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USE OF BIOFERTILIZER AS EFFECTIVE TOOL FOR GROWTH AND YIELD IN SORGHUM (*Sorghum bicolor* L) PLANTS UNDER DIFFERENT SOIL MOISTURE

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ABSTRACT: **The goal of this study was the evaluate of the effects of inoculation *Rhizobium leguminosarum* (R.l) and *Bradyrizobium japonicum* (B.j) strains, as plant growth promoting rhizobacteria (PGPR), with ½ rates of recommended quantities of NPK fertilizer (R.Q.F) on the growth, total count bacteria and yield components of two sorghum cultivars; Dorado and Shandaweel grown under different levels of soil moisture (100, 60 and 40% of field capacity). The plants received four treatments; R.Q.F (control), ½ rates of R.Q.F. without inoculation and ½ rates of R.Q.F with either of strain. Two samples of plants were collected after 45 and 70 from sowing date. The data obtained revealed that both inoculation treatments with half NPK greatly increased the total bacteria count and most probable number for Azotobacter spp. and Azospirillum spp. on rhizosphere and roots soil surface of sorghum. The results also clearly confirmed that the inoculation treatment led to a significant increase of root length, leaf area, fresh matter of shoots and roots over the control treatment at 60 and 40 % of field capacity. The corresponding yield values of Shandaweel were 17.3 and 19.2%**

over the control at 60% of F.C after *R. leguminosarum* and *B. japonicum* inoculation, respectively. Meanwhile, it was 7.25 at 60% of F.C with inoculation of *R. leguminosarum* and 1.89% at 40% of F.C after inoculation with *B. japonicum* in Dorado cultivar. Therefore, the biofertilizer is considered to be excellent as the effective tools to reduced chemical fertilizer as well as irrigate water and consequently the cost and pollution.

Key words: *Bradyrhizobia, growth regulator, nitrogen, sorghum, yield.*

INTRODUCTION

Sorghum (*Sorghum bicolor* L.) ranks the fourth in average as a cereal crop, after wheat, maize and rice. Its importance comes from its adaptation to a biotic stress such as drought, salinity and high temperature. On the other hand, *Rhizobium* is known to survive in the soil and the rhizosphere of legumes and non-legumes. Non-symbiotic Plant Growth Promoting Rhizobacteria (PGPR) are often used as inoculates, however, they are not as effective as entophytic bacteria (Antuon *et al.*, 1998). These bacteria have the advantage of living within the plant tissue, protecting the plant from super infection by soil bacteria and recolonizing the plant surface after some stress situation in the soil (Kozyrovska *et al.*, 1997). The drought stress and beneficial impacts of PGPR are though after some stress situation to be direct plant growth promotion by the excreting auxins, anti-microbial substances and associative nitrogen fixation (Chiarini *et al.*, 1998). Also, increased uptake of nutrients such as N, P and K (Kapulinik *et al.*, 1985) has been suggested as one of the mechanism by which PGPR increased growth and crop yield (Höflich *et al.*, 1997 and Galal *et al.*, 2001). Moreover, both bacterial strains differ in their growth characters; R. leguminosarum– fast growing in rhizosphere and execrate phytohormones in root which transfers up to shoot and possibly increases leaf area, while *B. Japonicum*– slow growing and its effect on growth of root under drought stress conditions.

Therefore, the present study aimed to investigate the interactive effects of rhizobial inoculation and NPK fertilization doses on the growth, as well as symbiotic N_2-fixation and productivity of two sorghum cultivars grown under different levels of water stress

MATERIALS AND METHODS

Two pot experiments were conducted at the greenhouse of Biological Nitrogen Fixation Unit, Agricultural Research Center (ARC), Giza, Egypt, during 1999 and 2000 growing seasons. Two sorghum cultivars (Dorado and Shandaweel) were supplied by the Field Crops Research Institute, ARC, and were sown on 21 June 1999 and 18 June 2000, respectively. Five seeds of sorghum were sown in each pot (30 cm in diameter contained 10 kg sandy loam soil, which obtained from El-Nubaria as a reclaimed region). Seedlings were thinned for only two per pot Soil sample was collected to analysis both of physical and chemical properties as following:

Soil physical properties: sand 66.94%, silt 27.9%, clay 5.86%, textural class (sandy loam), S.P. 41.6%, pH 7.72, E.C (dS m^{-1}) 1.4, $CaCO_3$ 4.2%.

