the level of chemical fertilization resulted in lower N, P and K contents of leaves while combining bio-fertilization enhanced N, P and K contents compared to plants received only chemical fertilizers without bio-fertilization.

Higher N and P fertilization combined with bio-fertilization of Biogein and Phosphorine mixture had the best effect on increasing N, P and K contents of leaves. Bio-fertilization markedly increased the N, P and K contents of leaves which can be attributed to the fact that bio-fertilizers application such as Microbein and the mixture of Biogein and Phosphorine resulted in nitrogen fixation and increased availability of other mineral nutrients. EL-KARAMANY et al. (2000) indicated that the positive effects of bio-fertilizers on growth and productivity of plants could be attributed to the effect of different strain groups of microorganisms such as nitrogen fixers, nutrients mobilizing group which improve the availability of metals and increase the levels of extractable N, P, K, Fe, Zn and Mn.

Effects of chemical and bio-fertilization treatments on hormonal changes

The high growth and yield of tomato plants in response to bio-fertilization application cannot be explained by only compensating some of the plant nutritional requirements. The measurements of hormonal contents of tomato plants in this study help exploring the possible roles of bio-fertilizations on promoting plant growth and productivity. The effect of chemical and bio-fertilization on hormonal changes of tomato plants is illustrated in Tab. 4. Bio-fertilization treatments had positive effects on the hormonal changes of tomato plants compared to non-inoculated plants. The contents of gibberellins (GA3), indole acetic acid (IAA) and Cytokinins increased in response to bio-fertilization treatments especially at the treatment of Biogein and Phosphorine mixture, indicating that bio-fertilization had pronounced effects on the hormonal changes of tomato plants.

Tab. 3: Effects of chemical and bio-fertilization treatments on chemical composition of leaves.
Analysis of variance refers to 1st or 2nd season. Least Significant Difference (L.S.D.) at 5% was used to compare means within each column.

	Treatments	N%	P%	K%
			1st season	
100% NP	Microbein	4.13	0.72	3.74
	Biogein+Phosphorine	5.16	0.94	4.31
	Without biofertilizers	3.42	0.64	3.06
75% NP	Microbein	4.25	0.68	3.69
	Biogein+Phosphorine	4.98	0.92	4.25
	Without biofertilizers	3.32	0.62	3.04
50% NP	Microbein	4.04	0.65	3.63
	Biogein+Phosphorine	4.71	0.85	4.27
	Without biofertilizers	3.32	0.56	3.01
L.S.D. at 5%	(Biofertilization)	0.07	0.01	0.02
	(Chemical fertilization)	0.07	0.01	0.02
	(Interaction)	0.12	N.S.	0.04
			2nd season	
100% NP	Microbein	3.68	0.62	3.31
	Biogein+Phosphorine	4.88	0.9	4.08
	Without biofertilizers	3.25	0.57	2.77
75% NP	Microbein	3.95	0.63	3.43
	Biogein+Phosphorine	4.63	0.85	3.95
	Without biofertilizers	3.22	0.6	2.95
50% NP	Microbein	3.8	0.61	3.41
	Biogein+Phosphorine	4.57	0.82	4.41
	Without biofertilizers	3.19	0.54	2.89
L.S.D. at 5%	(Biofertilization)	0.06	0.01	0.02
	(Chemical fertilization)	0.06	0.01	0.02
	(Interaction)	0.10	0.02	0.04

The inoculation by some microorganisms encouraged the production of some activating hormones, which play an important role for plant growth and development. As shown in Tab. 4, bio-fertilization increased contents of IAA, Cytokinins and GA3. FORLANI et al. (1995) and EL-KHAWAS (1995) reported that several bacterial strains isolated from the rhizosphere of various crops were able to produce auxins. On the other hand, CACCIARI et al. (1989) indicated that phytohormones can be produced from different microorganisms such as *Azospirillum brailense* and *Arthrobacter giacomelloi* in single and mixed batch culture and resulted in higher productivity of gibberellins, cytokinins and auxins. On tomato plants, BANERJEE and CHANDRA (1978) observed high amounts of IAA produced by N-fixing bacteria. Moreover, RODELAS et al. (1997) stated that the main mechanism by which some bacteria such as *Azotobachter* and *Azospirillium* can benefit plant development and yield may not be fully understood unless bacterial production of biologically active substances such as phytohormones, amino acids and water soluble vitamins are related to growth promoting ability of bacterial strains. The present study demonstrated that bio-fertilization had a pronounced effect on increasing contents of stimulating hormones. In addition to the effects of bio-fertilizers on compensating some of the nutrients required by plants, these hormones promoted plant growth and productivity.

Tab. 4: Effects of chemical and bio-fertilization treatments on Gibberellins (GA3), Indole acetic acid (IAA) and Cytokinins contents of tomato leaves.
Least Significant Difference (L.S.D.) at 5% was used to compare means within each column.

