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RESPONSE OF MAIZE VEGETATIVE GROWTH AND YIELD TO PARTIAL N-MINERAL REPLACEMENT BY BIOLOGICAL NITROGEN FIXATION UNDER DIFFERENT SOIL MOISTURE STRESSES

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ABSTRACT

This study aims to minimize the possible adverse fears of human health and environmental risks resulted from the used mineral fertilizers, particularly the new varieties of maize plants that are classified as excessive nitrogenous use. To achieve this target a field experiment was conducted on a clayey soil cultivated with maize (*Zea mays L.*) at El Wanysa village, Itsa district, El Fayoum Governorate, during the summer season of 2004. Partial replacement of 75, 50 and 25 % of the recommended N-mineral dose for maize was carried out using seed inoculated with Notroben (*Azospirillum brasilense*) as biological nitrogen fixation bacteria under the different available soil moisture depletions of 30, 50 and 70 %. Vegetative growth parameters (plant height, ear length and diameter), crop yield (grain and straw), grain quality (100 kernel weight and protein percent) and some nutrients uptake (N, P and K) by plant were taken as criteria for evaluating the applied treatments.

The obtained data showed that the applied partial replacement of 25 % N-mineral dose by N-bio fixation under 50 % available soil moisture depletion exerted a positively significant effect on the studied plant criteria, i.e., increasing the vegetative growth parameters of plant height, ear length and diameter by 3.23, 1.78 and 2.29 %, respectively as compared to the full N-mineral dose. The corresponding relative increases were 10.51, 4.48, 2.65 and 11.32 for straw yield, grain yield, 100 kernel weight and grain protein content %, respectively. Also, it exhibited relatively high N, P and K contents reached 16.67, 11.36 and 6.78 % for maize straw vs 11.34, 20.00 and 16.12 for maize grain, respectively. While, relatively low values were recorded in the treatment of maize seeds inoculated with N-fixation bacteria alone. It is worthy to mention that the other combinations of 25 and 50 % N-mineral with inoculated maize seeds exhibited relatively low values than that obtained at the full N-mineral dose.

As for the available soil moisture depletion status (ASMD), data revealed that the integrated use of 50 % SMD had a greater beneficial effect as compared to both of 30 and 70 % ASMD. The negative effect was more noticeable in soil plots received 70 % ASMD, this may be due to the unbalanced soil water-air relations that lead to reducing the photosynthesis activity as well as the adverse relations between hormones and biological processes in the whole plant organs. Moreover, irrigating maize plants at 50 % SMD was achieved a significantly increase for the water use efficiency, where it tended to reduce at 30 and 70 % ASMD by 36.06 and 13.85 %, respectively. This may be due to the plant roots can be extract more soil water from a greater depth under moderate stress as compared to those irrigated at a relatively wet or drought levels.

From the abovementioned results, it is evidence that maize plants able to overcome a pronounced amount of the N-requirements (about 25 %) from the biological nitrogen fixation (via seeds inoculation with *Azospirillum brasiliense*) under 50 % of the available moisture depletion. This is undoubtedly of great importance due to the superiority was not only taken as a criterion for increasing the outputs of vegetative growth and crop yield for maize plants or rationalize of costly N-mineral

fertilizers, but also for minimizing the possible adverse fears of both human health and environmental risks resulted from the used N-mineral fertilizers. Moreover, the beneficial effect of the biological nitrogen fixation may be enhanced the biological activity in the decomposition of organic substances which have ability to improve soil moisture regime, and in turn encouraging the released nutrients particularly the micronutrients as well as the fixed nitrogen is considered as a storehouse in more mobile or available forms to uptake by plant roots.
Keywords: Maize, N-mineral fertilizers, biological nitrogen and soil moisture stress.

INTRODUCTION

Maize is one of the major field crops either in Egypt or the World, where it ranks the third one after wheat and rice. It is used primarily as feed crop and industrial purposes for oil and starch extraction. The management practices concerned with soil moisture content (i.e., using different irrigation intervals) as well as nitrogenous fertilizer resources (mineral, organic and bio-fertilizers) play vital and important role for maize vegetative growth and yield. Concerning the importance of soil moisture stress, data obtained from a field experiment by El Ganayni *et al.* (2000) showed that shortening irrigation intervals delayed flowering, decreased number of leaves/plant and 100 kernel weight of maize. On the other hand, increasing the available soil moisture depletion to 20 % gave the highest grain yield, followed by 35 and 50 % (Taha, 2001). The previous results explained the importance of the seasonal soil moisture depletion for maize, which their average values were 513, 489 and 415 mm under irrigation intervals of 12, 18 and 24 days, respectively (Saied, 2002). Moreover, the impact of both soil moisture depletions and nutrient resources on elemental composition of plant organs and their yields are also of importance for the growing crops. The same author (1997) found that nitrogen concentration in maize influenced significantly by the water regime, while phosphorus and potassium concentrations were not affected. Also, Lagrono and Lothrop (2003) reported that yield losses reached 10-75 % and 10-50 due to drought and low nitrogen fertilization, respectively.

