. Arab Gulf J. scient. Res. 4 (1), pp. 53-68 (1986)

Forage Potentialities of *Kochia indica* and *K. scoparia* in Arid Lands with Particular Reference to Saudi Arabia

M.A. Zahran

Department of Botany, Faculty of Science, Mansoura University, Mansoura, Egypt.

ABSTRACT. The genus *Kochia* comprises species that are salt tolerant and/or drought resistant. Being rich in nutritive constituents and palatable to livestock, rabbits and poults, these plants may be introduced as non-conventional forage crops in arid lands.

Two *Kochia* species (*K. indica* Wight and *K. scoparia* (L.) Schrad.) are studied. For *K. indica*, seed germination and growth of seedlings were examined under different salinity levels. The response of *K. indica* to mineral nutrients was also tested.

Field experiment was conducted to study: germination, growth and vegetative yields of *K. indica* and *K. scoparia* in a salt affected land of the arid western region of Saudia Arabia. The available artesian saline water was used for irrigation.

The results obtained reveal that *Kochia* plants may be cultivated under salinity and high temperature stresses. Their vegetative yields and hay can be used as green and dry fodders, thus presenting a solution for the problem of the shortage of forage in arid lands.

Low meat production is one of the food problems of the countries of the arid and semi-arid regions. The problem is often exacerbated by the increasing demands.

The natural plant covers of these regions comprise a considerable number of palatable species belonging to families: gramineae, leguminosae, cruciferae, compositae, chenopodiaceae, labiatae, nitrariaceae, ...etc. These palatable species are reliable natural range plants where their vegetative or dry yields are high enough to maintain a continuous fodder supply. Unfortunately, this cannot be secured under the arid and semi-arid climates. As rainfall of these areas is generally low, the vegetative yields of these naturally growing range plants are not enough to meet the animal requirements. Apart from that, it will not be possible to find pure natural vegetation of these palatable plants only since other unwanted and/or

poisonous species are also present. It is apparent that a promising solution is to propagate certain palatable xerophytes and/or halophytes under drought and/or salinity stresses using the available water for irrigation.

Kochia species have attracted the attention of range ecologists in many countries: El-Shishiny (1953), El-Shishiny and Thoday (1953), Draz (1954), Thoday (1956), El-Shishiny *et al.* (1958), Borkowshi and Brest (1965), Tandon and Agarwal (1966), Coxworth *et al.* (1969), Malcolm (1969), Shiskina and Tagisbaev (1970), Coxworth (1970), Rasulov (1971), Malcolm (1971, 1972), Golovchenko and Makhamadzhanov (1972), Kernan *et al.* (1973), Golyadkin *et al.* (1974), Malcolm (1974), Sadek (1974), Kamdamov (1976), Abu Ziada (1978), Durham and Durham (1979), Malcolm (1980), Zahran and Amin (1982), ...etc. These plants are drought resistant and/or salt tolerant and are grazed by animals in their natural stands.

The objective of this work is to experiment with *K. indica* Wight and *K. scoparia* (L.) Schrad. to shed some light on their performance under saline conditions and the possibility of introducing them as non-conventional forage crops in saline and arid regions.

General Remarks

K. indica and *K. scoparia* are annual bushy herbs which belong to the family chenopodiaceae. Their principal tap roots extend downwards in the soil for more than 3 metres carrying many secondary roots. Tey have long stems (more than 3.5 metres under favourable conditions) which are cylindrical and richly branched. The stems and branches are softer in *K. scoparia* than in *K. indica.* The leaves of both species are linear-lanceolate and fleshy, but their colours vary; whitish green in *K. indica* and deep green in *K. scoparia.* Flowers are small, regular and bisexual. The fruit (nut) contains one small, oval, bouyant and black seed.

Geographically, *K. indica* belongs to the Irano-Turanian Saharo-Sindian region (Tackholm and Drar 1954). It is native in India (Drar 1952), but is widespread, being recorded in the area between India and Morocco: Punjab (Bamber 1961); Morocco (Dahadiez and Marie 1934); Lahore (Kashyap and Joshi 1936); Karachi and Sind (Hasanain and Rahman 1957); Palestine and Jordan (Zohary 1962), Algeria (Quezel and Santa 1963), West Pakistan and Kashmir (Steward 1972), Egypt (Tackholm 1974), Saudi Arabia (Migahid 1978), ...etc. *K. indica* is a salt tolerant bush that grows in the salt affected and calcareous soils in Egypt (Sadek 1974 and Abu Ziada 1978), see photo 1.