Chemical properties: total nitrogen 0.011%, organic matter 0.52%, Ca^{++} 4.20 meq L^{-1}, Mg^{++} 2.3 meq L^{-1}, Na^{+} 1.49 meq L^{-1}, K^{+} 0.8 meq L^{-1}, HCO^{-}_3 1.23 meq L^{-1}, Cl^{-} 2.5 meq L^{-1}, $SO^{=}_4$ 5.06 meq L^{-1}, P 2.18 ppm, Fe 2.2 ppm, Zn 0.42 ppm and Mn 0.91 ppm. Soil physical and chemical properties were analyzed as described by Piper (1950). Pot experiments during the two growing seasons included four treatments (for each cultivar) with four replicates as follows: 1- *R.Q.F. (control) 2- ½ rates of R.Q.F. (control). 3- ½ rates of R.Q.F. + *R. leguminosarum*. 4- ½ rates of R.Q.F. + *B. japonicum*. And each treatment replicated five times. These treatments were arranged in a complete randomized block design according to Sendecor and Cochran (1980). Pots experiments were kept at different water regime levels; 100%, 60% and 40% of F.C using Moisture meter after two weeks from sowing. Table (1) shows the source of 12 strains used in this study. The strains were purified

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*RQF:= The recommended quantity of NPK fertilizer; which are 120kg N, 48 kg P_2O_5 and 30 kg K_2O/ feddan and maintained on yeast extract mannitol agar (Vincent, 1970), and stored at -70°C in yeast extract mannitol of both containing 20% glycerol. 10 cm^3 of both culture ($x10^9$ cell/ml) was added four times to each pot, one at planting and three subsequent applications at one-week intervals. The uninoculated sorghum plants received only bacterial culture medium as described by (Sabry *et al.*, 1997). Most Probable Numbers (MPN) of *Azospirillium spp.* and *Azotobacter spp.* In the rhizoid adhering to the roots surface samples, were estimated only at 70 day after planting (Table 1). The standard dilution technique according to Vincent (1970) with the semi-solid malate medium (Dobereiner, 1980) and modified ashby's medium (Hegazi and Neimela, 1976) for *Azosperillium spp.* and *Azotobacter spp.*, respectively, were involved. The total bacteria count was estimated by using the plate count technique according to Vincent (1970) with nutrient agar medium (Bridson, 1978). The pots were kept at different regime levels, 100%, 60% and 40% field capacity using moisture meter after two weeks from sowing.

Table 1: Strains of rhizobia and bradyrhizobia used in this study.

Bacteria	Strains	Source
Rhizobium leguminosarum bv. *phaseoli*	127k 80C, NB554	A (Nottingham Univ.,UK)
	ARC301, ARC 310	B (ARC, Giza, Egypt)
bv. *trifolii*	SU 157	A
	ARC 101,ARC 103	B
Bradyrhizobium japonicum	USDA SPC4	A
	USDA HH303	C (United State, Dept. of Agric,
	USDA 205	C USA)
	ARC 500	B
	ARC 501	B

Two samples of plant of each treatment were collected after 45 and 70 day from sowing date and morphological characters; plant height, root length, number of leaves/ plant and leaf area, were recorded. The plants separated into shoot and root and the fresh as well as the dry matter for both were determined. At harvest, the yield components; dry weight of panicle and straw, height of panicle and grain yield (g/plant) were also determined.

The growth data and yield components were subjected to statistical analysis, and the means were determined using L.S.D. test (5%), according to Sendecor and Cochran (1980).

RESULTS AND DISCUSSION

It is important to mention here that the obtained results during both experimental seasons exhibited the same clear and decisive trend. Therefore, the tabulated and discussed data of the various determinations represent the recorded results in the second season.

