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Growth and aloin production of *Aloe vera* and *Aloe eru* under different ecological conditions

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ABSTRACT

Aloe vera and *Aloe eru* plants were grown in big pots (25 Kg soil) under different ecological conditions, i.e. direct sunlight and diffused light with different irrigation treatments (weekly, two weekly and three weekly intervals), saline water and green manure addition were also investigated. Two types of soil were used; loamy sand and sandy loam and repeated measurements were obtained in the different seasons. Higher growth was obtained for plants grown under shade irrigated weekly with fresh water and fertilized with *Acacia saligna*. High aloin production was obtained under shade and water stressed plants grown in loamy sand soil. Irrigation with brackish water also gave high aloin production.

KEYWORDS: *Aloe vera*, *Aloe eru*, aloin, anthraquinone glycosides.

INTRODUCTION

The present study aims to review suitable ecological conditions for the cultivation of two varieties of *Aloe* under semi-natural conditions to obtain the highest biomass and content of medicinal products which are used in many pharmaceutical industries. Recent research concluded that *Aloe* emodin appears to have some protective effects not only against hepatocyte death, but also on the inflammatory response subsequent to lipid peroxidation (Arosio *et al.* 2000). We focused here on the effect of different irrigation levels, direct sunlight and diffuse light. Manassah *et al* (1981), Mc Daniel (1985) and Nobel *et al.* (1991), reported that *Agave sisalana* leaves, sprouts and fresh and dry weights increased with short irrigation intervals. Mustafa (1995) and Yepez *et al.* (1993) emphasized that a high biomass of *Aloe vera* was obtained with short irrigation intervals (8 days). Schaik *et al.* (1997) studied the effects of irrigation and N on the vegetative growth of *Aloe barbadensis* in Aruba, they found that drought reduced vegetative reproduction by suckers. Diaz & Gonzalez (1986) noticed that *Aloe vera* grown under natural trees shadow and in poor soil increased the accumulation of biomass compared with plants grown under direct sunlight. Rafael & Hector (1990) studied shade tolerance of *Xanthosoma sagittifolium*, they found that plants grown in shade had greater foliage dry weight ratios, biomass and chlorophyll.

Pasternak *et al.* (1986), Fuentes *et al.* (1988) and Fuentes & Rodriguez (1988) reported that the height of leaves and sprouts of different *Aloe* spp. were reduced with increasing salinity, while carbohydrates and glycosides were increased. The same results were obtained by Kock (1980), Upchurch (1981) and Nobel & Berry (1985) on *Agave spp.*

Mustafa (1995) suggested that in *Aloe vera*, 0.1% salinity result in an increase in growth parameters while 0.4% salinity reduces growth parameters. Additionally Mustafa (1995) demonstrated that the highest amounts of compound carbohydrates were obtained with 0.4% salinity while the highest amount of crude aloin and barbaloin were obtained with 0.2% salinity. Sacks *et al.* (1995) emphasized that *Aloe vera* suffered winter injuries, reported as a colour change of the epidermis, drying out of the upper parts of the leaves and loss of 5% gel production.

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Smith & Carreia (1990) stated that carbohydrate content and anthraquinone glycosides increased in water stressed *Aloe* plants. Mustafa (1995), Yaron (1992) and Tawfik (1984) demonstrated that short intervals of irrigation of *Aloe* increased chlorophyll content but reduced amino acid content.

MATERIALS AND METHODS

Aloe vera L. and *Aloe eru* Berger were selected for the present study.
Soil analysis: The mechanical analysis of the soil was done using sieve mechanism. pH, EC and organic matter were determined according to Jackson (1960).
Growth criteria: The criteria adopted were measured seasonally and included number of leaves, leaf length and number of sprouts. The biomass of the plants (2 years old) was determined at the end of the experiment as accumulation of fresh weight (Kg/plant) and as dry weight (g/plant). Three replicates were used.
Plant analysis: Chlorophyll content was determined according to Vernon & Seely (1966). Total carbohydrate content was investigated by Dubois *et al.* (1956). Crude aloin, aloin and combined anthraquinones were determined according to Mahran *et al.* (1958), Fairbairn & Simic (1963) and Yamamoto *et al.* (1985). Total free amino acids were determined according to Selim *et al* (1978) Free proline was determined according to Bates *et al.* (1973).
Mineral composition N, P, K, Mg, Ca and Na contents in leaves were determined according to A.O.A.C. (1975).

