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Improving Soil Physical Properties and its Effect on *Acacia tortilis* Seedlings Growth Under Field Conditions

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Abstract: The present study aimed to establish *Acacia tortilis* seedlings with a minor amount of water through improving the soil physical properties by adding different soil conditioners during the early growth stages of *Acacia*. Three soil conditioners were added to the soil holes in the field before transplanting; gel, organic matter and a mixture of both. Four hundred *Acacia tortilis* seedlings at the same age and height were transplanted in the field on different treatments and many vegetative parameters were used to measure the growth rate of the seedlings. These parameters included shoot height, number of compound leaves, vitality, water content of both shoot and root system, number of lateral roots and both length and width of the root system. Results showed that seedlings transplanted on soil enriched with gel produced the highest values of leaflets, shoot height, vitality, width of root and water content of both shoot and root system and the lowest values in root length. While the mortality rate were very low for the seedlings cultivated on gel-enriched soil, it was the highest for seedlings cultivated on the organic matter-enriched soil and soil enriched with mixture of both gel and organic matter.

Keywords: *Acacia tortilis*, gel, organic matter, soil conditioners, South Sinai, water stress-drought–soil fertilizers

Introduction

Egypt as a developing country is in need to use its natural biological resources to generate a reasonable income due to its exploding population. In the last 20 years, the wild vegetation of South Sinai has been endangered which resulted in disappearance of palatable species, rarity of trees and change in vegetation composition (Moustafa *et al*., 2001).

Acacia tortilis is one of the most useful trees in the Egyptian desert due to its role in desert ecosystem and its multipurposes use in the indigenous Bedouins' life. In the meantime, this tree is under great stress of cutting, grazing, infection of seeds by insects and fungi and unmanaged developmental projects including constructions of houses and hotels on large scales. These stresses have led to failure of *A. tortilis* seedlings establishment.

Infact, *Acacia* species allover the world are subjected to various important economic studies including growth, seed predation, production and germination (Simmons, 1987; Banerji *et al*., 1988; Boughton, 1989; Hoffman *et al*.,1989 and Dunham, 1989). Many studies have been carried out to investigate the regeneration, distribution and succession in *Acacia* species communities in different regions of the world (Liang, 1987; Pieterse and Cairns, 1987; Skelton, 1987; Kushalapa, 1988; McCaw, 1988; Ashton and Chappill, 1989; Woodell, 1990; Johansson and Kaarakka, 1992 and Diouf and Grouzis 1996).

Due to the great stress on *A. tortilis* in South Sinai (very arid lands with harsh conditions), Egyptian Environmental Affairs Agency (EEAA) ran two main programs in order to conserve the *Acacia* in Sinai. The first program dealt with protecting and monitoring the expected changes that would occurred in the *Acacia tortilis* populations upon removing these stresses through fencing and the second focused on producing *A. tortilis* seedlings (mass production) and transplanting these seedlings to the natural habitats (rehabilitation). Because water is considered as a treasure in extremely arid ecosystems, our main objectives of this study were:

1- Reducing the amount of water needed in the early stages of *A. tortilis* by adding different conditioners that can increase the soil water holding capacity in the field.

2- Investigating which one of applied soil conditioners is the best and that would be associated with highest rate of plant growth rate.

3- Reaching the farthest wilting point for *Acacia tortilis* seedlings cultivated under these different soil conditioner through various irrigation intervals regimes.

Materials and Methods

Collecting seeds: The pods of *Acacia tortilis* sub sp. *tortilis* were collected from Wadi Mandar that is located near Sharm El-Sheikh area in South Sinai during summer seasons of 1999 and 2000, in paper bags and kept in a refrigerator at 10°C. Only sound seeds were used to run the experiments. The selection of sound seeds was based on different morphological criteria such as color, size and being uninfected.