Regarding, morphological characters in the first sample in Table (2), the results showed no different obtained as a result of the treatments with the second sample (Table 3). Thus, we focus on the second sample data. Comparing the effect of different treatments on the morphological characters of sorghum cultivars (Table 3), the result referred that although the all treatments had no significant effects on the plant height of non-stressed Dorado plants (100% of F.C.), a marked or significant reductions in the plant height of stressed plants were recorded after the plants received ½ rates of R.Q.F and grown under either 60 or 40% of soil moisture levels. When added ½ rates of R.Q.F with inoculation of rhizobia, considerable significant increase in the plant height values over the respective values of the plants received only the half dose of NPK fertilizer. The plant heights of such plants exceeded the respective value of the control plants (received R.Q.F) when inoculated with *B. jabonicum* strain under both levels of soil moisture; 60% and 40% of F.C. Shandaweel cultivar appeared similarly response by this treatment, with only exception is that the non-stressed plants as well as stressed ones exhibited the same response when received ½ rates of R.Q.F. In addition, the superiority of *B. japonicum* was detected only with 40% of F.C. level. On the other hand, regardless only few exception, the response of the number of leaves and root length of both cultivars plants of the various treatment was similarly to that described for their plant heights, with special referring the superiority of *B. japonicum* in increasing significantly the root length of Shandaweel plants under 60% F.C. level. Moreover in the same cultivars, the inoculation with both strains induced significant

Table 2: The interaction effects of biofertilizer treatments and NPK fertilization dose on the mean values of growth parameters of 45 days-old plants of two sorghum cultivars grown under different water stress levels during 2000 season.

Growth parameters	Plant height (cm)	Root length (cm)	No. of leaf	Leaf area (cm^2)	F. M. of shoot (g)	F.M. of Root (g)	D.M. of shoot (g)	D.M. of Root (g)
Dorado	100% of F.C.							
R.Q.F	70	40	5	178.3	3.68	1.09	0.70	0.48
½ rate of R.Q.F	31	22	5	57.4	1.88	0.34	0.16	0.14
½ rate of R.Q.F + R.I	52	36	5	177.4	4.20	1.07	0.60	0.49
½ rate of R.Q.F + B.J	47	27	5	166.9	2.60	0.85	0.51	0.31
Shandaweel								
R.Q.F	70	39	5	179.2	5.40	1.40	0.55	0.40
½ rate of R.Q.F	44	31	4	100.6	2.76	0.74	0.49	0.33
½ rate of R.Q.F + R.I	67	32	5	178.6	5.01	1.10	0.82	0.38
½ rate of R.Q.F + B.J	56	39	5	183.6	3.40	1.32	0.62	0.43
L.S.D (5%)	16.3	9.8	0.43	57.6	1.4	0.41	0.25	0.16
Dorado	60% of F.C							
R.Q.F	70	40	5	350	6.5	1.81	0.64	0.61
½ rate of R.Q.F	49	27	5	79	1.6	1.00	0.31	0.22
½ rate of R.Q.F+ R.I	67	39	5	240	8.1	6.71	0.73	0.96
½ rate of R.Q.F+ B.J	54	17	5	313	7.1	1.77	0.53	0.44
Shandaweel								
R.Q.F	67	49	5	317	7.8	6.5	1.50	2.50
½ rate of R.Q.F	49	24	5	77	1.4	1.66	0.24	0.20
½ rate of R.Q.F+ R.I	67	33	5	186	4.2	2.34	0.49	0.42
½ rate of R.Q.F+ B.J	63	47	5	312	8.3	6.31	1.41	2.38
L.S.D (5%)	15.1	12.5	0.40	112.2	2.9	1.38	0.37	0.58
Dorado	40% of F.C							
R.Q.F	73	33	5	330	5.4	3.20	0.79	1.30
½ rate of R.Q.F	39	18	5	30	1.2	1.17	0.22	0.06
½ rate of R.Q.F+ R.I	62	32	5	315	3.9	3.10	0.74	1.10
½ rate of R.Q.F+ B.J	58	34	5	229	5.0	1.55	0.83	0.31
Shandaweel								
R.Q.F	70	25	5	159	4.2	1.30	0.56	0.57
½ rate of R.Q.F	47	19	4	58	1.7	1.20	0.23	0.22
½ rate of R.Q.F+ R.I	62	27	5	169	4.9	1.51	0.75	0.54
½ rate of R.Q.F+ B.J	51	24	5	80	2.1	1.27	0.37	0.49
L.S.D (5%)	17.2	7.7	0.46	97.2	1.74	0.78	0.21	0.35

