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Determination of nutritional value and lignocellulosic biomass of six halophytic plants grown under saline irrigation in South Sinai

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Abstract: Forage resources deficiency is considered one of the basic constraints to improving animal productivity in arid and semi-arid regions in Egypt. Utilization the marginal resources, i.e. saline soils and salt affected water for producing unconventional animal feed ingredients to be used when the traditional forage crops are not available or in short supplies. To achieve the aforementioned objectives, six halophytic plants were transplanted at 6 February 2014 (*Atriplex nummularia, Sueada fruticosa*, *Lucaena leucocephala, Myoporum serratum, Artemisia monosperm* and *Kochia scoparia*) in the model farm of National Research Centre, Al Tour, South Sinai, under drip irrigation system with saline water (EC : 8.7 dSm^{-1}). Vegetative samples were taken 100 days after transplanting. Results showed that, these plants attained a wide range of crude protein content (CP) varying from 9.68 % in *Leucaena leucocephala* to 13.68 % in *Atriplex nummularia*. These halophytic plants could be considered as good fodders because of their palatability for all animal species, in addition to their moderate content of protein. Meanwhile the highest values of crude fiber (CF) amounted to 25.57% was recorded in *Myoporum serratum,* the highest values of Ash and ADF amounted to 30.11 and 27.36 % were recorded in *Kochia scoparia*, the highest values of NDF amounted to 16.35 % was recorded in *Atriplex nummularia,* the highest values of EE and NFE amounted to 4.32 and 47.02 % was recorded in *Sueada fruticosa* respectively. On the other hand, *Sueada fruticosa* recorded the lowest values for CF, Ash, ADF, NDF as compared with the other plant species. These grasses are salt tolerant with high bio-reproductive mass to produce ligno-cellulosic biomass of good quality (20.02–32.65 % cellulose, 18.44–24.78 % hemi-cellulose for ethanol production. therefore, these species –and other halophytes with similar characteristics are promising candidates for bioethanol production.

Introduction

Recent trends and future demographic projections suggest that the need to produce more food and fiber will necessitate effective utilization of salt-affected land and saline water resources. World agriculture is facing a lot of challenges like producing 70% more food for an additional two billion people by 2050 while at the same time fighting with poverty and hunger, consuming scarce natural resources more efficiently and adapting to climate change[1]. The world’s population is expected to reach 9 billion in 2050. This increase, together with accelerating urbanization, water scarcity, desertification and the negative impact of climate changes on crops production, will exert upwards pressure on food demand and critically undermine efforts for sustainable development. Moreover, currently 98% of the global water is seawater, 20 % of the world’s irrigated land is salt affected and/or irrigated with waters containing elevated levels of salts[2]. Therefore, an integrated approach for solutions is required through economic, social and environmentally sustainable developmental opportunities[3]. Cultivation of halophytic plants seems to be an ideal management practice of such soil types, when fresh water is not sufficient[4]. Halophytic forage plants *such* as *Atriplex nummularia, Sueada fruticosa*, *Lucaena leucocephala, Myoporum serratum, Artemisia monosperm* and *Kochia scoparia* are highly salt tolerant halophytic forage plants grown well in coastal salt marsh. It has a special place in newly emerging farming systems, especially in coastal areas and where freshwater resources are not available or in short supply. It is environmentally smart crops because it can ensure food security, contribute to energy security, guarantee environmental sustainability, tolerate the impacts of climate change (water stress, salt stress and high temperatures), increase livelihood options, sequester CO_2 and bioremeiate salt affected soil. Growing these plants can increase sustainable productivity, strengthen farmers' resilience, reduce agriculture's greenhouse gas emissions and cause transformation of agriculture, in the way we grow food, feed and biofuel and treat the environment[5]. Thus freeing fresh water and high quality soil for food and feed and bringing poor land into production. Most of the halophytic plants tolerate multiple harvesting. They are also capable of recovering and maintaining a fresh productive biomass up to 20 ton $ha^{-1}year^{-1}$. The value of crude protein varied between 8.32 to 10.2 % which seems fair enough to cover the nitrogen requirements of grazing animals[6,7].