Germination, transplantation and irrigation: *Acacia tortilis* seed is characterized by a waxy, hard (stony) testa, which make its germination impossible under normal conditions. High percent of germination was obtained by soaking seeds in concentrated Sulfuric acid for 20 minutes, or in boiling water for 30 minutes. The treated seeds were washed thoroughly by water (6 times) in order to rinse the Sulfuric acid and then were planted directly into soil. A mixture of 2 mm-sieved sandy soil, vermiculite and peat moss (1:1:1) was used as a seed bed for germinating and growing *Acacia tortilis*. Five seeds were placed in each pot, which were transferred out door directly after seeding. Each pot was watered two times weekly at early morning until the seedlings emerged and been transplanted. The emergence of cotyledonary leaves was noticed one month after seeding. A commercial mineral-rich nutrient (Superfeed, 19/19/19 + Mg + T.E.) was sprayed on all small seedlings two times before they being transplanted into the field in order to supply the seedlings with macro and micronutrients. This aimed to have strong and vigorous seedlings and avoid the dropping in seedlings number usually associates with transplanting into the field. This mineral-rich nutrient is composed of Nitrogen (19%), Phosphorus P_2O_2 (19%), Potassium K_2O (19%), Magnesium MgO (1%), Fe EDTA (0.1%), Mn EDTA (0.05%), Zn EDTA (0.03%), B (0.02%), Cu (0.01%) and Mo (0.005).

Four hundred similar seedlings were selected and transplanted to the field. The selection based on morphological characters such as shoot height, presence or absence of cotyledonary leaves, presence or absence of spins and plant vigorous. Four rectangular areas (3x6 m) were chosen in the field as a transplantation site with four irrigation cycles, one in each rectangle, with different intervals; 10, 15, 20 and 25 days. Each rectangle had ten seedlings and divided into 4 lines; each was used in a soil treatment; gel, organic and mixture, beside the control. In organic matter treatment for each seedling, 600 gm of organic manure were soaked in 900 ml of water for about 30 min before being used in transplantation (according to Thompson and Troeh, 1978). In gel treatment, 5 gm of the gel (specifications or commercial name) were soaked in 900 ml of water (according to a personal pilot experiment) for 24 h before being used in transplantation. The gel plus organic manure mixture was prepared by adding 2.5 gm of gel soaked in 900 ml water for 24 h to 300 gm organic matter.

Vegetative parameters: A number of vegetative parameters were used to measure and evaluate the growth of *Acacia tortilis* seedlings under different treatments. These parameters were shoot height; number of leaflets per plant, vitality of each individual plant, water content of both shoot and root system and length of spins. The vitality was ranked according to a scale formed of 6 degrees based on the plant condition and color of leaf. This scale was modified from Braun-Blanquet (1932), Misra and Puri (1954) and Daubenmire (1968). The index is (0) for brown or nearly dead (permanent wilting point) plant, (1) for absolutely yellow dry, (2) for moderately yellow, (3) for slightly yellow in the lower leaves, (4) for normal or some yellow leaflets and (5) for excellent healthy plant (vigor).

Mortality: The growth or decline in *A. tortilis* planted populations under different soil treatment were viewed using mortality rates in order to select the best soil conditioner with least mortality rate.

Statistical assessment: Statistical evaluation of the obtained data was carried out by two statistical tests, Analysis of Variance (ANOVA) and t-test, using microcomputer program SYSTAT (1987).

Results

Effect of soil conditioners on vegetative parameters: The effect of soil conditioners on the transplanted *Acacia tortilis* seedlings (gel, organic matter, mixture of both gel and organic matter) was assessed for measured and recorded vegetative and growth parameters.

Vitality: At the first and second readings (after one and two months of transplanting), the maximum vitality was obtained in plants transplanted into soil enriched with gel under 10 days irrigation intervals regime, followed by those plants transplanted into soil enriched with gel under 15, 20 and 25 days irrigation intervals regime and the control plants under all irrigation intervals regimes. At both the third and fourth readings, the vitality of plants transplanted into soil enriched with gel and control plants was almost the same under all irrigation intervals regimes. While the vitality of plants transplanted in soil enriched with mixture of gel and organic matter at the first reading was slightly better under 15 and 20 days irrigation intervals regimes than plant transplanted into soil enriched with organic matter only, it was the same under all the other irrigation intervals regimes. Starting from the second reading (2 months),