R.I: *Rhizobium leguminosarium* B.J: *Bradyrhizobium japonicum*, F: fresh, D: dry, M: matter
R.Q.F: recommended quantities of NPK fertilize

Table 3: The interaction effects of biofertilizer treatments and NPK fertilization dose on the mean values of growth parameters of 70 days-old plants of two sorghum cultivars grown under different water stress levels during 2000 season.

Growth parameters	Plant height (cm)	Root length (cm)	No. of leaf	Leaf area (cm^2)	F. M of shoot (g)	F.M of Root (g)	D.M of shoot (g)	D.M of Root (g)
Dorado	100% of F.C.							
R.Q.F	107	41	10	291	97.1	94.2	18.1	24.0
½ rate of R.Q.F	101	31	10	209	56.1	85.5	7.7	18.0
½ rate of R.Q.F+ R.I	101	43	10	301	94.9	125	15.7	29.5
½ rate of R.Q.F+ B.J	102	41	11	289	78.2	98.5	13.6	25.2
Shandaweel								
R.Q.F	130	30	14	462	84.3	81.2	17.6	25.1
½ rate of R.Q.F	85	29	8	345	55.0	52.3	14.6	11.8
½ rate of R.Q.F+ R.I	127	31	12	469	99.1	97.0	19.4	28.6
½ rate of R.Q.F+ B.J	121	32	11	398	83.2	85.3	15.4	23.5
L.S.D (5%)	6.4	3.7	1.2	23.5	1.6	14.7	2.4	5.5
Dorado	60% of F.C.							
R.Q.F	118	42	11	321	69.2	100	14.9	21.6
½ rate of R.Q.F	105	36	9	220	42.6	86	6.6	14.1
½ rate of R.Q.F+ R.I	116	40	11	358	74.1	112	15.2	25.2
½ rate of R.Q.F+ B.J	123	40	13	371	90.3	114	15.9	28.4
Shandaweel								
R.Q.F	116	36	12	355	80.2	53.8	17.0	11.9
½ rate of R.Q.F	91	25	8	269	42.1	13.9	9.7	4.2
½ rate of R.Q.F+ R.I	112	41	11	374	86.0	70.0	20.5	15.9
½ rate of R.Q.F+ B.J	110	54	11	301	67.7	55.0	15.6	12.5
L.S.D (5%)	6.9	4.8	1.4	57.8	10.3	5.6	2.4	3.1
Dorado	40% of F.C							
R.Q.F	107	34	11	263	72	80.	16.3	13.5
½ rate of R.Q.F	98	31	9	166	39	28	6.8	9.0
½ rate of R.Q.F+ R.I	104	37	10	247	68	86	14.1	14.3
½ rate of R.Q.F+ B.J	112	39	12	300	86	99	19.2	17.3
Shandaweel								
R.Q.F	120	34	12	238	82	76	16.4	14.9
½ rate of R.Q.F	99	30	8	135	37	25	8.8	6.2
½ rate of R.Q.F+ R.I	117	42	12	324	77	79	14.2	16.3
½ rate of R.Q.F+ B.J	122	40	12	349	81	97	15.2	19.4
L.S.D (5%)	8.7	2.4	1.1	61.3	12.7	16.4	2.5	1.9

R.I: *Rhizobium leguminosarium* B.J: *Bradyrhizobium japonicum,* F: fresh, D: dry, M: matter. R.Q.F: recommended quantities of NPK fertilizer.

