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# Salicornia Production in Kuwait

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**Abstract:** Kuwait lacks the resources for agricultural development and plant production, but there are growing (high) interest with the public and the government for plant cultivation. The soil is sandy in texture with low fertility content of nutrients and low water holing capacity. The irrigation water is limited to desalinated sea water which is very expensive, brackish water that is to saline for crop production and treated sewage water which is not available for crop production due to lack of deliveries. The cooperation with University of Arizona and Kuwait Institute for Scientific Research in halophyte trial had positive result in *Salicornia* trials in Kuwait. The scientific findings show the possibility of utilizing the arid land with poor quality in soil properties and sea water to produce plant that can be use for animal production. Various tasks were implemented such as site selection, irrigation water delivery, sand storm control, nutrients application, plants selection and local staff training. The results show that *Salicornia* can replace alfalfa in Kuwait for 25% as initial results and utilization more method of nutrient application with flooded sea water to increase crop production. The objective was to evaluate the production and utilization of the halophyte (salt-plant) *Salicornia* under Kuwaiti conditions. An agronomic testing site in the Medairah area, was identified, prepared and planted with Salicornia. Water erosion reduced stand establishment initially and severe mobile sand inundated the plots, terminating the first season's trials after 120 days. The experimental plots were irrigated with highly saline water (25,000-33,000 mg/l total dissolved salts), similar in total salt content to seawater. Feeding trials were made on sheep. The first year's work found that Salicornia grew well in Kuwait for 120 days when irrigated only with highly saline brackish water and that Salicornia forage can partially replace conventional forage as a source of roughage and energy for small ruminants. Adjustments have been made for the second season in order to make Salicornia Kuwait's first seawater-irrigated crop with a potential for reducing forage imports and increasing the degree of self- sufficiency in animal feed.

**Key words:** Salicornia · Seawater · Kuwait · Nutrient · Salinity · Irrigation and forage

## INTRODUCTION

The term halophyte was coined by Schroder [1], to apply to plants that can be grown under saline conditions. As recent as 1972 [2] it was pointed out that scientists still did not know much about halophytes. Walsel [2] emphasized that we were principally ignorant of the metabolic adaptations and direct physiological processes enabling plants to survive under saline conditions. Ion uptake, germination regulation, salt retention and extrusion, growth and such other processes in plants under saline conditions, were relatively unknown. With modern agricultural practices, increasingly using water of poor quality, has contributed to the process of adding excess salts to soil, as well as increasing contamination of underground water sources. Salinity is a common phenomenon and one of the basic features of the arid and semi-arid regions throughout the world [3]. Saline coasts, particularly, are formed all over the world, under semi-arid and arid regions. According to Massoud [4], about 7% of the total surface area of the world is covered by salt affected land. Some geographic areas have been saline since the beginning of man's memory, while others have become or are becoming saline in modern times [5-9]. It has, in fact, been estimated that every year another 200,000 hectors of arable land become too saline for conventional farming-because of saline accretions resulting from irrigation with brackish water (3000 mg/l.) [10]. Also while Massoud [4] considers 7% of the total surface area of the whole world to be saline, Rains [9] feels that 40% of all arable land of the world now has enough salinity to reduce agronomic potentials. While its impacts are detrimental the world-over, its adverse implications are most

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exaggerated in hot arid environments [11]. It has also been estimated that more than 50% of all irrigated land of the world has been damaged by secondary salinization [12]. These workers pointed out that the non-productive, salt-affected lands of the world could be used to produce halophytic non-conventional crops of economic value. The cultivation of saline non-productive lands with halophytes, which can be irrigated regularly with seawater, may be considered, also, as a biological way to bring about land reclamation [13-15]. Halophytes have potentials as oilseeds, range, forage, ornamentals, grasses, trees, paper and drug Industries and others.

Preoccupation with freshwater (freshwater is one word) agriculture is the consequence of having selected and domesticated for use, plants that have freshwater origins, which is the case with most of the plants currently grown commercially in Kuwait. This is appropriate for intensive production, or controlled environment agriculture. It is not appropriate, however, to think of plants of fresh-water origin, for propagation within the open-field climate, land and water resource bases of Kuwait. Kuwait simply does not have fresh water for open-field agriculture. Its only sweet-water source is that which is obtainable through desalination, which is cost prohibitive for open-field agriculture, particularly where, due to its hot arid environment, evaporation and evapotranspiration run rampant

Inland, Kuwait's groundwater resources are all highly brackish (7,000-8,000 mg/l.), which already requires a considerable amount of manipulation for salt-tolerance among the traditional agricultural crops although genetic diversity exists and much progress can and will be made over the near to long-term, in adopting plants to tolerate this kind of salinity.

