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ESTABLISHING OF EXTENSIVE ROOF GREENING BY USING TWO DIFFERENT SUCCULENT SPECIES GROWING IN TWO DIFFERENT SOIL MIXTURES AND WATERING RATES

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ABSTRACT

The current research aimed to create an extensive green cover on existing flat roofs of buildings to gain its aesthetical, environmental, economic and social benefits. It was carried out in Belquas City, Dakahlia Governorate from September 1998 till October 2000 using two different species of succulent plants, i.e. *Delosperma cooperi* and *Aptenia cordifolia*, grown in two different soil mixtures and irrigated with two different watering rates. The basic ingredients of the tested soil mixtures were clay, sand and bean straw. The used watering rates were 8 and 16 liters / m^2. The experiment area was a flat roof of three stories building with 2% gradient.

Certain measurements were conducted to characterize the tested soil mixtures and to determine the growth and development of the tested plants.

The obtained results showed that the tested succulent plants reached a 100% covering within the first year of the experiment. The covering spreading of *Aptenia cordifolia* was faster than *Delosperma cooperi*. The tested soil mixture (clay+ sand + bean straw) was more suitable than the mixture (clay + sand) for growth and development of the used succulent plants. N, P and K contents of the tested soil mixtures decreased along the period of experiment. The tested plant species grew better when irrigated with water application of 8 liters / m^2, as compared with water application of 16 liters / m^2.

According to the current results, it is possible to establish an extensive green cover under climatic conditions and circumstances in Egypt with relatively low cost, simple technology and care arrangements on the available and unused open areas of roofs on the existing buildings.

INTRODUCTION

The densely populated Egyptian cities have a great shortage of green areas such as gardens, parks, promenades and other green elements. In these cities, besides the increasing of land values, there is hardly available vacant land which could be converted with green elements into green areas. In addition, many of the available public green areas will continue to be used as built up land or roads building land. The urban density is increasing as ground level green space decreases due to development pressure.

During the last few years, many Governorates attempted, when possible, to compensate for the loss of urban green areas by creating new ones. Unfortunately, these new green areas often ended up as arbitrarily scattered patches of vegetation in a sea of concrete and asphalt.

The flat roofs of building in our cities represent many areas of neglected surfaces in urban landscapes. Building rooftops, usually considered forgotten spaces and deserts in biological terms, are valuable opportunities for expanding usable space and increasing the environmental, aesthetic, economic and social values of the build environment. The provision of green cover on these flat roofs offers an opportunity to ameliorate some of the negative impacts of higher density development in the cities. The greening of rooftops of buildings cannot, of course, compensate for the loss of ground green spaces and its subsequent ramifications; however, the planting of these roofs can ultimately play an important part in the improvement of the surrounding environment.

Green roof technology is not new. It has been popular in Europe for more than 25 years (Scholz-Barth, 2001). The planting of green cover on roofs has, beside the recreation value, many positive climatic and aesthetic effects on the building which is situated and its surrounding (Trillitzsch, 1979; Kaiser, 1981; Liesecke, 1985; Kolb and Schwarz, 1986; Kolb and Trunk, 1987; McPherson, 1994; Johnston and Newton, 1997; Beckman et *al.*, 1997 and Scholz-Barth, 2001).

There are two basic types of roof greening or green roof systems: intensive and extensive (Liesecke, 1983 and 1985; Zimmermann, 1987; Liesecke *et al.*, 1989; FLL, 1992; Boivin and Challies, 1998; Peck et *al.*, 1999 and ZinCo, 2000). Intensive green roofs, otherwise known as "roof gardens", have thick layer of growing medium (soil-based) ranging in depth from 50 - 100 cm, and can support the growth of ornamental lawn, shrubs, bushes and trees. Due to the great weight of growing medium, the building must be designed and engineered to accommodate extra load requirements. Unlike extensive green roofs, roof gardens are characterized by their high capital cost, intensive planting and high maintenance requirements. These care arrangements such as irrigation, fertilizing, mowing and weeding are similar to green spaces on the ground.

Extensive roof greening involves thin layer of lightweight growing medium (5 – 20 cm) planted with horizontally spreading and low growing vegetation, which has shallow root systems. Extensive green roofs are characterized by their little or no irrigation and fertilization, minimal maintenance requirements and low capital cost. The vegetation for extensive roof greening includes plants that are able to withstand harsh rooftop conditions such as intense heat and drought, require little care and thrive in shallow growing media. Therefore, succulents and xeromorphic are the most suitable plants for extensive roof greening (Heinze, 1982 and 1985; Müssel and Kiermeier, 1983; Grosse-Wilde, 1987; Kolb and Schwarz, 1987; Kolb and Trunk, 1987; Krupka, 1987; Pahlke, 1989; Gomez and Gomez, 1996 and Boivin, 1997).

Extensive roof greening is a way for creating green cover on existing roofs quickly and much less costly than intensive green roofs. Therefore, it becomes worldwide more and more popular.

While the extensive greening follows mostly on roofs of existing buildings, the load bearing capacity of these roofs must be enough. In order to keep the loading on roofs as low as possible a thin layer of growing medium and lightweight substrate mixtures are increasingly being used. The

Europeans use combinations of synthetic porous mineral substrates like lava, pumice, swelling clay, swelling shale and slag (Krupka, 1986; Liesecke, 1989; FLL, 1992 and ZinCo, 2000). The physical characteristics of these media, such as aeration, water-holding capacity and hydraulic conductivity, must also be addressed.

In Egypt, the planting of extensive green cover on the flat roofs of existing buildings is a suitable method to utilize its many positive effects and create new green areas closed to home with relatively low cost and simple care arrangements on the available and unused open areas on these roofs. The load resulting from the green cover must be exactly calculated before planting. The calculation must also be based on its water saturated state. The roof of building must have enough load bearing capacity.

The used lightweight substrate mixtures from the Europeans for extensive green roofs are too expensive to import, however, so domestic sources must be located.

There are many problems resulting from the bad characteristics of either sandy or clayey soils as a growing media when they are used alone. Many researchers did their best to find a good media for producing both better plant growth and high quality plants. They used many natural and artificial materials like peat, compost, rice hulls, bitumen and hydrogels to improve the water and nutrients holding capacity of sandy soils and also to enhance the drainage and aeration of clayey soils. Also, they found that using mixture (1:1) of clay and sand had a good influence on increasing the plant growth, fresh and dry yield of some ornamental plants (El-Tantawy, 1981; Mohammed, 1992 and Shehata *et al.*, 2002).