Animal feeding studies demonstrate that organic constituents of halophytes are highly digestible, and that diets containing moderate levels of halophyte ingredients are readily consumed by livestock. It also contains cellulose and hemicelluloses varied between 25.14 to 31.23%, this cellulosic biomass can be use for ethanol production. They can compete favorably with other conventional sources for biofuel production. It provides an option of selecting perennial, high biomass plants that contain suitable ligno-cellulosic material for conversion into ethanol and can be grown without encroaching upon arable land and fresh water. These Halophytic plants are abundant in nature, are outside the human food chain and require low maintenance which makes them relatively inexpensive to grow[8].

Materials & Methods

A field Experiment was carried out in the model farm of National Research Centre, Al Tour, South Sinai, to investigate strategy of using saline water for producing unconventional crops in salt affected soil under South Sinai conditions. Six Halophytic plant species (*Atriplex nummularia, Sueada fruticosa*, *Lucaena leucocephala, Myoporum serratum, Artemisia monosperm* and *Kochia scoparia*) were transplanted in El Tour, South Sinai at 6th Feb 2014. grown under drip irrigation system with saline water (EC : 8.7 dSm^{-1}), water analysis of Abo Kalam Well are presented in Table (1). Experiment was laid out in completely randomized block (1.5 x 2 m distance between plants) i.e. 1400 plants /fed., the mechanical and chemical analysis of the soil was carried out by using the standard method described by[9], Table (2). Each plant was fertilized with 50 g calcium superphosphate (15.5% P_2O_5) and 30 g potassium sulphate (48.0 % K_2O) and 60 g urea (46.5% N) mixed with 100 g green manures (compost). Vegetative samples were taken 100 days after transplanting. Then samples of each species , washed, dried thoroughly, then dried at 70° C to constant weight in an aerated oven to determine crude protein (CP), crude fiber (CF), ether extract (EE) and ash by standard analytical methods[10]. Nitrogen free extract (NFE) was calculated by the following formula: % NFE = 100-(%CP + %CF + %EE + %ash) the ligno-cellulosic biomass analysis is related to plant fiber estimation. We used the method of [10] involving multifunction process for the separation of cellulose, hemi-cellulose and lignin from the other constituents of ligno-cellulosic biomass Halophytic plants species under the experiment, their classification and their adaptation strategy are presented in Table (3).

Table (1): Water analysis of Abo Kalam well, El Tour. South Sinai.

pH		**7.49**
EC dS^{-1}		**8.7**
Soluble cations Meq/L	**K^+**	**0.5**
	Na^+	**69.2**
	Mg^{++}	**11.9**
	Ca^{++}	**21.6**
Soluble anions Meq/L	**SO4--**	**26.6**
	Cl-	**74.2**
	HCO3-	**2.4**
	CO--	**-**

Table (2): Mechanical and chemical analysis of the soil.

Depth		00 – 30 cm	30 – 60 cm
Soil texture		Sandy soil	Sandy soil
pH		8.1	8.4
EC dS^{-1}		15.1	4.52
Soluble cations Meq/L	K^+	0.4	0.24
	Na^+	112.0	27.0
	Mg^{++}	28.8	5.5
	Ca^{++}	60.5	12.5
Soluble anions Meq/L	$SO4^{--}$	61.0	10.64
	Cl^-	139.0	31.0
	$HCO3^-$	2.7	3.6
	CO^{--}	-	-

Table (3): Adaptation strategy, family, Habit and life strategy of the tested halophytic plant species.