According to Durham and Durham (1979), *K. scoparia* originates in Eurasia. It has apparently been in America since 1900, being recorded in Colorado in the late 1930s and in Texas in the late 1940s. It is not recorded in Egypt and other countries of Africa (Tackholm 1974) nor in the Arabian Peninsula (Dickson 1955, Halwagy and Macksad 1972, Migahid 1978, Zahran 1982). Early in 1980, *K.*

scoparia has been introduced by the author to Saudi Arabia and Egypt. Phillips and Launchbaugh (1958) state that "*K. scoparia* is an extremely drought tolerant annual bush having 5 m deep root".

The chemical analysis of *K. indica* grown in Egypt (Draz 1954) reveals that the contents of the green branches and hay are, respectively, as follows: 84.19% and 7.68% water, 0.36% and 1.56% fat, 3.41% and 17.61% crude protein, 5.21% and 35.92% N-free extract, 4.11% and 22.92% fiber and 2.72% and 14.31% ashes. According to Abu Ziada (1978), the shoot and root systems of *K. indica* contain: 0.706% and 0.373% soluble sugar; 4.738% and 6.295% total carbohydrates and 294 mg% and 85 mg% alkaloids respectively. Erickson and Al-Moxon (1947), Sherrod (1971, 1973), Finley and Sherrod (1971) found that *K. scoparia* contains a high amount of protein (17.9%) and a low amount of fiber. The digestibility of the protein fraction was slightly less for *K. scoparia* than for alfalfa, the reverse is true for fiber digestibility. Coxworth *et al.* (1969) estimated that the average seed production of *K. scoparia* as 2170 kg/ha. In general, seeds of *Kochia* plants are short lived and do not remain viable in soil more than one year (Chepil 1946, El-Shishiny *et al.* 1958, Sadek 1974, ...etc.). This may indicate that *Kochia* can be eliminated by plowing the plants before they produce seeds.

Ecophysiological Studies

In this investigation, a few experiments were carried out on *K. indica* in order to understand the effects of salinity on germination, the tolerance of seedlings to salinity and their response to mineral nutrition. Trials of field propagation of *K. indica* and *K. scoparia* were also performed.

A) Germination Experiment:

a- Material and Methods:

Germination of *K. indica* seeds was tested in Petri dishes (9 cm diameter) containing filter paper moistened with distilled water or with solutions of different concentrations of NaCl (0.1, 0.2, 0.3, 0.5, 1.0, 2.0, 2.5 and 3.0%). Ten ml of distilled water (or NaCl solution) were added to each Petri-dish. Duplicate dishes were used for each treatment and fifty seeds of *K. indica* were sown in each Petri-dish. The experiment started on January 12, 1977 and continued for 3 weeks. Observations were made every 24 hours. Emergence of radicle and plumule was taken as the criterion of successful germination.

b- Results:

Effect of different salinity levels on the germination of *K. indica* seeds (Table 1) showed that germination was highest when *Kochia* seeds were watered with distilled water (control dishes) or with dilute solutions of NaCl. Increased NaCl concentration caused lengthening of the periods of 100% germination from 8 days

in the control dishes to 13, 18 and 18 days in the dishes treated with 0.1, 0.2 and 0.3% NaCl solutions, respectively. Data show that *K. indica* seeds can germinate, though at a low rate, under salinity as high as 3% NaCl.

Table 1. Germination experiment on the seeds of *Kochia indica* under different levels of salinity: number of germinated seeds (daily records).

