

## Chapter

# Performance of Water Desalination and Modern Irrigation Systems for Improving Water Productivity

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## Abstract

Desalination is the process that is performed to remove excess salts from water to become potable or agriculture. This applied science is now concerned by many countries suffering from water shortage. Over the next ten years, this science is expected to grow significantly due to the expected water crises in many countries. The consumption of energy in the desalination process is one of the important problems and difficult obstacles that need to be overcome. The Egyptian water strategy should include increasing amount of desalinated water to more than 50%, especially since Egypt is in a very rich location in saltwater sources and they can be utilized to the maximum extent possible. The researchers have attempted to develop varieties of some traditional crops such as wheat, saline resistant to salinity using local selective ecotourism techniques and using genetic engineering through which saline-tolerant genes are added, but it can be said that so far these efforts have not resulted in the production of candidate seawater breeds. The maximum salinity of irrigation water in the long term, even for the most salt-tolerant crops such as date palm, is still less than 5 mmol.

**Keywords:** saline water, irrigation system, water management, desalination, magnetic water

## 1. Introduction

### 1.1 Salt farming toward a greener future

Saline farming is based on the cultivation of crops and plant varieties that can tolerate high levels of salinity and temperature. Its idea originated primarily from nature itself and from the growth of naturally salty plants on sandy beaches, tidal areas, saline lands, and other saline-flooded areas [1–4]. The most prominent example of this type of plant is the mangrove plant, also known as the Crimea or Shura, which is heavily distributed on the shores of the Red Sea and the shores of the Arabian Gulf. The Crimea—and this type of plant in general—adapts to

the saline environment in more than one way and mechanism. Salts, which are collected and then disposed or adapted to the saline environment in the place they are found, contain a high degree of salinity [5, 6]. Some researchers have tried to mimic these natural conditions by using saline water to irrigate and grow some plant and crop species. One may succeed in adapting to high salinity and continuing to grow and produce [7]. The first attempt began in 1949, but the expansion of research and scientific experimentation on the cultivation of saline plants began only in the late seventies of the last century. Since then, many scientific institutions, such as Arab research centers, have been actively trying to develop new techniques for salt farming and to develop new varieties of salt-tolerant plants and crops, whether from major food crops such as wheat and barley or from other plants that can be exploited as natural pastures or fodder for livestock [8–10]. However, the concept of saline agriculture is not only to improve the ability of some plants to grow and mature in a harsh saline environment and to irrigate and plant certain plant and crop species with high salinity water but also to use brine or improve some of their properties or specifications, such as sugar concentration in fruit [11–14].

In general, it is possible to confirm that the process of developing saline farming techniques and the production of saline-resistant plant species took two different scientific approaches: the first was the application of genetic engineering technique to genetically and geologically transform traditional plants and transform them from being saline to tolerant. While the second approach is based on the cultivation of saline plants that can tolerate salinity and try to expand their cultivation in the wild and agricultural fields for use as food crops or animal feed or for the production of oilseeds.

The expansion of saline agriculture can be of greater benefit, such as the exploitation of arid and semi-arid lands, which sometimes have abundant amounts of brackish water unsuitable for conventional agriculture. Cultivating some suitable crop types and increasing their production will help to achieve food security [15–17]. Similarly, marginal beaches exposed to tidal movement can also be exploited for feed farming or other plant species that can be used to produce energy (biofuels) or to extract pharmaceuticals or oils [18–20].

Salt farming can also contribute to increasing the efficiency of the use of water resources by conserving potable water or traditional agriculture, which in turn helps to achieve water security and reduce migrations and conflicts resulting from the lack of water, land degradation, and increased drought. In addition, salt farming techniques can also contribute to improving the productive efficiency of some crops or improving the quality and characteristics of certain crops, thereby achieving high economic returns [21–24]. Saline farming can also contribute to mitigating the effects of global warming leading to climate change. This is due to its role in increasing agricultural land and green plant areas that absorb carbon dioxide from the atmosphere [25–29].

As such, salt farming can support traditional agriculture and raise pressure in it, since the requirement of traditional agriculture is to find less water-consuming ways and increase agricultural production to meet the growing demand for food and staple crops. Traditional agricultural activities are the main consumers of drinking water by 70%, followed by industrial activities by 20%, and other activities.

Pibars and Mansour [30] found that severe soil water deficit (SWD) decreased grain yield of winter wheat, while slight SWD throughout the growing season did not reduce grain yield or water productivity. This result indicates that water supply can be reduced somewhat without significant decrease in grain yield. Moreover,

investigations conducted by [31, 32] show that deficit irrigation can increase the net farm income. Barley, considered as a tolerant plant [33], occupies large cultivated areas in arid parts of Tunisia. Many experiments have been conducted on barley cultivated in small private farms in southern Tunisia [34] and the results demonstrate the potential of irrigation management practices in reducing the effects of salinity on both yield and soil salinity. In addition, [35] showed that yield reduction under deficit irrigation during the whole growing season was about 5% and 20% of the total irrigation water was saved.