The extensive green roof will function if the vegetation is successful, so it is necessary to use native plants or proven adaptive species, because they can withstand climatic extremes on rooftops, are already adapted to our environment and will require less maintenance and care.

The current research aimed to study:

1- The possibility to create and preserve an extensive green cover on a flat roof of existing building under our local climate and conditions
2- The growth and development of two different succulent species growing in two different soil mixtures
3- Certain characteristics concerned the tested soil mixtures
4- The influence of these soil mixtures and watering rates on the growth and development of the tested succulent species.

MATERIALS AND METHODS

The present research was conducted from September 1998 till October 2000 to study the growth and development of two different succulent species planted in two different soil mixtures to create an extensive green cover on flat roofs of buildings. The experiment was carried out as follows:

Location: At Belquas City, Dakahlia Governorate, Egypt. The experiment area was a flat roof of three stories building with 2% gradient.

Studied Plants: - *Delosperma cooperi,* Hook.f., Fam. Aizoaceae
- *Aptenia cordifolia,* L.f., Fam. Aizoaceae

Tested soil mixtures: The basic ingredients of the tested soil mixtures were clay, sand and broken bean straw. The soil mixtures were prepared in weight percentage. The first soil mixture (medium 1) was prepared from clay and sand (1 : 1). The second soil mixture (medium 2) was prepared from medium (1) and broken bean straw (2 : 1).

Preparation the experimental area for planting: The roof area was already painted with a double coat of 3 cm thickness bitumen layer and afterwards covered with a polyethylene sheet (400 micron thickness) to protect the roof surface from the harmful effect of drainaged water and root penetration.

The experiment area was divided into replication areas using a 25 cm height frame. The dimensions of each replication area were 1 x 1 m. Each soil mixture represented 50% of the replication areas and randomly distributed on the roof. The prepared soil mixtures were applied in each replication area with a compacted thickness of 15 cm. Boivin and Challies (1998) and Peck *et al.* (1999) recommended a minimal substrate thickness of 15 cm for extensive roof greening under arid conditions. This enables root systems to better establish themselves and increases the ability of plants to resist adverse weather conditions.

Planting: The tested two species of succulents were prepared a month before planting as a 5 cm rooted cuttings growing in 6 cm diameter pots. On September 1st 1998, the rooted cuttings were planted in the tested soil mixtures at a density of 16 plant /m^2 (25 cm distance between each other).

Each succulent species was replicated six times in each soil mixture. The experimental replications were randomized distributed.

After planting the succulent species, all replication areas were saturated immediately with water only without any fertilizers addition. Along the period of this experiment, no fertilization was carried out according to Fischer *et al.* (1994) and Fischer (1995).

Water application: Extensive green roofs require generally no irrigation, except under prolonged dry conditions. Selecting plants that tolerate arid conditions like succulents, heat and drought resistant, reduces the frequency and amount of water supply.

The irrigation of the tested plant species was followed with two different watering rates, which represented 25 % and 50 % from the lowest field capacity of the tested soil mixtures. Half of replicates was irrigated with 8 liters / m^2 once a week from April to September and every two weeks from October to March. The other half was irrigated with 16 liters / m^2 once a week in the first period and every two weeks in the second one.

Measurements of the experiment:

1. Comparative measurements of the tested soil mixtures:

Certain characteristics of the used soil mixtures along with their influence on the growth and development of the plants were measured.

* **Chemical analysis:** Some chemical analysis of the used soil mixtures; available N, P and K ppm, pH value and electric conductivity (E.C. ds/m), were determined (Table 1 and 2) at the beginning of experiment and every six months according to Jackson (1967).

* **Mechanical analysis:** The mechanical analysis (Table 3 and 4) was carried out, once at the beginning of experiment and another time at the end, to determine the particle size distribution of the tested soil mixtures using the International Pipette Method as described by Piper (1950).
* **Layer thickness:** The loss of the layer thickness of the tested soil mixtures was measured at the end of experiment.

2. Comparative measurements of the tested plants:

The growth and development of the tested succulent species along the experiment was determined by using the following measurements:
* **Ground cover percentage:** The percentage of ground cover of each plant species growing in each soil mixture was estimated monthly from October 1998 till September 2000. The procedure applied in that respect used a wooden grid (1x1 m) internally divided by wires to small squares (10 x 10 cm each). The divided grid was placed on each replicate of the soil mixtures and the covering green area was calculated for each small square. The calculations for all small squares were added to each other to represent the total percentage of green area/replicate (Kaiser, 1981).
* **N, P and K determination:** N, P and K percentage for succulent species grown in each soil mixture was determined at the beginning and at the end of the experiment according to Jackson (1967).
* **Dry matter weight:** Dry matter weight was obtained at both the beginning and the end of the experiment for the two species of succulents. Dry matter was obtained by drying the fresh sample at 70°C in oven till constant weight.
* **Chlorophyll pigments and carotene content:** Chl. a, Chl. b and carotene contents in tested plants were measured at the end of the experiment for each treatment directly after cutting the fresh plant leaf samples using the method described by Moran (1982).

Statistical analysis: The obtained data were statistically analyzed as a factorial (3 factors, 2 levels each) in a complete randomized block design according to Snedecor and Cochran (1967). Means were compared using the New-L.S.D. test at 5% level.

RESULTS AND DISCUSSION

1. Comparative measurements of the tested soil mixtures

1.1. Chemical analysis

Tables (1) and (2) represented some soil chemical analysis which were carried out every 6 months along the experiment duration.

It was noticed that the available (N) in both media was decreased when they were planted with either *Delosperma cooperi* or *Aptenia cordifolia.*

Available (P) decreased also in both media which were planted with *Delosperma cooperi* and *Aptenia cordifolia*. Potassium also took the same trend.