Date	Salinity Levels (NaCl %)								
	Dist. H_2O	0.1 NaCl	0.2 NaCl	0.3 NaCl	0.5 NaCl	1.0 NaCl	2.0 NaCl	2.5 NaCl	3 NaCl
12/1/1977									
13	19	12	2	1	1	1	0	0	0
14	31	25	12	11	2	1	0	0	0
15	31	39	13	19	7	4	0	0	0
16	39	45	25	20	9	5	0	0	0
17	41	45	31	20	10	7	0	0	0
18	46	48	32	20	13	8	0	0	0
19	49	49	36	22	16	9	0	0	0
20	50	49	36	34	20	10	0	0	0
21	50	49	36	34	26	11	3	0	0
22	50	49	38	35	29	13	18	0	0
23	50	49	38	35	30	13	19	1	0
24	50	49	41	39	36	18	22	4	0
25	50	50	42	46	38	20	23	4	0
26	50	50	42	47	39	21	23	6	1
27	50	50	42	47	42	21	23	11	3
28	50	50	42	47	42	21	23	11	3
29	50	50	43	47	42	34	23	12	4
30	50	50	50	50	45	37	27	13	5
31	50	50	50	50	45	38	34	14	6
1/2/1977	50	50	50	50	45	40	34	17	6
2	50	50	50	50	45	40	34	17	6
% germination	100	100	100	100	90	80	68	34	12

B) Salinity Tolerance Experiment:

a- Material and Methods:

On April 15, 1977, 80 seedlings of *K. indica* (4-6 days age, 3-5 cm high) collected from a natural stand on a salt-affected soil of the deltaic Mediterranean coast of Egypt, were transplanted in 16 pots (14 cm diameter and 14 cm depth). Eight pots were filled with sand and the remainder with silty soils. In each pot five comparable *K. indica* seedlings of approximately the same height were transplanted. The plants were watered with fresh water once every 72 hours for 6 weeks. On May 26, 1977, the sand pots were divided into 4 sets of 2 pots each. They were

irrigated with equal amounts (one L) of fresh water (control set) and 0.5, 2 and 3% NaCl solutions for the second, third and fourth sets respectively. The same was done for the pots containing silty soil. Application of NaCl solution was carried out once, thenceforth all pots were irrigated with fresh water at regular intervals with quantities of water which would keep the soil at its field capacity. The experiment continued for 2 month and the shoots of *K. indica* were harvested on July 26, 1977. Plant height and fresh and dry weights were determined.

b- Results:

Table 2 includes the rsults which show that *K. indica* seedlings succeeded to grow normally after being irrigated with saline solution as high as 3% NaCl. The results were analysed statistically by the correlation coefficient or "r" test (Poole 1974). Positive correlations (+ 0.5 for sandy and + 0.6 for silty soils) occurred between the measured parameters (height and fresh and dry weights) of *K. indica* and the concentration of NaCl solutions up to 3%. The highest fresh and dry weights were recorded in pots filled with silty soil and watered with 3% NaCl solution (Means = 3.67 kg/pot and 0.99 kg/pot respectively). Under the same treatment in pots filled with sand, the means of fresh and dry weights were 1.14 kg/pot and 0.24 kg/pot respectively. Under all salinity levels, *K. indica* plants gave higher vegetative yields in silty soil than in sandy soil.

Table 2. Salinity tolerance in *Kochia indica*.

Parameters	Fresh water		0.5% NaCl		2% NaCl		3% NaCl	
	Silt	Sand	Silt	Sand	Silt	Sand	Silt	Sand
Height (cm)	19.7	8.5	16.4	15.4	17.1	11.2	16.2	8.4
Fresh weight (kg)	2.93	0.69	2.98	1.42	2.84	2.42	3.67	1.14
Dry weight (kg)	0.83	0.20	0.88	0.38	0.66	0.43	0.99	0.24

C) Mineral Nutrition Experiment:

a- Material and Methods:

On March 28, 1977, the mineral nutrition experiment started using 480 *Kochia* seedlings (age = 4-6 days, 3-5 cm height) which were transplanted in 48 pots (10 seedlings in each pot), half of which were filled with sand and the remainder with silty soil. All the pots were irrigated with fresh water once every 72 hours for about one month. First addition of nutrient solution (Arnon solution diluted to 1/5) was on April 27, 1977.

Pots of sandy soil were divided into four sets (each set of 6 pots). The same

was repeated for the pots of the silty soil. The first set of each type of pots were irrigated with fresh water (control pots), the second with complete nutrient solution, the third with nutrient solution lacking nitrogen (−N) and the fourth with nutrient solution lacking phosphorus (−P), see Table 3. The experiment continued for three months during which irrigation of plants in each pot was carried out with 1 L of fresh water every 72 hours and 1 L of the specific nutrient solution every 15 days. Half of the plants were harvested on June 25, 1977 and the second half on July 25, 1977.

Table 3. Constituents of the nutrient solution used in the mineral nutrient experiment. (Arnon diluted 1:5).

