



## Original article

Performance evaluation of *Chrysopogon zizanioides* under urban conditions of KuwaitMajda Khalil Suleiman<sup>a,\*</sup>, Narayana Ramachandra Bhat<sup>a</sup>, Sheena Jacob<sup>a</sup>, Meali Al-Burais<sup>b</sup><sup>a</sup> Desert Agriculture and Ecosystems Program, Environment and Life Science Center, Kuwait Institute for Scientific Research, P.O. Box 24885 Safat, 13109, Kuwait<sup>b</sup> Techno Economics Division, Kuwait Institute for Scientific Research, P.O. Box 24885 Safat, 13109, Kuwait

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## ABSTRACT

Plant physiological and morphological attributes should be critically evaluated for selecting any species for landscaping projects. The selection of a species should be based on the evaluation of its adaptability, noninvasiveness, growth potential, and performance under the prevailing local arid conditions for their aesthetic looks, soil stabilization, and afforestation values. *Chrysopogon zizanioides* (Vetiver), is suitable for Kuwait because it can withstand fluctuating temperatures ranging from  $-14$  to  $55$  °C with unique physical and physiological characteristics. Despite the successful growth performance of Vetiver in landscaping projects mostly in several tropical countries, it has not been utilized and evaluated in the Arabian Gulf region. The objective of the current study was to evaluate the performance of selected ten cultivars of Vetiver (ODV-1, 8, 9, 13, 17, 21, 23, Silent Valley, Urlikal, and Pannimedu) in the deficient soil and environmental conditions of Kuwait in urban landscape at minimal maintenance. It is suggested that based on visual greenery effect and overall growth performance cultivars, Pannimedu, Silent Valley, ODV-13, ODV-8 and ODV-9 can be considered for landscaping projects in Kuwait. To obtain the superior crown volume (which considers height and canopy) cultivar Pannimedu is suggested and to get a bushy growth (considering the number of tillers) cultivar ODV-13 and ODV-8 is found to be suitable.

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## 1. Introduction

Kuwait is an arid country with extremely hot summers with frequent sandstorms, cold winters, low rainfall, sparse vegetation, and highly eroded saline top soil which is deficient in nutrient and organic matter content (Shahid et al., 2003; KISR, 1999). Extreme climatic conditions and water availability are the limiting factors that affect plant growth and development in Kuwait. Drought and salt tolerant plants with minimal nutrient requirement are best suited for use in landscaping and gardening projects in arid countries like Kuwait. As the existing ornamental plant list is inadequate to meet the rising demands of the ever increasing landscape projects, it is necessary to include more native/exotic plants for

diversified greenery plans. However, continuous and determined research is essential while introducing exotic plants in various greenery and desert rehabilitation activities. Selection of plants to be included/ introduced in the landscape projects to ensure diversification should be based on the evaluation for their adaptability, non-invasiveness, growth performance, and potential under the prevailing local arid conditions for their aesthetic looks, soil stabilization, and afforestation values. Testing the performance of the selected plants under the prevailing environmental conditions is also necessary to understand the scope and extent of utilization in large projects.

*Chrysopogon zizanioides* L. Roberty, commonly known as Vetiver was introduced to Kuwait as part of a project conducted by Kuwait Institute for Scientific Research (KISR), and was planted at the Urban Demonstration Garden of KISR in September 2005 (Suleiman and Bhat, 2011). Vetiver is a xerophytic and hydrophytic grass that has several exceptional qualities such as tolerance of hot weather conditions, slope stabilization and rehabilitation, soil and water conservation, reclamation of degraded lands, coastal dune stabilization, erosion control, ecological rehabilitation, tolerance of heavy metals, and growth in polluted soils (Wang, 1991; Laing and Ruppenthal, 1991; Bharad and Bathkal, 1990; Materne and

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Schexnayder, 1992; Yoon, 1993; Truong et al., 1991; Limtong, 2010; Grimshaw, 2006a; Tansamrit, 2008; Roongtanakiat and Chairaj, 2001; Sanguankao et al., 2010; Johne et al., 2008; Chomchalow, 2011; Suleiman et al., 2013). The ability of Vetiver to increase soil moisture content, moisture, and nutrient retention, and to reduce soil run off (Grimshaw, 2006a; Juliard, 2006; Truong, 2006) may also prove beneficial especially in the drought conditions of semi-arid regions. Efficiency of Vetiver in removing the heavy metals and other harmful substance from urban landfills and water bodies is an important benefit to Kuwait, where pollution due to oil spillage during war and industrial wastewater are unresolved issues (Xia et al., 2002; Percy and Truong, 2003; Shu, 2003, Liao et al., 2003; Datta et al., 2013; Materechera, 2010; Truong, 2006).

Some of the cultivars of this plant, particularly those that are imported from south India are late or low flowering, sterile or unable to produce seeds (Lavania, 2000; Gupta and Pareek, 1995). The cultivars from south India are sterile and not stoloniferous. The plant is reproduced vegetatively, but do not invade adjacent area as Bermuda grass and couch grass (Grimshaw, 2006b). Thus, concerns over the aggressive growth and invasiveness of this plant and its subsequent negative impacts on the local landscape may not be substantiated (Dafforn, 2000). These attributes make Vetiver a high potential plant to grow under the prevailing environmental conditions of Kuwait. Initial studies on adaptability of Vetiver in Kuwait were conducted by Kurup et al. (2008) focusing on five cultivars from India. Objective of the present study is to evaluate the performance of ten selected Vetiver cultivars in the deficient soil and environmental conditions of Kuwait in an urban setting with minimal tending practices.

