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Water Requirements of Peanut Grown in Sandy Soil under Drip Irrigation and Biofertilization

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Abstract: A field trial was conducted during summer season in Shalatien Research Station that belonged to (D.R.C.), sandy soil to elucidate the combined effect of irrigation quantity, irrigation intervals and biofertilization under drip irrigation system on water consumptive use, water use efficiency (WUE), peanut yield and yield components. Also, soil microbiological properties were studied. Seed inoculation with *Rhizobium* led to highly increase in nodules number comparing with *Azotobacter* which led to decrease the decomposition of organic matter in soil. Temperature of June and July led to increase the number of *Rhizobium*, *Azotobacter* and PDB comparing with April and May months. Plants which treated with triple inoculation led to highest yield and its component. Also, the yield, water consumptive and water use efficiency by groundnut plants increased as irrigation water amount increased and irrigation intervals decreased. The superior effect on pod yield (1824 kg/fed.) was obtained as a result of applying 983.73 mm irrigation quantity (Q_2), which was calculated from Penman-Monteith equation and distributed every day under inoculation the seeds by *Rhizobium* + *Azotobacter chroococcum* + *Bacillus megaterium*. Such increase reached nearly 11 folds relative to ($Q_1I_3Bio_0$) treatment. The highest value of water use efficiency was obtained by applying the triple treatment of biofertilization (Bio_4), and irrigation with (Q_2) distributed every day. Data stated that applying $Q_2I_1Bio_4$ treatment can produce the highest groundnut yield and save 763.19 m^3 water/feddan (comparing with applying Q_3) which can irrigate another area.

Key words: Water use efficiency, Water requirement, Consumptive use, Biofertilizers, Soil microbes, peanut.

INTRODUCTION

With increasing concerns about the environment, better use of the natural resource base, less use of chemicals and efficient use of irrigation water have become increasingly important goals of sustainable agriculture in Egypt, Inoculation of seeds or soil with effective strains of *Bradyrhizobium* sp., *Azotobacter* sp., and phosphate dissolving bacteria (PDB). *Bacillus megaterium* is a common practice. Treatment with the different bacteria or mixing of it increased growth indirectly by changing the microbial balance in the rhizosphere (Kloepper and Schroth, 1981) by: having the ability to fix atmospheric nitrogen, producing iron chelating siderophores (Schippers, 1988) and by phyto-hormones or other plant growth is enhancing compounds. Some bacteria produce organic acids which solubilizing inorganic and organic forms of phosphorus and other minor elements that are normally unavailable to plants.

Inoculation of wheat, sorghum, rice, corn and legumes with the aforementioned bacteria alters root morphology increases numerous plants shoots and eventually increase the yield of many crops. These changes have been attributed to inoculation induced enhancement of mineral uptake by plants, therefore causing an increase in accumulation of both dry matter and minerals in the stem and leaves of the plant (Kapulnik *et al*., 1985 and Mervat and Dahdoh, 1997). Nour El-Din (1995) noticed that the plant of Taverniera aegyptiaca in Wadi Hagul didn't bear root nodules in its natural habitat.

Peanut has been long used as a dietary component particularly for its high protein and oil content, besides other compounds. Its uses in industry have been numerous especially oil extraction. It contains about 30% protein and is rich in vitamins B and C. The oil content ranges between 38 - 50 % depending on the variety and the environmental conditions. It thrives well in the newly reclaimed soil specially calcareous and sandy soils, thus its cultivation can be extended as much as needed and as followed by other circumstances, without interfering in the crop rotation of old cultivated land. But as sandy soils are lacking fertility, appropriate biofertilization program should be applied. In recent years, some evidences have been gathered that the

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application of biofertilizers and bacterial inoculation to peanut plant resulted in the optimum growth, nodulation and nitrogen fixation as well as highest yield (Joshi *et al*. 1987 and Singh & Dayal, 1992). The present study was, therefore, conducted to study the effect of inoculation with *Bradyrhizobium* sp., *Azotobacter* chroococcum, *Bacillus megaterium* (PDB), in combined effect of each two of them and tri-interaction of them on plant growth, substances produced, total bacterial counts in different root regions, number of nodules/plant and dry weight of nodules during nodule formation. Also, to minimize water consumption for optimal crop production and calculate water use efficiency, water economy and irrigation scheduling under drip irrigation system as affected by biofertilization in newly reclaimed desert soils.

MATERIALS AND METHODS

A substantial experiments was conducted at Shalatien Research Station in 2005 (15th March - 2nd August), the station is located at 22° to 24° N latitude, 35° 30\ to 36° 30\ E longitude. Tables (1 a & 1b and 2) show some physical and chemical characteristics of the studied soil and irrigation water. The analysis of the used organic manures, which was mixed thoroughly with 0-20 cm soil surface layer two weeks before planting, was shown in table (4), they determined according to Richards (1954).

Table 1a: Some physical properties of the studied soil in Shalatien Experimental Station.

Depth, cm	Particle size distribution %					T.C	Pd (g/cm^3)	Moisture content %
	Coarse sand	Mod. Sand	Fine sand	Silt	Clay			
0-20	3	31	61	3	2	Sandy	1.66	4.85
20-40	6	22	66	4	2	Sandy	1.69	4.53
40-60	5	25	61	6	3	Sandy	1.68	4.42
60-80	5	29	57	6	3	Sandy	1.67	4.66
80-100	5	30	56	6	3	Sandy	1.66	3.81
100-	5	31	55	6	3	Sandy	1.65	3.81

Table 1b: Some chemical properties of the studied soil in Shalatien Experimental Station.