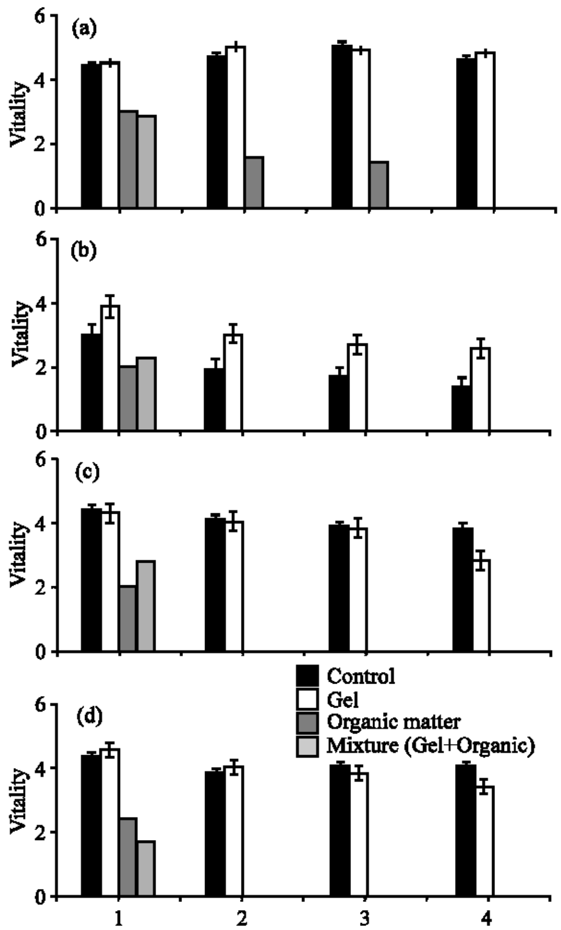

Fig. 1: The change pattern in the vitality of *Acacia* seedlings cultivated on four soil types (Control, gel, organic matter, mixture of gel and organic matter) and irrigated every 10, 15, 20 and 25 days (a, b, c and d)

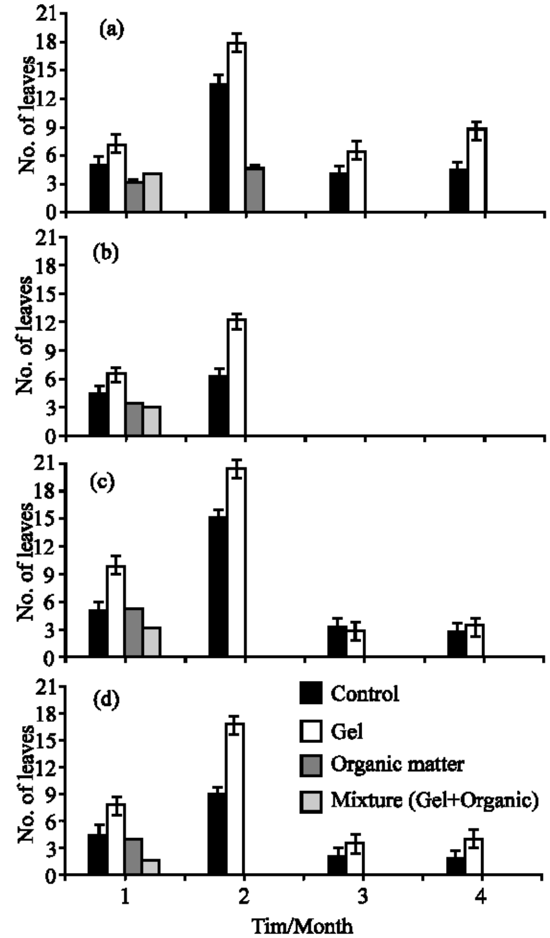

Fig. 2: Showing the change pattern in the number of leaves of Acacia seedling cultivated on four different types of soil (Control, gel, organic matter and mixture of gel and organic matter) and irrigated every 10, 15, 20 and 25 days (a, b, c and d respectively)

all the plants transplanted into soil enriched with organic matter or mixture of organic matter and gel under all irrigation intervals regimes died or almost so (Fig. 1).

