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Responses of *Trigonella foenum-graecum* to Water Deficit

O.A. KHAFAGI*, A.S. HAJAR**, and S.M. IBRAHIM**
**Department of Botany, College of Science, Girls, Al-Azhar University, Cairo, Egypt.*
***Department of Biological Sciences, Faculty of Science, King Abdulaziz University, Jeddah, Saudi Arabia*

ABSTRACT. *Trigonella foenum-graecum* was grown in different soil moisture treatments (100 "control" 75, 50 & 25%). The responses of this plant were investigated (Photosynthetic pigments, plant dimensions, weights, mineral contents, carbohydrate, nitrogen and proline). Most of the studied variables were decreased by the decrease of soil moisture in the early stage of the plant growth (first harvest). The plant weights were less affected than plant dimensions. The root lengths and weights were practically unaffected by water deficit treatments. The most affected elements by the water deficit was phosphorus, and the least affected by these was magnesium. The overall outcome of the present study was suggested that *T. foenum* can develop water deficit tolerance mechanism as the plant progress in age.

Introduction

In Saudi Arabia, *Trigonella foenum-greacum* can grow successfully and cope with the semiarid climate (*e.g.* on terraces on the slopes of the south west mountains (800-2650) m.a.s.l.). Traditionally natives in these areas grow this plant depending on rainfall.

Trigonella is a member of family leguminosae. The plant root, therefore, live symbiotically with the nodular bacteria, which can fix nitrogen, thus the plant is beneficial for the soil. The plant may be eaten as a vegetable and the seeds known to be good source for protein, carbohydrates, and contain active medicinal substances (Ibrahim, 1995). In the present work, the responses (phosynthetic pigments, plant dimensions, weights, mineral contents, carbohydrate, nitrogen and proline) of the locally grown *T. foenum* to water deficit treatments (100 'control', 75, 50 & 25%) were studied. This is to have some insight into the interaction process between water deficit as a major ecological factor in Saudi Arabia and this plant which has a reasonable degree of importance in the daily life of the people in this part of the world.

Material and Methods

Seeds of *Trigonella foenum* were sown in perforated 20 cm diameter plastic pots, each containing 2 kg of soil, composed of a mixture of 2 mm sieved soil and peatmoss (2-1 by volume). The pots were placed in the green house at Botany Dept., King Abdulaziz University, Jeddah, Saudi Arabia (1995) at 28± 2°C and 14 hours day time, under natural sunlight and irrigated with fresh water till 4 weeks when complete germination took place. The pots were then divided into four groups of eight pots with six plants in each plot, each group was treated with one of the four different soil moisture treatments (100, 75, 50 and 25%). The 100% soil moisture was equivalent to soil field holding capacity, and the other treatments (from 75-25%) were derived as percentage of the determined soil field holding capacity. Each of the appropriate soil moisture treatment was maintained constant according to the method used by Premachandra *et al.* (1992) and Hajar (1996). Four harvests were made (12 plants in each harvest) after two, four, six and eight weeks of the start of the treatments.

In each harvest, the responses of *T. foenum* to water deficit were studied, using the following parameters: The phosynthetic pigments, which were determined according to (Metzner *et al.*, 1965) and growth (plant height, leaf area, root length, number of leaves per plant, shoot & root fresh and dry weight). The dry weight was determined after the fresh plants were dried in oven at 75°C to for 48 hours constant weight. Water content was then determined using the formula:

$$\text{Water content} = \frac{\text{fresh weight} - \text{dry weight}}{\text{dry weight}} = \text{g water / g dry matter.}$$

Minerals (Cg, Mg, K, Na & P), were determined by grinding the dry stem samples into fine powder and assayed for mineral determinations using the wet digestion method (Humphries, 1956). Phosphorus was determined according to Woods and Mellon (1941); and total carbohydrates were determined according to Fales (1951); total nitrogen by Delory (1949); Proline by Bates *et al.* (1973) methods. The data were statistically analyzed to calculate the least significant differences (L.S.D.). At least six replicates were used in every case.