Recently, World face a great problem either in the human health or in the environmental pollution. This problem is more related to the excessive use mineral or chemical fertilizers, especially those of nitrogenous ones. In addition, the use of intensive and non-rational rates of N-mineral fertilizers increased the costs of agricultural productions. A pronounced amount of N-mineral is leached with the drainage water and leads to pollute the biological media of natural water resources, causing the possible adverse fears of human and animal health in addition to environmental risks. Interest in the N-excessive use, it could be partially attributed to the advent of high yielding crop cultivars under assured perennial irrigation. Today, there is a renewed interest in biological nitrogen fixation or N-recycling occurred by seed inoculation with non-symbiotic N-fixers. This target plays an important role for improving soil fertility and its productivity as well as increasing crop yields and decreasing N-mineral requirements (Kennedy and Tchan, 1992). Moreover, the periodical application of this natural source to soils has gained momentum in the recent past and called "bio-fertilization, clean agriculture and bio-agriculture". The integrated use of the N-natural sources and mineral fertilizers is considered the best option not only for reducing the previous enormous consumption of chemical fertilizers, but also maintain soil fertility status and help to sustain crop productivity, as well as, to increase fertilizer use efficiency in soil (Singh *et al.*, 1999; Bhatia *et al.*, 2001 and Palm *et al.*, 2001).

Omer *et al.* (1991) reported that seed inoculation with some bacteria species of biological nitrogen fixation could save up to half of field rate of N-mineral fertilizer, and at the same time increased yields of grain and straw of cereal crops. Mishra *et al.* (1995) and Salem (2000) showed that the highest grain yield of maize has been obtained under sub optimal N-bio-mineral fertilizer (partial substitution N-mineral by seed inoculation with Azotobacter bacteria) and water condition. The exudates of bacterial strains act as plant growth promoters and apparently stimulate growth mainly throughout modifying root development, which improve macronutrients, micronutrients and water uptake, particularly in the early stages of plant development (El Komy *et al.*, 1998).

The current work aimed at evaluating the partial N-mineral substitution by an alternative N-source supplied from N-bio fixation throughout the inoculation of maize seeds by Notroben (*Azospirillum brasilense*) under different available soil moisture depletion to produce un-chemical polluted grains by using a clean or bio-agriculture.

MATERIALS AND METHODS

The objective of the current study aims to evaluate the role of 25, 50 and 75 N-mineral substitution by N-source supplied from N-bio fixation under different available soil moisture depletions, i.e., 30 (I1), 50 (I2) and 70 (I3) of available soil moisture, applied to a clayey soil cultivated with maize (*Zea mays L.*) plants at El Wanysa village, Itsa district, El Fayoum Governorate.

Field experiment:

A field experiment was carried out during the summer season of 2004. The identified combinations between the N-mineral and the N-bio fixation were conducted on the basis of 25, 50 and 75 % substitution of the recommended dose of nitrogen according to the Egyptian Ministry of Agriculture (120 kg N/fed). N-mineral fertilizer was applied as ammonium nitrate (33.5 % N) and added at two equal doses before the first and second irrigations. Maize seeds (Giza 310) was inoculated with Notroben (*Azospirillum brasilense*) supplied from Agriculture Research Center, Giza, Egypt) at the rate of 1 kg/fed before sowing (10^{th} of June, 2004). The recommended doses of P and K as superphosphate fertilizer (15.5 % P_2O_5) and potassium sulphate (48 % K_2O) alone and the control treatment (no treated soil) were also included either during soil preparation for cultivating for P or after 15 and 40 days from planting for K. The treated soil plots were subjected to applied different irrigation intervals after the first irrigation for achieving the different available soil moisture depletion under consideration.

The agricultural practices of maize were carried out as usual from sowing to harvesting. Data in Table 1 represent some physical, chemical and fertility characteristics of the experimental soil throughout the root zone (0-60 cm), according to the standard methods outlined by Klute (1986) and Page *et al.* (1982).

In a split-plot design with 3 replicates, the subplots were devoted to identify the effective role of N-bio fixation. The following treatments were applied in the experimental plots that have an area of 3.0 x 3.5 m^2 for each one and including 5 ridges with 3 m long and 70 cm apart.

Table 1: Some soil physical, chemical and fertility characteristics of the experimental field.