Table (1): Some soil chemical properties for the two types of growing media planted with *Delosperma cooperi.*

Period of analysis	Growing medium	Available N ppm	Available P ppm	Available K ppm	pH	E.C ds/m
Oct. 1998	medium (1)	35	10	200	7.9	2.21
(Before cultivation)	medium (2)	35	10	200	7.9	2.21
April 1999	medium (1)	25	7.3	175	7.9	1.94
	medium (2)	20	9.3	160	7.9	2.03
Oct. 1999	medium (1)	20	7.0	168	7.8	1.72
	medium (2)	15	8.4	130	7.7	1.94
April 2000	medium (1)	10	6.6	150	7.8	1.28
	medium (2)	10	6.4	124	7.7	1.89
Oct. 2000	medium (1)	5	6.3	140	7.7	1.19
	medium (2)	5	5.3	120	7.6	1.85

* Medium 1 : Clay + Sand 1:1
* Medium 2 : Clay + Sand + Bean straw 1:1:1

Table (2): Some soil chemical properties for the two types of growing media planted with *Aptenia cordifolia.*

Period of analysis	Growing medium	Available N ppm	Available P ppm	Available K ppm	pH	E.C ds/m
Oct. 1998	medium (1)	35	10	200	7.9	2.21
(Before cultivation)	medium (2)	35	10	200	7.9	2.21
April 1999	medium (1)	25	6.3	170	7.9	1.81
	medium (2)	25	9.0	160	7.9	1.86
Oct. 1999	medium (1)	20	5.8	165	7.9	1.28
	medium (2)	15	8.0	140	7.8	1.70
April 2000	medium (1)	10	5.5	155	7.8	0.85
	medium (2)	10	6.2	130	7.7	1.63
Oct. 2000	medium (1)	5	5.0	140	7.8	0.47
	medium (2)	5	4.8	120	7.7	1.54

* Medium 1 : Clay + Sand 1:1
* Medium 2 : Clay + Sand + Bean straw 1:1:1

These results may be related to the depletion of these elements by plant uptake and nitrogen volatilization besides there was no fertilization additions to study the influence of media only. The pH and E.C values were decreased along the experiment period in both media planted with either *Delosperma cooperi* or *Aptenia cordifolia*. These variations in both, soil pH and E.C might be attributed to the irrigation water effects in addition to the roots rhizosphere effect. The obtained results by El-Gala *et al.* (1994) were in accordance with these results.

1.2. Mechanical analysis

Tables (3) and (4) showed the particle distribution of the two tested soil mixtures planted with *Delosperma cooperi* and *Aptenia cordifolia* respectively.

It was noticed that, at the end of the experiment, the total sand and silt portions were decreased in medium 1 (clay + sand) when it was planted with either *Delosperma cooperi* or *Aptenia cordifolia*. Otherwise, the clay portion was increased.

In medium 2 (clay + sand + bean straw), it was determined that, at the end of the experiment after two years, the bean straw portion strongly decreased by both succulent species. This is of course the result of the disintegration of this organic substances. The portions of total sand, silt and clay were accordingly highly increased.

Table (3): Soil particle distribution of the two tested growing media planted with *Delosperma cooperi*.

Growing medium	Time of determination	Clay %	Silt %	Total sand %	Bean straw %
Clay : Sand 1 : 1	- before planting	14.8	20	65.2	0
	- at the end of experiment	17.8	18	64.2	0
Clay : Sand: Bean straw 1 : 1 : 1	- before planting	9.9	13.3	43.5	33.3
	- at the end of experiment	13.5*	16.4*	61.1*	9*

*** Consideration of the analyzed bean straw which influenced particle size distribution**

Table (4): Soil particle distribution of the two tested growing media planted with *Aptenia cordifolia*.

Growing medium	Time of determination	Clay %	Silt %	Total sand %	Bean straw %
Clay : Sand 1 : 1	- before planting	14.8	20	65.2	0
	- at the end of experiment	17.8	18	64.2	0
Clay : Sand: Bean straw 1 : 1 : 1	- before planting	9.9	13.3	43.5	33.3
	- at the end of experiment	10.6*	21.6*	57.8*	10*

*** Consideration of the analyzed bean straw which influenced particle size distribution**

1.3. Layer thickness of the tested soil mixtures

A lossening of the originally 15 cm thickness took place over the two years experiment period in both soil mixtures. The (clay + sand) mixture showed a layer thickness of an average 14 cm after two years. While the (clay + sand + bean straw) mixture had marked a smaller layer thickness of 5 cm at the end of the experiment. This could be attributed to as well the disintegration of the organic substances as sludging and sagging this soil mixture.

These results agreed with those of Kolb (1986) and Liesecke (1989). They reported that the substrate will experience losses in volume not only due to natural setting processes, but also through the removal of material during normal maintenance. Substrate mixtures with higher organic content tend to suffer a further reduction in volume through mineralization (the breakdown of the organic compounds).

2. Comparative measurements of the tested plants

2.1. Behavior of the two types of succulent plants on the covering percentage

Data in Table (5) showed that the covering percentage for the two succulent plants varies significantly during the four growing periods. *Aptenia cordifolia* had the highest covering percentage during three periods from Oct. 1998 to March 1999, from April to Sept. 1999 and from April to Oct. 2000 while *Delosperma cooperi* had the highest covering percentage during the period from Oct. 1999 to March 2000. Therefore, it can be concluded that *Aptenia cordifolia* could be recommended for use in green roofs as compared with *Delosperma cooperi* because it had the highest covering percentage during the most of the growing period under the Egyptian circumstances.

2.2. Effect of the two types of growing media on the covering percentage

Table (5) also revealed that the two types of growing media had highly significant differences between them in their effect on the covering percentage of the succulent plants grown on them. The succulent plants grown in the (clay + sand) mixture (1:1) had the highest covering percentage in the four growing periods as compared with those grew in the (clay + sand + bean straw) mixture (1:1:1). These results agreed with El-Gendy *et al.* (1995).

In spite of obtained results, it could be advised to use the second medium (clay + sand + bean straw) for many reasons. First, to decrease the economical cost, second to reduce the loading effect on the building roof i.e. it must be 220 kg from the first medium (clay + sand) for each replicate (1x1 m) but 55 kg are enough from the second medium (clay + sand + bean straw) for each replicate also, third, to the improving effect of the bean straw on the soil physical and chemical properties of the growing medium.

In addition, because the difference in the covering percentage between the first and the second medium in the last growing period was only about (7%) for the first medium (clay + sand) in spite of the highly significant difference between them.

2.3. Effect of the two rates of water application on the covering percentage

Data in Table (5) showed also that the two rates of water application had highly significant differences in their effect on the covering percentage of succulent plants during the growing periods. The water application rate of 8 liters / m^2 resulted in the highest covering percentage during the growing periods from April 1999 to Sept. 2000. On the other hand, the irrigation with 16 liters / m^2 had the highest covering percentage during the first growing period from Oct. 1998 to March 1999 where the succulent plants were planted in this period.

These results indicated that the used succulent species required more water supply (16 liters / m^2) in the first growing period after planting in order to reach a higher covering percentage. Subsequently, they were able to give higher covering percentage with lower irrigation rate (8 liters / m^2). These results agreed with those obtained by Kolb and Trunk (1987), Liesecke *et al.* (1989), Pahlke (1989), Boivin (1997), ZinCo (2000) and Scholz-Barth (2001). They reported that succulent plants used for extensive roof greening have to be periodically watered until they become established, thereafter they require little irrigation. They reported also that the succulent plants have a very high water holding capacity, a developed mechanism to reduce leaf evaporation and low water requirements.