Complimentary to selection efforts for salt tolerance in traditional crops for brackish water use, lays the potentials for using the sea as a resource. The world has 22,000 miles of hot-arid coast lines [9]. Kuwait has vast unused areas, within reasonable proximity to the coast. Kuwait's seawater has salinity values of about 42,000 mg/l (TDS). Plants that tolerate these salinities are halophytes. Many have grown wild through the years and are seen today in isolated salt flats and marshes. There is no overriding reason why wild plants tolerating high salinity could not have been selected and domesticated through the years. The probable reasons of the past were that it was simpler to merely buy plants from plentiful areas. Recently (July 11, 2004), however, the world has reached a population of 6 billion people, 2 billion more than just 30 years ago. Greater and greater numbers of this population are living in hot arid areas. Also with these circumstances and those associated with it, comes the need for some food security in Kuwait and also some non-oil business potential which most assuredly lies within its midst.

Kuwait Institute for Scientific has recognized that for agriculture to expand in Kuwait's environment with salty water, sandy soil and harsh climates, major efforts must be made to select and adapt plants that can tolerate the salt and the heat, on the one hand, while on the other hand exploiting the potentials of those plants with inherent tolerance. To achieve this end, KISR had prepared a comprehensive "Conceptual and strategic Framework for plant Biosaline and Biothermal Program Development in Kuwait" [16]. The strategic Framework consists of a Master Plan highlighting the work was done over the long-term and an Operational plan stating the projects to be pursued and international linkages to be developed over the next 5-year period to help to move the nation agriculture forward. This project represents the first project was initiated under this jointly prepared strategic framework.

It is clear that, Kuwait needs to exploit halophytic potentials and propagate seawater coastline agriculture, to compliment the salt tolerant traditional crops being developed for inland "brackishwater served" open-fields. At the outset such a challenge would seem to be a highly costly, time consuming, formidable task. Fortunately, scientists and technologists have been pursuing these challenges for several years. The purpose of this special project was to jump the several years and expenditures that would otherwise be required for non-commercially productive development and join in partnership with the leaders in the field, in order to accelerate pre-commercialization assessments and chart further development needs

## MATERIALS AND METHODS

Initial surveys were made in southern Kuwait in the vicinity of Al-Khiran, with the objective of identifying an agronomic testing site that would be representative of a significant region for eventual commercial production. The Sabkah areas closest to the Arabian Gulf had low infiltration rates and limited area extent. The beaches and adjacent areas composed largely of shells and shell fragments had infiltration rates exceeding 40 cm per hr. Neither of these regimes was considered to be ideal for eventual commercial production of Salicornia using flood irrigation with seawater. A review of geologic surfical sediments led to an in-depth examination of Kuwaitis northern coastal areas where the soils are primarily composed of sand. Detailed soil surveys, including digging of pits to study the soil profiles and the measurement of long-term infiltration rates, led to the selection of a site at Medairah about 1 km from the shore of Kuwait Bay and nearly half-way between the communities of Jahra and Subiya. It was selected to be representative of at least 10,000 ha of land suitable for commercial production of *Salicornia,* located further North on the mainland of Kuwait adjacent to Bubiyan Island, which was not easily accessible at the time, for security reasons. The infiltration rate at the Medairah site ranges from 7 to 17 cm/hr with a mean of 13 cm/hr, which was considered on the high side for flood irrigation, but promising for eventual commercial production using drop-tube irrigation.

It was decided to tap the locally abundant and highly saline groundwater found at depth in the region, as the Medairah site was more than 2 km from deep water in Kuwait Bay. A drilling program led to the installation of a deep water production well with a capacity of 72 cubic meters per hour (m3/hr). The groundwater encountered at 10 m, the depth of the static water table at the Medairah site, has a salinity of 10 ppt. The water becomes more saline with depth, reaching a salinity of more than 100 ppt below 100 m. The intake well screen was located at a depth of about 50 m in order to obtain water with salinity similar to seawater. Continued pumping at and above the design rate of 60 m3/hr over a period of several months led to an increase in the Total Dissolved Solids (TDS) in the well water from 27 parts per thousand (ppt) at completion of the well. The higher pumping rates were drawing water from greater (more saline) depths into the well. Pumping rates were limited to a maximum of 40 cubic meters per hour in order to prevent the salinity of the well water from exceeding that of seawater. This was successful and salinity levels stabilized at 34,000-36,000 mg/l.