## 2. Materials and methods

### 2.1. Study site and experimental design

An area of 500 m<sup>2</sup> was selected at KISR's Urban Demonstration Garden (UDG) in Salmiya, Kuwait, considering availability of direct sunlight and proximity to irrigation. The top soil was loosened after clearing the debris. Drip system was used for irrigation. Ten sterile Vetiver cultivars (ODV-1, ODV-8, ODV-9, ODV-13, ODV-17, ODV-21, ODV-23, Silent Valley, Urlikal, and Pannimedu) were procured from international sources and planted on January 30, 2011. A randomized complete block design with five replications of 10 cultivars and three slips per cultivar per replication was used to ascertain the plant's response to the micro-climate in the urban conditions, including their potential for use in greenery enhancement projects. Control plot were not planted with Vetiver. Planting holes of 30 cm width and 30 cm depth were prepared at 1 m × 1 m spacing. The backfill soil mixture was prepared using peat moss, perlite, and sand (1:1:1v/v). A surface mulch of organic material was applied to a depth of 5 cm at the time of planting. The plants were allowed to harden and establish for two months. The physical and chemical properties of soil mix used for refilling of planting holes were analyzed prior to planting. The data on plant height, canopy, basal width and number of tillers were recorded at 0 (March 2011), 150 (August 2011), 300 (January 2012) and 480 days (July 2012) after establishment. The first recorded data at the end of the establishment period were considered as the initial data.

### 2.2. Data collection and analysis

Physical and chemical properties of soil, water, and planting medium were analyzed at Soil Chemistry Laboratory and Central Analytical Laboratory of KISR as per procedures prescribed by USDA (1996) and APHA (2005) (Table 1). Composite soil samples

**Table 1**

Reference methods used for soil and water analysis.

Sl. No.	109537538100Test description analysis/preparation	Reference method
1	pH	8C1b (USDA, 1996) pg.411
2	Electrical conductivity	8A3a (USDA, 1996) pg.407
3	Calcium	6N1a (USDA, 1996) pg. 638
4	Magnesium	6O1a (USDA, 1996) pg.645
5	Sodium	6P1a (USDA, 1996) pg.650
6	Potassium	6Q1a (USDA, 1996) pg.652
7	Carbonate and bicarbonate	6I I (USDA, 1996) pg.283
8	Chloride	4500-Cl-D (APHA, 2005)
9	Nitrate	ISO 7890-1-1986 (instrument manual)
10	Sulphate	EPA 375.4 (instrument manual)
11	Bulk density	4A3a (USDA, 1996)
12	Porosity	USDA Hand book No.60.6:40
13	Saturation percentage	USDA Hand book No.60.6: 27a

were collected before the initiation of the experiment and at the end of the trials. To analyze the organic matter content, the composite soil samples were collected at 30, 60 and 90 depth from the Vetiver planted area and at 30 cm depth in the controls area. The parameters analyzed for soil and planting medium were bulk density, porosity, saturation percentage pH, electrical conductivity (EC), calcium (Ca), potassium (K), magnesium (Mg), sodium (Na), chloride (Cl), sulphate (SO<sub>4</sub>), nitrate (NO<sub>3</sub>), carbonate (CO<sub>3</sub>), and bicarbonates (HCO<sub>3</sub>). Organic carbon was determined by the Walkley and Black (1934) and expressed in percentage. Organic matter was determined by multiplying the organic carbon value with 1.7 and is expressed as a percentage. Percentage increase in organic matter content at the end of the experimental period was calculated using the following formula.

Percentage increase in organic matter

$$= \frac{\text{Final value} - \text{Initial value}}{\text{Initial value}} * 100$$

Soil was dried overnight at 105 °C, and the moisture content was determined at dry weight basis and expressed in percentage. The parameters analyzed in water samples were pH, EC, total dissolved salts (TDS), Ca<sup>2+</sup>, K<sup>-</sup>, Mg<sup>2+</sup>, Na<sup>2+</sup>, boron (B), SO<sub>4</sub><sup>-</sup>, CO<sub>3</sub><sup>-</sup>, HCO<sub>3</sub><sup>-</sup>, NO<sub>3</sub><sup>-</sup>, and Cl<sup>-</sup>. Data on plant height, canopy, basal width and number of tillers were recorded at 0, 150, 300 and 480 days after planting (DAP). Crown volume was calculated from the recorded plant height and canopy using the following formula (Thalen, 1979):

$$\text{Crown Volume} = \frac{1}{6} \pi \times D1 \times D2 \times h$$

where D1 is the horizontal diameter of the crown, D2 is the vertical diameter of the crown, h is the height of the plant, and  $\pi$  equals 3.14. Relative growth (Suleiman et al., 2013) in plant height, canopy, and number of tillers was calculated as follows:

$$\text{Relative Growth (\%)} = \frac{\text{Final value} - \text{Initial value}}{\text{Initial value}} * 100$$

Visual greenery effect ratings for the selected cultivars (Frank et al., 2013) were recorded in terms of Grades 1 to 3 (with 3 being the highest). Data on temperature, relative humidity, and rainfall were recorded from the Weather Station at Salmiya.