These results means that adding gel to transplanting soil slightly enhances the vitality of *A. tortilis* seedings in the first two months, while adding organic matter (manure) or mixture of organic matter and gel results in low vitality in the first month of transplanting and causes death afterward.

Shoot system: In all readings, the counted number of compound pinnate leaves (Fig. 2) showed that plants transplanted into soil enriched with gel had more leaves (higher minimum, maximum and mean), followed by control plants. While plants irrigated by 20 days intervals regime resulted in the highest mean number of leaves at the first\ reading (1 month), it was 10 days irrigation intervals regime which gave the highest number of leaves at the rest of readings (2, 3 and 4 months). Irrigating with 15 days intervals regime resulted in the lowest mean number of leaves in all readings allover the tested irrigation regimes. Plants transplanted into soil enriched with organic matter or organic matter and gel had (more or less) similar results.

At the first reading (first), the maximum mean height of *A. trotilis* was obtained in plants transplanted into soil enriched with gel at 10, 15 and 20 days irrigation intervals regimes and was followed by plants transplanted into soil enriched with organic matter, control and mixture of

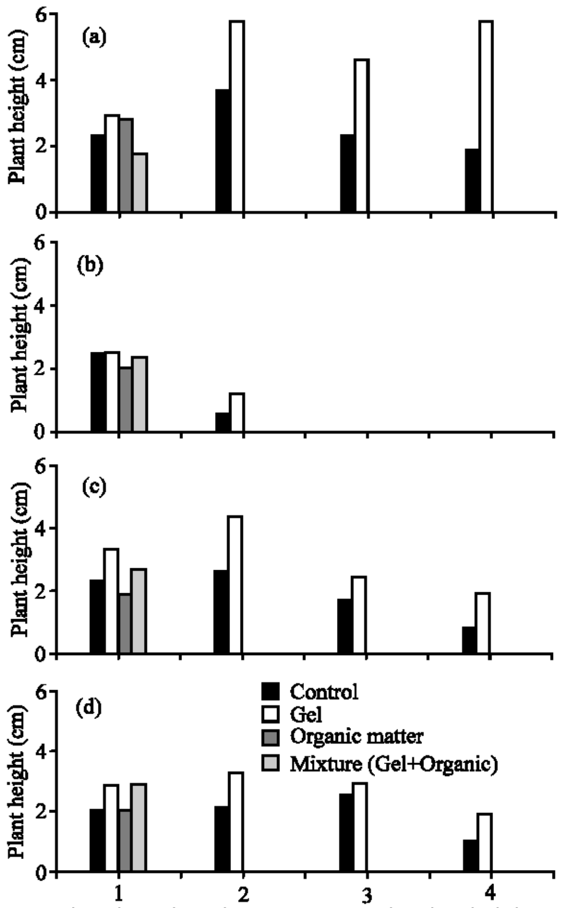

Fig. 3: Showing the change pattern in the height of *Acacia* seedlings cultivated on four different types of soil (Control, gel, organic matter and Mixture of gel and organic matter) and irrigated every 10, 15, 20 and 25 days, (a, b, c and d respectively)

organic matter and gel, respectively. But in 25 days irrigation intervals regime, it was the mixture-enriched soil which gave the highest mean height followed by gel. At the rest of readings (2, 3 and 4 months), the trend was clear and fixed where the maximum mean height was obtained in plants grown on gel-enriched soil and followed by control plants, while complete dryness or even death was the fate of all plants grown on either organic matter-enriched or mixture-enriched soils. One can conclude that plant height in gel treatment has been found to have the highest and followed by the control plants (Fig. 3).

The results of estimating water content in shoot system showed that control plants and those grown on gel-enriched soil had more than 15% mean water content, while those grown on either organic matter and mixture–enriched soil, had mean water content slightly over 8% (Fig. 4d).