Depth, cm	EC dS/m	pH	$CaCO_3$%	Cations me/l				Anions me/l			
				Na^+	K^+	Ca^{++}	Mg^{++}	$CO_3^=$	HCO_3^-	Cl^-	$SO_4^=$
0-20	0.77	7.7	2.30	0.62	0.49	3.66	2.91	-	0.42	3.92	3.33
20-40	0.66	7.6	1.10	0.63	0.40	2.82	2.75	-	0.42	3.09	3.09
40-60	0.49	7.5	0.85	0.55	0.39	1.99	1.96	-	0.36	2.80	1.90
60-80	0.50	7.5	0.60	0.51	0.42	2.81	1.26	-	0.38	2.65	1.95
80-100	0.36	7.3	0.58	0.48	0.38	1.92	0.80	-	0.26	1.75	1.61
100-120	0.34	7.3	0.55	0.32	0.38	1.19	1.51	-	0.39	1.52	1.49

Table 2: Chemical analysis of irrigation water.

EC dSm^{-1}	PH	Cations, meq/l				Anions, meq/l				SAR
		Ca^{++}	Mg^{++}	Na^+	K^+	$CO_3^=$	HCO_3^-	Cl^-	$SO_4^=$	
1.2	7.6	0.49	0.30	0.30	0.11	-	0.12	0.68	0.38	0.78

The treatments was arranged in split - split plot design with 4 replicates and cultivated by peadnut (*Arachis hypogaea*). The potential evapotranspiration that calculated as corresponding to Penman-Monteith (Allen *et al*., 1998) approach depending on the meteorological data which presented in Table (3). Three applied irrigation water doses, ETm, were obtained from the product of the potential evapotranspiration (ETo) by crop coefficient for every growth stage and multiplying by 0.8, 1.0 and 1.2. The applied irrigation water was added through trickle irrigation system which has 95% application efficiency, Table (4).

Table 3: Meteorological data of Shalatien Station of 2005 during the cultivated period.

Year	Month	Av. Tmp. °C	Max. Tmp °.C	Min. Tmp. °C	Total Slr. W/m2	RH %	Av. WS Km/h	Max. WS Km/h	ETO mm.
2005	March	20.96	26.44	16.17	0.23	55.01	12.83	35.42	6.09
	April	25.18	30.56	20.01	0.29	53.15	12.99	37.80	6.98
	May	28.65	34.44	23.32	0.32	48.43	12.73	37.57	8.27
	June	29.94	35.80	24.64	0.32	47.08	12.41	39.03	8.84
	July	32.37	39.70	26.89	0.31	43.77	11.51	35.84	9.41
	August	33.34	39.79	28.78	0.27	48.88	11.17	35.34	13.61

Table 4: Net irrigation water treatments at different growth stages.

Irrigation water quantities	Growth stages									
	Initial		Vegetative		Flowering		Yield formation		Total applied water	
	mm	m^3 / fed.	mm	m^3/ fed.	mm	m^3/ fed.	mm	m^3/ fed.	mm	m^3/ fed.
Q_1 (80%)	53.68	225.47	170.38	715.61	285.56	1199.35	277.36	1164.89	786.98	3305.33
Q_2 (100%)	67.11	281.84	212.98	894.52	356.95	1499.18	346.69	1456.12	983.73	4131.65
Q_3 (120%)	80.53	338.21	255.58	1073.41	428.34	1799.01	416.03	1747.37	1180.47	4894.84

Three treatments for irrigation application intervals were chosen i.e., daily (I_1), every two days (I_2) and every three days (I_3). Fresh liquid culture medium of 72 hr. old pure local strain of either *Azotobacter chroococcum* and *Bacillus megaterium* (PDB) isolated from rhizosphere of broad bean plants in Shalatien Experimental Station, purified and identified according to Bergey's manual (1984). *Bradyrhizobia sp.* was provided by the department of soil microbiology laboratory of D.R.C. Cairo, Egypt. Inocula of *Bradyrhizobia sp., Azotobacter chroococcum* and *Bacillus megaterium* (PDB) strains were obtained by growing them separately on Y.E.M. (Vincent, 1970), Ashby's and on modified Bunt and Rovira medium (Abdel-Hafez, 1966), respectively for 7 days at 28C°. Suspension of cells of these strains containing about 10^8 cells ml^{-1} was used as standard inocula.

Peanut seeds were successively washed and mixed with the biofertilizer inoculation. Each seedbed was cultivated with three seeds and then thinned later to 2 seedlings. The field was directly irrigated to provide suitable moisture for inocula. Seeds of uninoculated controls were treated in the same manner but without microorganisms. Treatments involved; 1) Five biofertilization treatments which comprised**,** Bio_1 (*Rhizobium*), Bio_2 (Rhizobium + *Azotobacter chroococcum*), Bio_3 (*Rhizobium + Bacillus megaterium*), Bio_4 (*Rhizobium + Azotobacter chroococcum + Bacillus megaterium***)** and Bio_0 as a control treatments.