Salts	Complete Nut. (+NP)	Omit Nitrogen (−N)	Omit Phosphorus (−P)
KNO_3	0.131 g/L	KCl	KnO_3
$Ca(NO_3)_2$	0.131 g/L	$CaCl_2$	$Ca(NO_3)_2$
$NH_4H_2PO_4$	0.023 g/L	KH_2PO_4	NH_4NO_3
$MgSO_47H_2O$	0.1 g/L		
$FeSO_47H_2O$	0.5% 0.2 ml/L		
Tartaric acid	0.4%		
$MnCl_24H_2O$	0.9 mg/L	The same in both cases	
H_3BO_3(Boric acid)	1.43 mg/L		
$CuSO_45H_2O$	0.04 mg/L		
$ZnSO_47H_2O$	0.11 mg/L		
$(NH_4)_2MoO_4$	Traces		

* Check pH adjust to 5.5 or 6.0 with 0.01 N NaOH.

b- Results:

Table 4 shows the following:

1. Generally, *Kochia* plants of control pots showed the lowest vegetative yields when compared with plants treated with nutrient solution.

2. *Kochia* plants showed better vegetative yields in pots filled with silty soil than those of sandy soil.

3. Phosphorus seems to be a most important element for the vegetative growth of *K. indica*. This is obvious when we compare the dry weights of plants growing in pots treated with complete nutrient solution (containing phosphorus) with the other pots treated with nutrient solution lacking phosphorus. The presence of nitrogen seems to hinder the uptake of phosphorus by the plant from soil.

Table 4. Vegetative growth of *Kochia indica* at the beginning (A), at first harvest (B), and at second harvest (C) after the supply of mineral nutrients.

Parameters		Control		Complete nutrient		Nutrient without nitrogen		Nutrient without phosphorus	
		Silt	Sand	Silt	Sand	Silt	Sand	Silt	Sand
Height (cm)	A	14.60	7.50	18.80	8.8	19.00	9.40	18.2	8.2
	B	36.54	20.60	43.00	26.00	42.00	27.90	39.50	24.90
	C	44.37	24.80	50.30	29.74	46.50	27.70	45.70	28.40
Fresh weight (g)	A	1.17	0.60	1.57	0.64	2.12	0.79	1.80	0.61
	B	5.04	2.50	7.57	3.80	8.68	4.44	6.70	3.12
	C	10.28	3.70	12.40	5.20	12.20	8.17	11.80	4.15
Dry weight (g)	A	0.31	0.16	0.51	0.25	0.56	0.27	0.51	0.16
	B	1.60	0.72	2.33	0.95	2.76	1.22	2.25	0.88
	C	2.94	0.91	3.43	1.46	3.94	1.70	3.30	1.49

D) Field Experiment:

A field experiment was carried out in the arid western region of Saudi Arabia where shortage of green fodder, especially in summer, is a real problem. The experiment was conducted in Bahra area (midway between Jeddah and Makkah) at the mid-stream part of Wadi Fatma that drains into the Red Sea near Jeddah). The climate of the area is generally arid: hot and dry. Mean maximum temperatures ranges between 28.4°C in winter and 39.5°C in summer and mean minimum temperatures range between 16.3°C in winter and 28.4°C in summer. The absolute maximum and minimum temperatures are: 48.4°C and 11.4°C respectively. Rainfall is mainly in winter and is usually less than 100 mm. But, like other parts of the arid lands, cloudbursts may cause unexpected torrents. Relative humidity ranges between 25% in winter and 64% in autumn, 100% humidity is not unusual during summer-autumn period. The minimum relative humidity may be as low as 3% during autumn (Saudi Arabian Annual Environmental Report 1977).

The site of the experiment was selected in a salt affected land near a saline artisian well (5325 ppm TDS). This land, which was dominated by *Suaeda monoica* (salt tolerant perennial shrub) was cleared from its natural vegetation, prepared and divided into plots (35 plots, 7×7 m each). On February 7th 1981, a soil profile was dug, soil samples were collected and analysed (US. Salinity Lab. Procedure 1954). Results indicate that the soil is alkaline (pH = 8.12 in the surface layer, 8.8 in the subsurface layer and 8.88 in the bottom layer). The highest amounts of soluble salts (EC: 1200 micromohs/cm) were detected in the surface layer. Salinity decreased in the middle and bottom layers to 249 and 185 micromhos/cm respectively. The soil texture varies from sandy to sandy loam.