It is of interest to point out that every meter square from the experimental planted medium received (624) liters in the first water treatment (8 liters / m^2), while it received (1248) liters in the second water treatment (16 liters / m^2) during the whole growing period. Accordingly, the water use efficiency in the first water treatment was higher than that of the second one.

Therefore, because of increasing the water use efficiency, economically decreasing the application costs and the highest covering percentage, the low water rate (8 liters / m^2) is preferable to be applied under these conditions. The work of Omar *et al.* (1989) and Hammad *et al.* (1990) coincided these results.

Table (5): Effect of succulent species, soil types and water application on covering percentages of succulent plants.

Treatments	Covering %			
	October 1998 to March 1999	April to September 1999	October 1999 to March 2000	April to September 2000
A: Succulent species:				
Delosperma cooperi	38.77	80.56	97.81	85.15
Aptenia cordifolia	40.72	82.38	96.42	98.19
F-Test	**	**	**	**
B: Soil types:				
Clay + Sand	63.63	98.40	100.00	95.28
Clay + Sand + Bean straw	15.85	64.53	94.24	88.06
F-Test	**	**	**	**
C: Water application:				
8 liters / m^2	37.14	84.72	98.90	93.02
16 liters / m^2	42.35	78.22	94.34	90.32
F-Test	**	**	**	**

** High significant

2.4. The interaction effects among succulent species, medium types and water application rates on the covering percentage

Table (6) and Figs.(1&2) represented the interaction effect of plant species, medium types and water application rates on the covering percentage of succulent plants during the duration from Oct. 1998 to March

1999. It was noticed that *Delosperma cooperi* had the highest covering percentage when planted in the (clay + sand) mixture and irrigated with 16 liters / m^2. *Aptenia cordifolia* showed no significant differences in covering percentage between the two water application rates, when the plants grew in the (clay + sand) mixture.

Table (7) and Figs.(1&2) showed the previous interaction effect during the period from April to Sept. 1999. It was observed that the plants of the two succulent species grown in the (clay + sand) mixture had higher covering percentage than those grown in the (clay + sand + bean straw) mixture. In addition, there were no significant difference in covering percentage between the two water application rates, when the plants were grown in the (clay + sand) mixture. Therefore, the watering rate of 8 liters / m^2 is preferable because of increasing the water use efficiency when compared with 16 liters / m^2.

Data of the interaction effect from Oct. 1999 to March 2000 in Table (8) and Figs.(3&4) indicated that *Delosperma cooperi* had no significant differences in the covering percentage when grown in the (clay + sand) mixture and irrigated with 8 or 16 liters / m^2, and also when planted in the (clay + sand + bean straw) mixture and irrigated with 8 liters / m^2. *Aptenia cordifolia* had the same results. Along with this growing period, both succulent species planted in the (clay + sand) mixture and irrigated with 8 or 16 liters / m^2 had a 100% covering.

Table (9) and Figs.(3&4) showed the results of the interaction effect during the duration from April to Sept. 2000. It was noticed that *Aptenia cordifolia* had the highest covering percentage when it was planted in the (clay + sand) mixture and irrigated with 8 or 16 liters / m^2, where no significant differences were found between them. In addition, a 100 % covering was reached when *Aptenia cordifolia* planted in the (clay + sand + bean straw) mixture and irrigated with 16 liters / m^2.

Delosperma cooperi had the lowest covering percentage when planted in the (clay + sand + bean straw) mixture and irrigated with 16 liters / m^2.

2.5. N, P and K determination

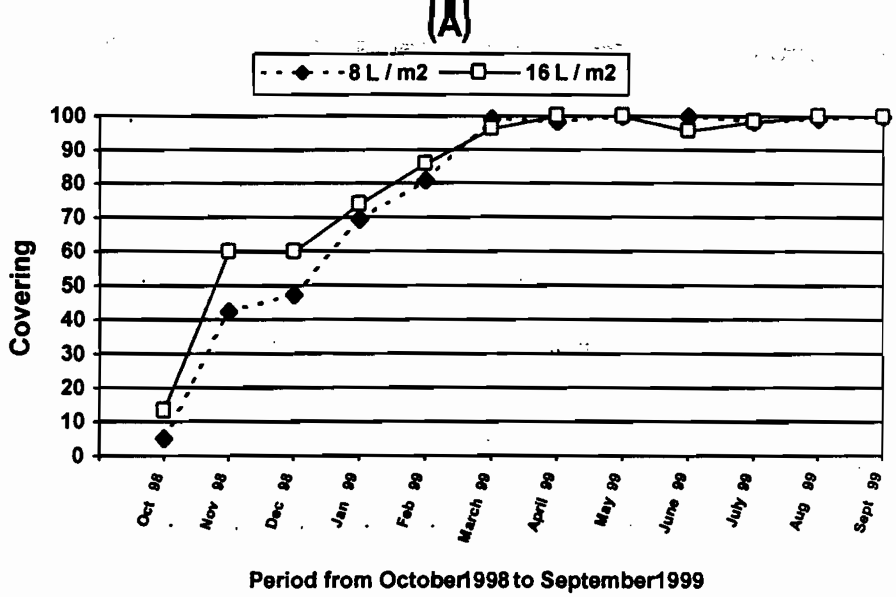
Data in Table (10) showed the percentage of N, P and K in the used plant species before planting in the two types of growing media and at the end of the experiment. It was observed that the N, P and K percentage in the plants growing in the mixture of (clay + sand + bean straw) at the end of the experiment was higher than in those planted in the (clay + sand) mixture. This result may be due to the decomposition of the organic matter (bean straw) which was contained in the growing medium (clay + sand + bean straw) and its effect on the solubility of P and K bearing minerals in addition to the improving effect on the physical and chemical characteristics of the growing media.

Table (6): Covering percentages of succulents as affected by plant species, growing medium and water application from October 1998 to March 1999.