Results and Discussion

The effect of water deficit on the leaf pigments of *T. foenum* is shown in Table 1. The responses of Chl. a & b to water deficit were varied from one harvest to another, thus in young plant (harvests 1&2) chls. a & b significantly decreased by the decrease in soil-moisture. In older age (harvest 4) chl. a increased by the decrease in the soil moisture, and that was significant in the 50 & 25% soil moisture content while at 25% soil moisture content treatment chl. b was increased significantly. The carot. pigment did not show much difference in the first harvest, but was significantly higher in the water deficit treatments compared to control, in harvests 2 & 4. The total pigments have followed similar trends to that of chl. a. Results in Table 1 hence show that chls. a, b, carot. and total pigments contents in the leaves were higher in the older plants (harvest 4) and at lowest soil moisture treatment (25%). This may suggests that the plant tolerance to water deficit can be improved with age. This is consistent with previous reports (Moursi *et al.*, 1978 and Hajar *et al.*, 1996 c).

TABLE 1. Effect of water deficit on pigment content (mg/g/fresh weight) of *Trigonella foenum.*

Variable	Harvest no.	% Soil moisture			
		100	75	50	25
Chl. a	1	4	3.56	3.44	3.52
	2	1.77	1.45	1.09	0.88
	3	1.5	0.92	0.9	1.78
	4	4.65	4.82	5	6
L.S.D : At 5% W. deficit **0.3** Age **0.32** interaction **0.11**					
Chl. b	1	3.85	3.18	3.01	3.01
	2	1.5	1.0	0.83	0.5
	3	0.83	0.67	0.5	1.17
	4	4.36	4.02	4.86	5.7
L.S.D : At 5% W. deficit **0.36** Age **0.4** interaction **0.13**					
Carot.	1	0.32	0.23	0.25	0.28
	2	0.28	0.72	0.66	0.62
	3	2.88	2.08	2.03	2.10
	4	3.14	3.42	2.76	3.26
L.S.D : At 5% W. deficit **0.22** Age **0.2** interaction **0.07**					
Total pigments	1	8.17	6.97	6.7	6.81
	2	3.55	3.17	2.58	2
	3	5.21	3.67	3.43	5.05
	4	12.15	12.26	12.62	14.96
L.S.D : At 5% W. deficit **0.9** Age **0.89** interaction **0.33**					

The adverse effect of the water deficit on the plant dimensions (plant height, leave area, root length) and number of branches and leaves was not significant (Table 2). However, plant dimensions and the number branches and leaves increased with age even in the water deficit treatments (50 & 25%). Table 2 also showed that the root length was least affected. This coupled with the results obtained for other plant dimensions and both branches and leaves numbers could account for in the plant tolerance to water deficit, specially with age progress.

The adverse effects of water deficit on the growth of plant species were well documented (Ibrahim, 1995; and Al-Zahrany, 1996). Nevertheless, the non-significant effect noticed in the present study agrees with some previous works (Hussein and Firgany, 1980).

A decrease was occurred in the fresh and dry weights of the shoot by the decrease in the soil moisture (Table 3), but the decrease was significant in the low soil moisture treatments (50 & 25%). Root fresh % dry weights were less affected by water deficit.

TABLE 2. Effect of water deficit on plant dimensions (cm), number of branches and leaves of *Trigonella foenum*.