## **1.2 The need to use seawater in irrigation**

There are about 295 million hectares of coastal desert land in the world, where about 17% (about 50 million hectares) is level 0% slope lands, it's suitable for irrigated agriculture (in terms of soil type, the land slope, and there is no competition for the other uses), and it's expected that the land will increase the irrigated areas in the desert regions by about 80%. The common regions for such use are the different deltas of some rivers where coastal sediments constitute sedimentary desert lands such as the Nile River (Egypt), Euphrates River (Iraq), and Colorado River (US), where the sedimentary coastal delta is often suffering from secondary salinity problems. Many places suffer from desertification [36, 37].

Such spaces can be introduced into economically valuable agricultural production by cultivating halophytes using seawater. The sandy coastal desert along the coast of the Red Sea and the Arabian Gulf, as well as the Indian Ocean and the Gulf of California, are suitable for this type of use, adding additional areas suitable for irrigation by seawater. Many coastal plains of the sea, as well as in the northern coastal plains of Australia and some areas close to population centers or some large cities such as Cairo, Baghdad, Bombay, and Karachi, are also common for such use. This is a great opportunity to invest in the production of animal feed from halophytes, which reduces the pressure on the use of fresh water and available agricultural land and reduces overgrazing on relatively few grasslands [38, 39].

It was projected that the desalination technology would provide nuclear power, where it could provide a cheap source of energy for seawater desalination that could be used for agricultural and land reclamation. But to some extent, these techniques are still expensive and require high investment. Therefore, the direct use of seawater in agriculture is an optimistic and great hope for agricultural development along the coastal deserts by growing salinity-rich and economically profitable crops [11–13].

Some researchers have tried to cultivate traditional crops on seawater such as barley, which can at least complete their life cycle on seawater in temperate climates [40–42]. Furthermore, it has been assumed that breeding programs for such crops can be developed to improve their salinity tolerance and to create mutations of resistance or salinity. But so far, no conventional crops have been found that can produce an acceptable economic yield under irrigation conditions in the sea in the coastal desert climate [43]. Recently, a new approach has been proposed: to attempt to settle or rehabilitate and cultivate saline-loving plants that grow naturally in such conditions for agricultural production and thus can be used as a natural resistance to salinity. Some countries, such as North Africa, have begun using this technique to produce seeds and halophytes using seawater. About 15 years ago, the University of Arizona began field experiments to cultivate halophytes in many parts of the desert world [44].

With increased experience and information, experimental plots were increased from 0.5–1 ha to 20–40 ha experimental farms, and different irrigation methods

ranging from conventional surface irrigation to pivotal irrigation, which is about 250 ha, were used. [45].

Halophytes were selected to produce seeds from which oil is extracted, known as *Salicornia bigelovii* torr. Other varieties, such as Atriplex, longitudinal shrubs, and saline and other types of succulent plants, were tested for salinity. It was enough for the growth of most halophytes, which were salinity tolerant; nevertheless, the growth rate of these plants decreased by 50% due to irrigation by sea water.

However, in field trials, the results showed that the annual yield and seed yield may be equal to or greater than the yield of any traditional crops irrigated with fresh water. The biomass crop can be produced in the range of 17–34 ton/ha, which contains 11–23 ton/ha organic matter from halophytes and using seawater in field experiments for 6 years. An annual oil crop of 2 ton/ha of oilseed crop (equivalent to soybeans or other oil crops) was obtained [46–49].

The reason for the highest ability of halophytes to produce yields despite the deleterious effect of salinity of seawater is due to having many compensatory factors in such coastal spots where they do not compete with grasses or other pests and that halophytes have biological talent and ability that are high on photosynthesis and growth [22, 50–52]. In this chapter, we provide a revision about the possibilities of this new technology and how to assess the economic feasibility of different ways of using seawater in the production of animal feed. The final aim of the chapter is to find the suitable methods of water desalination and to use modern irrigation systems for the improvement of strategic crops in Egypt.

## **2. Materials and methods**

### **2.1 Salinity of irrigation water and how to solve it**

Drilling wells is the main problem when it comes to saline water and then it does not take long to find that it is salted, and hence the farms have a great role in the search with you for realistic solutions to address the salinity of irrigation water [53]. The different methods of desalination are as follows: (1) distillation by mixing fresh water with saline water, (2) method of magnetic water, and (3) using seawater in agriculture with high-tolerant plants.

#### *2.1.1 Water salinity and agriculture*

Water salinity is defined as the ratio of total soluble salts (sodium chloride, calcium sulfate, magnesium sulfate, and various bicarbonate salts) in 1 l of water [54].