All plots which bounded by 1.5 m wide levees to avoid horizontal water infiltration, were fertilized by the equivalent of 20 m^3 and 200 kg/fed. organic manure (Table 5) and superphosphate, respectively, which thoroughly mixed with 0-20 cm soil surface layer before planting, 30 and 24 units of N and K_2O as ammonium nitrate and potassium sulphate. The later two fertilizers were added as three equal doses, after 14, 30 and 45 days from planting.

Table 5: The properties of the applied organic manure.

Organic manure	Organic carbon %	Total nitrogen %	Organic matter %	C/N ratio
Sheep waste	23.71	2.06	40.76	11.51

The soil moisture content was gravimetrically determined for 4 depths; 0-20, 20-40, 40-60 and 60-80 cm, immediately before and after 1 day of irrigation. The actual evapotranspiration (ETa) for each stage as well as for the total season were calculated. After harvest, peanut yield components (fresh yield, dry weight and pod yield /fed.), were recorded for each plot. Water use efficiency (kg/m^3) was calculated according to Giriappa (1983).

Microbiological analysis of soil at vegetative stage and at the end of experiment included the determination of total microbial counts and PDB by plating on Bunt and Rovira agar medium and on the same medium after modification (Abdel-Hafez, 1966), respectively. The most probable number (MPN) of *Azotobacter* was determined after incubating the tubes at 28C° for 7 days on modified Ashby's medium (Abdel-Malek and Ishac, 1968). Estimates of number of *Azotobacter* by MPN technique was calculated using Cochran's tables (Cochran, 1950).

RESULTS AND DISCUSSION

Peanut Yield:

Data presented in Table (6) show the effect of irrigation water quantities, intervals and bio-fertilizers on fresh and dry weights (ton/fed). Irrigation water quantity has no significant effect on the yields. Increasing the irrigation intervals decreased significantly the two weights. While the applied of bio-fertilizer was superior in increasing the fresh and dry yields.

The interaction between irrigation water quantity and bio-fertilizer has resulted insignificant effects on both weights, the maximum increase was obtained when applied triple inoculation of bio-fertilizer under irrigation with the lowest water quantity ($Q_1 \times Bio_4$ treatment). Such increase reached to 73.4 and 71.1 % (for fresh and dry weights, respectively) relative to irrigation by the same water quantity without bio-fertilizer

Table 6: Effect of irrigation water quantities, intervals and biofertilization on fresh and dry peanut weights (ton /fed.)

Irrigation water quantities	Irrigation intervals	Bio-fertilizer treatments									
		Bio_0		Bio_1		Bio_2		Bio_3		Bio_4	
		Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Q_1	I_1	1.58	1.21	1.63	1.38	1.94	1.44	2.33	1.74	2.74	2.07
(80%)	I_2	1.50	1.11	1.59	1.20	1.87	1.38	2.24	1.70	2.72	1.99
	I_3	1.24	0.91	1.51	1.12	1.79	1.32	2.18	1.57	2.68	1.94
Q_2	I_1	1.13	0.91	1.98	1.37	2.12	1.51	2.49	1.61	2.54	2.15
(100%)	I_2	0.94	0.72	1.68	1.27	1.91	1.41	2.35	1.44	2.43	1.60
	I_3	0.80	0.59	1.55	1.08	1.76	1.28	2.28	1.44	2.34	1.58
Q_3	I_1	1.28	0.98	2.03	1.43	2.24	1.57	2.52	2.17	2.84	2.26
(120%)	I_2	1.14	0.84	1.79	1.28	2.04	1.45	2.42	1.54	2.72	1.80
	I_3	0.85	0.66	1.65	1.17	1.92	1.44	2.38	1.35	2.49	1.57
LSD 5%	Fresh	Dry		Fresh	Dry		Fresh	Dry			
Q	0.15	0.13	I	0.10	0.11	Bio	0.19	0.18			
Q×I	0.11	0.13	Q×Bio	0.13	0.11	I×Bio	0.20	0.11			
Q×I×Bio	0.17	0.15									

Bio_0: Control uninoculated. Bio_1: inoculated with *Rhizobium*.
Bio_2: inoculated with *Azotobacter*. Bio_3: inoculated with *Rhizobium* and *Azotobacter*. .
Bio_4: inoculated with *Rhizobium*, *Azotobacter* and PDB

application. Also, the interaction between irrigation intervals and bio-fertilizer has the same previous trend, but the increase in fresh and dry yields reached to 103.5 and 109.3 %, respectively, for I_1Bio_4 relative to I_1Bio_0 treatments. Concerning the interaction of all treatments on the peanut fresh and dry yields, it is clear that the lowest value was associated with the treatment of irrigation water quantity (Q_2 added every 3 days (I_3) without application of biofertilizer. While the highest values (2.84 & 2.74 ton/fed., for fresh yield and 2.26 & 2.07 ton/fed., for dry yield, with insignificant difference) were resulted as irrigated by highest water quantity (Q_3) and the lowest water quantity (Q_1), respectively, added every day both under application triple inoculation with *Rhizobium*, *Azotobacter* and PDB (Bio_4) treatment**.** This indicate that it can be used the lowest depth of irrigation water to produce fresh and dry peanut yield.

This finding is in consistent with those reported by Anter *et al.,* 1985; Mervat, 1998. The positive effect of inoculation with Rhizobium or *Azotobacter* is mainly attributed to N2-fixation and the production of growth promoting substances, Reynders and Vlassak (1979) and Abdel Monem *et al.* (2001).