The collected data were analyzed using one-way analysis of variance (ANOVA) and Duncan's Multiple Range test to ascertain the significant differences among cultivars (Little and Hills, 1978). The relative growth in the various plant growth parameters

was analyzed after the base-10 log transformation of the data (McDonald, 2009).

### 3. Results

#### 3.1. Soil and water analysis

Analysis results indicated that planting medium was neutral and weakly saline. The soil remained slightly alkaline and moderately saline throughout the experimental period. Ca, K, and Mg content in the soil remained low (Tables 2 and 3). The irrigation water used for this trial was saline with high TDS, Ca, K, and Mg levels (Table 4). The planting medium was neutral and weakly saline (Tables 5 and 6). The results also indicated that the average organic matter content at various depths in the planted and at the control site increased at the end of the experimental period. At 30 cm depth, the organic matter content of the soil near the Vetiver increased by 53% when compared to 30% in the control area. The percentage of increase at various depths (30 cm, 60 cm and 90 cm) were higher than the increase in control area. Average organic matter content at 30 cm was higher than that of the control site at 30 cm depth at the end of the experimental period (Table 7).

#### 3.2. Weather analysis

Data on air temperature and rain recorded at the Urban Demonstration Garden site in Salmiya are detailed in Table 8. Temperature during winter (December–February) dropped to 3 °C and summer (June–October) was extremely harsh with temperature reaching 50 °C. Total rainfall received during 2011 was 69 mm well below the average rainfall of 113 mm (Omar et al., 2007).

#### 3.3. Growth parameters

The average relative growth in height, canopy, crown volume and number of tillers are presented in Tables 9–12 respectively. At 480 DAP, taller cultivars were Pannimedu, Silent Valley, ODV-23, and ODV-9. Additionally, the highest average relative growth in height was observed in cvs. Silent Valley, Pannimedu, ODV-23, and ODV-8. Average plant canopy of various cultivars also varied significantly ( $p \leq 0.01$ ), and the highest average plant canopies were recorded in cvs. Pannimedu, followed by Silent Valley, ODV-9, Urlikal and ODV-8. The overall performance of cultivars in relative growth in canopy was more or less similar in all cultivars with the highest value recorded in ODV-17 (625.03%). Though there was no substantial variations in crown volume of various cultivars at 150 DAP, significant variation was observed at 300 and 480 Dap among the cultivars. Cv Pannimedu topped the list followed by Silent Valley, ODV-13, ODV-9 and ODV-8. However, rel-

**Table 2**  
Chemical properties of the soil at the urban demonstration garden in Salmiya.

Parameter	Initial	Mid	Final
pH	7.60	7.70	7.5
EC (mS/cm)	7.93	7.2	6.97
Ca <sup>2+</sup> (mg/kg)	212.67	216.25	210.5
K <sup>-</sup> (mg/kg)	11.79	10.50	10.5
Mg <sup>2+</sup> (mg/kg)	52.62	62.50	52.5
Na <sup>2+</sup> (mg/kg)	175.45	155.00	135.5
SO <sub>4</sub> <sup>2-</sup> (mg/kg)	436.33	432.00	430.25
Cl <sup>-</sup> (mg/kg)	306.09	302.00	304.25
HCO <sub>3</sub> <sup>-</sup> (mg/kg)	21.23	35.56	33.16
CO <sub>3</sub> <sup>-</sup> (mg/kg)	<1.00	<1.00	<1.00
NO <sub>3</sub> <sup>-</sup> (mg/kg)	83.79	73.32	72.08

**Table 3**  
Physical properties of the soil at the urban demonstration garden site in Salmiya.

Parameter	Initial	Mid	Final
Sand (%)	87.60	82.60	80.60
Silt (%)	4.00	11.00	9.40
Clay (%)	8.40	6.40	10.00
Texture	Sand	Sand	Loamy sand
Bulk density (g/cm <sup>3</sup> )	1.57	1.51	1.49
Porosity (%)	41.85	41.70	40.87
Saturation (%)	18.33	25.00	22.22

**Table 4**  
Chemical analysis results of irrigation water from the urban demonstration garden in Salmiya.

Parameter	Initial	Mid	Final
pH	7.50	7.70	7.40
EC (mS/cm)	4.79	4.81	3.71
TDS (mg/l)	2480.00	2510.00	1900.00
Ca <sup>2+</sup> (mg/L)	501.00	445.00	394.70
K <sup>-</sup> (mg/L)	18.61	19.50	22.50
Mg <sup>2+</sup> (mg/L)	128.00	136.00	108.40
Na <sup>2+</sup> (mg/L)	493.00	555.00	346.30
B (mg/L)	1.35	1.00	1.20
SO <sub>4</sub> <sup>2-</sup> (mg/L)	1132.00	992.00	1016.00
HCO <sub>3</sub> <sup>-</sup> (mg/L)	105.21	84.96	94.90
CO <sub>3</sub> <sup>-</sup> (mg/L)	<0.10	<0.10	<0.10
NO <sub>3</sub> <sup>-</sup> (mg/L)	62.91	76.64	60.30
Cl <sup>-</sup> (mg/L)	840.00	920.00	951.00