#### *2.1.2 Salinity of groundwater used in irrigation systems*

Increasing the irrigation of saline groundwater reduces the strong attraction between the soil granules, thus reducing the interstitial spaces, causing difficulty in spreading the roots. This reduces the rate of root absorption of the water by the osmotic properties. The roots are burned, and the leaves of the plants and some branches are burned. Advanced sedimentation occurs when reverse osmosis occurs, causing the plant to die completely. In general, it is not correct to say that water salinity is treated, but it can be said that there is control over the effect of irrigation with saltwater [55]. Refs. [56–65] found the most important methods to control the salinity of irrigation with saltwater and to mitigate its harmful effects on plants (salinity treatment of water), which are mentioned in **Table 1**:

<b>I</b>	<b>Methods applied to the crop</b>
1	Cultivation of plants suitable to the degree of salinity of water, and this is the origin in the process of avoiding damage to the salinity of irrigation water.
2	When growing vegetable crops, the number of seedlings in acres or the quantity of seeds, to compensate for the loss of death or absence of germination or delay, must be increased.
3	It is recommended to spray micro-elements in paper in the form of Edita, and attention must be given to marine algae and amino acids to further encourage the plant to withstand the conditions that cause stress.
4	Potassium fertilization, especially in the form of potassium silicate, has an important role in resistance to salt stress and reduction of transpiration of the plant.
<b>II</b>	<b>Methods applied to the irrigation management and water sources</b>
1	Irrigation in the early morning and after sunset is preferred, because the sun rays lead to increase the proportion of water vapor from the surface of the soil and thus increase the accumulation of salts, and night irrigation causes the washing of salts and its interaction with the soil components of sand and clay and therefore less emphasis on the soil surface. It is then easy to wash with acid and saline treatment compounds.
2	Agriculture can be done in the upper third of the bottom lines to evaporate the floating of salts in the upper part of the line.  The irrigation system should not be used permanently if the salinity ratio exceeds 1300 ppm. This is due to the rapid evaporation of the water when spraying with water, leaving the salts around the plant, causing severe damage, even death.
3	The drainage must be improved by continuous tillage to facilitate the washing of salts during heavy irrigation, especially the soil salts do not accumulate with water salts and cause serious damage.
4	The interval between the irrigation must be reduced to maintain high content of soil moisture.
5	Some farmers have recently moved to the work of a fish tank and duck before sacrificing water in irrigation pipes.
<b>III</b>	<b>Methods applied to the process of cultivation</b>
1	Adding the organic material before planting at a rate of 10 tons of compost per feddan works to hold water and transmit without evaporation and increase the permeability of the soil.
2	Turning the soil with hard plows must be avoided, especially in the desert lands, to avoid moving the salts from the depth of the soil to the top again.
3	Increasing the rates of fertilization with humic and fulvic ability to increase the capacity of cationic exchange of soil, and generally works on: PH regulation of the soil where hydroxic acid combines with calcium carbonate and produces free calcium and releases CO <sub>2</sub> , which dissolves in water, forming a carbonic acid that makes the soil relatively acidic and increases its ability to absorb nutrients. Humic acid combines with sodium chloride, a component of sodium hydroxide, an organic complex that releases chlorine, a gas that inhibits pathogens in the soil.
4	Cultivation of windbreaks early because of their important role in reducing the speed of wind and reduce the temperature of soil, and with it increase the rate of water lag after irrigation and reduce the impact of harmful salts.

**Table 1.**  
*The most important methods to control the salinity of irrigation of saltwater and to mitigate its harmful effects on plants.*

## **2.2 Solving the problem of soil salinity: how to reduce the salinity of underground water?**

With the expansion of the reclamation of saline land, the increase in water scarcity, and the dependence of countries on well water, however, the problems of salinity have increased and have become even more threatening to agricultural production [66]. Investors began to look for ways to solve the problem of soil

salinity, and researchers were interested in developing ways to reduce the proportion of salts in water [66–69]. In this report, we offer you several golden tips, which are the summary of experience and science in dealing with the problems of salinity in your farm or field: It is not wise for farmers in saline lands to wait to overcome the full salt problem before starting the commercial production cycle. Rather, it is wise to coexist with the problem and gradually overcome it by preparing the root region to coexist with the permitted limits of growth.

Soil permeability relationship with irrigation capacity of saline water: Land with good permeability is tolerated by irrigation with saline water up to 3000 ppm without the accumulation of salts or causing a problem [70]. Poor soil permeability is precipitated by water salts even if salinity is 200 ppm due to the accumulation of salts over time [71]. Calcium nitrate and urea were used as an alternative to nitrate as a source of nitrogen and calcium. Fertilizers containing sulfate, such as potassium sulfate, magnesium, manganese, and zinc, were used. Sulfuric acid is usually used through the irrigation operation by the (fertigation) techniques, whereas nitric and phosphoric acids are used with the organic matter during preparation for each new crop.

To reduce the harmful effect of salts in the well water, we must modify the ionic structure by adding some chemicals [72–74], which helps to precipitate the harmful constituents of carbonates and bicarbonates. The following relationships should also be known: sodium absorption ratio (SAR)/electrical conductivity (EC)/leaching ratio (LR), especially when using saline water, so that the soil does not deteriorate and decrease production. How to reduce the effect of water salinity on crops? To overcome the problem of salinity and achieve the highest productivity in the presence of salts, irrigation periods with the installation of long washing irrigation to remove the salts from the root area must be rounded. If the proportion of sodium in the irrigation water is to be considered, the approximate percentage of calcium or magnesium must be adjusted by adding calcium throughout the year.

The best source of calcium here is the agricultural gypsum because of its multiple benefits, which we will talk about in a separate report. Reducing salinity of wells by choosing irrigation method.