Fifty experimental plots 20 m x 8 m were constructed for conducting agronomic research trials with Salicornia. The total planted area of the experimental halophyte test farm established at the Medairah site was limited by the availability of saline irrigation water and the high infiltration rate of the soil. The entire site, including the research farm and the support facilities covered an area of 5 hectares (200 m x 250 m) hectares) was enclosed with a chain-link boundary fence. A diesel- electric generator was installed to provide power to the well pump and support facilities. The support facilities include: living space for resident workers, field laboratory, storage space for agricultural supplies and equipment, an elevated tank for storing freshwater trucked to the site for domestic use and a sewage disposal system. The permanent deep water well pump was installed in the production well at Medairah.

The coastal areas of Kuwait were investigated for appropriate site/sites for testing and evaluating *Salicornia* performance and production. Accessibility to seawater was evaluated. Drainage needs if any were sketched as well as soil samples were analyzed and land characteristics were assessed. Other areas in Kuwait were identified for suitable experimentation and eventual commercial production. Impact of project activities on soil and water resources was evaluated..Based on the major characteristics of the soil, an appropriate irrigation system were chosen and designed. Pumps and pipes were installed to provide up to 1000 $m^3$/hectare/day, depending on the salinity of the soil, but generally, at least an amount of water equivalent to twice the potential evapotranspiration rate, in order to provide for plant growth and leaching of salts.

All plots were hand-seeded according to the following method: plot wetted just prior to seeding; plot raked lightly; phosphate fertilizer, Triple Super Phosphate (0-46-0 NPK), applied at rate equivalent to 100 kg per ha; seeds broadcast by hand at a rate of 30 kg/ ha of pure live seed; plot raked again; plot rolled; plot irrigated at low rate to minimize seed wash-out. Treatments included: a replicated nitrogen fertilizer trial and observation trials on Salicornia ecotypes and poultry manure.

The second season trials were similar in design to those of the previous season. Emphasis was given in replicated experiments to means of reducing the leaching of nitrogen fertilizers from the root zone by testing slow-release compounds and the reduction of infiltration rates by the sub-surface application of a chemical soil stabilizer. Observation trials were made on date of seeding and the performance of several *Salicornia* ecotypes, including *Salicornia herbacea*, the locally occurring *Salicornia* in Kuwait. A pre-plant application of phosphorus was incorporated into the soil of all treatments, as before. The research plots were divided in half and leveled to reduce soil erosion and seed washout by the applied irrigation water.

Seedlings were executed with a "Brillion Seeder", at depths and rates prescribed by ERL. Planting was taken in November. Efforts were made to increase "stand" of seeded crops. The sites were irrigated after seeding and approximately every four days thereafter. Fertilizer application varied, depending on the characteristics of the soil, from about 50 kg of urea/ha to 400 kg/ha, applied over the 200-day growing period. Each site was divided into 5 strips for replication purposes, involving seeding, fertilizer and harvesting time.

Portions of the crops were harvested by hand for experimental purpose and others were cut and baled as appropriate. The fodder (mature and pre-mature, depending on replicate), was chopped, washed and dried for animal feeding, with limited trials being carried out on direct, unwashed materials.

In April a two-month sheep-feeding trial was initiated at the KISR Sulaibya Research Site utilizing *Salicornia* harvested from the Kalba Agriculture Farm in Sharjah, UAE. Fifty-four, seven-month old Australian wether lambs were distributed randomly among 6 dietary treatments. Each treatment was fed to 9 lambs that were individually housed in 1 m x 1.5 m stalls in a well-ventilated barn. Data collected during the sixty-day experimental period-included initial and monthly body weights, daily feed consumption and mortality.

A second-sheep feeding trial was conducted in the spring at the same KISR research facility in Sulaibya using *Salicornia* harvested from the Kalba Agriculture Farm. Five diets were fed to 6 newly-weaned (4 month old) local Kuwaiti sheep (i.e., 4 Naeami and 2 Erbei per treatment). The level of total crude protein in all diets was adjusted by varying the composition of the concentrate to be within the range of 16-17%. The parameters measured were the same as in the first trial.