On February 10, 1981, seeds of *K. indica* (obtained from Egypt) and *K.*

scoparia (obtained from Texas, U.S.A.) were sown. The seeds were seated at 3-4 cm depth in soil. Plots were irrigated with the artesian saline water at weekly intervals. After about 3 weeks, only a few seeds of *Kochia* germinated. Low germination was attributed either to the non-viability of most of the seeds and/or the deep seating of seeds in soil. Thus, sowing was repeated on March 3, 1981 by seating *Kochia* seeds at less than 1 cm. This time, germination percentage was high, most of the seeds germinated after 4 and 10 days for *K. scoparia* and *K. indica* respectively. Growth of plants continued normally (photo 2). On May 20, 1981, *i.e.* after irrigation with the artesian saline water for 11 weeks, a second profile was dug and soil samples were collected and analysed. Results reveal that soil salinity (expressed by EC) increased from 1200 to 2000 micromhos/cm in the surface layer, from 249 to 500 micromhos/cm in the second layer and from 185 to 300 micromhos/cm in the bottom one. Although associated with increase in air temperature, such increase of soil salinity did not show adverse effects on the growth of the individuals of both *Kochia* species. At the end of May 1981, the plant cover of the plots was more than 80%. The plants attained their maximum vegetative growth during July-August period, *i.e.* summer forage production (photo 3). On August 20, 1981, the height, horizontal branch estension and fresh weights of 20 representative bushes of each of *K. indica* and *K. scoparia* were determined. It was found that *K. indica* forage production was relatively higher (mean height = 235 cm, mean branch extension = 280 cm and mean fresh weight = 8.5 kg/bush) than that of *K. scoparia* (mean height = 220 cm, mean branch extension = 240 cm and mean fresh weight = 5.6 kg/bush). The statistical assessment of the data obtained from this experiment indicated that there was positive correlation between the vegetative yield (forage production) and the other parameters measured, namely: height of plants and branch extension: $r = +0.6$ and $+0.55$ for *K. indica* and *K. scoparia* respectively, Poole 1974).

K. indica and *K. scoparia* changed to brownish yellow during September 1981 (Photo 4). Plants dried in October - November period (Photo 5). Seeds were collected in December 1981. Profuse amounts of seeds were produced from both *Kochia* species. This accounts for the high nutritive value of *Kochia* hay.

In their natural stands in Egypt *(K. indica,* Abu Ziada 1978) and in Texas, U.S.A. (*K. scoparia,* Durham and Durham 1979) *Kochia* plants germinate in February. But, if the seeds can germinate also during summer, we can take two vegetative crops each year and thus, the economic value of *Kochia* plants will be increased. This has been realized by sowing *K. indica* in another piece of land on the same site in June 2, 1982. Germination of seeds and plant growth using the artesian saline water for irrigation were successful (Photo 6). In October 1982, the height of *K. indica* bushes was more than 2 m and the vegetative yield was up to 55.3 tons/ha (green forage). These results may emphasize the importance of *Kochia* plants. Apart from being salt tolerants and/or drought resistant, rich in nutritive substances and palatable to livestock and poults, they can be planted at any season of the year.

Photo 1. *Kochia indica,* natural stand, salt affcted land, Mediterranean Coast, Egypt.

Photo 2. Two month growth of *Kochia indica* and *K. scoparia*, experiment of the salt affected land, Bahra area, Saudi Arabia (April, 1981).

Photo 3. Mature *Kochia indica* bushes, Bahra experiment, Saudi Arabia. Notice the height of the plants and the side extension of their branches (August 1981).

Photo 4. Bushes of *Kochia scoparia* (Foreground) and *K. indica* (background) at the beginning of the dryness of the field experiment at Bahra salt affected land, Saudi Arabia (September 1981).

Photo 5. Dry bushes of *Kochia indica* carrying great amounts of seeds, Bahra experiment, Saudi Arabia (October, 1981).

Photo 6. Seedlings of *Kochia* plants of the second year field experiment at Bahra salt affected lands, Saudi Arabia (June 1982).