When sprinkling and high-water salinity, water droplets should be observed to be large and not misty. Irrigation is done at night so that the evaporation process decreases, and the salts are deposited on the leaves of the plant. Frequent drip irrigation without changing the lines or completely immersing the entire land once or twice a year will exacerbate the problem of salinity in the soil. In addition, irrigation of agricultural banks that have drainage water for farms and adjacent fields is the most dangerous to the future of the soil and will not be able to reduce the deterioration and desertification in the future. The large number of composts with fertilization of ammonium nitrate causes the salinity of the soil to be increased.

### **2.3 Salinity ratio suitable for agriculture**

The problems of soil and water salinity are endless, and we have asked hundreds of questions about the best methods to be relied upon in agriculture. In the next report, we will review together important information on this subject, with an indication of the salinity ratio suitable for agriculture [75, 76]. Possible agricultural methods to avoid and reduce salinity damage based on nonreclaimed saline lands can be utilized as follows: Agriculture is on high lines with agriculture in the lower half of the miles because the salts bloom at its peak. The same method can be followed when farming on the terraces with the work of a small pyramid rise in the center of the terrace in order to bloom salts. Winter crops are preferred where the salt damage is less than that in the summer crops, and planting is preferred by seedling [57]. Drip irrigation helps to collect salts away from plants, so that the soil is washed from the accumulated

salts before planting the next crop. Methods of solving the problem of salinity of the soil to obtain the salinity ratio suitable for agriculture: Salinity treatment is not easy, so it is necessary to control and coexist with salts in soil. So as not to exceed the limits allowed by the integration of agricultural operations of plowing, fertilization, irrigation, drainage and treatment of salinity by following this process (**Figure 1**).

Where soil samples are not analyzed, the following system shall be followed: The plowing of the earth is two orthogonal slits. To wash the soil, wash by irrigation by immersing or spraying with sprayers at a rate of 100 m<sup>3</sup> per feddan once a week. Soil salinity testing is recommended after each washing routine to determine the effect of washing on salinity and to know whether the washing process is continuing. Add 20 m<sup>3</sup> of my squash per feddan + 200 kg superphosphate—this is for growing vegetables. [45] In case of trees, 5 m<sup>3</sup> + 50 kg superphosphate is added to the line of agriculture only, and the mixture is divided into 60 cm depth and 80 cm width. It is preferable to sterilize organic compost by sun or use organic manure. The organic fertilizer is composted in one area and is well soaked to saturation and covered with plastic for 2–3 months. Fertilizer rates are added with the addition of appropriate washing requirements with a good drainage system.

#### 2.4 How are the washing needs of the plants that are added to the irrigation water determined to help achieve the appropriate salinity ratio for the plant?

This is done by the following equation:

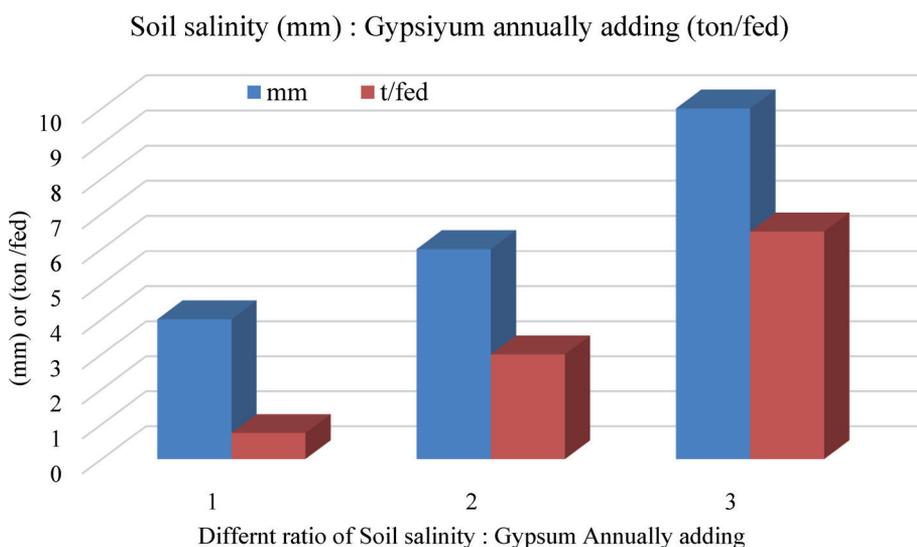
Laundry needs = salinity of irrigation water (mm) × (100/plant tolerance rate of salinity).

Example: The wet needs of potato plants irrigated with water with an electrical conductivity of 1 mm/cm at 25°C are required [42].

The E<sub>Ce</sub>, where there is no crop shortage, is 1.7 millimhos.

Solution: washing needs of potato = 1 × (100/1.7) = 59%.

In order to avoid any shortage in the potato crop, which is infused with salted water 1 ml/cm, it is necessary to increase the amount of water needed for each irrigation [48]. This is 59% as washing needs to wash the accumulated salts in the area of root spread and drain away from the root zone.



**Figure 1.**  
 The ratio between mean of soil salinity and amount of gypsum annually adding. (1) 4 mm: 0.75 ton/fed;  
 (2) 6 mm: 3 ton/fed; (3) 10 mm: 6.5 ton/fed.

It is noted that these washing needs calculated in the example are very high and may not be followed, especially because of the lack of irrigation water or the absence of good drains [40].