Group 1 Alfalfa control (100%)
Group 2 Basal control diet (50%alfalfa+50% concentrate)
Group 3 *Salicornia* (SOS-7) high protein fodder as total replacement for alfalfa (100%)
Group 4 *Salicornia* (SOS-7) high protein fodder as partial replacement for alfalfa in basal diet (25% alfalfa + 25% Salicornia "SOS- 7" fodder + 50% concentrate)
Group 5 Salicornia (SOS- 7) high protein fodder as limited replacement for alfalfa in basal diet (37.5% alfalfa + 12.5% of Salicornia "SOS- 7" fodder + 50% concentrate)

Nutritional analytical evaluations and sheep (homogeneous breeds) feeding trials (10 Lambs per treatment) were carried out, in the Aridland Agricultural Department animal science nutritional laboratories and in the Sulaibya farm facilities, so that animals feeding studies were initiated in January. Salicornia fodder and meal were analyzed to determine their amino acid profiles, fatty acid profiles, proximate analysis, non-protein nitrogen, energy and inorganic composition. Some of these analyses were carried out at different stages of plant maturity. These data were been used in refining the rations for the subsequent animal feeding trials.

The data were analyzed using Dunkan's Multiple Range Test to ascertain the significant differences among treatments [17].

## RESULTS AND DISCUSSION

Remedial measures to protect the Medairah site from mobile sand were designed and implemented in the summer. They included a v-shaped corrugated metal fence to stop and divert most of the sand blowing into the site from the northwest (the prevailing wind direction): a series of shade cloth windbreaks approximately 1 meter in height surrounding the site to reduce mobile sand damage from winds blowing from other directions: similar 1.5 to 2.0 m windbreaks located at the North and South end of each research plot, to reduce damage from blowing wind and sand: and chemical stabilization of 10,000 $m^2$ of soil adjacent to the research plots. A sand monitoring and management program was initiated which included the measurement of the amount of sand blowing onto the Medairah site from the direction of the prevailing winds (NW). The results of these measurements are expressed in terms of equivalent kilograms of sand impinging upon the site daily across a line one meter in length, normal to the prevailing wind direction. The mean of 16 two- week observation periods between September 12 and June 9, was 34.6 kg/m/day with a minimum of 0.04 kg/m/day and a maximum of 161.3 kg/m/day (all calculated over 2 week observation periods). Readings on single days were often in excess of 1000 kg/m/day. The most frequently occurring rate (mode) was between 1-5 kg/m/day. To put these readings in perspective, 1000 kg of sand is approximately equivalent to a half cubic meter of sand. Therefore, a square hole 1 meter on a side would be filled to a depth of 50 cm in a single day by mobile sand entering the site at a rate of 1000 kg/m/day.

The date of seeding observation trial clearly indicated that early October is the best month for maximum biomass production. Plants seeded on October 1 or October 15 had approximately 50% more biomass than plants seeded either two weeks earlier (September 14) or later (November 1). Plants seeded on January 1, had less than half the biomass of plants seeded in October. There were no significant differences in the plant biomass

Table 1: Mean body weight gain, feed consumption and feed conversation ratio of Australian wither lambs fed several rates of washed *Salicornia* (SOS-7) hay, KISR, Sulaibya, Kuwait (experimental period 60 days)

| Treatment number | SOS-7 in diet (%) | Crude protein content of diet (%) | Body weight gain (g/hay/day) | Feed consp. (g/hd/day) | FCR (g/feed/gain) |
|---|---|---|---|---|---|
| 1 | 0 | 10.6 | 93.7 ab [i] | 1046 b | 11.2 |
| 2 | 0.0 | 12.2 | 142.7 a | 1040 b | 7.3 |
| 3 | 12.5 | 11.7 | 154.7 a | 1228 a | 7.9 |
| 4 | 25.0 | 11.3 | 114.7 a | 1076 b | 9.4 |
| 5 | 50.0 | 10.4 | 45.4 b | 895 c | 18.2 |
| 6 | 100.0 | 7.0 | -78.5 c | 633 d | - |

[i]The means followed by the same letter are not statistically different at p 0.01

production or the water requirements of the 3 treatments *in* the irrigation experiment. The air- dried biomass, estimated from 0.25 $m^2$ samples on May 1, taken from all the plots, was equivalent to 27 tons/ ha. The seedlings in the portion of the plot, which was hydro-seeded, were a little later in emerging than those seeded by hand, presumably due to the extra layering of material above the seeds. However, the final stand establishment was indistinguishable from the hand-seeded portion of the plot. Additional experiments on hydro seeding are required before this means of seeding can be recommended.