RESULTS AND DISCUSSION

Characteristics of the two types of soil used are as follows: Loamy sand soil (78.8% sand, 8.0% silt and 13.2% clay) with pH 8.4. Organic matter was 0.67% and E.C. 0.36. Sandy loam soil (62.7% sand 19.2% silt and 18.1% clay) with pH 8.7. Organic matter was 0.81% and E.C. 0.42.
Growth parameters: Number of leaves/plant are represented in Figs 1,2. It is obvious that the number of leaves/ plant of *Aloe vera* was higher than that of *Aloe eru*. Significant increases are detected in plants grown in diffused sunlight over plants grown under direct sunlight. The results also indicated that plants fertilized by *Acacia saligna* leaves and irrigated weekly recorded the highest growth. Plants irrigated every 3 weeks showed significant decrease in growth.
Leaf length (Figs. 3,4) showed a similar trend as number of leaves/plant, as does the number of sprouts (suckers)/plant (Figs. 5,6).
Biomass: The biomass for the two *Aloe* species are represented in Figs. 7,8. Biomass of *Aloe vera* was higher than that of *Aloe eru*. Significant increases in biomass are noticed for plants grown under shade than plants grown under direct sunlight. Plants treated with *Acacia saligna* gave the highest records. Water stressed plants recorded significant decreases in biomass as compared to controls. Salt stressed plants produced higher biomass than the water stressed plants.
Total carbohydrate content (Figs 9 and10): Total carbohydrate content (g/100 g dry wt.) is greater in *Aloe vera* than in *Aloe eru*. Significant increases in total carbohydrate content were detected for plants grown under direct sunlight, but not in over plants grown under diffused sunlight. Maximum carbohydrate contents were recorded in April due to high plant metabolic activity. The highest records of total carbohydrates, of the two *Aloe* species, were taken in plants irrigated weekly with brackish water followed by plants irrigated every 3 weeks, while plants irrigated weekly with fresh water recorded the lowest values.
Leaf crude aloin (Figs. 11a): Crude aloin content (g/100 g fresh wt.) is higher in *Aloe vera* than in *Aloe eru*. Significant increases in crude aloin are noticed for plants grown under diffused sunlight compared to plants grown under direct sunlight with high irradiance. Plants irrigated every 3 weeks exhibited the maximum recorded percentage of crude aloin, followed by salinized

plants. Plants irrigated every 2 weeks with fresh water gave similar amounts of crude aloin as plants treated with green manure. Minimum values of crude aloin were obtained from plants irrigated weekly with fresh water.

Leaf aloin content (Figs. 11b): Leaf aloin content (mg/g dry wt.) measurements were parallel to those for crude aloin except in the case of plants irrigated with brackish water which gave higher values for best aloin content than the other treatments.

Total anthraquinone (mg emodin/g dry wt.): The data presented in Fig. 12 indicated that emodin content in *Aloe eru* is higher than in *Aloe vera*. Significant increases in emodin were noticed in plants grown under diffused sunlight but not in those grown in direct sunlight. Plants treated with *Acacia saligna* gave the highest amount of emodin followed by plants irrigated every 3 weeks, then plants irrigated with brackish water. *Aloe* glycosides are favoured by *Aloe vera* under diffused sunlight irrigated with brackish water and loamy sand soil.

Free amino acids and proline content (mg/g dry wt.): Figs 13a and b indicate that *Aloe vera* revealed slightly lower free amino acid content in all treatments than *Aloe eru.* Free amino acid content is lower in plants grown under diffused sunlight than in those grown under direct sunlight. The highest record of free amino acid content was obtained for salinized plants in *Aloe vera*, followed by water stressed plants. However, *Aloe eru* presented the maximum value of amino acid content in water-stressed plants irrigated with fresh water every 3 weeks.