Therefore, the tolerance of the plant for salinity is calculated on the basis of the ECe score, where a 25% reduction in yield occurs in case of potatoes at ECe = 3.8.

Thus, the washing requirements of potato =  $1 \times (100/3.8) = 26\%$  more than the amount of water assessed for each irrigation as washing needs to wash the accumulated salts in the area of spreading the roots and away from them. Commercial sulfuric acid is injected with irrigation water at a rate of 2 l per feddan per week for a month. This removes the salts from the roots and removes them on the surface of the soil, thus improving the growth of the plants. Some natural compounds and raw materials are used for the treatment of salinity.

## **2.5 Magnetic water to overcome saltwater and make it suitable for agriculture**

Many countries in the world, including the Arab countries, suffer from the loss of water of the river. Therefore, desalinated saltwater is available from seawater and groundwater. In fact, there are several techniques to desalinate salty water, including the following:

1. Chemical deposition using CaO lime
2. Distillation
3. Electrical switchboard
4. Ion exchangers
5. Membranes or so-called reverse osmosis
6. Evaporation and condensation by the rays of the sun

There is an excellent way to decompose using magnetic separation. This efficiently removes up to 99% and more. This is because of the salinity of the water (the presence of positive ions and other negative ions), but these ions do not attract toward the magnet, so scientists thought of the physical center attracted by the negative ions and positive ions and attracted them to the center of magnets and this is called Feret  $\text{Fe}_3\text{O}_4$ , which is thrown in the saline water to be reanalyzed and attracted to the negative and positive ions by the magnetic field, which penetrates water for purifying it. Electrical dialysis has been commercially known since the 1960s, 10 years before reverse osmosis. The cost is effective for desalination of saline water wells and makes the decision for attention in this regard. The electrolysis technique is based on the following general principles. The electrolysis unit consists of several hundred pairs of cells connected to each other by electrodes called a compound of membranes. Feeding water flows simultaneously through passages through the cells to provide the flow of desalinated water as the concentrated water passes through the compound.

Based on the design of the system, it is possible to add chemicals in the compound to reduce the voltage and prevent the formation of crusts. Feed water must be treated from the outset to prevent substances that sweat membranes or block narrow channels in cells from entering the membrane compound. Feed water is rotated through the compound with a low-pressure pump to overcome water resistance as it passes through narrow passages. A rectifier is often installed to convert the oscillating current into a direct current supplied to the electrodes from outside

the membrane complexes. Final treatment includes water stabilization and processing for distribution, which may include the removal of gases such as hydrogen sulfide or alkaline modification.

## **2.6 Selection of soil preparation site**

Land processing and settlement are important factors in irrigated agriculture, especially when using seawater in irrigation. As is known in irrigated agriculture, salts tend to accumulate and redistribute in the soil sector, where salinity occurs in the field. For example, high areas are increasingly accumulating salt. Therefore, the land should be divided into pieces that may be different in size, but attention should be paid to settling the soil surface in one piece.

Many soil species have been successfully used in clay land to sand dunes and it is important that the soil is good for natural drainage. It is therefore necessary to plow the soil to a depth of 1 m to improve drainage especially in heavy land. When sandy soil is compressed under the surface layer, it must be prepared in terms of deep plowing, surface tillage, settlement, agriculture, and irrigation.

Although many halophytes bear high ground water, interest in drainage is an important factor in resisting salinization. In the case of heavy land, shallow banks must be made in the form of a letter V, at a depth of half a meter, and in dimensions of 10–20 m, to be drained into deep drains and can be drained through water pumps back into the sea.

The surface of the desert sea has a shallow reservoir of groundwater saline that extends to several kilometers of sea level. However, irrigation by seawater will cause damage to any groundwater reservoir. Therefore, hydrological studies should be carried out for the aquifers of the area to be used for irrigation by seawater (depth—quality—quantity). The hydrophysical characteristics of the soil must be studied. If the site is located next to a mountain range parallel to the coast as in the case of the Red Sea, the fresh water that collects under the mountain valley or on the sandy shoreline must be maintained.

One of the most important restrictions on the use of seawater to produce halophytes is how to manage water. It is necessary to prevent the accumulation of salts in the rhizosphere. This is a condition other than freshwater irrigation where irrigation is based on the level of soil moisture. In traditional irrigation conditions, irrigation occurs when the soil moisture is reduced to 50%. However, in the case of seawater irrigation and the lack of ground moisture to 50%, the salinity level in the root zone is twice the salinity level of seawater, which has a severe effect on the plant. For most halophytes, it was found that the moisture deficiency should not exceed 25% to reduce the chance of increasing salt concentration between the irrigation in the soil sector. It is also necessary to add washing needs about 25% or more in each rye to wash the salts and expel them below the root area.

Short irrigation and high-salt washing are therefore key to achieving success and achieving high yields of halophytes using seawater. For example, in the case of sand dunes or sandy beaches, irrigation should be carried out regularly on a daily basis during the summer season, while in sandy soil, which can't retain enough water, irrigation can be done every day and every 10 days in the winter season.