**Table 5**  
Chemical properties of the planting medium at the urban demonstration garden in Salmiya.

Parameters	Values
pH	7.20
EC (mS/cm)	3.58
Ca <sup>2+</sup> (mg/kg)	127.20
K <sup>-</sup> (mg/kg)	100.80
Mg <sup>2+</sup> (mg/kg)	38.96
Na <sup>2+</sup> (mg/kg)	135.20
SO <sub>4</sub> <sup>2-</sup> (mg/kg)	261.20
Cl <sup>-</sup> (mg/kg)	262.00
HCO <sub>3</sub> <sup>-</sup> (mg/kg)	71.44
CO <sub>3</sub> <sup>-</sup> (mg/kg)	<1.00
NO <sub>3</sub> <sup>-</sup> (mg/kg)	80.45

**Table 6**  
Physical properties of the planting medium at the urban demonstration garden in Salmiya.

Parameters	Values
Bulk density (g/cm <sup>3</sup> )	1.57
Porosity (%)	39.85
Saturation (%)	40.00

ative growth rate in crown volume was higher in ODV-17, ODV-23 and ODV-8.

Wide variation in basal width of cultivars was noticed only at 300 DAP, and cv. Urlikal attained highest basal width (Data not shown). Cultivars ODV-13 and ODV-8 produced the highest average number of tillers at 300 and 480 DAP. However, there was no significant variation in the relative growth for these parameters among the various cultivars. Although cv. ODV-13 exhibited consistent dominance in number of tillers, cv. ODV-8 recorded highest average relative growth in tillers. Irrespective of cultivars, there was no considerable increase in basal width and tillers after 300 DAP.

**Table 7**  
Soil organic matter content at various depths at the performance trial site.

Depth (cm)	Average organic matter content (%)			Percentage increase in organic matter
	Initial	Mid	Final	
Planted area at 30 cm	1.42 ± 0.2	2.15 ± 0.5	2.18 ± 0.5	53.52
Planted area at 60 cm	0.76 ± 0.1	1.26 ± 0.3	1.41 ± 0.3	85.53
Planted area at 90 cm	1.03 ± 0.1	1.48 ± 0.4	1.41 ± 0.2	36.89
Control area at 30 cm	1.13 ± 0.1	1.24 ± 0.06	1.47 ± 0.1	30.09

**Table 8**  
Weather data recorded at urban development garden in Salmiya.

Month	Air temperature (°C)			Total rain (mm)
	Maximum	Minimum	Average	
Jan-11	26.66 ± 0.3	6.88 ± 0.5	14.77 ± 0.5	15
Feb-11	30.05 ± 0.4	2.37 ± 0.4	15.50 ± 0.4	2
Mar-11	35.97 ± 0.6	9.75 ± 0.5	20.31 ± 0.4	29
Apr-11	31.04 ± 0.8	28.91 ± 1.0	26.65 ± 1.0	22
May-11	35.91 ± 0.7	33.58 ± 0.7	32.89 ± 0.7	1
Jun-11	43.84 ± 1.1	31.39 ± 0.8	35.39 ± 1.0	0
Jul-11	47.14 ± 0.4	32.88 ± 0.4	37.34 ± 0.4	0
Aug-11	46.30 ± 0.3	31.39 ± 0.3	37.46 ± 0.3	0
Sep-11	41.72 ± 0.4	27.9 ± 0.4	34.54 ± 0.4	0
Oct-11	30.34 ± 0.9	23.81 ± 1.0	26.86 ± 0.9	0
Nov-11	23.21 ± 0.6	15.74 ± 0.7	19.46 ± 0.6	0
Dec-11	19.18 ± 0.2	9.91 ± 0.4	14.13 ± 0.3	0
Jan-12	18.2 ± 0.4	9.69 ± 0.6	13.63 ± 0.5	19.4
Feb-12	19.69 ± 0.4	11.51 ± 0.5	15.33 ± 0.3	31
Mar-12	22.74 ± 1.0	14.14 ± 0.6	18.09 ± 0.5	0
Apr-12	32.97 ± 0.6	20.82 ± 0.51	26.29 ± 0.5	13.2
May-12	39.09 ± 0.5	27.65 ± 0.24	33.04 ± 0.3	1.2
Jun-12	44.19 ± 0.5	31.53 ± 0.34	37.64 ± 0.3	0
Jul-12	46.00 ± 0.15	33.03 ± 0.36	39.25 ± 0.3	0
Aug-12	45.31 ± 0.4	32.22 ± 0.34	38.44 ± 0.3	0
Sep-12	42.10 ± 0.4	28.56 ± 0.41	34.82 ± 0.3	0