The effect of various treatments on pod weight (kg /fed.) is presented in Table (7) which reflects that application of both water doses and biofertilizers increased the peanut pod significantly, while applied irrigation every 3 days decreased it significantly. The interaction effect of applied irrigation quantities and irrigation intervals showed significant increase on pods weight over Q1I1 treatment Also, the interaction effect of applied irrigation doses and biofertilizers showed the same trend. For the interaction effect of applied irrigation

Table 7: Effect of irrigation water quantities, intervals and biofertilization on pod peanut weight (kg /fed.)

Irrigation water quantities	Irrigation intervals	Bio -fertilizer treatments				
		Bio_0	Bio_1	Bio_2	Bio_3	Bio_4
Q_1	I_1	220	566	704	710	894
(80%)	I_2	184	500	552	640	620
	I_3	162	388	484	582	444
Q_2	I_1	526	872	1014	1486	1824
(100%)	I_2	448	640	1000	1212	1406
	I_3	440	522	866	1100	1388
Q_3	I_1	658	1210	1350	1701	1890
(120%)	I_2	602	1020	1284	1352	1586
	I_3	520	1000	1174	1206	1400
LSD 5%						
Q	101.00	I	111.23	Bio	113.56	
Q×I	98.87	Q×Bio	78.99	I×Bio	90.23	
Q×I×Bio	78.89					

intervals and biofertilizers, data revealed that the lowest pod weight was associated with applying wide irrigation interval without biofertilization (I_3Bio_0) with insignificant effect under applying the other two intervals, however the other treatments showed a significant increases. With respect to the interaction effect of all studied treatments, data showed that the lowest pod yield was resulted at applying the lowest water quantity which distributed every 3 days without biofertilizer (162 kg/fed.) with non significant difference when distributed the same irrigation water dose every 1 or 2 days. All other treatments showed a significant increase

over the lowest value. The superior effect (1824 kg/fed.) was obtained as a result of applying 983.73 mm irrigation quantity, which was calculated from Penman-Monteith equation and distributed every day under inoculation the seeds by *Rhizobium* + *Azotobacter chroococcum* + *Bacillus megaterium*. Such increase reached nearly 11 folds compared to lowest peanut pod yield.

The presented results agree with those of Haqqani and Pandey (1994) and Sheteawi and Tawfik (2007) who postulated that higher pod yield obtained with biofertilizer depends on the concept of higher supplying rate of N and P occurring as a result of N-fixation, also, with decreasing water stress.

Water Consumptive Use (ETa):

Data presented in Table (8) show that ETa values were gradually increased as plant growth progressed and reached their maximum at flowering stage. This trend may be due to the less demand for water by the growing plants as they reached their maximum growth. Also, the actual consumptive use of water by peanut plants (for every stage or total season), was increased as the dose, number of irrigation and /or biofertilizer addition.

Table 8: Actual evapotranspiration (ETa), mm of peanut crop at every stage and seasonal as affected by irrigation quantity, interval and biofertilization.

Irrigation water quantities	Irrigation intervals	Biofertilizer	Growth stages				Seasonal	
			Initial	Vegetative	Flowering	Yield formation	mm	m^3/fed.
Q_1	I_1	0	40.21	141.87	240.63	249.58	672.29	2823.62
		1	41.00	142.33	254.42	242.52	680.27	2857.13
		2	42.22	145.98	258.76	248.01	694.97	2918.87
		3	43.01	150.00	261.21	252.78	707.00	2969.40
		4	43.71	154.04	266.74	260.20	724.68	3043.67
	I_2	0	38.88	141.01	242.20	227.86	649.95	2729.79
		1	39.01	143.22	246.00	231.91	660.14	2772.59
		2	40.55	144.95	248.31	235.59	669.40	2811.48
		3	41.62	147.58	250.44	240.00	679.64	2854.49
		4	42.73	148.49	252.48	241.03	684.72	2875.83
	I_3	0	35.88	135.21	198.78	214.12	583.99	2452.76
		1	37.00	136.77	230.85	216.33	620.95	2607.99
		2	38.12	138.10	233.97	219.82	630.01	2646.04
		3	39.22	140.25	235.78	222.95	638.20	2680.44
		4	40.82	142.84	237.62	224.85	646.13	2713.73
Q_2	I_1	0	50.98	173.58	300.69	273.66	798.91	3355.42
		1	51.55	175.22	304.00	275.78	806.55	3387.51
		2	52.89	176.99	305.87	276.91	812.66	3413.17
		3	53.56	178.88	307.45	280.00	819.89	3443.54
		4	54.97	180.81	309.58	281.46	826.81	3472.62
	I_2	0	47.01	165.50	284.58	258.25	755.34	3172.43
		1	49.33	168.20	287.33	261.58	766.44	3219.05
		2	51.01	170.52	290.54	263.23	775.30	3256.26
		3	52.12	172.23	292.14	266.84	783.33	3289.99
		4	53.53	174.11	294.41	269.59	791.64	3324.89
	I_3	0	46.71	161.22	271.55	249.00	728.48	3059.62
		1	48.22	163.53	274.89	251.65	738.29	3100.82
		2	49.10	164.32	277.45	254.11	744.98	3128.92
		3	50.22	166.55	280.00	256.35	753.12	3163.10
		4	51.48	168.91	281.44	258.85	760.68	3194.85
Q_3	I_1	0	53.66	183.97	320.00	284.59	842.22	3537.32
		1	58.84	188.54	322.20	288.21	857.79	3602.72
		2	61.03	191.87	325.55	291.41	869.86	3653.41
		3	62.22	194.99	328.14	294.28	879.63	3694.45
		4	63.73	196.79	331.54	296.80	888.85	3733.16
	I_2	0	52.09	197.53	291.87	268.00	809.49	3399.86
		1	56.66	180.71	294.98	270.99	803.34	3374.03
		2	58.24	183.25	297.55	274.66	813.70	3417.54
		3	60.00	187.88	308.25	276.59	832.72	3497.42
		4	61.74	189.01	311.79	278.43	840.96	3532.03
	I_3	0	51.65	173.45	292.30	261.58	778.98	3271.72
		1	54.75	177.54	295.87	264.86	793.02	3330.68
		2	56.45	178.20	297.63	266.23	798.51	3353.74
		3	58.11	180.62	300.00	268.90	807.63	3392.05
		4	59.65	183.28	301.61	270.67	815.20	3423.85