## **2.7 Planning the establishment of a seawater farm**

The most important factor required for the establishment of a seawater farm is that there is a source available, close to seawater and at a low cost. The cost of seawater supply is the largest investment in this type of project, and it exceeds the other factors such as irrigation method, quantity of water required, and agricultural practices required.

Usually, in the case of direct supply of seawater, it is a sea pier extending into the sea where pipes are drawn to fetch water by pumps. Irrigation channels must be constructed in the fields of the project, all of which affect the coast in terms of appearance and other uses of the coast. The movement of water and various marine organisms and the properties and effect of seawater on the rust of metals used in these marine environmental installations and the movement of waves, winds, and hurricanes are many difficult problems that must be considered and taken into account when designing. Solutions are usually expensive.

The alternative approach is indirect supply through wells to collect seawater, thus avoiding many of the above problems. Therefore, in the case of a groundwater reservoir, seawater wells are the best solution, but the limited capacity of the well may be a problem (many of these wells have been discovered despite their presence on the seashore in many studies). After a source of seawater is found, the next task is to connect the water to the root area, which can take many forms according to the irrigation method used. In the case of small spaces that can be used, simple irrigation method of watering where a system can be characterized by the rapid flow of water in open channels or light PVC pipes or plastic tubes can be folded. In the case of larger areas, the sprinklers can be used with either the axial or the lateral spray where the water is distributed homogeneously on the ground even if the ground is not precisely leveled.

### **3. Results**

#### **3.1 Field design**

Several designs of submerged ponds were successfully tested on the Abu Dhabi-type saltfish land. The design was modified to benefit from the tide and root movement rather than the use of pumps in the submerged ponds and was tested in Jubail, Saudi Arabia. The Sabkha lands are usually sedimentary, with a low filtration rate (less permeability) to the extent that 1 ha or more of a single irrigation outlet can be submerged, since the Sabkha field is not divided into separate basins, but the entire area is submerged.

In this method, the field is surrounded by a narrow barrier of soil and distributed within the barrier and at a depth of 1 m. A water pipe passes through the seawater during the tides to submerge the irrigation channels at a depth of half a meter to distribute the water to 10 m. A gate is also set up to control the level of water in the field. In order to fill the field, the gate is closed. The sea water (either as a result of the tide movement or using a pump) can pass through the main irrigation pipe to the irrigation channels and plant lines. A pump is often needed.

This method has been successfully tested in Mangrove, *Salicornia*, Abu Dhabi, where it has grown on Sabkha land, using seawater 50 g/l in irrigation. Soil salinity prior to planting was reduced from 80 to 120 g/l in a 10 cm layer by seawater washing for 1 week using 3 successive immersion and drainage cycles with salinity reduced to 50 g/l. The irrigation was done every 2–3 days in summer and every 4–5 days in winter.

It is worth mentioning that most of the water used is lost in surface drainage and therefore the water use efficiency is low. This design is suitable only in the case of Sabkha land, which can rely on the tidal and root water in irrigation without the need to use pumps.

It is the most widely used method of surface irrigation. This experiment was conducted on a sandy loam in Kino Bay, Mexico. *Salicornia* has been cultivated as an oilseed crop in 20 ha as a commercial farm since 1986. The farm was divided into

1 ha. The seawater well was used for irrigation from 5 to 10 days after germination and the water used was 3–4 m/200 days for yield. This rate falls within conventional crop rates, but irrigation efficiency is relatively low because about half of the added water is lost under the root zone.

### 3.2 Center pivot sprinkler irrigation

Salicornia has been cultivated, where watering can be used in the first 100 days (up to the floriculture stage) and then the pipes have been used to connect to connect the water to the ground level next to the growing plants. The amount of water used for irrigation and washing was about 2–3 m and the growth period of the crop is 250 days (about 1.25–1.5 times the evaporation rate). The machines and pipes used in this system must be resistant to the impact of seawater.

### 3.3 Drip irrigation

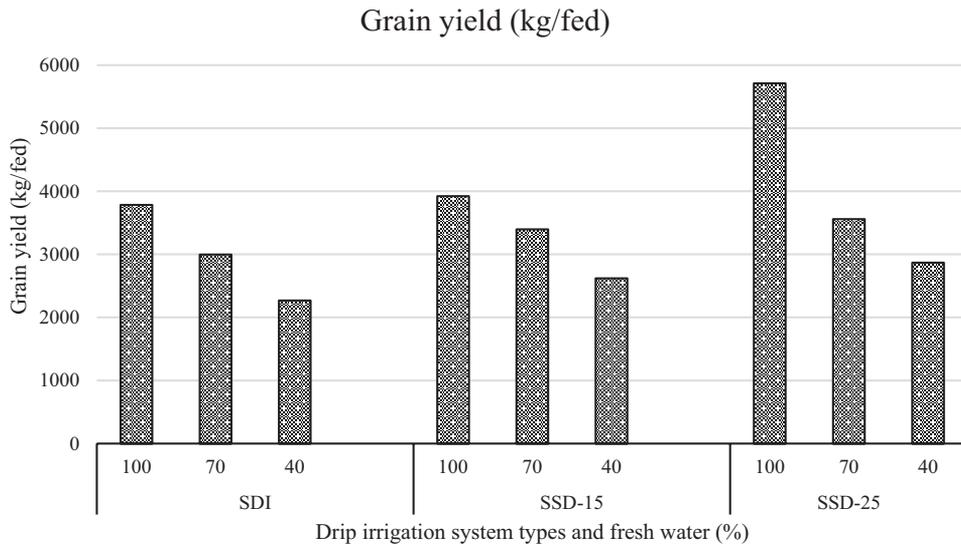
Drip irrigation using seawater is used to irrigate the Atriplex shrubs. A high yield was obtained. No salinity and clotting problems were observed. The irrigation is continuous daily, and salt accumulation is more frequent when burying the pores in the soil rather than on the soil surface.