Plant species	Adaptation strategy to salinity	Family	Habit	Life strategy
Atriplex nummularia	Excretive	Amaranthaceae	Tree	Perennial
Suaeda fruticosa	Succulence	Amaranthaceae	weed	Annual
Leucaena leucocephala	Succulence	Fabaceae	Tree	Perennial
Myoporum serratum	Excretive	Scrophulariaceae	Shrub	Perennial
Artemisia monosperm	Tolerant	Asteraceae	Shrub	Annual
Kochia scoparia	Excretive	Amaranthaceae	Shrub	Annual

Results & Discussion

Nutritional values of the tested halophytic plants species

Halophytic plant species vary considerably in their chemical composition and nutritive value as indicated in Table (4). There were significant differences in the content of crude protein (CP), crude fiber (CF), Ash, ether extract (EE), nitrogen free extract (NFE), acid detergent fiber (ADF) and neutral detergent fiber (NDF) among the tested halophytic forage species. These plants attained a wide range of crude protein content (CP) varying from 9.68 % in *Leucaena leucocephala* to 13.68 % in *Atriplex nummularia*. These halophytic plants could be considered as good fodders because of their palatability for all animal species, in addition to their moderate content of protein. Meanwhile the highest values of CF amounted to 25.57% was recorded in *Myoporum serratum,* the highest values of Ash and ADF amounted to 30.11 and 27.36 % were recorded in *Kochia scoparia*, the highest values of NDF amounted to 16.35 % was recorded in *Atriplex nummularia,* the highest values of EE and NFE amounted to 4.32 and 47.02 % was recorded in *Sueada fruticosa* respectively. On the other hand, *Sueada fruticosa* recorded the lowest values for CF, Ash, ADF, NDF as compared with the other plant species. Similar results were obtained by[11,12,13]. Some of these plants have a considerable nutritive value which compete that of the traditional forage plants[7]. In this regards, the nutritive value of six halophytic shrubs (*Acacia saligna, A. nummularia, A. semibaccata, A. halimus, P.distichum and S. litoralis*) naturally grown in the Mediterranean coastal zone in Egypt was evaluated by[14]. Nutrient contents varied among all halophytic plants including *Atriplex spp*. Most of these plants were high in CP such as *A. nummularia* and *S. litoralis* (18.2 and 17.8% DM, respectively). A major aim is to evaluate the potential of local halophytes for wide economic use under the circumstance of El Tour, South Sinai Governorate in the light of the progressive shortage of fresh water resources and soil salinization. Major research topics are to identify and select plant species tolerant to salt stress by selecting and using biomarkers to characterize halophytes, to evaluate the possible use of non conventional water such saline water, to select halophytes of a potential importance in the field of human or animal nutrition[15]. He added that, recent advances in selecting species with high biomass and protein levels and the ability to survive a wide range of environmental conditions including salinity. In this concern, [16]stated that, at 20 dS/m, the fresh yield of *Atriplex lentiformis, Atriplex nummularia* and *Atriplex halimus* reached nearly 25.0, 16.9 and 14.6 t/ha.

Table (4) Nutritional values of the tested halophytic plants.

Plant species	CP	CF	Ash	ADF	NDF	EE	NFE
Atriplex nummularia	13.68	21.65	26.35	26.15	16.35	2.95	35.37
Sueada fruticosa	11.36	18.65	18.65	22.36	12.65	4.32	47.02
Leucaena leucocephala	9.68	31.65	29.57	24.36	14.36	2.44	26.66
Myoporum serratum	10.65	25.57	27.36	25.65	12.54	2.46	33.96
Artemisia monosperm	12.98	21.67	29.68	26.32	15.36	2.19	33.48
Kochia scoparia	11.77	24.68	30.11	27.36	13.35	2.75	30.69
LSD 5%	0.98	1.55	1.97	1.88	0.87	0.15	2.03

DM:dry matter, CP: crude protein, CF: crude fiber, ADF: acid detergent fiber, NDF:natural detergent fiber, EE: ether extract, NFE: nitrogen free extract.