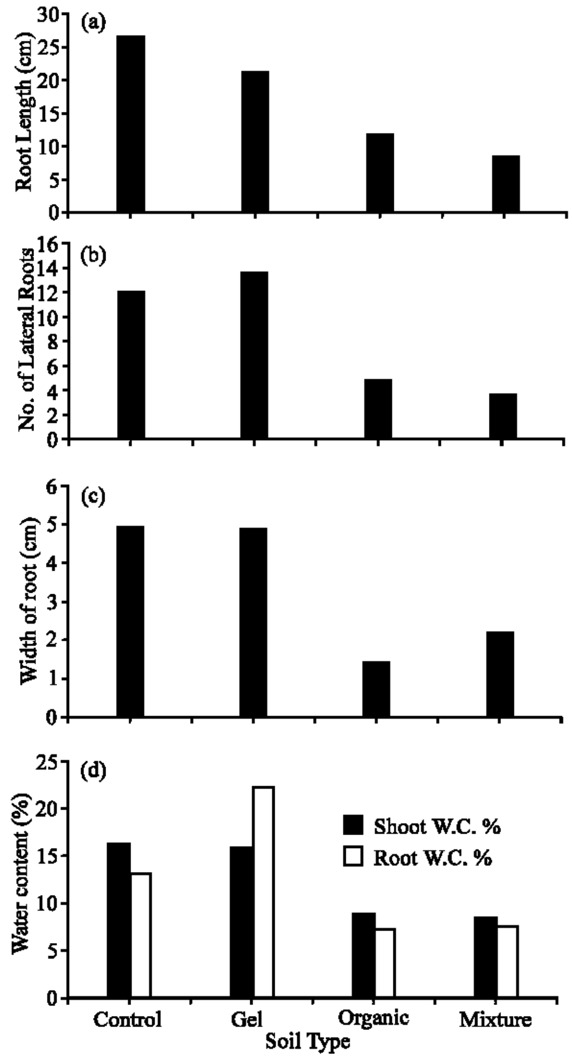

Fig. 4: (a, b, c and d) shows root length, number of lateral roots, root width and water content of both shoot and root systems for *Acacia* transplanted on different soil types, respectively

Root system: The longest *A. tortilis* average root length (38.67 cm) for any irrigation regime was recorded in control plants for 25 days irrigation intervals regime. The highest mean root length for the four irrigation regimes was recorded also in control plants followed be plants grown on gel-enriched soil, while plants grown on soil enriched with either organic matter or mixture of organic matter and gel has short roots in comparable to control plants and those grown on gel-enriched soil (Fig. 4a). There was no detected relationship between the root length and irrigation regimes for all treatments.

The number of the lateral roots varied in the seedlings and was the largest in plants transplanted into gel-enriched soil, followed directly with control plants (Fig. 4b), while

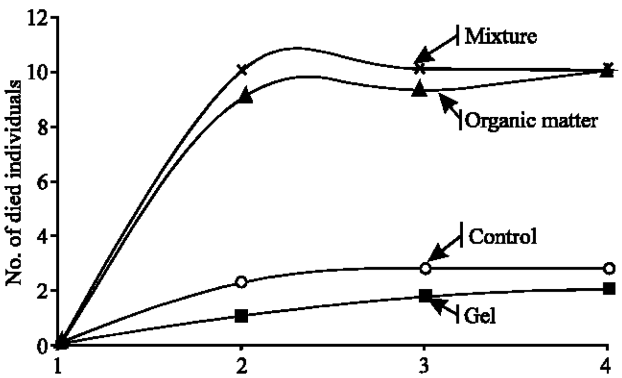

Fig. 5: The mortality change along the first, second, third and forth readings for the four used soil conditioners (control, gel, organic matter and mixture of gel and organic matter)

the number of the lateral roots was few in the seedlings transplanted into soil enriched with organic matter or mixture (Fig. 4b). In all different irrigation regimes, the distance between any two opposite lateral root reached its maximum value in control plants and those transplanted into gel-enriched soil, while it was decreased sharply in plants transplanted into soil enriched with organic matter and gel mixture and gave the lowest width in plants grown on organic matter-enriched soil (Fig. 4c).

The water content was relatively high in those seedlings transplanted into gel-enriched soil. It decreased in control plants and showed a low percentage in plants transplanted into soil enriched with either organic matter or mixture of organic matter and gel (Fig. 4d).