Pibars and Mansour [30] compared sprinkler, surface drip, subsurface drip, and furrow irrigation to produce potato and sunflowers in the new reclaimed lands. Subsurface drip irrigation (SDI) with a 20-kPa irrigation criterion was among the most productive irrigation systems.

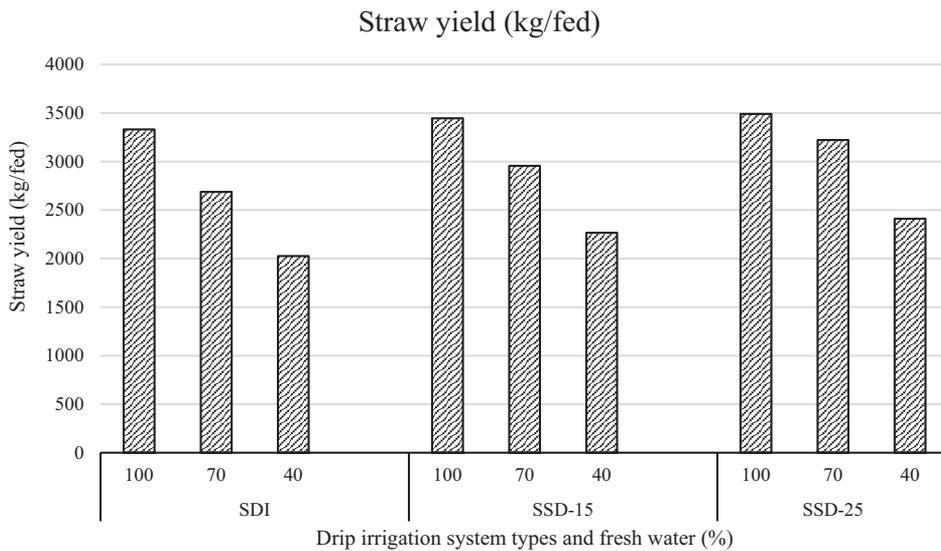
Pibars et al. [32] studied four options for managing drip irrigation of potatoes in North Dakota. Automation of the irrigation based on a soil water tension irrigation criterion at 30 kPa had relatively high water use efficiency. Tayel et al. [27] compared automated controlled SDI irrigation with the conventional semiclosed seepage subirrigation in Florida. The conventional irrigation system is under criticism because of surface runoff and nutrient contamination of adjoining waterways. The SDI system required more electrical energy but used 36% less water to obtain the same potato yield. Mansour et al. [42] examined irrigation-scheduling options for drip-irrigated potatoes. For sprinkler-irrigated potato, extensive work has been done on potato responses to N fertilizer and N losses, but relatively few studies have studied potato N fertilization and loss under drip irrigation.

Sprinkler irrigation at different irrigation criteria was compared to surface drip and buried drip irrigation (with a range of fertilization treatments), for potato yield and grade in Minnesota [3]. Less water was required using either drip irrigation system. Surface drip and buried drip were among the most productive systems for total and marketable yield. Furthermore, drip irrigation or sprinkler irrigation (at a relatively dry soil criteria) reduced nitrate leaching under potato compared to normal sprinkler irrigation [13] reporting that reduced nitrogen rates did not affect potato yield, when irrigated with a subsurface drip system. In **Figures 2–5**, the effect of different drip irrigation systems and different saline water on wheat grain, straw yield and wheat grain, and straw water productivity is shown.

Mansour and Aljughaiman [22] showed that drip irrigation had potential as an economically viable potato production method in the southeastern United States. Optimized irrigation rates were 99–86% of the water called for in their irrigation model. Ref. [29] examined tape depth and emitter spacing on tuber yield and grade of Norgold Russet potato in Lubbock, Texas. Tape depth or emitter spacing did not influence potato yield, but the proportion of misshaped tubers was greater when the tape was buried at 0.2 m than with shallower placement. Soil temperature was