**Table 9**  
Comparison of the average plant height of vetiver cultivars at the urban demonstration garden in Salmiya.

Cultivar	Average height (cm)				Average relative growth in height (%)
	Initial	150 DAP	300 DAP	480 DAP	
ODV-1	46.80 ± 2.1 abc	95.00 ± 3.7 b	109.67 ± 5.21 a	119.73 ± 4.00a	156.03 ± 10.4 abc
ODV-8	42.87 ± 2.4 ab	105.00 ± 4.8bc	134.07 ± 7.07b	129.73 ± 6.18 ab	196.97 ± 24.1 cde
ODV-9	53.67 ± 3.0 cd	102.47 ± 4.1 bc	152.87 ± 8.33 b	149.27 ± 7.95 cd	171.79 ± 19.4 bcd
ODV-13	54.80 ± 2.4 d	103.33 ± 4.8 bc	139.86 ± 7.09 b	131.20 ± 5.79 abc	135.11 ± 19.5 ab
ODV-17	41.80 ± 2.9 ab	80.40 ± 4.1a	110.13 ± 4.70 a	115.60 ± 5.42 a	171.59 ± 32.2 bcd
ODV-21	53.73 ± 2.5 cd	93.33 ± 4.8 b	112.13 ± 7.31 a	120.00 ± 5.93 a	114.05 ± 18.2 a
ODV-23	43.60 ± 2.3 ab	102.67 ± 5.7 bc	144.13 ± 8.03 b	146.60 ± 6.92 bcd	235.99 ± 10.1 de
Silent Valley	39.67 ± 1.5 a	103.33 ± 2.6 bc	146.27 ± 6.88b	144.87 ± 5.42 bcd	262.48 ± 16.9 e
Urlikal	48.07 ± 3.1bcd	92.50 ± 4.5 ab	109.78 ± 5.22a	120.71 ± 5.63a	150.28 ± 24.1abc
Pannimedu	48.13 ± 1.9 bcd	112.87 ± 3.9 d	154.27 ± 6.50b	158.00 ± 5.87 d	227.46 ± 12.7 de
Significance	**	**	**	**	**

DAP: Days after planting.

The means followed by the same letter are not statistically different at  $p \leq 0.01$ .

The data were analyzed using SPSS analysis of variance (ANOVA) procedure and Duncan's Multiple Range test.

\*\* Significant at  $P \leq 0.01$  level.

The phenological condition, pest, and disease occurrence in the plants were monitored throughout the growth period. Flowering was observed from 240 DAP, and 100% of the ODV-8 plants flowered. ODV-1 recorded the lowest flowering percentage (47%) followed by Urlikal (60%) and ODV-21 (67%) (Table 13). No incidence of pest or disease was noticed (Fig. 1).

### 3.4. Visual greenery effect

The cultivars were scored for visual greenery effects with scores ranging from 1 to 3 (with 3 being the maximum positive greenery effects). The results presented in Table 14 showed significant dif-

ferences between the average grades of the cultivars throughout the experimental period. Drying of leaves was observed during the winter months in all of the cultivars (after 300 DAP). Overall, cv. Pannimedu produced the most visual greenery effects. This was equally followed by cvs. Silent Valley, ODV-23, and ODV-9 except at 480 DAP.

### 4. Discussion

Although many studies were conducted worldwide about the performance of Vetiver grass in response to fertilizers, its performance under non-fertilized conditions has yet to be explored

**Table 10**

Comparison of the average plant canopy of vetiver cultivars at the urban demonstration garden in Salamiya.

Cultivar	Average canopy (cm)				Average relative growth in canopy (%)
	Initial	150 DAP	300 DAP	480 DAP	
ODV-1	13.87 ± 0.63 bc	53.33	74.53 ± 2.63abc	87.60 ± 3.46 cd	533.09 ± 24.6abc
ODV-8	12.67 ± 0.82 abc	59.00	76.93 ± 2.99 cd	86.40 ± 3.27 bcd	592.65 ± 71.5c
ODV-9	12.13 ± 0.60 ab	55.00	75.07 ± 2.48 abc	87.40 ± 4.13 cd	619.87 ± 46.4 c
ODV-13	17.20 ± 0.10.7e	58.47	77.73 ± 2.29 cd	85.33 ± 2.63 bcd	416.01 ± 50.6a
ODV-17	10.60 ± 0.37 a	49.60	66.40 ± 2.45a	77.27 ± 3.23ab	625.03 ± 44.2 c
ODV-21	14.13 ± 0.67 bc	54.93	67.13 ± 2.73ab	74.87 ± 2.14a	434.11 ± 30.9ab
ODV-23	13.73 ± 1.11bc	54.13	75.67 ± 2.33bc	80.87 ± 2.78abc	505.94 ± 50.3abc
Silent Valley	13.87 ± 1.16bc	52.40	76.80 ± 3.35 cd	88.80 ± 2.31 cd	558.86 ± 61.4 bc
Urlikal	13.21 ± 0.99 abc	52.86	71.00 ± 3.35abc	87.00 ± 2.89 cd	575.57 ± 69.4c
Pannimedu	15.40 ± 1.06 de	53.27	84.73 ± 3.82 d	93.13 ± 3.94 d	513.93 ± 28.0 abc
Significance	**	NS	**	**	*

DAP: Days after planting.

The means followed by the same letter are not statistically different at  $p \leq 0.01$ .

The data were analyzed using SPSS analysis of variance (ANOVA) procedure and Duncan's Multiple Range test.

NS – Not Significant.

\*\* Significant at  $P \leq 0.01$  level.\* Significant at  $P \leq 0.05$  level.**Table 11**

Comparison of the average crown volume of vetiver cultivars at the urban demonstration garden in Salamiya.