Mortality: The mortality curve demonstrated in Fig. 5 shows that highest mortality rates occurred in plants grown on both soil enriched with organic matter and mixture, particularly in the second reading, which represent the little efficiency of such two soil conditioners. On the other hand, the lowest mortality rates were achieved by using gel. The efficiency of gel as a soil conditioner is mainly due to its ability to preserve water and nutrients for a time and hence the plant will not face the danger of drought and subsequently decreasing in the mortality rate appeared.

Statistical assessment: The ANOVA test is shown in Tables 1 and 2, both two-ways and one-way ANOVA, respectively. One-way analysis of variance for the vegetative parameters had shown that there are significant variations in the number of leaves and the plant height at all irrigation regimes (10, 15, 20 and 25 days). Moreover, vitality showed a significant variation at irrigation intervals 10, 20 and 25 (Table 2). Two-way

Table 1: Two way analysis of variance of different vegetation parameters (height, vitality and number of leaflets)

	Analysis of variance (two ways)		
Vegetation parameters	Source of variation	F	*P*
Shoot height	Watering period	5.927	0.001
	Soil conditioners	17.643	0.000
	Interaction	2.742	0.006
Vitality	Watering period	5.519	0.001
	Soil conditioners	32.301	0.000
	Interaction	6.866	0.000
Number of leaves	Watering period	12.022	0.000
	Soil conditioners	68.740	0.000
	Interaction	4.656	0.000

Table 2: Output results of one way analysis of variance (ANOVA) including the shoot height, vitality and number of leaflets

Vegetation parameters	Irrigation period (days)	F	*P*
Shoot height	10	9.00	0.00
	15	3.06	0.04
	20	4.63	0.01
	25	3.35	0.03
Vitality	10	29.02	0.00
	15	0.37	0.77
	20	17.33	0.00
	25	5.77	0.00
No. of leaflets	10	33.00	0.00
	15	4.27	0.01
	20	20.33	0.00
	25	27.84	0.00

Table 3: Shows the differences in the number of leaflets of Acacia seedlings transplanted on different soil conditioners

Irrigation period	Parameters	t-value	*p*-value
10	Gel	-0.205	0.842
	Organic matter	7.144	*0.000*
	Mixture	7.144	*0.000*
15	Gel	-1.186	0.266
	Organic matter	1.819	0.102
	Mixture	1.819	0.102
20	Gel	2.443	*0.037*
	Organic matter	3.847	*0.004*
	Mixture	3.847	*0.004*
25	Gel	-3.647	*0.005*
	Organic matter	4.146	*0.002*
	Mixture	4.146	*0.002*

Table 4: T-values and their significance for the mortality of *Acacia* seedlings cultivated on different soil conditioners

	Irrigation period	t-values	*P*
10	Gel	-1.500	0.168
	Organic matter	6.000	0.000
	Mixture	6.000	0.000
15	Gel	2.449	0.037
	Organic matter	1.000	0.343
	Mixture	1.000	0.343
20	Gel	-0.429	0.678
	Organic matter	3.674	0.005
	Mixture	3.674	0.005
25	Gel	-0.429	0.678
	Organic matter	3.674	0.005
	Mixture	3.674	0.005

analysis of variance showed that there are significant variations for plant height with different irrigation regimes, soil conditioners and the interaction between different soil conditioners (Table 1). The same test were done for vitality and the number of leaves which showed also significant variation through watering intervals, soil conditioners and the interaction between different soil conditioners (Table 1).

The results of the t-test are presented in tables 3 and 4 for number of leaves and mortality, respectively. The t-test results for the number of leaves showed significant variations between control against both organic matter and mixture at 10, 20 and 25-day irrigation regimes. Control against gel soil conditioner showed a significant variation through irrigation intervals 20 and 25-day. On the other hand, t-test for the mortality rates showed significance between control and both organic matter and the mixture at irrigation intervals 10, 20 and 25-days.