increases with root length over the control plants at 60 and 40% of F.C levels. As for the leaf area (Table 3) it could be noticed that the reduction of NPK fertilization caused a significant reduction in this regard either in the non-stressed control plants or under both levels of water stresses. When the plant treated with ½ rates of R.Q.F was associated with the biofertilizer inoculation, the trusted plants of both cultivars significantly exceeded in their total leaves area those received either R.Q.F or ½ rates of R.Q.F whatever water stress level. The data of fresh matter of either roots or shoots of both cultivars plants clearly showed that the reduction of 50% of the recommended NPK fertilization caused a considerable significant reduction in both the fresh weight of both shoots and roots compared with the full fertilized plants under all water stress levels, especially the dramatic reductions of 40% of F.C. When the reduced fertilization was combined with the inoculation the significant increases in the fresh weight of both organs were detected over the respective values of those received only the half NPK and even significantly surpassed the control plants which received the complete NPK dose, in several cases. On the other hand, similar trend of dry weight of shoot or roots as a result of both strains under all water stress was obtained

The data of almost all morphological parameter clearly suggested the superiority of *B. japonicum* at 40% of F.C. level in both cultivars.

The most interesting findings in the obtain data regarding dry matter accumulation (Table 3) is that the dry matter accumulation in both roots and shoots of the plants received only ½ rates of R.Q.F + inoculation, was more than double of that in the plants received only ½ rates of R.Q.F in both cultivars and even significantly exceeded the respective values of the full-fertilized control plants in several cases. Whatever the stress levels, which strongly emphasize the favorable effects of rhizobial inoculation in enhancement growth root and dry matter accumulation in the plant organs especially with *B. japonicum* strain treatment. This means that the rhizobium inoculation of sorghum plants has promotive effects in the plant growth especially the roots dry weight and consequently their function in the uptake of water and nutrients. Similar results were reported by Rao (1993), Yanni *et al.* (1995), Rashad and Ismail (2000) and Ghallab and Salem (2001). The significant favorable effects of biofertilizers on the growth and productivity of the treated plants may be explained on the basis of the beneficial effects of bacteria on the nutrient availability, vital enzymes, hormonal stimulating effects on plant growth or increasing of photosynthetic activity. Many investigators previously reported supportive evidences for this view. Bashan *et al.* (1989) reported that *Azospirillum* and *Pseudomonas* improved wheat growth through the significant increases in dry matter accumulation in both roots and shoots of treated plants. Also, Bashan and Levanony (1990) proposed several possible modes of action of *Azospirillum* on plant growth: N_2-fixation, which contributes N to the plant, hormonal effects, which alter plant metabolism and growth, general improvement in the growth of the entire root system, resulting in enhanced mineral and water uptake. Moreover, Creus *et al.* (1997) pointed out that *Azospirillum brasilense* inoculation stimulated the relative elongation rate of shoots, the fresh weight, fresh: dry weight ratio, water content values and relative water content in the shoots of inoculated plants than in untreated wheat seedlings. In addition, Bhattarai and Hess (1998) reported that *Azospirillum* + Vesicular Mycorrhizae (VAM) inoculation enhanced the root and shoot growth of wheat at early stage as compared with NPK alone, which induced an increase of shoots and spike dry weight. Recently, Sabry *et al.* (2000) found that inoculation of wheat with rhizobia only or mixed with VAM fungi at 50% N-fertilizer level increased shoot and root dry weights.

The effect of Rhizobial inoculation and NPK fertilizers on the total count of bacteria, *Azospirillum spp.* and *Azotobacter spp.* population in rhizosphere and root surface is presented in Table (4). The results revealed that the population of these strains increased as a result of inoculation of *R. leguminosarum* and *B. japonicum* strains with half NPK dose treatments compared with full and half NPK alone. Moreover, the total bacteria count and Most Probable Numbers (MPN) of *Azospirillum spp.* were higher with *R. leguminosarum* than *B. japonicum* inoculation, but a reverse trend was detected with the

Table 4: Effect of Rhizobial inoculation and N-fertilization on total count bacteria, *Azospirillum spp.* and *Azotobacter spp.* population in rhizosphere and root surface soil