Cultivar	Average crown volume (m <sup>3</sup> )				Average relative growth in crown volume (%)
	Initial	150 DAP	300 DAP	480 DAP	
ODV-1	0.003 ± 0.0005 ab	0.153 ± 0.02 a	0.311 ± 0.03 abc	0.487 ± 0.07 ab	15431.21 ± 0.04 bc
ODV-8	0.003 ± 0.0004 ab	0.190 ± 0.02 a	0.410 ± 0.05 bcd	0.473 ± 0.04 ab	20040.11 ± 0.07 c
ODV-9	0.003 ± 0.0004 ab	0.167 ± 0.02 a	0.442 ± 0.05 de	0.553 ± 0.05 b	19462.56 ± 0.07 c
ODV-13	0.006 ± 0.0008 c	0.192 ± 0.02 a	0.437 ± 0.04 cde	0.485 ± 0.05 ab	9285.39 ± 0.07 a
ODV-17	0.002 ± 0.0003 a	0.113 ± 0.01 a	0.265 ± 0.03a	0.382 ± 0.04 a	21404.25 ± 0.08 c
ODV-21	0.004 ± 0.0004 ab	0.154 ± 0.02 a	0.269 ± 0.03a	0.368 ± 0.03 a	10967.31 ± 0.05 ab
ODV-23	0.003 ± 0.0005 ab	0.163 ± 0.02 a	0.405 ± 0.04 bcd	0.505 ± 0.05 ab	21164.11 ± 0.08 c
Silent Valley	0.004 ± 0.0006 ab	0.149 ± 0.01 a	0.448 ± 0.05 de	0.566 ± 0.04 b	19467.04 ± 0.07 c
Urlikal	0.003 ± 0.0005 ab	0.145 ± 0.02 a	0.303 ± 0.04 ab	0.476 ± 0.04 ab	16289.21 ± 0.08 bc
Pannimedu	0.004 ± 0.0006 bc	0.174 ± 0.02 a	0.561 ± 0.06 e	0.728 ± 0.08 c	19116.13 ± 0.05 c

DAP: Days after planting. The means followed by the same letter are not statistically different at  $p \leq 0.001$ .**Table 12**

Comparison of the average number of tillers of selected cultivars at the urban demonstration garden in Salamiya.

Cultivar	Average number of tillers				Average relative growth in number of tillers (%)
	Initial	150 DAP	300 DAP	480 DAP	
ODV-1	3.4 ± 0.2 a	130.5 ± 13 ab	144.5 ± 14 ab	141.1 ± 13 a	3864.6 ± 395 ab
ODV-8	4.5 ± 0.4 ab	188.8 ± 18 cd	202.3 ± 20 cd	193.8 ± 18 bc	4144.8 ± 755 b
ODV-9	4.3 ± 0.3 ab	153.9 ± 17 abc	169.2 ± 18 bc	158.7 ± 16 ab	3379.1 ± 502 ab
ODV-13	7.1 ± 0.8 c	213.8 ± 19 d	225.6 ± 20 d	207.1 ± 19 c	2806.3 ± 234 a
ODV-17	4.3 ± 0.4 ab	125.6 ± 12 ab	140.6 ± 13 ab	136.0 ± 12 a	3019.3 ± 413 a
ODV-21	5.9 ± 0.6 bc	149.6 ± 12 abc	161.7 ± 13 abc	158.7 ± 15 ab	2609.2 ± 410 a
ODV-23	5.5 ± 0.7 b	162.6 ± 20 bc	175.4 ± 20 bc	167.7 ± 18 abc	2964.2 ± 459 a
Silent Valley	5.3 ± 0.5 b	160.3 ± 11 bc	166.9 ± 15 abc	161.2 ± 15 ab	2837.9 ± 445 a
Urlikal	4.8 ± 0.4 ab	117.0 ± 13 ab	116.1 ± 17 a	125.4 ± 13 a	2472.9 ± 461a
Pannimedu	5.2 ± 0.6 b	108.0 ± 6 a	135.2 ± 10 ab	129.1 ± 9 a	2510.2 ± 264 a

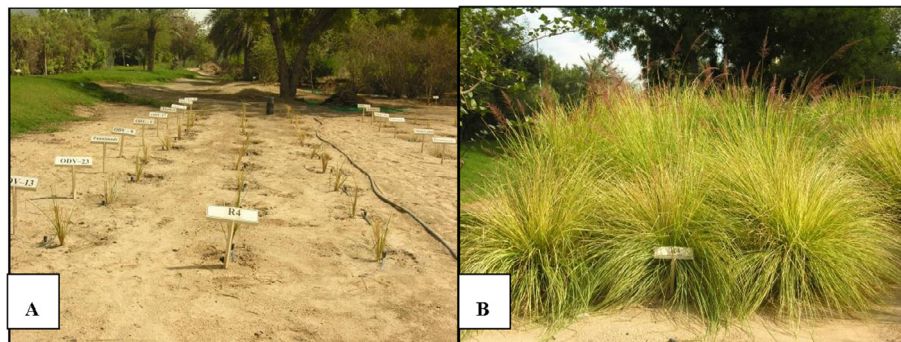
DAP: Days after planting. The means followed by the same letter are not statistically different at  $p \leq 0.01$ .