Soil characteristics	Soil depth (cm)		
	0-20	20-40	40-60
1. Soil physical properties:			
Particle size distribution %			
Sand	23.91	22.28	19.34
Silt	33.86	34.15	34.67
Clay	42.23	43.57	45.99
Textural class	Clayey	Clayey	Clayey
Bulk density (gcm^{-3})	1.22	1.28	1.39
Particle density (gcm^{-3})	2.63	2.67	2.68
Total porosity %	53.61	52.06	48.13
Hydraulic conductivity (cm/hr)	0.97	0.81	0.53
Field capacity %	44.42	41.18	38.96
Wilting point %	18.38	20.95	21.74
Available water %	26.04	20.33	17.22
2. Soil chemical properties:			
pH (1:2.5 soil water suspension)	7.68	7.85	7.93
EC (dSm^{-1}, soil paste extract)	2.13	2.65	3.04
Soluble ions (meq/l):			
Ca^{++}	4.83	8.46	9.58
Mg^{++}	3.17	4.97	6.33
Na^{+}	12.96	13.29	14.86
K^{+}	0.43	0.38	0.23
CO_3^{--}	0.00	0.00	0.00
HCO_3^{-}	2.27	2.65	2.76
Cl^{-}	12.25	14.92	17.54
SO_4^{--}	6.87	9.53	10.70
$CaCO_3$ content %	6.69	5.18	4.53
Organic matter content %	2.05	1.56	1.12
3. Some macronutrients status:			
Total nitrogen %	0.096	0.078	0.072
Available P (mg/kg soil)	11.20	9.48	8.75
Available K (mg/kg soil)	643.29	587.51	570.02

T1. Recommended N-mineral fertilizer dose.
T2. 25% of the recommended N-mineral fertilizer dose in combination with inoculated maize seeds.
T3. 50% of the recommended N-mineral fertilizer dose in combination with inoculated maize seeds.
T4. 75% of the recommended N-mineral fertilizer dose in combination with inoculated maize seeds.
T5. Inoculated maize seeds.

Maize plants were collected from each plot at vegetative growth to determine plant height, ear length and diameter.

Plant samples were separated at the harvest into grains and straw, then determining their yields, their contents of NPK (Page *et al.*, 1982) or protein (multiplying N % x 6.25) and 100 kernel weight. In addition, crop water relations were determined as follows:

a. Seasonal water consumptive use (ETc), which calculated as a water depth in cm using the following equation (Israelsen and Hansen, 1962):

Cu = (Q2-Q1) bd . D/100 where

Cu= Consumptive use (cm).
Q2= Soil moisture % 48 hours after irrigation.
Q1= Soil moisture % before irrigation.
bd= soil bulk density (gcm^{-3}).
D= Soil depth (cm).

b. Water use efficiency (WUE), which calculated using the equation of Vites (1965) for grain yield, as follows:

WUE = Grain yield in kg/fed/actual consumptive use in m^3/fed

The obtained data of plant parameters were statistically analyzed according to the methods suggested by Gomez and Gomez (1984) using the L.S.D. values at 0.05 level of significance.

RESULTS AND DISCUSSION

1. Maize growth as affected by the applied treatments:

The growth parameters (i.e., plant height, ear length and diameter) of the representative maize plants lead to a good knowledge about the effects of soil moisture stress as well as nitrogen fertilization using either N-mineral fertilizer or N-bio fixation, as shown in Table 2. The results obtained showed that executing the inoculation of maize seeds with *Azospirillum brasilense* in conjunction with ¾ of the recommended N-mineral dose (T4) at soil moisture depletion 50 % registered a positive response for all the studied growth parameters. This beneficial effect could be indicated by the significant increases for the studied growth parameters, where the relative increments percent in the values of plant height, ear length and diameter reached 3.23, 1.78 and 2.29 %, respectively as compared to the full dose of N-mineral treatments. While, the relatively lower values recorded in the treatment of maize plants inoculated with N-fixation bacteria (T5). It is worthy to mention that the other combinations of 25 and 50 % N-mineral with inoculated maize seeds (T2 and T3) exhibited relatively lower values than that obtained at the full N-mineral dose. These findings are in harmony with those obtained by Mishra *et al.* (1995).

In here, the importance of the superiority for the applied N-bio fixation was not only taken as a criterion for increasing the outputs for maize crop or rationalize of costly N-mineral fertilizers, but also for minimizing the possible adverse fears of both human health and environmental risks resulted from N-mineral fertilizers (Palm *et a.l,* 2001). Thus, supplying N-bio fixation for plant varieties need an excessive use mineral or chemical fertilizers, especially those of nitrogenous ones, is undoubtedly of great importance. In general, the superiority of applied N-bio fixation bacteria is more attributed to their biological activity in the decomposition of organic substances, which have ability to improve soil-moisture regime, enhancing the released nutrients and fixed nitrogen as a storehouse in more mobile or available forms to uptake by plant roots (Salib, 2002).

Table 2: Maize plant parameters at vegetative growth as affected by the applied treatments.