	Rhizosphere soil (S)						Root surface soil (R)					
Cultivar	Dorado			Shandaweel			Dorado			Shandaweel		
F.C.%	100	60	40	100	60	40	100	60	40	100	60	40
Treatment	Total count bacteria (10^4/g dry soil)											
.Q.F	450	490	240	500	310	.0	960	850	640	980	710	750
½ rate of R.Q.F	520	480	310	480	360	212	1700	1450	1300	1910	1500	1220
½ rate of R.Q.F + R.l	9600	7500	5300	9900	7600	5400	6900	42000	22000	6200	43000	2000
½ rate of R.Q.F + B.j	8400	6200	4900	8300	5900	3100	6100	40000	19000	54000	31000	18000
	Azospirillum (10^2/g dry soil)											
R.Q.F	111	92	70	140	100	82	990	730	300	850	710	580
½ rate of R.Q.F	193	112	99	172	151	113	13000	11000	8900	14000	12000	9100
½ rate of R.Q.F + R.l	400	293	210	422	280	129	23000	19400	10500	21000	19300	10400
½ rate of R.Q.F + B.j	300	210	194	350	260	117	21000	16200	9100	19000	22500	8200
	Azotobacter (10^2/g dry soil)											
R.Q.F	50	42	33	55	49	29	192	80	98	601	976	389
½ rate of R.Q.F	110	83	41	99	75	48	215	200	112	1120	990	997
½ rate of R.Q.F + R.l	190	160	59	180	186	67	2110	990	920	3900	3200	1138
½ rate of R.Q.F + B.j	204	188	72	199	198	69	2390	1210	1140	4500	3600	1200

R.Q.F: recommended quantities of NPK fertilizer
R.l: *Rhizobium leguminosarium* B.J: *Bradyrhizobium japonicum*

population of *Azotobacter*. In general, total count and MPN of *Azospirillum spp.* and *Azotobacter spp.* declined with increasing drought stress level and quite a difference was observed between both cultivars examined.

Regarding rhizosphere soil and root surface soil, the results are presented in Table (4) showed that both rhizobial inoculation with ½ rates of R.Q.F treatments gave higher of total bacteria count than the control plants. While in stressed plants, *R. leguminosarum* was tolerant to stress with number of *Azotobacter spp.* and *Azospirillum spp* in Shandaweel and Dorado, respectively. In contrast, *B. japonicum* showed more tolerant strain than *R. leguminosarum* with Shandaweel at 40 and 60% of F.C. in numbers of bacteria and *Azospirillum spp.*, respectively.

Therefore, it can be

suggested that, increasing of microbial population density may attributed to nitrogenase activity for nitrogen fixing microorganisms in particular. This finding was agreed with data of Baldoni *et al.* (1986) and Martin *et al.* (1989). The main target of PGPR is the enhancement of symbiotic relationships for associative N_2-fixation (Alexander, 1984) and biological control of soil- plant pathogens (Watrud *et al.,* 1985).

The results also revealed that ½ rates of R.Q.F alone gave higher populations of total bacteria, *Azospirillum spp.* and *Azotobacter spp.* than R.Q.F treatment. This means changes in micro flora including nitrogen-fixing bacteria, which responded to roots exudates to enhance growth. Therefore, photosynthetic production is responsible for supporting growth, changes in rhizosphere and root surface micro flora including N_2-fixation, in particular, and efficiency of N_2-fixation in many rhizosphere and phyllosphere systems (Balandreau *et al.,* 1975). Hammouda (2000) reported that the rhizosphere and root surface soil of sorghum plants exhibited greater number of *Azospirillum spp.* than rice plant.