Regarding to the interaction effect of irrigation water quantity and intervals on the ETa, it was found that the highest values were obtained as a result of applying the highest irrigation amount which distributed every day, while, the lowest values were obtained as a result of applying the minimum irrigation water dose which distributed every 3 days. Also, the interaction effect of irrigation water quantity and biofertilizer, data showed that the highest values were obtained as a result of applying the highest irrigation amount and biofertilizer (triple inoculation); in contrast, the lowest values were obtained as a result of applying the minimum irrigation water amount and without biofertilizer addition. Respecting the interaction effect of irrigation intervals and biofertilizer addition, it was found that the highest values were obtained as a result of irrigation every day with applying triple inoculation biofertilizer, while the lowest ones were obtained as a result of 3 days interval without biofertilizer treatment.

In spite of the interaction effect of irrigation water quantity, intervals and biofertilizer treatment on the ETa of stages or total season, data indicated that the highest values were associated with applying the highest irrigation water quantity distributed every day under inoculation the seeds by *Rhizobium* + *Azotobacter* chroococcum + *Bacillus megaterium*, while the lowest values were associated with applying the lowest irrigation water quantity distributed every 3 days without inoculation the seeds by biofertilizer, such difference reached 52.20 %.

The presented results agree with the findings of Gaber and El-Dosouky (1993) who found that the values of total consumptive use of water by cowpea plants were increased as the amounts and/or number of irrigation increased.

Water Use Efficiency (WUE):

The obtained data of water use efficiency in kg of pod/m^3 of consumptive water are presented in Table (9). The data indicate that the WUE by peanut pod increased with increasing irrigation water quantity and/or with applying biofertilizer. While it decreased as irrigation interval increased. The highest value of water use efficiency (0.53 kg/m^3) was obtained by applying the triple treatment of biofertilization (Bio_4), and irrigation with 983.73 mm water calculated from the Penman-Monteith equation distributed every day. Such treatment gave 1824 kg pod/ fed., which decreased by non significant difference less than the pod yield obtained by adding the triple treatment of biofertilization (Bio_4), and irrigation with 1180.47 mm water (Q_3) distributed every day. The same trend was emphasized by El-Boraie (2006) on irrigation frequency of some rapeseed varieties. Also, Sheteawi and Tawfik (2007) stated that applying biofertilizer increased WUE where it enhanced plant efficiency in absorbing water and nutrients from the soil.

Table 9: Effect of irrigation water quantities, intervals and biofertilization on water use efficiency of pod (kg/m^3).

Irrigation water quantities	Irrigation intervals	Bio -fertilizer treatments				
		Bio_0	Bio_1	Bio_2	Bio_3	Bio_4
Q_1	(I_1)	0.08	0.20	0.24	0.24	0.29
(80%)	(I_2)	0.07	0.18	0.20	0.22	0.22
	(I_3)	0.07	0.15	0.18	0.22	0.16
Q_2	(I_1)	0.16	0.26	0.30	0.43	0.53
(100%)	(I_2)	0.14	0.2	0.31	0.37	0.42
	(I_3)	0.14	0.17	0.28	0.35	0.43
Q_3	(I_1)	0.19	0.34	0.37	0.46	0.51
(120%)	(I_2)	0.18	0.30	0.38	0.39	0.45
	(I_3)	0.16	0.30	0.35	0.36	0.41

Data stated that applying $Q_2I_1Bio_4$ treatment can produce highest peanut yield and save 763.19 m^3 water from every feddan (comparing applying Q_3) that can use to cultivate another areas.

Effect of Treatments on Total Microbial Counts:

Initial total microbial counts in the soil before cultivation was $12.5X10^3$ cfu g^{-1} dry soil (Table10). Generally, the counts at plant maturity were higher than those of initial stage and all the treatments exceeded the control, This means that just cultivation (control treatments) enhance the microbial growth to be more than four times that of uncultivated soil (initial). Another increase in counts was associated with the use of biofertilizer either in the form of single strain or mixed culture. The highest count was associated with the mixed of *Bradyrhizobium* sp. + *Azotobacter chroococcum* + *Bacillus megaterium* to be 243.1×10^4 cfu g^{-1} dry soil. However, total microbial counts increased with daily irrigation interval (I_1) and 120% water irrigation quantity (Q_3).