Based on biomass measurements made on May 5, ammonium nitrate appears to be the superior source of nitrogen whether applied at a seasonal rate of 200 or 400 kg N/ha. The latter was used as the standard fertilization source and rate for all experiments other than the nitrogen fertilization trial. Plants given 400 kg N/ha of ammonium nitrate reached a height of 50 cm by early June. Flower head formation was first noted in these plants 195 days after seeding.

Plots given single pre-plant applications of Osmocote at a rate of 200 kg N/ha had the highest biomass production of all the treatments in which nitrogen was applied in a slow-release formulation. The coating on the KISR Poly Coated Urea (PCU) fertilizer preparations dissolved within 4 months thus releasing the urea unevenly over the total growth period. Consequently, the plants in the plots given PCU fertilizers were approximately equal in size to the control plots, given no nitrogen fertilizer by early May. The growth of the plants in the single plot given poultry manure at rate of 400 kg N/ha was better than the PCU treated plots, but not as vigorous as the ammonium nitrate treated plots.

The ecotype Santa Rosa Chica matured several months earlier than S0S-7. The plot was harvested for seed on June 16. At that time the biomass was estimated to be equivalent to approximately 15 mt/ha. The seed yield was not determined, but the germination rate was equal to that of the original seed source (e.g. 30%). The Santa Rosa Grande ecotype was ganglier and slightly larger than S0S- 7 in the Medairah plots. In its natural habitat, near Kino Bay in Sonora, Mexico, it is several times the size of S0S-7, but its seed yield is not as great. The performance of the other ecotypes was not up to the S0S-7 standard. Salicornia herbacea grew at a much slower rate than S0S-7 planted about the same time. The advantage of S. herbacea is that it is able to survive the intense summer heat. Therefore, it might make a good off-season fodder crop on fields whose primary crop is S0S-7.

The mean body weight gain of the Australian wether lambs over the 60-day treatment period was the highest for treatments containing some fraction of alfalfa. Animals fed Treatment 5, with 50% SOS-7 and 50% concentrate, had significantly lower rate of gain (45.4 gm/hd/day) than animals in Treatments 2, 3 and 4 where the SOS-7 hay ranged from 0 to 25%. The sheep that were fed only SOS-7 (Treatment 6) had a net weight loss. Weight gain is highly correlated with the amount of crude protein in the diet. Diets containing less than 8.9% protein have negative growth rates. Treatment 6, composed solely of Salicornia hay, had a crude protein content of 7.0%. The low protein content of this dietary treatment was primarily responsible for the low rate of growth observed by the animals consuming it.

The feed consumption of the wether lambs in Treatment 3 (12.5 % SOS-7) was significantly higher than all the other treatments (i.e., 1228 gm/hd/ day). The sheep in other treatments containing some alfalfa and either 0 or 25% *Salicornia* had the next highest feed consumption rates, ranging from 1046 to 1076 gm/hd/ day. Animals fed treatments containing no alfalfa and the highest rates of Salicornia hay had the lowest feed consumption levels.

Therefore, it appears that Salicornia can be incorporated into the diet of sheep at a rate up to 25 %. However, highest growth rates were achieved with 12.5% Salicornia. However, initial indications were that animals in all treatments were growing well, except initially, when the animals in Treatment 1 (containing 50% SOS-7) lost weight during the first two weeks. After one month their weights stabilized.

## CONCLUSIONS

*Salicornia* appears to be a potentially promising and productive seawater irrigated fodder crop for Kuwait. Once protected from the onslaught of mobile sand, it produced biomass yields similar to the better yields achieved in Mexico. Additional trials will be required to ascertain the seed yields, but initial observations appear promising. Sheep appeared to accept in their consumption rates diets containing up to 25% *Salicornia*. Growth was clearly related to the total crude protein content of the diets. Therefore, in future trials it is important to supplement the diet with an adequate amount of high protein concentrate which could eventually be contributed by Salicornia meal itself. Some research is needed in the native Salicornia for more cultivation in Kuwait and adaptation for local use and more selection of new halophyte available within various germplasms bank within various countries. Though the impact of seawater irrigation on soil properties and its effect on yield and quality of *Salicornia* during subsequent years is a crutial issue (which is not the main objective of this study) that has to be addressed in the future research programs.

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