The data of yield components of both cultivars as affected by different treatments in both first and second seasons (Table 5) clearly show that the height of Dorado panicle although showed considerable significant reduction in the plants received 50% of NPK dose at 100% F.C., it also showed slight decrease at 60% of F.C. and significant increase at 40% of F.C as compared with the full-fertilized plants. When reduced fertilization with inoculation of *R. leguminosarum* strain, a considerable increases in such height, which significantly surpassed the control at 60 and 40% of F.C. Meanwhile, the inoculation with *B. japonicum* strain resulted in significant increase over the control only at 40% of F.C. The dry matter of Dorado panicle although showed significant reduction at 100% of F.C., however, it unaffected at 60, and significantly decrease at 40% of F.C with ½ rates of R.Q.F treatment. When comparing grain yield (g/plant) of Dorado plants, the result referred that, plants which received only ½ rates of R.Q.F showed drastic significant reduction in the grain yield in comparison with the full-fertilized plants. Following inoculation with *R. leguminosarum* strain, the yield of inoculated plants could approach the control yield at 100 and 40 and exceeded it at 60% of F.C. Meanwhile, the inoculation with *B. japonicum* strain results in a similar yield to the control at 60 and 40% of F.C. The most important comparison here is that when comparing the grain yield (g/plant) of Dorado cultivar, which was suffering from the double stress (nutrient stress and water stress, i.e. 60 or 40% of F.C.) without inoculation, the grain yield was 25.6 and 15.1% at 60 F.C. and 40% of F.C., respectively as compared with the non-stressed plant. Such plants when inoculated with *R. leguminosarum* strain, their yield was increased to 86.1 and 60.5% at 60 and 40% of F.C., respectively, meanwhile the inoculation *B. japonicum* strain increased such yield to 80.2 and 62.8% at 60 and 40% of F.C, respectively as compared with the non-stressed control yield.

Table 5: Effect of biofertilizer treatments and NPK fertilization doses on yield components of two sorghum cultivars grown under different levels of water stress during 1999 and 2000 seasons.

	Height of panicle						Dry weight of panicle						Grain yield (g)/ plant					
Cultivar	Dorado			Shandaweel			Dorado			Shandasweel			Dorado			Shandaweel		
F.C.%	100	60	40	100	60	40	100	60	40	100	60	40	100	60	40	100	60	40
	Season 1999																	
Treatment																		
R.Q.F	21	26	20	24	21	18	17	12	10	16	13	9	6.9	5.8	4.9	6.4	5.1	4.2
½ rate of R.Q.F	13	12	10	-	-	-	11	3	3	-	-	-	4.1	1.4	0.8	-	-	-
½ rate of R.Q.F + R.l	20	24	19	18	19	16	16	12	9	14	10	8	6.4	5.1	4.7	5.7	4.2	3.2
½ rate of R.Q.F + B.j	19	25	17	22	17	15	15	11	8	14	11	9	5.8	4.7	3.2	5.9	4.9	3.8
L.S.D (5%)	2.88						2.12						1.18					
	Season 2000																	
R.Q.F	23	20	10	23	20	19	22	12	10	18	20	13	8.6	6.9	5.3	8.1	5.2	7.1
½ rate of R.Q.F	9	18	14	11	-	-	13	12	4	6	-	-	2.9	2.2	1.3	1.9	-	-
½ rate of R.Q.F + R.l	22	23	21	22	18	19	19	11	10	17	17	10	8.5	7.4	5.2	7.1	6.1	5.4
½ rate of R.Q.F + B.j	18	20	19	22	16	17	17	11	9	18	18	11	7.3	6.9	5.4	7.9	6.9	5.6
LSD (5%)	2.15						1.9						0.92					

R.l: ***Rhizobium leguminosarium*** **B.J:** ***Bradyrhizobium japonicum***

R.Q.F: recommended quantities of NPK fertilizer

This clearly indicate that the rhizobial inoculation with appropriate strains could be successfully compensate the absence of 50% of NPK dose as well as increasing the sorghum plants to water or drought stress and consequently increasing their productivity. With Shandaweel cultivars, panicles were produced from the plants suffering from the absence of 50% of NPK dose in addition to the water stress either at 60 or 40% of F.C. Such panicle was produced only at 100% of F.C. and showed a considerable significant reduction in their height and dry matter in addition to the grain yield of such plants. With inoculation and reduced fertilization rate under water stress conditions, the height of panicle showed similar values to that of the control plants at the all soil moisture levels except the significant reduction at 60% of F.C. with *B. japonicum* strain. Such significant reduction was recorded with the dry matter of panicle with both strains at 60 and 40% of F.C. The inoculation with *R. leguminosarum* strain increased the grain yield over the control at soil moisture 60% of F.C and significant reduced at 40%. With inoculation *B. japonicum* strain, the grain yield significantly surpassed the control yield at 60% of F.C. and showed significant reduction at 40% of F.C. This clearly indicates that the inoculation was more effective with Dorado than Shandaweel cultivars under high drought stress. The corresponding yield values of Shandaweel were 17.3 and 19.2% over the control at 60% of F.C after *R. leguminosarum* and *B. japonicum* inoculation, respectively. Meanwhile, it was 7.25 at 60% of F.C with inoculation of *R. leguminosarum* and 1.89% at 40% of F.C after inoculation with *B. japonicum* in Dorado cultivar.. Unfortunately, no yield was obtained at 60% and 40% of only half-fertilized plants to complete the comparison. Amera and Dahdoh (1997) and Sabry *et al.* (2000) indicated that *Azotobacter, Azospirillum, Pseudomonas* and *Azorhizobium* each alone on in mixture improved total plant dry weight and grain yield of wheat.