Plant species	Growing medium	Water application	Covering % October 1998	November 1998	December 1998	January 1999	February 1999	March 1999	Mean
Delosperma cooperi	Clay + Sand	8 liters / m²	5.17	42.33	47.33	69.50	80.83	99.17	57.38
		16 liters / m²	13.17	59.83	59.83	73.67	85.83	96.33	64.77
	Clay + Sand + Bean straw	8 liters / m²	5.00	10.33	10.33	17.33	22.00	17.33	13.72
		16 liters / m²	7.17	14.67	14.67	20.67	25.33	32.67	19.19
Aptenia cordifolia	Clay + Sand	8 liters / m²	9.17	67.83	67.83	77.50	81.67	88.00	65.33
		16 liters / m²	14.17	66.33	66.33	76.00	85.67	93.67	67.02
	Clay + Sand + Bean straw	8 liters / m²	7.00	11.67	11.67	13.33	14.50	14.50	12.11
		16 liters / m²	9.83	16.17	16.17	18.83	22.17	27.17	18.39
LSD at 5%			7.71						

Table (7): Covering percentages of succulents as affected by plant species, growing medium and water application from April 1999 to September 1999.

Plant species	Growing medium	Water application	Covering % April 1999	May 1999	June 1999	July 1999	August 1999	September 1999	Mean
Delosperma cooperi	Clay + Sand	8 liters / m²	98.33	100.00	100.00	98.33	99.17	100.00	99.30
		16 liters / m²	100.00	100.00	95.67	98.33	100.00	100.00	99.00
	Clay + Sand + Bean straw	8 liters / m²	19.50	88.17	80.17	54.17	84.17	100.00	71.03
		16 liters / m²	31.50	70.83	60.67	22.00	51.50	80.83	52.88
Aptenia cordifolia	Clay + Sand	8 liters / m²	90.00	98.00	100.00	100.00	99.17	100.00	97.86
		16 liters / m²	95.83	100.00	100.00	96.67	94.17	98.00	97.44
	Clay + Sand + Bean straw	8 liters / m²	24.83	64.33	93.17	67.50	80.50	93.67	70.66
		16 liters / m²	29.67	63.83	83.00	60.83	66.00	78.00	63.55
LSD at 5%			5.25						



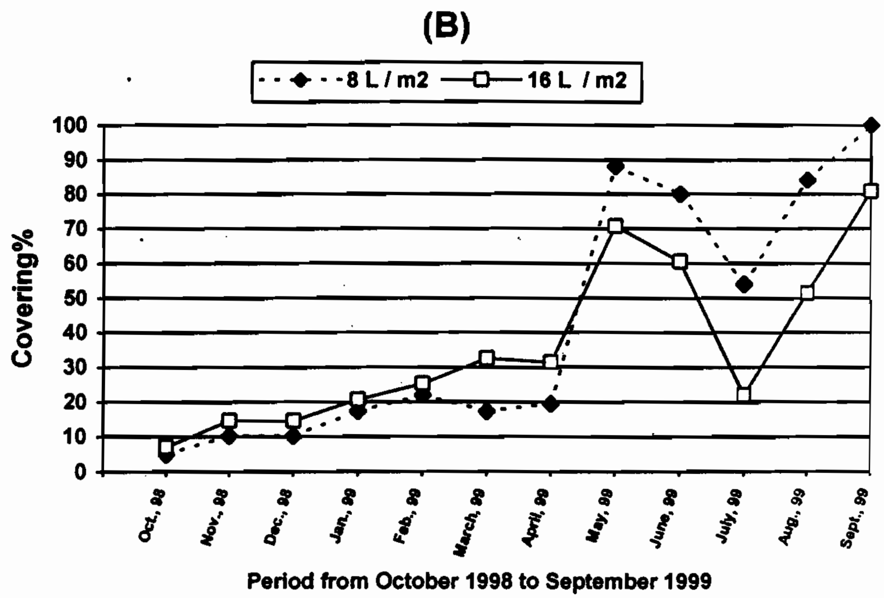


Fig. (1): Covering percentage from October 1998 to September 1999 of *Delosperma coopri* planting in mixture of clay + sand (A) and clay + sand and bean straw (B) at different watering rates.