Variable	Harvest no.	% Soil moisture			
		100	75	50	25
Plant height	1	32.9	29.8	29.6	27.8
	2	44.3	41.7	34.7	32.5
	3	53.1	50.8	37.35	34.7
	4	61.5	52.7	43.9	38.4
L.S.D : At 5% W. deficit **3.7** Age **3.73** interaction **1.31**					
Leaf area (cm^2)	1	10.39	8.5	6.06	4.38
	2	11.45	10	6.63	5.13
	3	12.07	9.67	7.66	5.99
	4	13.08	10.58	8.25	6.47
L.S.D : At 5% W. deficit **0.5** Age **0.51** interaction **N.S.**					
Root length	1	13.6	13.3	9.86	10.4
	2	14.16	14.9	10	8.33
	3	13.33	9.5	11.5	10.83
	4	15.4	13.23	11.5	12.10
L.S.D : At 5% W. deficit **N.S.** Age **3.51** interaction **N.S.**					
No. of branches	1	14	12.7	11.3	9
	2	18.7	17.7	14.7	11.7
	3	19.33	22.7	13.7	10.7
	4	27.7	23	20.7	10.3
L.S.D : At 5% W. deficit **1.2** Age **4.3** interaction **1.5**					
No. of leaves	1	42	40	36.66	32
	2	54.33	53.33	43.66	37
	3	63.33	62.33	41.66	32
	4	77.33	67.66	44	25.33
L.S.D : At 5% W. deficit **8** Age **8.4** interaction **2.97**					

Both shoot & root water contents were decreased generally by the decrease in the soil moisture in the first three harvests, but increased with the decrease in the soil moisture in the fourth harvest. Similar trend was noticed by the increase in age. This all suggest that the plant developed a water deficit tolerance as it is progressing in age. Moreover the root dimensions and weights were practically unaffected by water deficit. Water deficit is known to decrease plant weights (Loomis and Worker, 1983; Ambujam and Manickam, 1990 and Hajar *et al.*, 1966a). It is however known that plant weights are less affected by water deficit than plant dimension (Hajar *et al.*, 1996 a). It is also well known that root are less affected than shoot (Nunes *et al.*, 1977 and Hajar *et al.*, 1996a). *Plant water content usually decrease* with the decrease in the soil moisture (Wample and Thornton, 1984) but however this may increase with age (Hajar *et al.*, 1996a).

TABLE 3. Effect of water deficit on plant weights (g) of *Trigonella foenum*.

Variable	Harvest no.	% Soil moisture			
		100	75	50	25
Shoot fresh weight	1	3.94	3.3	2.15	1.28
	2	4.36	3.88	2.71	1.26
	3	6.1	4.42	3.47	1.43
	4	5.06	3	2.07	1.36
L.S.D : At 5% W. deficit **1.02** Age **1** interaction **NS**					
Shoot dry weight	1	0.56	0.46	0.32	0.25
	2	0.8	0.76	0.57	0.29
	3	1.28	0.99	0.99	0.43
	4	1.51	0.87	0.59	0.31
L.S.D : At 5% W. deficit **0.2** Age **0.24** interaction **0.08**					
Root fresh weight	1	0.18	0.30	0.14	0.11
	2	0.19	0.09	0.07	0.01
	3	0.07	0.08	0.04	0.02
	4	0.08	0.01	0.13	0.06
L.S.D : At 5% W. deficit **0.08** Age **0.07** interaction **N.S.**					
Root dry weight	1	0.02	0.03	0.02	0.01
	2	0.02	0.02	0.01	0.01
	3	0.02	0.02	0.02	0.01
	4	0.03	0.03	0.02	0.01
L.S.D : At 5% W. deficit **0.008** Age **0.008** interaction **NS**					
Shoot water content	1	85.59	84.64	85.12	80.41
	2	81.44	80.18	78.9	77.02
	3	78.87	77.54	71.17	69.29
	4	69.64	71.06	71.74	77.4
L.S.D : At 5% W. deficit **4.3** Age **4.28** interaction **1.51**					
Root water content	1	82.98	88.92	83.34	66.38
	2	78.55	74.58	74.48	45
	3	66.15	70.4	57.77	32.25
	4	57.31	69.99	75.66	82.50
L.S.D : At 5% W. deficit **3.9** Age **3.9** interaction **1.38**					