N-treatments	Soil moisture depletion %			Mean	Statistical data of L.S.D.		
	I1	I2	I3		Treat.	0.05	0.01
Plant height (cm)							
T1	218.20	220.67	192.97	210.61	T	3.07	5.00
T2	209.90	213.33	184.23	202.49	I	5.43	12.95
T3	213.83	219.53	192.40	208.59	TI	1.55	2.35
T4	221.90	227.80	201.83	217.18			
T5	202.10	212.17	81.17	198.48			
Mean	213.19	218.70	190.52	207.47			
Ear length (cm)							
T1	22.20	24.17	20.17	22.18	T	0.29	0.47
T2	20.23	21.30	18.47	20.00	I	0.51	1.21
T3	21.57	23.63	19.87	21.69	TI	0.15	0.22
T4	22.67	24.60	20.87	22.71			
T5	18.90	20.67	15.96	18.51			
Mean	21.11	22.87	19.07	21.02			
Ear diameter (cm)							
T1	4.91	5.24	4.59	4.91	T	0.27	0.45
T2	4.69	4.79	4.36	4.61	I	0.48	1.15
T3	4.88	5.01	4.39	4.76	TI	N.S.	N.S.
T4	5.01	5.36	4.67	5.01			
T5	4.51	4.59	4.31	4.47			
Mean	4.80	5.00	4.47	4.75			

T1=100 N-mineral; T2, T3, T4 =75, 50, 25% N-mineral + N-bio; and T5= N-bio
I1, I2 and I3=Soil moisture depletion at 30, 50 and 70 % of available water content

As for the available soil moisture depletion status (ASMD), data in Table 2 reveal that the integrated use of 75 % dose N-mineral combined with N supplied from bio-fixation at 50 % ASMD had a great beneficial effect, which caused significant increases in the values of the studied maize growth parameters as compared to both of 30 and 70 % ASMD. The adverse effects were more noticeable in soil plots received 70 % soil moisture depletion as compared to those of 30 %, where the relative reduces % in T4 reached 12.87 and 2.66 for plant height, 17.87 and 8.51 for ear length and 14.78 and 6.99 % for ear diameter, respectively.

In general, the aforementioned results of soil moisture stress, increasing (30 % ASMD) or decreasing (70 % ASMD) soil moisture stress, may be attributed to the unbalanced soil water-air relations that lead to reducing the photosynthesis activity and unbalanced relations between plant hormones and biological processes in the whole plant organs. These adverse conditions in the treated soils are undoubtedly of great importance throughout the vegetative growth and dry matter accumulation in the maize plants, and may cause flower defoliation (Kerlous-Amany, 1997). On the other hand, the beneficial effect of 50 % available soil moisture depletion could be explained by enhancing plant growth and protecting soil fertility in the long run, that can be achieved through maintaining a good soil water-air relation for mechanism of nutrients uptake by plant roots. Thus, these favourable soil conditions are more related to a suitable medium in which seeds can germinate, roots can grow and more necessary nutrients can be available (Davies *et al.*, 1982).

2. Maize yield, grain quality and elemental composition:

a. Grain, straw yields and grain quality:

With respect to the beneficial effect of the applied N-bio fixation to the experimental soil on the maize yield (straw and grain yields) and grain quality (100 kernel weight and protein content in grain), results illustrated in Table 3 show a positively and significant increase in each of the aforementioned plant parameters in T4 (75 % N-mineral in combination with N-bio fixation at 50 % available soil moisture depletion) as compared to the other studied treatments. As mentioned before, such beneficial effect being dependent on the nature of concerned biological activity at a favourable soil condition of water-air relations. The latter's enhancing the organo-metalic forms as a storehouse and increasing nutrients availability or mobility in soil, consequently encouragement the mechanism of water and nutrients uptake by plant roots.

Generally, it could be concluded that the increases in the studied maize parameters at harvest were extending closely parallel to the corresponding vegetative growth values, as shown in Tables 2 and 3. That means the magnitude response could be depend on the nature of fertilizer used and the concerned attributable soil moisture stress, where the check soil plots with N-mineral combined with N-bio fixation at 50 % available soil moisture depletion exhibited relatively high values for maize parameters as compared to that received N-mineral alone. The corresponding relative increases reached 10.51, 4.48, 2.65 and 11.32 for the values of straw yield, grain yield, 100 kernel weight and grain protein content %, respectively, (Table 3).

Table 3: Maize plant parameters at harvest as affected by the applied treatments.