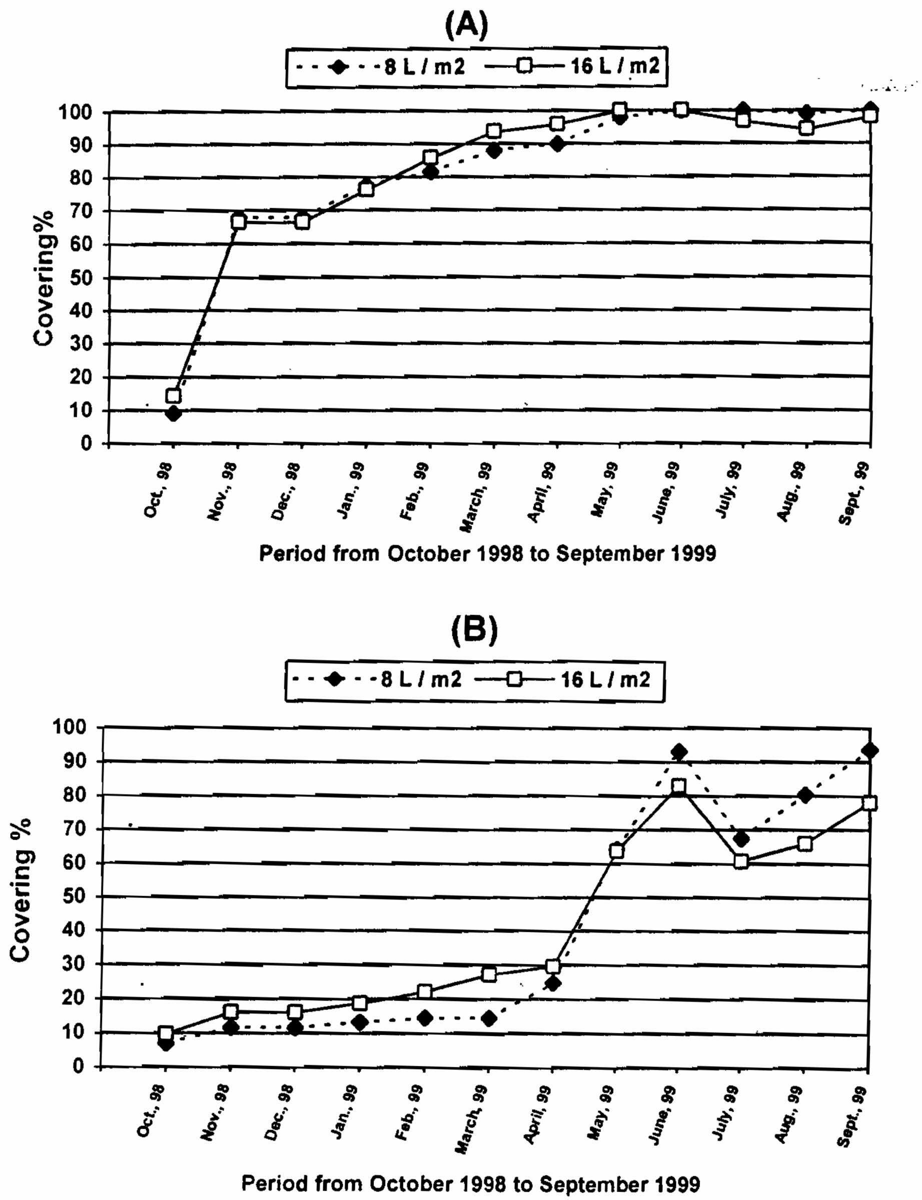


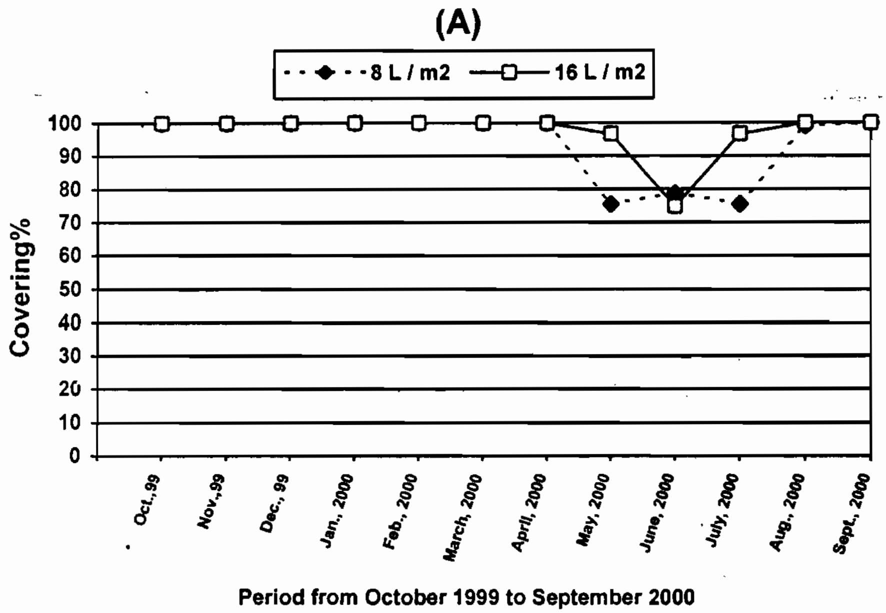
Fig. (2): Covering percentages from October 1998 to September 1999 of *Aptenia cordifolia* planting in mixture of clay + sand (A) and clay + sand and bean straw (B) at different watering rates.

Table (8): Covering percentages of succulents as affected by plant species, growing medium and [redacted]ater application from October 1999 to March 2000.

Plant species	Growing medium	Water application	Covering %						
			October 1999	November 1999	December 1999	January 2000	February 2000	March 2000	[redacted]ean
Delosperma cooperi	Clay + Sand	8 liters / m^2	100.00	100.00	100.00	100.00	100.00	100.00	1 [redacted]00.00
		16 liters / m^2	100.00	100.00	100.00	100.00	100.00	100.00	1 [redacted]00.00
	Clay + Sand + Bean straw	8 liters / m^2	100.00	100.00	100.00	100.00	99.17	100.00	[redacted]9.85
		16 liters / m^2	83.33	86.67	89.17	89.17	100.00	100.00	[redacted]1.39
Aptenia cordifolia	Clay + Sand	8 liters / m^2	100.00	100.00	100.00	100.00	100.00	100.00	1 00.00
		16 liters / m^2	100.00	100.00	100.00	100.00	100.00	100.00	1 00.00
	Clay + Sand + Bean straw	8 liters / m^2	98.33	100.00	100.00	100.00	100.00	100.00	[redacted]9.72
		16 liters / m^2	85.83	75.00	77.17	82.50	95.67	99.67	[redacted]5.97
LSD at 5%			2.60						

Table (9): Covering percentages of succulents as affected by plant species, growing medium and [redacted]ater application from April 2000 to September 2000.

Plant species	Growing medium	Water application	Covering %						
			April 2000	May 2000	June 2000	July 2000	August 2000	September 2000	[redacted]ean
Delosperma cooperi	Clay + Sand	8 liters / m^2	100.00	75.50	78.67	75.50	99.17	100.00	[redacted]8.14
		16 liters / m^2	100.00	96.67	74.83	96.67	100.00	100.00	[redacted]4.69
	Clay + Sand + Bean straw	8 liters / m^2	100.00	100.00	67.33	100.00	80.83	95.00	[redacted]0.52
		16 liters / m^2	89.17	63.50	53.17	63.50	59.00	75.00	[redacted]7.22
Aptenia cordifolia	Clay + Sand	8 liters / m^2	100.00	100.00	100.00	100.00	95.33	98.33	[redacted]8.94
		16 liters / m^2	100.00	100.00	100.00	100.00	96.17	100.00	[redacted]9.36
	Clay + Sand + Bean straw	8 liters / m^2	100.00	97.83	100.00	97.83	71.17	100.00	[redacted]4.47
		16 liters / m^2	100.00	100.00	100.00	100.00	100.00	100.00	1 [redacted]00.00
LSD at 5%			2.60						



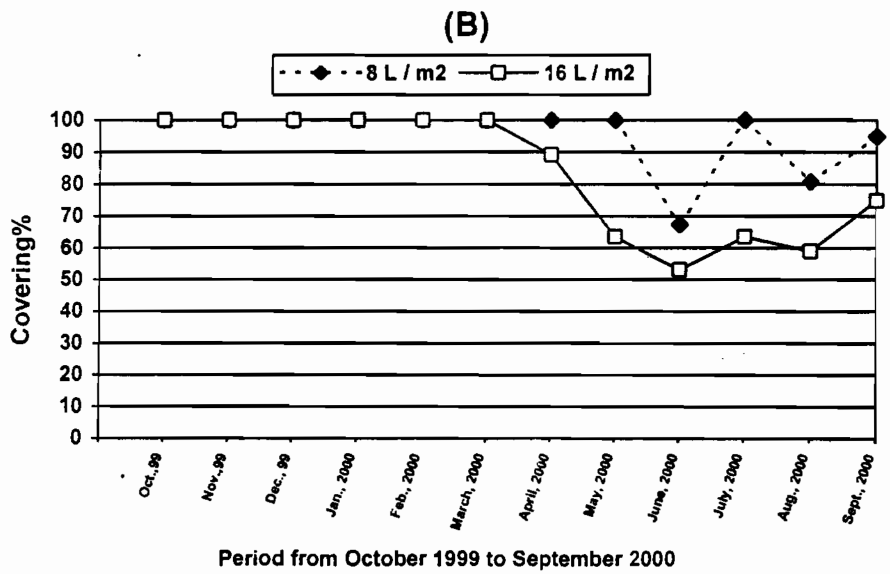


Fig. (3): Covering percentage from October 1999 to September 2000 of *Delosperma coopri* planting in mixture of clay + sand (A) and clay + sand and bean straw (B) at different watering rates.