Discussion and Conclusion

Current and escalating pressures on lands in arid and semi-arid regions, underline the need to explore alternate approaches to increasing productivity. One such approach is to consider utilization of plant resources that grow on land too saline and/or too dry for productive agriculture or to use saline or brackish water for irrigation. Shortage of forage production to feed domestic animals in arid and semi-arid countries is one of the major problems. Introduction of forage (wild) xerophytes and halophytes to be cultivated in these areas using the available water and under the prevailing hot climatic conditions may be the proper solution.

The present work explores the utility of the *Kochia* species and their cultivation under salinity and/or drought stresses. The results obtained show the following:

1. *Kochia indica* and *K. scoparia* are annual bushy herbs that may be considered as non-conventional forage-producing plants with nutritive values comparable to those of clover (*Trifolium alexandrinum* L.) and higher than those of many palatable xerophytes and halophytes, *e.g. Diplachne fusca* (L.) P. Beauv., *Chloris gayana* Kunth, *Panicum repens* L., *Traganum nudatum* Del., ...etc. but less than those of alfalfa (*Medicago sativa* L.) (Draz 1954 and Whyte *et al.* 1966).

2. Two *Kochia* species can be cultivated in arid lands using artesian saline water for irrigation.

3. Though *Kochia* plants contain alkaloids yet the amounts present are not harmful to animals. However, cattle fed on *K. scoparia* in Texas, U.S.A., gained about 0.4 kg/day without showing symptoms of toxicity (Durham and Durham 1979).

4. *Kochia* cultivation can be carried out two times/year, *i.e.* green and/or dry fodder can be secured all year around.

5. The hay of *Kochia*, with its great amounts of seeds, is a very rich dry fodder.

6. Further studies are needed to find out the suitable irrigation method and the best fertilizers that produce the highest vegetative yield with the richest nutritive values of *Kochia* plants. Also, the susceptibility of these plants to diseases has to be studied.

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(Received 12/12/1984;
in revised form 02/07/1985)

الامكانات الرعوية العلفية لنباتي كوخيا أنديكا وكوخيا سكوباريا بالمناطق الجافة ممثلة بالمملكة العربية السعودية

*** محمود عبد القوي زهران**

قسم النبات ـ كلية العلوم ـ جامعة المنصورة ـ المنصورة ـ مصر

يشتمل جنس كوخيا على أنواع من النباتات منها التي تتحمل ملوحة التربة ومنها التي تقاوم الجفاف ودرجات الحرارة العالية ولكون هذه النباتات غنية بالمواد الغذائية لحيوانات المراعي فقد جذبت انتباه علماء بيئة المراعي بالعالم لدراسة إمكانية إدخالها كمحاصيل علفية غير تقليدية بالمناطق الجافة وشبه الجافة بالعالم.

في هذا البحث عرض المؤلف نتيجة دراساته على نوعين من نباتات الكوخيا وهما:
كوخيا أنديكا وكوخيا سكوباريا حيث أجريت تجارب إنبات بذور ونمو بادرات نباتات كوخيا أنديكا وكذلك أجريت تجارب لمعرفة مدى استجابة هذه النباتات لأنواع التغذية النباتية المتنوعة.

* أجريت هذه الدراسة على مرحلتين المرحلة الأولى تمت في مصر خلال الفترة ما بين ١٩٧٦ ـ ١٩٧٧ بكلية العلوم ـ جامعة المنصورة والمرحلة الثانية تمت بالمملكة العربية السعودية خلال الفترة ما بين ١٩٨٠ ـ ١٩٨٢ عندما كان المؤلف معاراً للعمل بكلية الأرصاد والدراسات البيئية جامعة الملك عبد العزيز ـ جدة ـ المملكة العربية السعودية.

وقد أجريت تجارب حقلية لإدخال زراعة نباتات الكوخيا نوعي أنديكا وسكوباريا بالمملكة العربية السعودية باستخدام مياه الآبار الجوفية المالحة في منطقة بحرة التي تقع في منتصف الطريق بين جدة ومكة المكرمة.

وأوضحت النتائج أن نباتات كوخيا أنديكا وكوخيا سكوباريا يمكن زراعتها تحت الظروف المناخية الحارة والجافة مع ريها بمياه الآبار الملحية وأن الإنتاج الخضري لهذه النباتات يمكن أن يستخدم كعلف أخضر (أو جاف) للماشية والأغنام والدواجن بالمناطق الجافة خاصة وأنه يمكن الحصول على محصولين خضريين من هذه النباتات كل عام.