	Treatments	GA3	IAA	Cytokinins
		ng/g fresh weight		
100% NP	Microbein	46.28	36.78	29.05
	Biogein+Phosphorine	67.55	47.78	35.53
	Without biofertilizers	32.33	25.78	24.30
75% NP	Microbein	42.55	34.03	27.05
	Biogein+Phosphorine	63.80	42.55	38.29
	Without biofertilizers	27.28	25.05	22.83
50% NP	Microbein	39.58	31.55	25.04
	Biogein+Phosphorine	60.31	45.80	37.55
	Without biofertilizers	26.81	24.05	20.03
L.S.D. at 5%	(Biofertilization)	0.67	0.65	0.59
	(Chemical fertilization)	0.67	0.65	0.59
	(Interaction)	1.16	1.12	1.02

In conclusion, the present study showed that under sandy soil conditions, the application of bio-fertilizers had stimulating effects on the promoting hormones in plants, helped reducing the use of chemical and improved tomato growth and productivity. The use of mixture of some bio-fertilizers had the best effects in this respect.

References

ABDALLA, A.M., RISK, F.A., ADAM, S.M., 2001: The productivity of pepper plants as influenced by some fertilizers under plastic house conditions. Bull. Fac. Agric. 52, 625.

ALI, A.H., ABDEL-MOUTY, M.M., SHAHEEN, A.M., 2001: Effect of bio-nitrogen organic and in-organic fertilizer on the productivity of garlic (*Allium sativum*) plants. Egypt. J. Appl. Sci. 16, 173.

AMER, A.H., EL-SHIMI, I.Z., ZAYED, G.A., 2003. Response of tomato plants grown in newly reclaimed sandy soils to bio and mineral fertilization. Annals of Agric. Sc. Moshtohor 41, 925-938.

BADR, S.A., MARTIN, G.C., HARTMANN, H.T., 1971: A modified method for extraction and identification of abscisic acid and gibberellin-like substances from the olive (*Olea europaea*). Physiologia Plantarum 24, 191-198.

BANERJEE, M., CHANDRA, A.K., 1978: Auxin production potentiality of nitrogen fixers isolated from the phyllosphere of crop plants. Current Science 47, 962-963.

CACCIARI, L., LIPPI, D., PIETROSANLI, W., 1989: Phytohormone-like substances produced by single and mixed diazotrophic culture of *Azospirillum* and *Arthrobacter*. Plant and Soil 115, 151-153.

EL-KARAMANY, M.F., AHMED, M.K.A., BAHR, A.A., KABESH, M.O., 2000: Uilization of bio-fertilizers in field crop production. Egypt. J. Appl. Sci. 15, 137.

EL-KHAWAS, H.M., 1995: Idole acetic acid production by natural soil micro-residents. Egypt. J. Appl. Sci. 10, 575-582.

EL-SANAFAWI, E.M., 2006: Effect of some bio-fertilizers on growth and productivity of cucumber plants grown under plastic house conditions. J. Agric. Sci. Mansoura Univ. 31, 393-400.

FAO, 1980: Soils and Plant Analysis. Soils Bulletin 38, 250.

FORLANI, G., PASTORELLI, R., FAVILLI, F., 1995: Root colonization efficiency, plant growth promoting activity and potentially related properties-associated bacteria. J. Gene and Breed. 49, 343-351.

RODELAS, B., GONZOALEZ-LOPEZ, J., MARTINEZ, M.V., SALMERON, V., REVILLAS, J.J., SIERRA, S., 1997: Production of vitamins by soil diazotrophic microorganisms in soil. Biol. and biochem. 1, 39-45.

SNEDECOR, G.W., COCHRAN, W.G., 1967: Statistical methods (6th Ed.) Iowa State Univ. Press, Ames, Iowa, USA.

TROUG, E., MEYER, A.A., 1939: Improvement in denigess, calorimetric method for phosphorus and arsenic. Indian Engineering Annual., 136-139.

YAKOUT, G.M., GREISH, M.H., 2001: Responce of faba bean crop to phosphatic, foliar and bio-fertilization under new reclaimed sandy soil conditions. In: Horst, W.J., Schenk, M.K., Bürkert, A., Claassen, N., Flessa, H., Frommer, W.B., Goldbach, H., Olfs, H.-W., Römheld, V., Sattelmacher, B., Schmidhalter, U., Schubert, S., v. Wirén, N., Wittenmayer, L. (eds.), Plant Nutrition – Food security and sustainability of agro-ecosystems through basic and applied research, 850-851. Kluwer Academic Publishers, Dordrecht.

Address of the authors:

El-Tohamy, W.A. (Ph.D.) and H.M. El-Abagy (Ph.D.) Vegetable Research Department, National Research Center, Dokki, Cairo, Egypt. N.H.M. El-Greadly (Ph.D.), Botany Department, National Research Center, Dokki, Cairo, Egypt. E-mail: wael_eltohamy@hotmail.com

Dr. habil. N. Gruda Humboldt University of Berlin, Institute for Horticultural Sciences, Lentzeallee 55/57 14195 Berlin, Germany