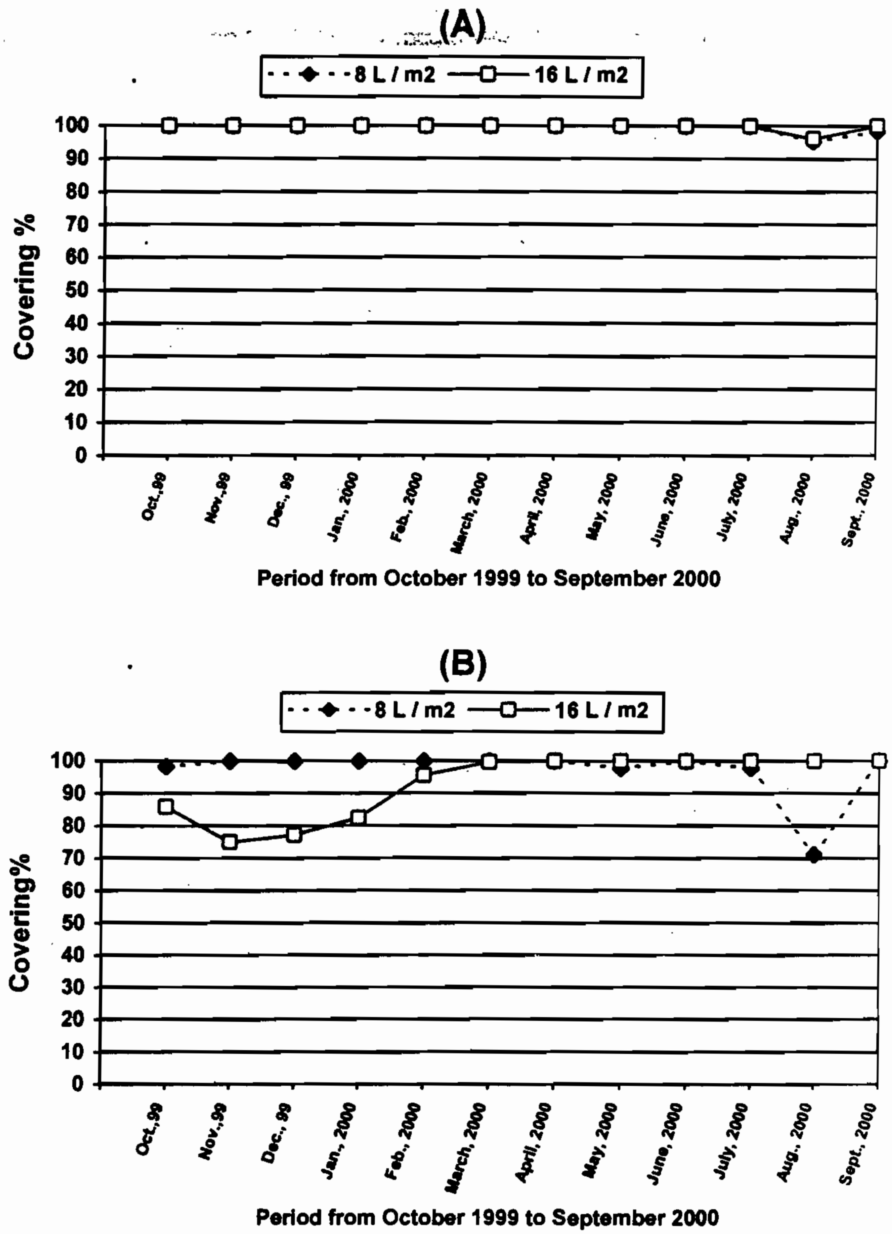


Fig. (4): Covering percentage from October 1999 to September 2000 of *Aptenia cordifolia* planting in mixture of clay + sand (A) and clay + sand and bean straw (B) at different watering rates.

Table (10): N, P and K % in the tested plants before planting and at the end of the experiment in both media.

Time of determination	*Delosperma cooperi*			*Aptenia cordifolia*		
	N	P	K	N	P	K
Before planting	1.4	0.11	0.81	1.5	0.17	0.79
At the end of the experiment in clay + sand	0.9	0.10	0.76	1.2	0.15	0.93
At the end of the experiment in clay + sand + bean straw	1.3	0.13	0.85	1.4	0.18	0.96

2.6. Dry matter

Table (11) represented the dry matter percentage in *Delosperma cooperi* and *Aptenia cordifolia* before planting and at the end of the experiment in both media. It indicated that the dry matter percentage increased at the end of the experiment in the growing medium (clay + sand + bean straw) as compared with that planted in the growing medium (clay + sand) for the two plants. This could be related to the improving effect of the organic matter (bean straw) contained in the growing medium (clay + sand + bean straw) on the soil physical and chemical properties. These results were in agreement with those of El-Kommos and Noor El-Din (1990).

Table (11): Dry matter % of the tested plants before planting and at the end of the experiment in both media.

Time of determination	*Delosperma cooperi*	*Aptenia cordifolia*
Before planting	8.59	7.53
At the end of the experiment in clay + sand	10.08	7.61
At the end of the experiment in clay + sand + bean straw	11.00	7.92

2.7. Chlorophyll a, b and carotene contents in the plant species planted in both growing media after 24 months

Data in Table (12) revealed that chlorophyll a, b and carotene content (mg/g fresh matter) for both succulent species planted in the growing medium (clay + sand + bean straw) were higher than those planted in the growing medium (clay + sand). This increase may be due to the decay of organic matter and mineralization of organic nitrogen which involved in the construction of plant chlorophyll and consequently reflected on plants growth.

Herein, it should be reported that the N percentages in the plants growing in the medium (clay + sand + bean straw) at the end of the experiment, represented in Table (10), were higher than those of plants growing in the medium (clay + sand). This could explain the reason of chlorophyll increase noticed in plants growing in medium (clay + sand + bean straw). Since, it is a well known fact that N deficiency limits chlorophyll formation and leaves color.