CONCLUSION

The obtained data in the

present study strongly emphasize the superiority of rhizobial inoculation in compensating of 50% of applied NPK fertilizer in addition to increasing to great extent the tolerance of sorghum plants to water stress at its both two levels 60 and 40% of F.C. This can be realize from the most interesting and important finding in the results of such inoculation treatments which is that the considerable increments recorded by the inoculated plant under nutrient and water stresses, which even exceeded the unstressed control plants in several cases. Therefore, the obtained data in the present study strongly confirmed the beneficial effects of rhizobial inoculation and suggested that, biofertilizer inoculation can be successfully applied in order to reduced the half of the consumed chemical fertilizers as well as to great extent, increasing sorghum tolerance against drought or water stress. Taking into consideration the economic point of view, such inoculation treatments could be applied to reduce the consumption of chemical fertilizer (by 50%) as well as to saving a great part of the used water for irrigation for sorghum cultivars which in turn minimizing the agricultural costs as well as the pollution of the Egyptian agriculture environment.

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استخدام التسميد الحيوى كمنشط فى تشجيع النمو والمحصول على نبات السورجم تحت ظروف مختلفة من الرطوبة الارضية

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تهدف الدراسة إلى تقيم استخدام سلالتين بكتريا الريزوبيا هما *R. leguminoserum,* و *B. japonicum* كمشجع لنمو النبات وبكتريا الريزوسفير مع أضافه نصف معدل التسميد المعدنى الموصى به على النموو العدد الكلى لبكتريا الريزوسفير، مكونات المحصول لصنفي السورجم (دورادو، شنداويل) النامى تحت مستويات مختلفة من الرطوبة الأرضية (١٠٠، ٦٠، ٤٠ % من السعة الحقلية). كان هناك أربع معاملات هى تسميد معدنى كامل، نصف معدل التسميد، نصف معدل التسميد + لقاح من سلالة الأولى، نصف معدل التسميد + لقاح السلالة الثانية. ثم أخذت عينتين نباتية بعد ٤٥ ، ٧٠ يوم من الزراعة. أظهرت النتائج أن كل من معاملتى التلقيح بالريزوبيا مع نصف معدل التسميد المعدنى أعطت زيادة فى العدد الكلى للبكتريا، والازوتوبكتر، والازوسبرليم فى منطقة الريزوسفير التربة المحيطة بالجذر. وقد أكدت النتائج أن معاملة التلقيح البكتيرى أدى إلى زيادة معنوية فى طول الجذر، مساحة الأوراق، وكذلك الوزن الطازج لكل من المجموع الخضرى والجذرى مقارنة بالكنترول عند مستوى ٦٠، ٤٠% من السعة الحقلية. بالنسبة لمحصول النبات فى صنف شنداويل زادت بسبة ١٧,٣ و ١٩,٢ % بالنسبة للكنترول تحت ظروف ٦٠% من السعة الحقلية بعد معاملة

التلقيح بالسلالة *R. leguminoserum,* *B. japonicum* على التوالى. بينما كان النسبة ٧,٢٥% مع سلالة *R. leguminoserum,* عند مستوى ٦٠% من السعة الحقلية و ١,٨٩ % عند مستوى ٤٠% مع السلالة *B. japonicum* فى صنف دوراد . لذلك يعتبر التسميد الحيوى هدف رئيسى وهام لخفض الأسمدة المعدنية وكذلك كمية المياة المستخدمة فى الرى والتكاليف والتلوث.