Table 10: Effect of irrigation water quantities, intervals and bio-fertilizers on total microbial counts in the rhizosphere of peanut plants.

Irrigation Water quantities	Irrigation Water intervals	Biofertilizer treatments									
		Total microbial counts (X 10^4) cfu* g^{-1}dry soil									
		Bio_0		Bio_1		Bio_2		Bio_3		Bio_4	
		Vegetating	Harvesting	Vegetating	Harvesting	Vegetating	Harvesting	Vegetating	Harvesting	Vegetating	Harvesting
Q_1 (80%)	(I_1)	5.4	11.1	19.4	37.4	34.3	67.2	46.2	57.2	80.5	102.8
	(I_2)	4.9	10.7	17.7	35.4	32.6	66.7	43.9	54.3	77.6	100.5
	(I_3)	4.8	10.0	14.6	31.0	29.6	59.9	41.3	49.4	72.0	92.8
Q_2 (100%)	(I_1)	9.3	17.7	30.2	58.6	54.9	106.5	77.2	91.6	129	162.0
	(I_2)	7.1	15.1	24.7	49.1	44.9	90.6	64.4	75.4	108.4	138.7
	(I_3)	5.9	13.5	21.5	43.5	26.7	79.1	56.3	66.2	94.3	119.8
Q_3 (120%)	(I_1)	14	26.9	46.3	88.3	84.2	160.4	119.5	140.5	198.9	243.1
	(I_2)	11	22.1	38.2	74.3	69.4	135.8	98.5	116.3	164.7	206.5
	(I_3)	9.4	19.2	31.5	62.4	58.5	115.9	83.4	97.4	139.2	176.2
LSD 5%	I	0.56	0.53	0.86	1.05	1.06	1.14	0.96	1.58	0.95	1.55
	Q	0.33	0.50	1.10	1.02	1.28	0.81	1.36	2.11	0.84	1.80
	I X Q	0.45	0.52	0.97	1.03	1.12	0.96	1.25	1.87	0.90	1.64

*Initial counts = 12.5 $X10^3$ cfu g^{-1}dry soil cfu: Colony forming unit.

The enhancement in microbial activity is a good parameter for many soil improvement indices. For examples rhizobia and *Azotobacter* produce growth promoting substances which enhance plant growth proliferate lateral roots and root hairs which increase nutrient absorbing surface (Toan, 2002). Also, inoculating seeds with phosphate dissolving bacteria (PDB) increases soluble phosphate in soil by producing some of acids which could be chelated with calcium and iron resulting in effective solubilization and utilization of phosphate (Saber, 1982 and Boutros *et al*., 1987).

Effect of Treatments on Total Fungi Counts:

Initial total fungi count in the soil before cultivation was found to be $1.2X10^2$ cfu g^{-1} dry soils. Table (11) shows the changing in the counts which tended to increase in all treatments, reaching a high maximum level at harvesting stage of inoculation treatments with the mixture of biofertilization with daily irrigation interval (I_1) and 120% water irrigation quantity (Q_3), which being 65.7 cfu g^{-1} dry soil. These fungi must be included pathogenic fungi which may cause hazard to plants such as root rot and wilt.

Table 11: Effect of irrigation water quantities, intervals and biofertilization on total fungi counts in the rhizosphere of peanut plants.

Irrigation water quantities	Irrigation water intervals	Biofertilizer treatments									
		Total fungi counts (X 10^3) cfu g^{-1}dry soil									
		Bio_0		Bio_1		Bio_2		Bio_3		Bio_4	
		Vegetating	Harvesting	Vegetating	Harvesting	Vegetating	Harvesting	Vegetating	Harvesting	Vegetating	Harvesting
Q_1 (80%)	(I_1)	3.3	1.6	5.8	11.2	10.6	20.2	13.9	17.1	24.2	30.8
	(I_2)	2.9	1.4	5.0	9.7	9.0	17.7	11.9	14.8	21.0	27.2
	(I_3)	2.2	1.0	3.4	7.2	6.7	13.8	9.2	11.1	15.9	20.4
Q_2 (100%)	(I_1)	5.8	3.0	9.7	19.1	17.9	35.1	25.3	29.8	42.6	53.6
	(I_2)	6.5	3.1	10.9	21.4	19.8	39.3	28.3	33.1	47.1	59.8
	(I_3)	4.6	2.2	7.7	15.0	14.0	27.4	19.5	23.4	33.0	42.1
Q_3 (120%)	(I_1)	6.8	3.3	11.3	22.0	21.7	40.0	29.6	34.6	49.3	65.7
	(I_2)	7.0	3.6	12.3	23.7	22.4	43.2	31.7	37.6	53.0	60.7
	(I_3)	5.8	2.8	9.50	18.7	17.5	34.8	25.0	29.2	41.8	52.9

*Initial counts = 1.2 $X10^2$ cfu g^{-1}dry soil

Effect of Treatments on Azotobacter Densities:

Nitrogen is a key nutrient for microbial growth. *Azotobacter* as an important group of organisms due to their activity in fixing atmospheric nitrogen was enumerated periodically. Table (12) shows that the highest counts were recorded at plant maturity. In control treatments begin to increase at vegetating stage then declined towards maturity growth stage of peanut plants. It may be due to several reasons such as: soil was very poor in nutrients, organic matter and the high temperature in this region especially in summer. The highest densities were recorded with *Azotobacter chroococcum* + *Bradyrhizobium* sp. (Bio_2) at daily irrigation interval (I_1) and

Table 12: Effect of irrigation water quantities, intervals and Bio- fertilization on densities of *Azotobacter* in the rhizosphere of peanut plants.