Lignocellulosic biomass in different plant species grown under saline irrigation.

Our target species have desirable cellulose/hemi-cellulose and low lignin contents which can lead to more sugar yield and subsequently more ethanol production through fermentation. It is evident from Tables(5) that the highest values for cellulose amounted to (32.65 %) was recorded in *Atriplex nummularia*, while the highest value of hemi-cellulose amounted to (24.78%) was recorded in *Kochia scoparia* and the highest value of lignin amounted to (13.54 %) was recorded in *Myoporum serratum*. Similar results were obtained by[17,13]. It is noteworthy that improving efficiency of agricultural systems through better management may have the potential of reducing the area of land required for food production by as much as 72% by the year 2050 [1] and make resources available for other usages such as biofuel but population growth demands that food production must double if food security is to be maintained. The feasibility of converting ligno-cellulosic vegetative biomass of plants into sugar, which is subsequently fermented to ethanol, opens new venues to tackle the problem of food or fuel[18]. Halophytes grow under conditions where both available water and soil are saline. Therefore use of halophytes as biofuel crop is advantageous because they do not compete with conventional crops for high quality soil and water and hence do not encroach on the resources needed for food crops[17] . Halophytes may have several unique features ranging from distribution and growth habitat to aspects of composition that make them a potentially interesting bioresource for biofuels. The conversion of ligno-cellulosic material into ethanol involves hydrolysis of cellulose through cellulase enzyme and fermentation of the sugar formed by yeast or bacteria. On conclusion, Sinai is of great interest from a biological point of view. Because of its geographic location at the junction of three continents and the climatic changes throughout its history, the peninsula is currently recognized as one of the central regions for biodiversity in the Middle East by the World Conservation Union[16]. The specie found promising in this study were *Atriplex nummularia* and *Kochia scoparia*. It have a considerable nutritional value and high cellulose/hemi-cellulose content and at the same time low content of lignin. So use of halophytic plants for ethanol production is an advantages for rural development especially if their land or water sources are salt affected and not suitable for growing convential crops.

This research suggests that halophytes can compete favorably with other conventional sources for biofuel production. It provides an option of selecting perennial, high biomass plants that contain suitable ligno-cellulosic material for conversion into ethanol and can be grown without encroaching upon arable land and fresh water. These plants are abundant in nature, are outside the human food chain and require low maintenance which makes them relatively inexpensive to grow. Many interrelated aspects need investigation but information on ligno-cellulosic biomass potential of a few species on a particular regional site opens opportunity of selecting future bio-ethanol candidates.

Table (5): Content of cellulose, hemi-cellulose and lignin in different plant species

Plant species	Cellulose %	Hemi-cellulose %	Lignin %
Atriplex nummularia	32.65	23.55	8.02
Sueada fruticosa	28.15	23.15	7.21
Leucaena leucocephala	21.54	18.56	12.65
Myoporum serratum	22.36	19.65	13.54
Artemisia monosperm	20.02	18.44	11.65
Kochia scoparia	27.36	24.71	9.52
LSD 5%	1.75	1.62	0.81

Conclusion

Salt-affected water and lands suffer from low agricultural productivity and significant environmental constraints. However, recent evidence suggests that by recycling and reusing saline water until it becomes inoperable for any economic activity and by returning salt-affected irrigated areas to higher levels of production, a significant contribution to food, feed and renewable energy production could be achieved without expanding the production area and obviating the associated challenges that this brings. The results indicate that these halophytic plant species are suitable for planting in saline habitats. These plants do not compete for good quality water and productive farmlands. They can be potentially used to produce huge amounts of biomass while grown with brackish water on salt affected land, without competing with conventional agriculture. The above results indicate that growing salt-tolerant plants in saline soil can improve the ecological environment and enhance land productivity. In addition, some halophytes have great economic value to be used as forage, fodder, biofuel production.

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