N-treatments	Soil moisture depletion %			Mean	Statistical data of L.S.D.		
	I1	I2	I3		Treat.	0.05	0.01
			Straw yield (ton/fed)				
T1	2.85	3.52	2.69	3.02	T	0.27	0.44
T2	2.39	2.80	2.05	2.41	I	0.45	1.14
T3	2.73	2.98	2.22	2.64	TI	N.S.	N.S.
T4	3.02	3.89	2.84	3.25			
T5	2.30	2.86	2.08	2.41			
Mean	2.66	3.21	2.38	2.75			
			Grain yield (Ardab/fed)*				
T1	17.64	20.69	17.22	18.52	T	0.58	0.95
T2	16.35	18.27	15.50	16.71	I	1.03	2.45
T3	16.60	20.74	16.35	17.90	TI	0.29	0.44
T4	18.47	22.03	17.52	19.34			
T5	15.08	17.85	14.63	15.86			
Mean	16.83	19.91	16.24	17.66			
			100 kernel weigh (g)				
T1	32.83	34.75	25.35	30.98	T	0.49	0.81
T2	30.65	33.08	23.88	29.20	I	0.83	1.98
T3	31.74	33.99	24.85	30.19	TI	0.25	0.38
T4	33.39	35.67	27.91	32.29			
T5	30.35	33.02	20.65	28.01			
Mean	31.79	34.08	24.53	30.13			
			Grain protein content %				
T1	16.75	18.19	14.13	16.38	T	0.66	1.15
T2	16.00	16.38	12.63	15.00	I	1.16	2.77
T3	16.50	16.81	13.00	15.44	TI	0.33	0.52
T4	17.63	20.25	16.13	18.00			
T5	14.88	15.25	11.00	13.69			
Mean	16.31	17.38	13.38	15.69			

T1=100 N-mineral; T2, T3, T4 =75, 50, 25% N-mineral + N-bio; and T5= N-bio
I1, I2 and I3=Soil moisture depletion at 30, 50 and 70 % of available water content
*Ardab=140 kg

As for the available soil moisture depletion (ASMD), data in Table 3 reveal that the integrated use of 75 % dose N-mineral combined with N supplied from bio-fixation at 50 % soil moisture depletion had a great favourable effect, which caused significant increases in the values of the studied maize parameters at harvest as compared to both of 30 and 70 % ASMD. The adverse effects were more noticeable in soil plots received 70 % ASMD as compared to those of 30 %, where the relative reduces % in T4 reached 36.97 and 28.81 for straw, 25.74 and 19.27 for grains, 27.80 and 6.83 for 100 kernel weight and 25.54 and 14.86 % for grain protein content %, respectively. These findings are in agreement with those reported by Saied (1997) who concluded that the decrease in maize grain yield was more related to the decrease of soil available moisture in the root zone, which reduced water and nutrients uptake.

b. Nutrient contents of maize straw and grain:

Studying the effect of applied treatments for either N-fertilization or available soil moisture depletion (ASMD) in the studied soil plots, (Table 4), it could be noticed that a parallel trend for the previous results was achieved for the macronutrient contents of N, P and K in both maize straw and grain yields, since the integrated use of 75 % dose N-mineral combined with N supplied from bio-fixation at 50 % ASMD gave the highest values.

Table 4: Nutrient contents % in maize straw and grain as affected by the applied treatments.

N-treatments	Soil moisture depletion %			Mean	Soil moisture depletion %			Mean
	I1	I2	I3		I1	I2	I3	
Nitrogen content %								
	Straw				Grain			
T1	2.36	2.58	2.03	2.32	2.68	2.91	2.26	2.62
T2	1.93	2.02	1.48	1.81	2.56	2.62	2.02	2.40
T3	2.29	2.31	1.88	2.16	2.64	2.69	2.08	2.42
T4	2.46	3.01	2.20	2.57	2.82	3.24	2.58	2.88
T5	1.97	2.05	1.75	1.92	2.38	2.44	1.76	2.19
Mean	2.20	2.39	1.87	2.15	2.61	2.78	2.14	2.51
Statistical data	L.S.D.				L.S.D.			
	Treat.	0.05	0.01		Treat.	0.05	0.01	
	T	0.22	0.38		T	0.24	0.41	
	I	0.39	0.94		I	0.42	1.00	
	TI	0.11	0.17		TI	N.S.	N.S.	
Phosphorus content %								
	Straw				Grain			
T1	0.36	0.44	0.31	0.37	0.32	0.40	0.25	0.32
T2	0.32	0.39	0.25	0.32	0.29	0.34	0.21	0.28
T3	0.34	0.41	0.28	0.34	0.31	0.37	0.23	0.30
T4	0.38	0.49	0.33	0.40	0.34	0.48	0.31	0.38
T5	0.22	0.27	0.18	0.22	0.19	0.21	0.15	0.18
Mean	0.32	0.40	0.27	0.33	0.29	0.36	0.23	0.29
Statistical data	L.S.D.				L.S.D.			
	Treat.	0.05	0.01		Treat.	0.05	0.01	
	T	0.03	0.05		T	0.02	0.04	
	I	0.05	0.13		I	0.04	0.09	
	TI	0 02	N.S.		TI	0.01	0.02	
Potassium content %								
	Straw				Grain			
T1	2.46	2.95	2.29	2 56	2.73	3.35	2.42	2 83
T2	2.39	2.51	2.20	2.37	2.32	2.77	2.18	2.42
T3	2.43	2.72	2.26	2.47	2.55	2.83	2.39	2.59
T4	2 74	3.15	2.53	2.81	2.80	3.89	2.57	3.09
T5	2.15	2.38	2.09	2.22	2.38	2.56	2.15	2.36
Mean	2.44	2 74	2.27	2.49	2.56	3.12	2.34	2.66
Statistical data	L.S.D.				L.S D.			
	Treat.	0.05	0.01		Treat	0.05	0.01	
	T	0.32	0 55		T	0.39	0.68	
	I	0.56	1.33		I	0.69	1.65	
	TI	N.S.	N.S.		TI	0.20	N.S.	