Irrigation water quantities	Irrigation water intervals	Biofertilizer treatments									
		Densities *Azotobacter* (X 10^2) cell g^{-1}dry soil									
		Bio_0		Bio_1		Bio_2		Bio_3		Bio_4	
		Vegetating	Harvesting	Vegetating	Harvesting	Vegetating	Harvesting	Vegetating	Harvesting	Vegetating	Harvesting
Q_1 (80%)	(I_1)	17.00	13.3	19.1	24.3	45.6	56.2	31.1	37.7	36.5	46.3
	(I_2)	13.3	9.7	13.5	19.1	32.0	41.2	21.9	26.1	25.6	33.7
	(I_3)	14.0	8.0	10.9	15.0	24.3	30.4	17.0	20.0	19.4	24.4
Q_2 (100%)	(I_1)	21.3	18.0	25.8	34.9	62.1	80.0	42.0	51.1	49.6	68.0
	(I_2)	18.3	13.7	18.9	25.5	43.2	53.0	30.4	36.1	34.5	43.7
	(I_3)	13.3	10.3	15.0	20.0	34.4	42.0	23.9	28.1	27.5	35.0
Q_3 (120%)	(I_1)	32.3	28.7	37.8	49.4	85.0	106.3	61.8	72.7	68.0	86.3
	(I_2)	26.0	22.7	28.9	38.5	70.2	86.3	47.5	56.1	56.2	71.9
	(I_3)	17.0	14.7	21.9	29.4	50.7	63.4	36.5	41.5	40.6	50.7

*Initial counts = 0.25 $X10^2$ cell g^{-1}dry soil.

120% water irrigation quantity (Q_3) being 106.3$X10^2$ cells g^{-1} dry soil as individual treatments: *Bradyrhizobium* sp. + *Azotobacter chroococcum* + *Bacillus megaterium* (Bio_4) of water quantities (Q_3) at daily irrigation interval (I_1) being 86.3$X10^2$ cells g^{-1} dry soil as combined treatments. These are equivalent to3.7 and 3.0 folds of counts comparing with uninoculated control (Bio_0) at harvesting stage. *Azotobacter* is previously proved to produce indole acetic acid, gibberellins and cytokinin - like substances (Ishac *et al.*, 1989 and Mighahed, 2004).

Effect of Treatments on Phosphate Dissolving Bacteria (PDB):

The initial count of PDB in the rhizosphere of *Arachis hypogea L.* was nil (Table 13). However their counts tended to increase in all treatments rather than the control by using different water quantities, irrigation water interval and by using different types of biofertilizers. The highest counts were recorded in treatments inoculated with the mixture of *Bradyrhizobium* sp. + *Azotobacter chroococcum* + *Bacillus megaterium* (Bio_4) of water quantities (Q_3) with one day of irrigation interval being 26.74 cfu g^{-1} dry soil.

Table 13: Effect of irrigation water quantities, intervals and biofertilization on phosphate dissolving bacteria (PDB) counts in the rhizosphere of peanut plants.

Irrigation water quantities	Irrigation water intervals	Biofertilizer treatments									
		Densities *Azotobacter* (X 10^2) cell g^{-1}dry soil									
		Bio_0		Bio_1		Bio_2		Bio_3		Bio_4	
		Vegetating	Harvesting	Vegetating	Harvesting	Vegetating	Harvesting	Vegetating	Harvesting	Vegetating	Harvesting
Q_1 (80%)	(I_1)	0.18	0	0.29	0.63	0.57	1.06	0.53	1.29	7.82	15.95
	(I_2)	0.00	0	0.27	0.51	0.41	0.78	0.45	1.14	7.59	15.04
	(I_3)	0.00	0	0.25	0.1	0.11	0.19	0.11	0.23	4.97	9.7
Q_2 (100%)	(I_1)	0.29	0	0.46	0.99	0.81	1.48	`0.80	1.86	9.89	19.3
	(I_2)	0.00	0	0.37	0.53	0.46	0.84	0.44	1.02	7.28	14.34
	(I_3)	0.00	0	0.63	0.30	0.78	1.72	0.55	1.71	7.76	15.15
Q_3 (120%)	(I_1)	0.47	0	0.73	1.68	0.98	2.16	1.28	3.16	13.91	26.74
	(I_2)	0.30	0	0.58	0.90	1.07	1.94	1.07	2.49	11.79	23.01
	(I_3)	0.17	0	0.49	0.50	0.86	1.39	0.71	1.67	9.47	18.18

*Initial counts = nil

Effect of Treatments on Nodulation Formation:

At the 28 days of cultivation, the number of nodules per peanut plant varied from 0 to 32 nodule/plant. Table (14) indicates that the highest value obtained under application of inoculants with *Bradyrhizobium* sp. + *Azotobacter chroococcum* + *Bacillus megaterium* (Bio_4) at 120% of irrigation water quantities (Q_3) at daily irrigation interval (I_1) being, which contain 32 nodule $plant^{-1}$, following by the inoculation with *Bradyrhizobium* sp. + *Bacillus megaterium* (Bio_3) in the treatments at daily irrigation interval (I_1) and 120% irrigation water quantities (Q_3) containing 29 nodule $plant^{-1}$. This reason could be attributed to the role of nitrogen fixing capacity by microorganism (Son *et al.*, 2001).