especially in the Middle East conditions. Xu and Zhang (1999) described that Vetiver can grow in various soils classified under entisols, inceptisols, alfisols, ustisols and oxisols. Soil Survey of Kuwait (KISR, 1999) indicated that Kuwait soils are calcareous in nature and classified into eight soil groups: petrogypsid, petrocalcids, aquisalids, torripsamments, haplocalcids, haplogypsid, and torriorhents which are under aridisols and entisols. The soil of Kuwait is moderate to very shallow in depth and the texture ranges from sand to loamy sand with low mineral holding capacity. While Kuwait's virgin soil is non-saline, its irrigation water quality is brackish, saline with dissolved salt concentration ranging from 3000 to 8000 ppm (Suleiman and Grina, 2003). Kuwait's soil is

known as being highly erodible; therefore, erosion control is crucial. This study proved excellent growth and performance of various Vetiver cultivars in the study area which had slightly alkaline and moderately saline soil without any additional provision of nutrients. Shengluan et al. (1994) reported that Vetiver can survive in soils with minimal organic matter content. In the study site, all the planted cultivars not only survived but also increased the organic matter content in soil when compared to control site. Exceptionally good fibrous root system of Vetiver can penetrate even the hardpans and crusted soil layers (Grimshaw, 2006a). It also plays a vital role in enhancing the soil nutrient availability and organic matter (Materechera, 2010). The

**Table 13**  
Flowering in various cultivars in the performance study.

Cultivar	Flowering (%)				
	240 DAP	300 DAP	360 DAP	420 DAP	480 DAP
ODV-1	20.0	26.7	33.3	46.7	46.7
ODV-8	100.0	100.0	100.0	100.0	100.0
ODV-9	66.7	86.7	86.7	86.7	86.7
ODV-13	86.7	86.7	86.7	86.7	86.7
ODV-17	0.0	26.7	40.0	80.0	80.0
ODV-21	40.0	66.7	66.7	66.7	66.7
ODV-23	86.7	86.7	60.0	93.3	93.3
Silent Valley	80.0	86.7	86.7	86.7	86.7
Urlikal	0.0	26.7	60.0	60.0	60.0
Pannimedu	40.0	86.7	86.7	86.7	86.7

**Fig. 1.** Vetiver plants during January, 2011 (A) and November, 2011 (B).**Table 14**  
Mean score of grades for visual greenery effect of various cultivars under evaluation at the urban demonstration garden in Salmiya.

Cultivar	Average Grade			
	Initial	150 DAP	300 DAP	480 DAP
ODV-1	2.38 ± 0.08 ab	2.53 ± 0.08 a	2.38 ± 0.13 ab	2.17 ± 0.06 ab
ODV-8	2.90 ± 0.05 e	2.77 ± 0.07 bc	2.22 ± 0.18 ab	2.00 ± 0.14 a
ODV-9	2.50 ± 0.09 abc	2.88 ± 0.05 cd	2.60 ± 0.15 bc	2.00 ± 0.10 a
ODV-13	2.67 ± 0.06 cd	2.83 ± 0.05 cd	2.37 ± 0.12 ab	2.13 ± 0.10 ab
ODV-17	2.70 ± 0.08 cde	2.62 ± 0.10 ab	2.35 ± 0.11 ab	1.95 ± 0.07 a
ODV-21	2.33 ± 0.11 a	2.50 ± 0.10 a	2.00 ± 0.19 a	2.2 ± 0.07 ab
ODV-23	2.78 ± 0.06 de	2.90 ± 0.05 cd	2.55 ± 0.15 bc	2.06 ± 0.10 ab
Silent Valley	2.76 ± 0.07 de	2.90 ± 0.05 cd	2.52 ± 0.18 bc	1.93 ± 0.10 a
Urlikal	2.56 ± 0.07 bcd	2.50 ± 0.20 a	1.97 ± 0.21 a	2.05 ± 0.09 ab
Pannimedu	2.90 ± 0.05 e	3.00 ± 0.03 d	2.90 ± 0.11 c	2.31 ± 0.12 c

DAP: Days after planting.

The means followed by the same letter are not statistically different at  $p \leq 0.01$ .

combined effect of Vetiver roots on soil binding property, nutrient availability, and reduction in soil runoff can be of great importance in the degraded arid ecosystem like Kuwait (Truong and Loch, 2004, Suleiman et al., 2013). However, future research should focus on the extent of increase and influence of other factors on the soil organic matter content in the long run. Weather data indicated the ability of Vetiver cultivars to adapt to temperatures ranging from 2 °C to 50 °C and relative humidity from 21% to 60% (Data not shown). In Australia, it exhibited unaffected growth even at -11 °C and survived in Georgia (USA) when the soil temperature reduced to -10 °C (Xu and Zhang, 1999). In Kuwait, all the cultivars survived temperatures ranging from 15.34 °C to 35.03 °C. Vetiver exhibited good growth under high temperatures indicating their suitability to arid conditions especially Kuwait which is supported by Kurup et al. (2008). Vetiver exhibited rapid growth in crown volume, basal width, and number of tillers during the first five months (150 DAP) which was complemented by temperature range 26 to 36 °C.