T1=100 N-mineral; T2, T3, T4 =75, 50, 25% N-mineral + N-bio; and T5= N-bio
I1, I2 and I3=Soil moisture depletion at 30, 50 and 70 % of available water content

While, the other combinations together the N-bio fixation alone exhibit an opposite trend for the studied macronutrient contents among the different soil moisture depletions for straw and grain yields of maize crop. The superiority for the applied treatment N-mineral combined with N-bio fixation at 50 % ASMD was achieved, since it exhibited relatively high values for N, P and K reached 16.67, 11.36 and 6.78 % for maize straw as compared to that received N-mineral alone, respectively. The corresponding relative increases reached 11.34, 20.00 and 16.12 for their values in grain yield, respectively (Table 4).

As mentioned before, such effect being dependent on the moisture content of concerned available soil moisture depletion along with its applied rate or the initial state in soil, especially its minimum and maximum ratio. It may be attributed to the poor soil aeration, at the excess moisture content (I1, 30 % ASMD), as well as the drought regimes (I3, 70 % ASMD) are caused more immobile form for a nutrient is the more its uptake, which depends on proximity of the activity of absorption mechanism by roots (Miller *et al.*, 1987). Generally it could be concluded that the N, P and K contents in straw and grain were extending parallel close to the corresponding available moisture depletions in soil plots (Table 4). The adverse effects that were noticeable in soil plots received 30 % and 70 % available soil moisture depletion as compared to those of 50 % of the T4 treatment reached 22.36 and 36.82 for N, 28.95 and 48.48 for P and 14.96 and 24.51 %, respectively for K in maize straw. The corresponding relative decreases reached 14.89 and 25.58, 41.18 and 54.83 and 38.93 and 51.36 for their values in grain yield, respectively.

3. Crop water relations:

a. Seasonal water consumptive use (ETc):

Data in Table 5 show that irrigating maize plants whenever 30 % available soil moisture depletion gave the highest value of seasonal water consumptive use (61.33 cm as an average for T4).

The reverse was true when irrigating maize plants at 70 % available soil moisture depletion, since it was recorded the lowest value (52.53 cm as an average for T4). It is worthy to mention that the highest value of seasonal water consumptive use was associated with the best treatment of integrated use of 75 % dose N-mineral combined with N supplied from bio-fixation at 50 % soil moisture depletion.

Therefore, it is concluded that increasing soil moisture stress led to a significantly decrease in daily ETc rate during the growing season months. Such findings are in harmony to those reported by Osman and Khalifa (2001) and Saied (2002) who found that the average values of water consumptive use for maize were 491 and 369 mm for 14 and 28 days irrigation intervals, respectively. The same authors added also that the values of water consumptive use increased with increasing the rate if nitrogen fertilization.

Table 5: Consumptive use (cm) of maize crop as affected by the different treatments.

N-treatments	Soil depth (cm)	Soil moisture depletion %			Mean
		I1	I2	I3	
T1	0-20	30.01	26.10	26.56	27.56
	20-40	22.38	16.52	13.19	17.36
	4060	6.37	9.76	11.63	9.25
	0-60	58.76	52.38	51.38	54.17
T2	0-20	28.91	23.13	22.30	24.78
	20-40	19.07	14.54	12.52	15.37
	4060	6.71	9.49	11.61	9.27
	0-60	54.69	47.16	46.43	49.42
T3	0-20	31.00	24.92	25.47	27.13
	20-40	20.31	15.98	13.15	16.48
	4060	7.17	10.62	11.81	9.87
	0-60	58.48	51.52	50.43	53.48
T4	0-20	33.10	26.45	26.41	28.65
	20-40	20.72	16.53	13.56	16.94
	4060	7.51	10.78	12.56	10.28
	0-60	61.33	53.76	52.53	55.87
T5	0-20	28.43	22.80	22.61	24.61
	20-40	17.88	14.15	12.12	14.72
	4060	4.41	9.51	10.91	9.27
	0-60	53.72	46.46	45.64	48.60
Statistical data		L.S.D			
		Treat.	0.05	0.01	
		T	1.64	2.67	
		I	2.90	6.91	
		TI	0.83	N.S.	