Proline content (mg/g dry wt.) showed remarkable variation under different treatments. Proline content exhibited appreciably lower values in plants grown under diffused sunlight than in those grown under direct sunlight. Proline content was much greater in plants irrigated every 3 weeks with fresh water followed by those irrigated with brackish water every week. This indicates that water or salt stresses significantly raise proline content.

*** In all figures:**
1= Irrigated weekly with fresh water
2= Irrigated every 2 weeks with fresh water
3= Irrigated every 3 weeks with fresh water
4= Irrigated with saline water 1g NaCl + 1g Ca Cl_2 + 1g $MgCl_2$ /L weekly.
5= Irrigated with fresh water + 250g/pot *Acacia saligna* leaves weekly.

Chlorophyll content (Tables 1 & 2): *Aloe eru* recorded higher contents of chlorophyll than *Aloe vera*. Chlorophyll a+b are noticeably higher in plants treated with green manure. Plants under diffused light had greatest chlorophyll content than plants grown under direct sunlight. The highest records of chlorophyll content were taken in April (spring) and the lowest content was taken in January (winter). This difference is attributed to the high metabolic activities performed in spring and autumn rather than in the cooler winter and warmer summer seasons.
Chlorophyll a/b ratio showed lower values, less than 3, a condition that characterises CAM plants.

Mineral composition (Tables 3a & b): Mineral contents (g/100 g dry wt.) of *Aloe vera* were slightly lower than those for *Aloe eru.* Increasing water supply produced higher mineral contents of plants.

The results provide information about the two *Aloe* species studied, with regard to different growth criteria and aloin content, and the affects of different environmental conditions. Previous studies aimed to enlighten the growers about the effects of brackish water irrigation and drought stress in the desert soil. Particular interest has been taken to contrast the growth of *Aloe* plants under direct sunlight and under shade of *Acacia saligna* trees for dual benefit of shade and organic matter added to the soil from fallen litter of leaves.

Generally, plant grown under shade produced higher biomass and higher aloin content than plants grown under direct sunlight in all treatment cases adopted. These are in accordance with Lee-Jinjae *et al.* (1996), Grindlay & Reynolds (1986) and Diaz & Gonzalez (1986), they reported that, cultivation of *Aloe vera* under a natural tree shadow increased the accumulation of biomass. Also Fuentes *et al.* (1988) stated that the two *Aloe* species gave the best crop in salty grounds with little precipitation, this information are in line with the present findings. Chlorophyll content is higher under diffuse light than under direct sunlight. A similar observation has been reported by Naidu *et al.* (1999).
Aloe vera exhibited higher total carbohydrates than *Aloe eru*, maximum content were recorded in April due to higher plant metabolic activity. Water and salt stressed plants recorded higher carbohydrates content than control. Results of Yaron (1992) and Smith & Carreia (1990) on *Aloe vera* are on line of the present observations. Water and salt stressed plants recorded higher yield of anthraquinone glycosides, Yaron (1992) and Mustafa (1995).

The present study reveals that water stressed plants produced high content of glycosides but, however, their vegetative growth is low. The final yield of aloin related to fresh weight is therefore low. Increased amino acids and proline content in water or salt stressed plants pointed out by many investigators who emphasized the adaptive rule of proline to water and salt stresses, Lee-Jinjae *et al.* (1996) and Tawfik (1984). The present findings in respect with mineral content are agree with Yaron (1992).

Source	df	F-value	Prob
Factor A	1	298.5	0.000
Factor B	1	168.7	0.000
Factor C	1	6.918	0.012
Factor D	4	262.4	0.000
AD	4	34.0	0.000
CD	4	2.5	0.053

Statistics for table 1: plant growth: Biomass (**fresh** wt. Kg/plant) (2 years old).

Source	df	F-value	Prob
Factor A	1	2253.0	0.000
Factor B	1	111.3	0.000
AB	1	6.8	0.012
Factor C	1	36.4	0.000
Factor D	4	299.3	0.000
BD	4	48.5	0.000

Statistics for table 2: plant growth: Biomass (**dry** wt. g/plant) (2 years old).