Table 14: Effect of irrigation water quantities, intervals and bio-fertilizers on the number of nodules and its dry weight (mg) per plant of peanut plants.

Irrigation water quantities	Irrigation water intervals	Biofertilizer treatments									
		No of nodules/ plant									
		Bio_0		Bio_1		Bio_2		Bio_3		Bio_4	
		28 days	42 days	28 days	42 days	28 days	42 days	28 days	42 days	28 days	42 days
Q_1 (80%)	I_1	0	0	14	19	17	21	19	23	20	25
	I_2	0	0	9	15	11	17	14	19	13	21
	I_3	0	0	7	14	8	15	9	17	10	18
Q_2 (100%)	I_1	0	0	17	23	20	25	22	27	26	32
	I_2	0	0	15	22	18	24	20	27	21	30
	I_3	0	0	13	20	15	22	17	26	19	29
Q_3 (120%)	I_1	0	0	22	27	27	30	29	33	32	36
	I_2	0	0	14	24	23	27	24	30	27	32
	I_3	0	0	9	22	21	25	23	27	25	30

At six weeks after cultivated, the mean value of nodules ranged from 0 to 36. The highest value recorded under (Bio_4) at 120% irrigation water quantities (Q_3) with daily irrigation interval (I_1) and significantly differences among treatments. On the other hand, data didn't record any nodules on the surface of peanut roots under uninoculated treatments, it may be due to one or more of these factors: the soil is very poor in its content of nutrient elements, organic matter, microorganisms content and the temperature is very high which arrived more than 55^0 in summer.

Effect of Treatments on Dry Weight of Peanut Nodules:

In the same trend date in Table (15) clearly show that the dry weight of nodules varied from 28.7 to 176.4 mg. The highest value obtained under application of *Bradyrhizobium* sp. + *Azotobacter chroococcum* + *Bacillus megaterium* (Bio_4) at 120% of irrigation water quantities (Q_3) at daily irrigation interval (I_1) which being 176.4 mg, following by *Bradyrhizobium* sp. + *Bacillus megaterium* (Bio_3) at 120% of irrigation water quantities (Q_3) at daily irrigation interval (I_1) which being 163.4 mg. This effect could be attributed to the role nitrogen fixing capacity of microorganisms. At six weeks after cultivation, the mean value of nodules weight ranged from 59.4 to 204.3 mg. The highest value recorded under (Bio_4) at (I_1) with (Q_3). This result indicated that inoculations seeds increased the dry weight of nodules compared with uninoculated ones.

Table 15: Effect of irrigation water quantities, intervals and bio-fertilizers on dry weight of peanut nodules (mg per plant).

Irrigation water quantities	Irrigation water intervals	Biofertilizer treatments									
		Dry weight of nodules (mg $plant^{-1}$)									
		Bio_0		Bio_1		Bio_2		Bio_3		Bio_4	
		28 days	42 days	28 days	42 days	28 days	42 days	28 days	42 days	28 days	42 days
Q_1 (80%)	I_1	0	0	60.6	87.7	79.0	97.3	87.1	108.6	93.4	118.2
	I_2	0	0	36.9	66.0	50.8	73.3	58.7	80.2	55.7	93.6
	I_3	0	0	28.7	59.4	38.5	66.0	39.1	73.2	43.0	78.3
Q_2 (100%)	I_1	0	0	83.0	114.3	100	122.5	109.5	134.6	127.4	163.2
	I_2	0	0	67.5	98.3	81.0	106.9	90.3	119.4	95.1	142.4
	I_3	0	0	58.5	91.8	68.1	100.5	75.8	114.8	86.2	129.7
Q_3 (120%)	I_1	0	0	124.4	149.4	151.9	165.8	163.4	184.1	176.4	204.3
	I_2	0	0	95.0	120.0	114.0	134.2	119.9	148.3	139.7	171.4
	I_3	0	0	88.3	110.0	105.0	125.0	113.4	135.0	123.3	149.8

In Summary, the obtained results indicated that inoculation with *Rhizobium*, *Azotobacter* and PDB increased the microorganisms' densities and peanut growth and yield.

Considerable increase was observed when plants were inoculated with *Rhizobium* and *Azotobacter*. This finding is in consistent with those reported by (Anter *et al.*, 1985; Mervat, 1998). The positive effect of inoculation with *Rhizobium* or *Azotobacter* is mainly attributed to N_2-fixation and the production of growth promoting substances (Reynders and Vlassak, 1979).

The improvement of peanut growth and yield may be attributed to one or more of the following factors:

1. Availability of more nitrogen due to N_2-fixation.
2. The production of growth promoting substances by *Azotobacter*.
3. The production of thiamin, nicotinic acid, pantothenic acid, biotin, pyridoxine, gibberellins and other compounds by *Azotobacter*. (Harper and lynch, 1979, and Mervat (2001).
4. The successful competition of the bacteria, which antagonizes root pathogens (Abdel-Ghafar *et al.,*1996 and Mervat, 2001)

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