The plant Ca content was significantly increased under water deficit treatments in the first harvest (Table 4), but was almost unaffected in all other three harvests (2-4). This may indicate that water deficit could affect *T. foenum* Ca content in its early stage only. Kramer (1983) suggested that plants accumulate more Ca at wilting point in order to tolerate water deficit, also El-Lawendy (1990) and Hajar (1996) have also observed similar results. Water deficit and age have no significant effect on the plant Mg content. Similar results were reported by Abd El-Rahman (1973) in some desert plants, and El-Lawendy (1990) beet plants. Hajar *et al.*, (1996b) stated that the age has no significant effect on the Mg content of *S. bicolor* shoot when grown under water deficit. The plant K was significantly decreased by the water deficit treatments and age in almost all harvests, but was more pronounced in the early stage (first harvest). The adverse effect of water deficit on K content of plant is well documented in many previous studies (Wilson, 1982; Binnie *et al.*, 1986; El-Lawendy, 1990 and Hajar *et al.*, 1996b).

TABLE 4. Effect of water deficit on the mineral contents (mg/g dry shoot) of *Trigonella foenum*.

Variable	Harvest no.	% Soil moisture			
		100	75	50	25
Calcium	1	17.8	14.7	12.0	20.8
	2	17.3	17.8	18.9	18.5
	3	14.2	18.8	17.0	18.1
	4	15.9	17.5	16.5	17.2
L.S.D : At 5% W. deficit **2.3** Age **NS** interaction **0.8**					
Magnesium	1	2.2	1.9	1.8	2.4
	2	2.2	1.8	2.1	2.3
	3	2.0	2.2	2.1	2.0
	4	1.7	2.5	2.7	2.1
L.S.D : At 5% W. deficit **NS** Age **NS** interaction **NS**					
Potassium	1	38.3	27.2	28.6	24.8
	2	20.42	20.9	21.9	22.5
	3	20.5	17.9	17.1	14.8
	4	20.9	14.4	14.2	14.2
L.S.D : At 5% W. deficit **0.43** Age **0.4** interaction **NS**					
Sodium	1	10.2	6.1	6.5	8.8
	2	10.7	7.7	6.7	10.6
	3	12.1	7.7	6.5	9.4
	4	9.4	13.2	9.3	12.5
L.S.D : At 5% W. deficit **2.6** Age **2.65** interaction **0.9**					
Phosphorus	1	6.7	4.5	4.3	4.7
	2	5.8	5.8	4.9	4.8
	3	6.4	5.9	5.1	4.8
	4	7.0	5.0	4.3	4.2
L.S.D : At 5% W. deficit **0.8** Age **0.8** interaction **0.03**					

The plant "Na" content was significantly decreased by the water deficit (75 and 50%) in the first three harvests, however, there was a clear increase in Na content by the decrease in soil moisture from 50 to 25% in all harvests. This may show a water deficit tolerance in *T. foenum.* The plant Na contents were increased in the later stage (fourth harvest) in the 75, 50 & 25% treatments, which indicate a positive effect of the age on plant grown under water deficit treatments. The decrease in Na contents reported in the present study agreed with that reported by El-Lawendy (1990). Similar to the increase of "Na" content in the *T. foenum* which grown in 25% treatment is that recorded by Hajar *et al.* (1996b) for *S. bicolor.*

It is clear that the plant "P" content were all less in the water deficit treatments than in the control (100%). This decrease was significant in harvests one and four. The adverse effect of water deficit on "P" plant content was more pronounced than on other elements (Table 4). This adverse effect on plant "P" is well known in other cases (Gates, 1955; El-Lawendy, 1990 and Hajar *et al.*, 1996b). In the present context, the overall positive relationship between the increase in *T. foenum* age and its content of most studied minerals could suggest a water deficit tolerance tendency in this plant.

Responses of plant carbohydrate, nitrogen and proline are presented in (Table 5). Carbohydrate was significantly decreased by water deficit in the first, second, and third harvests, but there was no significant differences between treatments in the fourth harvest. Plant carbohydrate content in this latter harvest was higher than in first three harvested (75, 50 % 25%). These results suggest that water deficit may affect the plant carbohydrate in the early stages, but not in the later growth stage. Moreover *T. foenum* increased its carbohydrate content with age. Other plant species were known to tolerate drought by increasing their carbohydrate content (Below *et al.*, 1981; El-Lawendy, 1990 and Hajar *et al.*, 1996b).