Source	df	F-vlaue	Prob
Factor A	1	1764.2	0.000
Factor B	1	145.6	0.000
AB	1	11.0	0.001
Factor D	4	4.2	0.005

Statistics for table 3: leaf crude Aloin (g/100 g fresh wt.)

Factors:
A: Plant species (*vera, eru*)
B: Sun light (direct, diffuse)
C: Soil (loamy sand , sandy loam)
D: Watering treatment (1-5)

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الملخص العربى

النمو وإنتاج الألوين فى نوعى الصبار ألوى فيرا وألوى إيرو تحت ظروف بيئية مختلفة

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هدفت الدراسة الحالية إلى إستجلاء الظروف البيئية المناسبة لزراعة نوعين من الصبار هما ألوى فيرا *Aloe vera* وألوى إيرو *Aloe eru*. واستخدم لذلك نوعين من التربة : رملية طمبية وطمبية رملية وكررت القياسات في المواسم المتتالية تحت ظـروف الظـل وأشـعة الشـمس المباشرة ودرس أثر خمسة معاملات للرى : ثلاثة بالماء العذب على فترات مختلفة (أسبوع – أسبوعين وثلاثة أسابيع) وبالماء العـادم قليـل الملوحة (3000 جزء فى المليون) وعند إضافة مخصب عضوي من أوراق نبات أكاشيا ساليجنا للتربة مع الري بالماء العذب.

وسجلات قيا سات النمو وتحليل النبات ويشمل المحتوى الكلوروفللى والكربوهيدرات الكلية ومحتوى النبات من الألوين الخام ومحتوى الألـوين والأنثراكينون ومحتوى الأحماض الأمينية والبرولين والتركيب المعدني. أنتج ألوى فيرا كتلة حيوية أعلى من ألوى إيرو وأظهـرت النباتـات النامية على التربة الرملية الطميية نمواً أعلى من النباتات النامية على التربة الطميية الرملية وأظهرت النباتات النامية فى الظل زيادة معنويـة للكتلة الحيوية عن النباتات النامية تحت أشعة الشمس المباشرة. أظهرت النباتات المسمدة بأوراق أكاشياساليجنا أعلى كتلـه حيويـة وسـجلت النباتات المروية بالماء العادم نمواً أعلى من النباتات التي تعرضت للإجهاد المائى. أنتج ألوى فيرا محتوى ألوين أعلى من ألوى إيرو وأنتجت النباتات النامية تحت الظل محتوى ألوين أعلى من نباتات الشمس وأظهرت النباتات المعرضة للإجهاد المائي (رى كل ثلاثـة أسـابيع) نسـبة مئوية أعلى من الألوين ولأن نموها الخضري قليل فإن الناتج النهائي للألوين نسبة إلى الوزن الخضري يكون قليلاً. ويحتـوى ألـوى إيـرو كلوروفيلا أعلى من ألوى فيرا وزاد محتوى الكلوروفيل فى نباتات الظل عن نباتات الشمس وبلغ أعلى تسجيل لمحتوى الكلوروفيل فى الربيـع وظهر أعلى محتوى كربوهيدراتى في نبات ألوى فيرا النامى تحت الشمس مع الرى بالماء العادم. ولوحظ أن أعلـى تسـجيلات للأحمـاض الأمينية الحرة والبرولين كانت بالنباتات المروية بالماء العادم قليل الملوحة.

أظهرت النتائج أن أفضل نمو وإنتاجية لنوعى الصبار ألوى فيرا وألوى إيرو هو تحت ظروف ظل أشجار أكاشياساليجنا مـع إضـافة سـماد عضوى أخضر من أوراق هذه الأشجار على تربة رملية طميية ومن الممكن تطبيق هذا فى مزارع الصبار وباستخدام الماء العادم في الـري يؤدى إلى إنتاج مرض بدون نقص كبير عن استخدام الماء فى الرى.