T1=100 N-mineral; T2, T3, T4 =75, 50, 25% N-mineral + N-bio; and T5= N-bio
I1, I2 and I3=Soil moisture depletion at 30, 50 and 70 % of available water content

b. Water use efficiency:

The water use efficiency, (Table 6), is expressed as kg grain/m^3 water consumed by the maize plants. This criterion has been used to evaluate the crop production under different applied treatments per unit of consumed water by the crop plants.

Data illustrated in Table 6 show that irrigating maize plants at 50 % available soil moisture depletion (I2) achieved a significantly increase for the water use efficiency value, and it tended to reduce when increasing or decreasing available soil moisture depletion to 30 % and 70 % by 36.06 and 13.85 %, respectively. These findings are in harmony with the scientific approaches that supposed the plant roots could be extract more soil water from a greater depth under moderate stress as compared to those irrigated at a relatively wet level. That means the stored water in soil at a moderate irrigation can be more available for roots as well as can be used with more efficiency. These results are in agree with those reported by Tisdale *et al.* (2001) and Taha (2001) who found that water use efficiency decreased with increasing soil moisture depletion, and stated tat the highest value was obtained under the irrigation regime of 20 % available soil moisture depletion.

Table 6: Water use efficiency (kg/m^3) of maize crop as affected by the different treatments.

N-treatments	Soil moisture depletion %			Mean
	I1	I2	I3	
Grain yield (kg/fed)				
T1	2469.6	2896.6	2410.8	2592.8
T2	2289.0	2557.8	2170.0	2339.4
T3	2324.0	2903.6	2289.0	2506.0
T4	2585.8	3084.2	2452.8	2707.6
T5	2111.2	2499.0	2048.2	2220.4
Mean	2356.2	2787.4	2273.6	2472.4
Consumptive use (m^3/fed)				
T1	2467.92	2199.96	2157.96	2275.14
T2	2296.98	19.80.72	19.50.06	2075.64
T3	2456.16	2163.84	2118.06	2246.16
T4	2575.86	2257.92	2206.26	2346.54
T5	2256.24	19.51.32	1916.88	2041.20
Mean	2413.74	2110.92	2069.76	2197.86
Water use efficiency (kg/m^3)				
T1	1.001	1.317	1.117	1.145
T2	0.997	1.291	1.113	1.134
T3	0.946	1.342	1.081	1.123
T4	1.004	1.366	1.112	1.161
T5	0.936	1.281	1.069	1.095
Mean	0.977	1.319	1.098	1.131
Statistical data		L.S.D.		
	Treat.	0.05	0.01	
	T	0.050	0.089	
	I	0.055	0.230	
	TI	0.096	N.S.	

T1=100 N-mineral; T2, T3, T4 =75, 50, 25% N-mineral + N-bio; and T5= N-bio
I1, I2 and I3=Soil moisture depletion at 30, 50 and 70 % of available water content

From the abovementioned results, it is evidence that maize plants able to overcome a pronounced amount of the N-requirements (about 25 %) from the biological nitrogen fixation (via seeds inoculation with *Azospirillum brasiliense*) under available moisture depletion of 50 %. This is undoubtedly of great importance due to the superiority was not only taken as a criterion for increasing the outputs of vegetative growth and crop yield for maize plants or rationalize of costly N-mineral fertilizers, but also for minimizing the possible adverse fears of both human health and environmental risks resulted from the used N-mineral fertilizers. Moreover, the beneficial effect of the biological nitrogen fixation may be enhanced the biological activity in the decomposition of organic substances which have ability to improve soil moisture regime, and in turn encouraging the released nutrients particularly the micronutrients as well as the fixed nitrogen is considered as a storehouse in more mobile or available forms to uptake by plant roots (Salib, 2002).

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إستجابة النمو الخضرى ومحصول الذرة الشامية لإحلال جزئى من النتروجين المعدنى عن طريق التثبيت الحيوى للنتروجين الجوى تحت ظروف نسب مختلفة من إستنفاذ الرطوبة الأرضية الميسرة

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تعتبر هذه الدراسة محاولة تهدف إلى الحد من المخاطر المحتملة على صحة الإنسان والبيئة المحيطة كنتيجة لإستخدام الأسمدة النتروجينية الكيميائية، خاصة فى حالة الأصناف الجديدة من الذرة الشامية المصنفة تحت الإستخدام الشرهه من النتروجين، ولتحقيق ذلك أجريت تجربة حقلية على أرض طينية بناحية قرية الونايسه مركز إطسا محافظة الفيوم خلال الموسم الزراعى الصيفى لعام ٢٠٠٤، وذلك لتحديد مردود إحلال جزئى ل ٧٥، ٥٠، ٢٥ ٪ من الإحتياجات الموصى بها من النتروجين المعدنى لمحصول الذرة الشامية عن طريق تلقيح البذور بال Notroben (*Azospirillum brasilense*) كمثبت حيوى للنتروجين الجوى تحت ظروف نسب مختلفة من إستنفاذ الرطوبة الأرضية الميسرة (٣٠، ٥٠، ٧٠ ٪)، آخذا فى الإعتبار مقاييس النمو الخضرى (طول النبات، إرتفاع وقطر الكوز)، إنتاجية المحصول (القش، الحبوب)، نرعية

الحبوب (وزن ١٠٠ حبة، نسبة البروتين ٪)، والمحتوى من بعض المغذيات (N, P and K) كمعاييرلتقييم المعاملات تحت الدراسة .