TABLE 5. Effect of water deficit on some metabolic products (Carbohydrate, Nitrogen & Proline) (mg/g dry shoot) *Trigonella foenum*.

Variable	Harvest no.	% Soil moisture			
		100	75	50	25
Total carbohydrates	1	287.5	43.0	38.2	112.3
	2	115.9	62.1	76.4	71.3
	3	119.3	83.0	74.6	87.1
	4	128.1	103.4	102.9	130.4
L.S.D : At 5% W. deficit **10.3** Age **10.2** interaction **0.7**					
Nitrogen	1	35.3	35	28.3	27
	2	14.1	17.5	20.0	23.5
	3	29.4	29.5	25.7	23.6
	4	25.6	25.8	26.7	27.0
L.S.D : At 5% W. deficit **10.4** Age **10.41** interaction **1.4**					
Proline	1	0.97	0.31	0.5	1.37
	2	0.14	0.25	0.52	1.61
	3	1.73	1.87	1.96	3.67
	4	3.89	1.97	1.99	3.86
L.S.D : At 5% W. deficit **1.6** Age **1.64** interaction **0.1**					

The plant nitrogen showed no significant differences among treatments or harvests, however, a trend of decrease was noticed in the first harvest, and increase in the remaining harvests (2-4). In this respect plant species do differ in their "N" responses to drought treatments, whereby some has no significant changes (Hajar *et al.*, 1996c), and some increase their "N" (El-Telwany, 1987). While others decrease their "N" (Wolf *et al.*, 1988). Hajar *et al.* (1996c) suggested that all or most of these responses can occur in the same plant at different growth stages and or different water stress treatments.

In the first harvest, the plant proline was decreased by the decrease in the soil moisture from 100% to 75%, but increased from 75% to 25%, however, non-significantly. Trends of increase in the plant proline by the decrease in soil moisture were recorded in harvests 2, 3 & 4, but nevertheless most of these were not significant. In all treatments there was a significant increase in the plant proline by age (between harvest 1 and 4).

Proline reported to be associated with water deficit (Shen *et al.*, 1990; Rabe 1990; Hajar *et al.*, 1996a & Hajar *et al.*, 1996b).

The combination of the present results suggested that *T. foenum* can develop water deficit tolerance as it is progressing in age. This therefore encourage to perform further investigations on the different aspects of the biology of this important plant, as it is a plant full of potentials.

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استجـــابات نبـــات الحلبـــة *Trigonella foenum-graecum* لنقـــص المـــاء

أم محمد أحمد خفاجي*، و عبد الرحمن سعيد حجر**، و سلما محمد إبراهيم**
* قسم النبات - كلية العلوم (بنات) - جامعة الأزهر
القاهـــرة - جمهورية مصر العربية
** قسم علوم الأحياء - كلية العلوم - جامعة الملك عبد العزيز
جـــدة - المملكة العربية السعودية

المستخلص . نميت نباتات الحلبة *T. foenum-graecum* في معاملات جفافية مختلفة (١٠٠ « معاملة ضابطة »، ٧٥، ٥٠، ٢٥٪ رطوبة) . ودرسة استجابات هذا النبات (أصباغ البناء الضوئي ، أبعاد النبات ، أوزانه ، محتواه المعدني ، الكربوهيدراتي ، النيتروجين والبرولين) .

تأثرت معظم هذه المتغيرات سلبًا بالجفاف أثناء العمر المبكر للنبات ، لكن أوزان النبات كانت أقل تأثرًا من الأبعاد . أما أطوال وأوزان الجذور فلم تتأثر عمليًا بالجفاف . وكان أكثر المعادن تأثرًا بالجفاف الفوسفور وأقلها تأثرًا المغنسيوم . على كل فالنتيجة العامة التي يمكن استخلاصها من هذا البحث أن نبات الحلبة يمكن أن يتأقلم مع الجفاف مع تقدم العمر .