Concerning carotene contents, an increase was obvious reaching more than one and half in *Aptenia cordifolia* growing in the medium (clay + sand + bean straw) when compared with the medium ((clay + sand), 0.011 and 0.018 mg/g fresh matter respectively. While, this observation was not clear in *Delosperma cooperi*. The role of carotenes is so important. Since, carotenes protect chlorophyll against photooxidation mentioned by Sistrom *et al.* (1956) and transfer energy to it as noted by Zscheile *et al.* (1942).

Table (12): Contents of Chlorophyll a, b and carotene in plants growing in both media after 24 months (mg/g fresh matter).

Growing medium	*Delosperma cooperi*			*Aptenia cordifolia*		
	Chl. a	Chl. b	Car.	Chl. a	Chl. b	Car.
clay + sand	0.077	0.032	0.024	0.027	0.103	0.011
clay + sand + bean straw	0.081	0.071	0.025	0.039	0.114	0.018

CONCLUSIONS

It is a known fact, that the densely populated cities in Egypt have a high shortage of green areas. The high land values and hardly available vacant land in or around the densely populated cities hinder the creation of new ground green areas.

The flat roofs of existing buildings are largely wasted spaces and represent numerous ecologically unused open areas.

The greening of rooftops has many advantages for the building owner, the environment and the community. It can help to reduce the pollution hazards, ameliorate meso- and microclimate, improve the aesthetic values, protect the roof membrane and improve building insulation.

Extensive roof greening is a suitable method to create new green areas, closed to home, on existing flat roofs of buildings under Egyptian climate and conditions. This Type of greening represent worldwide the most readily implemented of green roof construction because of its low weight, low maintenance and consequently lower cost.

According to the results of the current research, it was proved that, with minimal care arrangements, the establishing and preserving of extensive green cover on roofs of buildings is realizable under our local climatic conditions and circumstances. It is relatively simple to create this type of green roofs. An isolation layer to protect the roof surface from water and root penetration, a shallow layer of growing media and suitable plant species that grow rapidly and resist against heat and drought such as succulents, were sufficient to create an extensive green roofs. Maintenance should also be considered. Extensive green roofs require as little upkeep as possible. More water application was necessary in the establishment stage.

This type of green roofs can be incorporated into a range of new and existing buildings as long as enough load bearing capacity of roofs is available, in order to avoid any damage of the roof surface due to the additional load reserves and to warrant the security of buildings.

This research pointed out that the tested succulent species could be planted on roofs of buildings. They were able to reach a 100% covering within the first year of the experiment. During this period the covering percentages of the tested plants growing in the (clay + sand) mixture were higher than those of the plants growing in the (clay + sand + straw bean) mixture. In the second year of the experiment, however, there were no great differences between the two growing media in their effect on covering percentage of both succulent species. Therefore, on a long term, the mixture (clay + sand + bean straw) could be more preferable because of its lower weight.

After the establishment stage, the irrigation rate of 8 liters / m^2 weekly from April to September and one time every 2 weeks from October to March was sufficient for the tested plant species growing in both media to give higher covering percentages, when compared with the water application rate of 16 liters / m^2.

Aptenia cordifolia could be more preferable for establishing an extensive green cover under local climate and conditions in Egypt.

In this connection, it should be mentioned that the current research was the beginning to study the possibility to create an extensive roof greening under Egyptian conditions. Further studies in this subject are needed to be carried out, in order to find out the best construction methods to install this type of green roofs, the most convenient plant species, the most suitable layer thickness of the growing medium, the ideal composition of lightweight substrate mixtures as well as the effective methods of care arrangements such as irrigation and fertilization of the cultivated plants.

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إنشاء غطاء أخضر قليل التكاليف والجهد على أسطح المبانى بإستخدام نوعين من النباتات العصارية النامية فى نوعين مختلفين من مخاليط التربة ومعدلات الرى

[illegible]

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أجرى هذا البحث فى مدينة بلقاس – محافظة الدقهلية خلال الفترة من سبتمبر ١٩٩٨ وحتى أكتوبر ٢٠٠٠ حيث استخدم نوعان مختلفان من النباتات العصارية لزراعتهما فى نوعين مختلفين من مخاليط التربة وريهما بمعدلين مياه مختلفين. النباتات العصارية المختبرة هى ديلوسبيرما *Delosperma cooperi* و أبتينا *Aptenia cordifolia* . القوام الأساسى للتربة المختبرة كان طمى ورمل وتبن الفول المقطع. ولقد استخدم لرى هذه النباتات معدلان من المياه هما ٨ و ١٦ لتر / م٢ . المكان التى أجريت عليه التجربة كان سطح مستوى ذو ميل خفيف مقداره ٢ % لمبنى مكون من ثلاثة أدوار.

كان الهدف من هذا البحث هو دراسة إمكانية زراعة هذه النباتات العصارية على أسطح المبانى تحت الظروف الجوية المصرية وبالإمكانيات المتاحة بغرض إنشاء غطاء أخضر قليل التكاليف والجهد والإستفادة من فوائده البيئية والجمالية.

هذا ولقد أجريت عدة قياسات لتحديد خواص مخاليط التربة المستخدمة وكذلك لتتبع نمو وتطور النباتات المنزرعة.

ولقد أوضحت النتائج المتحصل عليها أن نوعى النباتات العصارية المستخدمة قد وصلت إلى نسبة تغطية مقدارها ١٠٠ % وذلك خلال السنة الأولى من البحث. وكانت نسبة التغطية على مدار التجربة للنبات أبتينا *Aptenia cordifolia* أعلى عند مقارنتها بتلك للنبات ديلوسبيرما *Delosperma cooperi* . خليط التربة المكون من طمى ورمل وتبن الفول كان أكثر ملائمة من الخليط المكون من طمى ورمل وذلك بالنسبة لنمو وتطور النباتات المنزرعة. نتيجة لعدم التسميد فلقد أنخفض محتوى مخلوطى التربة المستخدمة من النتروجين والفوسفور والبوتاسيوم على مدار التجربة. أما بالنسبة للرى فلقد أعطت النباتات المنزرعة نسبة أفضل للتغطية عندما رويت بمعدل ٨ لتر / م٢ (مرة أسبوعيا من أبريل إلى سبتمبر ومرة كل أسبوعين من أكتوبر إلى مارس) وذلك عند المقارنة بمعدل الرى ١٦ لتر / م٢ خلال نفس الفترات.

تبعا لنتائج هذا البحث فإنه من الممكن، بالإمكانيات المتاحة و تحت الظروف الجوية المصرية، إنشاء غطاء أخضر والمحافظة عليه على الأسطح المتاحة وغير المستخدمة للمبانى القائمة وذلك بتكاليف قليلة نسبيا و أبسط وسائل العناية.