Discussion: It is well known that *Acacia* species are widely distributed in the Middle East (including Sinai) and can survive under harsh environments (Andrews, 1952; Halvey and Orshan, 1972; Täckholm, 1974; Mahmoud, 1977; Migahid, 1978; Chaudhary, 1985; Batanouny, 1986 and Abulfatih, 1995).

However, sustainable development and conservation policies should be in action to protect our main components of biodiversity. In fact, conservation is primarily a precondition stage for starting saving policy for our plants. Generally, *Acacia* species allover the world were subjected to various important economic studies such as the growth, seed predators, production and germination of *Acacia* (Simmons, 1987; Banerji *et al.,* 1988; Boughton, 1989; Hoffman, *et al.*,1989 and Dunham, 1989).

Back to the main aim of the present study that was how to decrease the amount of water needed in the early stages of *A. tortilis* by adding up different conditioners that can augment the soil water holding capacity in the field and to investigate the best soil conditioners is the best and that would be associated with highest rate of plant growth rate.

The results obtained proved that gel soil conditioner was the most efficient soil conditioner for *Acacia tortilis.* This were clearly visible in various vegetation parameters measured, from these; vitality, number of compound leaves, shoot height, water content of both root and shoot, root length, root width and number of lateral roots.

It is well known that precipitation, intensity and annual variation, soil deposits, topography and vegetation physiognomy influence the availability of moisture furnished precipitation to the plants. In fact, these factors and the response of plants to their variations have been dealt with many studies (Kassas, 1956; Kassas and Imam, 1954 and Kassas and Girgis, 1970). It has been described by Hillel and Tadmor, 1962 that the effect of nature and roughness of soil surface on moisture availability is related to its capacity of water storage. This depends not only on the volume of water resources, but also on the depth of surface deposits; the shallower the deposits the lesser capacity of storage of moisture. The proportion of total evapotranspiration lost from the soil surface depends on the amount of vegetation cover and correlates with the nature of surface. The moisture availability also increases with increasing of the coarseness of surface cover, e.g. cover of cobbles conserves more moisture than the cover of gravels (Hillel and Tadmor, 1962). Besides, the natural stoney mulch on slopes retards runoff, prevents the formation of continuous crust and slows the rate of evaporation (Moustafa, 1990). Soil texture is one of the most important factors affecting moisture availability and subsequently the distribution of plants. Moustafa (1990) and Yohannes (1999) demonstrate the correlation between the fine and gravel fractions with the moisture availability. While moisture holding capacity increases with fine sand percentage, moisture storage increases and the loss by evaporation decreases with the gravel and coarse sand (Alizai and Hulbert, 1970).

It is quite similar to the present study, many studies proved that mixture of stones within the soil increases the depth of moisture penetration (Noy-Meir *et. al.,* 1973; Walter, 1973, Wentworth, 1981 and Moustafa and Zaghloul, 1996).

Also, mortality rates have provided an excellent estimate for the efficiency of using gel as soil conditioner. *Acacia tortilis* transplanted on gel soil type is found to have high number of leaflets and hence high vegetation cover. In the meantime highest values of plant height is clearly visible in *Acacia tortilis* transplanted in gel treated soils. This also is confirmed by the use of vitality scale, that also, *Acacia tortilis* transplanted in gel and also control soil types, has proved high vitality scale. Gel as a soil conditioner was acting as a natural trap for the moisture and pump it to the plant during the early stages of growth. Various methods of moisture conservation have been the subject of considerable research (Yohannes, 1999). It has been reported that surface mulching applied on different agricultural and horticultural crops reduces evaporation and helps conserve moisture for optimum plant growth (Ashutosh, 1994; Gupta *et al.*, 1995; Al-Darby *et al.,* 1990 and Moody *et al.*, 1963).

Other important parameters were used to assess the difference between these different soil types control, gel, organic and mixture, these parameters are the root length, number of lateral roots, width of root and water content of both root and shoot. All these parameters have given a clear image about the advantages and efficiency of using gel and control the growth of *Acacia tortilis* under field conditions.

In agreement with Crawely (1997), species conservation should begin when a species is found to be declining in numbers but is not yet threatened with extinction. Sometimes, if the decline is very rapid and a species is well known, concern for its survival is felt before it is endangered.

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