During this rapid growth phase (April–August, 2011) cv. Pannimedu recorded the maximum daily increase in height of 0.43 cm even when the average monthly temperature in May–August 2011 was higher than 33 °C. Previous studies conducted at China indicated rapid growth of Vetiver at 20–30 °C (Xu and Zhang, 1999). It is reported that Vetiver is superior in performance when compared to Bermuda grass (*Cynodon dactylon*), Rhodes (*Chloris guyana*) and saltwater couch (*Paspalum vaginatum*) under degraded and highly saline conditions (Taylor et al., 1989; Truong, 1996). The performance of all cultivars tested in the study was promising. Among the tested cultivars, though cv. Pannimedu and Silent Valley attained higher crown volume, it should be noted that these cultivars are tall growing when compared to ODV cultivars which in turn contribute to their increase in crown volume. Cultivar Pannimedu is a tall growing type, and ODV-8 and ODV-23 produced more tillers. The relative growth in the recorded growth parameters was lesser than the first five months i.e., March–August, 2011 (Fig. 2).

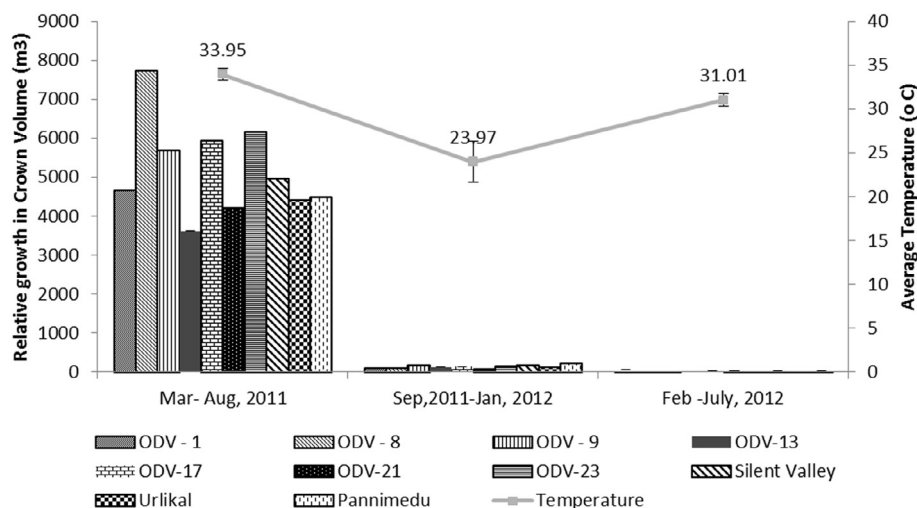


Fig. 2. Relative growth of Vetiver crown volume from March 2011 to July 2012.

Flowering initiated at 240 DAP in most of the cultivars except Urlikal and ODV-17. Although flowering in ODV-17 started late, 80% of the plants flowered at the end of 480 DAP. After the initiation of flowering, the relative growth of all the growth parameters decreased. At 300 DAP, the drying up and lodging of leaves was noticed. From the field experience, it is suggested that if pruned at 90 day intervals, new tillers would have been produced for efficient use in landscape purposes.

During the preliminary studies conducted at Kuwait (Kurup et al. 2008), when supplemental fertilizers (Nitrogen 10–20 ppm, Avicumis @5t/ha, phosphorous, and potash @22.5 t/ha) were used, the maximum number of tillers per clump was reported to be 300–400 after 8–9 months. However, in this study, in which no additional fertilizer was applied, 225 tillers were recorded in ODV-13 after 300 DAP. Height of Vetiver in the poor soils with white sand with little nutrients in Jiangxi province was around 1 m (Xu and Zhang, 1999). Although the height and biomass of Vetiver depend on the fertility of the soil (Xu and Zhang, 1999), the performance of various Vetiver cultivars in the poor soils of Kuwait without additional nutrients was commendable. Previous studies in Guangdong province indicated that pruning at 30 cm height when the plant reaches 150 cm produced 18.6 more tillers in 40 days when compared to control (Xia, 1995). Hence, it is suggested to prune the Vetiver plants while being used in landscape projects for better results. Although basal width is another important parameter of growth measurement, there was no significant variation in basal width among the cultivars at the end of the experimental period. Based on the scores for visual greenery effect and performance in terms of crown volume which took into consideration the plant height and canopy, Pannimedu, Silent Valley, ODV-13, ODV-8, and ODV-9 were found to be the preferred Vetiver cultivars for landscaping in Kuwait.

## 5. Conclusion

The current study evaluated the overall performance of Vetiver in an urban landscape project for landscape purpose. In conclusion, it is suggested that based on visual greenery effect and overall growth performance, cultivars, Pannimedu, Silent Valley, ODV-13, ODV-8 and ODV-9 can be considered for landscaping projects in Kuwait. To obtain the superior crown volume (which considers height and canopy) cultivar, Pannimedu is suggested, whereas for bushy growth (considering the number of tillers) cultivar ODV-13 and ODV-8 were found better. Pruning at 3 month intervals is

recommended to enhance growth. The scope of the current study was limited only to evaluate growth performance of 10 Vetiver cultivars. However, the mechanisms that could explain growth were not explored (role of nutrients, plant nutrient status, water use efficiency, etc.), and future studies should focus on these areas prior to large scale plantation efforts.

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