وتشير النتائج المتحصل عليها إلى أن إحلال جزئى مقداره ٢٥ ٪ من الإحتياجات الموصى بها من النتروجين المعدنى لمحصول الذرة الشامية عن طريق تثبيت النتروجين حيويا من الجو تحت ظروف إستنفاذ ٥٠ ٪ من الرطوبة الأرضية الميسرة قد أظهر تأثيرا ايجابيا ومعنويا على القياسات النباتية تحت الدراسة ممثلة فى زيادة معايير النمو الخضرى ب ٣,٢٣، ١,٧٨، ٢,٢٩ ٪ بالنسبة لطول النبات، إرتفاع الكوز وزيادة قطره على الترتيب مقارنة بمعاملة التسميد المعدنى للنتروجين الموصى به كاملا، كما وأن الزيادات المقابلة وصلت إلى١٠,٥١، ٤,٤٨، ١١,٣٢،٢,٦٥٪ بالنسبة إلى محصولى القش، الحبوب، وزن ١٠٠ حبة، المحتوى من البروتين ٪ على الترتيب . ولقد وجد أن هناك زيادات نسبية فى المحتوى من N, P and K وصلت إلى١٦,٦٧، ١١,٣٦، ٦,٧٨ ٪ على الترتيب بالنسبة للقش مقابل ١١,٣٤، ٢٠,٠٠، ١٦,١٢ ٪ على الترتيب بالنسبة للحبوب، بينما سجلت معاملة التسميد الحيوى منفردة أقل القيم، كما لوحظ أن جميع المعاملات المشتركة الأخرى (٢٥، ٥٠ ٪ نتروجين معدنى) قد سجلت أيضا قيما أقل مقارنة بمعاملة التسميد المعدنى للنتروجين الموصى به كاملا .

وبالنسبة إلى معاملات إستنفاذ نسب من الرطوبة الأرضية الميسرة، فان النتائج تشير إلى أن معاملة إستنفاذ ٥٠ ٪ من الرطوبة الأرضية الميسرة كانت أفضل المعاملات مقارنة بالنسبتين ٣٠، ٧٠ ٪، مع حدوث تأثير سلبى أكثر معنوية عند النسبة ٧٠ ٪، وربما يرتبط ذلك باختلال العلاقات ما بين هواء-رطوبة التربة والذى يؤدى إلى إنخفاض نشاط عملية التمثيل الضوئى وكذا يؤثر سلبيا على العلاقة ما بين الهرمونات والعمليات الحيوية فى أجزاء النبات المختلفة . كما وأن معاملة إستنفاذ ٥٠ ٪ من الرطوبة الأرضية الميسرة قد حققت زيادة معنوية فى كفاءة إستخدام مياه الرى بالنسبة لنباتات الذرة تقدر ب ٣٦,٠٦، ١٣,٨٠٪ عنه فى حالتى ٣٠، ٧٠ ٪ على الترتيب، وقد يرجع ذلك إلى قدرة الجذور على إستخلاص الماء من أعماق أكبر تحت ظروف النسبة المتوسطة من الإستنفاذ مقارنة بحالتى الترطيب أو الجفاف النسبى فى التربة .

و تدل النتائج السابقة على أن نباتات الذرة الشامية لها القدرة على تغطية كمية محسوسة من إحتياجاتها النتروجينية عن طريق تلقيح البذور بالنتروبين كمثبت حيوى للنتروجين الجوى Notroben (*Azospirillum brasilense*) تحت ظروف ٥٠ ٪ من إستنفاذ الرطوبة الأرضية الميسرة، وبدون شك فان ذلك يعتبر ذات أهمية ليس فقط بالنسبة لزيادة قياسات النمو الخضرى وكمية محصول الذرة أو تقليص تكاليف الأسمدة النتروجينية بل أيضا بالنسبة للحد من المخاطر المحتملة على صحة الإنسان والبيئة المحيطة، خاصة فى حالة أصناف الذرة الشامية الجديدة الشرهة للنتروجين، علاوة على أن عملية التثبيت الحيوى للنتروجين قد تساعد من النشاط الحيوى فى تحليل المواد العضوية والتى تحسن من السلوك المائى فى التربة، ومن ثم تشجع من تيسر المغذيات للنبات خاصة الصغرى منها، كما وأن عملية التثبيت الحيوى ذاتها تحفظ النتروجين فى صورة صالحة للإمتصاص بواسطة الجذور النباتية .