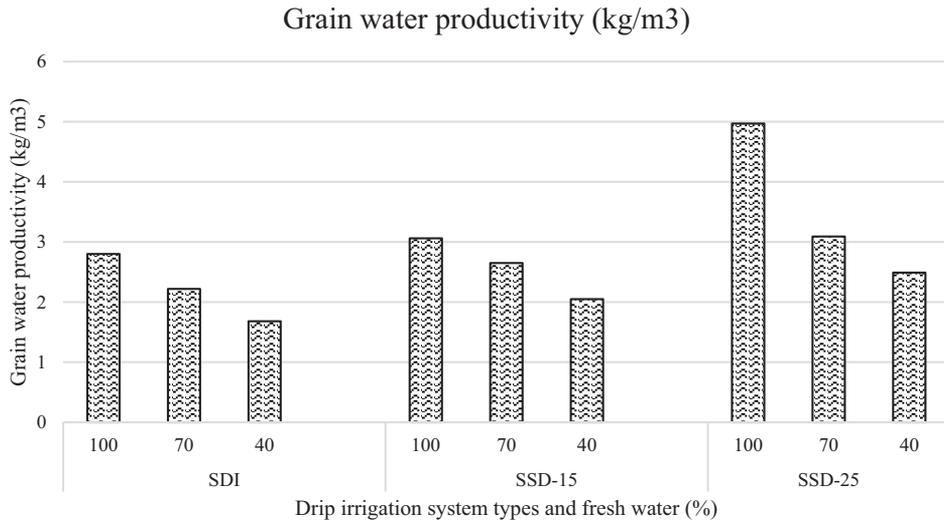


**Figure 2.** Effect of different drip irrigation system types and different saline water on wheat grain yield. SDI: surface drip irrigation; SSD-15: subsurface drip irrigation at soil depth 15 cm; SSD-25: subsurface drip irrigation at soil depth 25 cm.

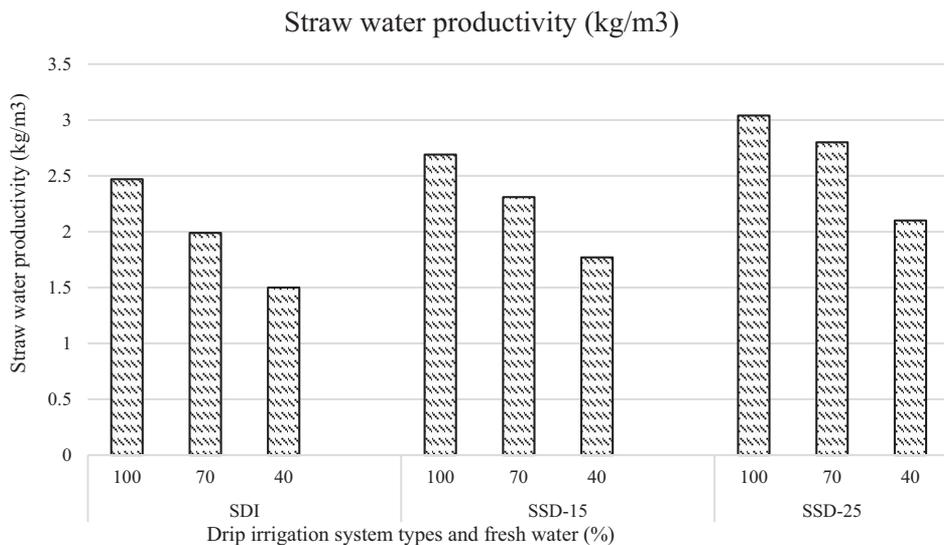


**Figure 3.** Effect of different drip irrigation systems and different saline water on wheat straw yield. SDI: surface drip irrigation; SSD-15: subsurface drip irrigation at soil depth 15 cm; SSD-25: subsurface drip irrigation at soil depth 25 cm.

greater with the tape at 0.2 m than at 0.1 or 0.025 m. El-Hagarey et al. [28] found that tape depths of 0.08 m (above the seed piece) and 0.46 m (below the seed piece) performed better than intermediate and greater depths. Tayel et al. [38] used 10 drip irrigation treatments to examine the effect of the timing of irrigation deficits on potato yield and water use efficiency in Spain. Irrigation deficits occurring during mid- and late-season tuber bulking were particularly damaging to yield. High yield was combined with high water use efficiency when irrigation deficits were restricted early in the season. Mansour et al. [49] investigated the performance



**Figure 4.** Effect of different drip irrigation systems and different saline water on wheat grain yield water productivity. SDI: surface drip irrigation; SSD-15: subsurface drip irrigation at soil depth 15 cm; SSD-25: subsurface drip irrigation at soil depth 25 cm.



**Figure 5.** Effect of different drip irrigation systems and different saline water on wheat straw yield water productivity. SDI: surface drip irrigation; SSD-15: subsurface drip irrigation at soil depth 15 cm; SSD-25: subsurface drip irrigation at soil depth 25 cm.

of ‘Umatilla Russet’ under drip irrigation in silt loam. The factors considered in the study were tape placement (one tape per row or one tape per two rows) and four soil water tension levels for automatically starting irrigation (1.5, 3.0, 4.5, and 6.0 bar). They concluded that drip tape placement had a significant effect on every variable except total marketable yield and bud-end fry color for which interactions of irrigation criteria with tape number were significant. Tape placement and irrigation criterion interacted to influence total yield, total marketable potatoes, and US No. 2 yield. Results indicated potato should be irrigated at 3.0 bar, given the silt loam soil and 2.5 mm water applied at each irrigation episode. The irrigation criterion

considered alone only influenced the total US No. 1 and over 340 g tuber weight categories. Potato cultivars were very different in their performance under drip irrigation [54].

The accumulated experience shows that seawater irrigation depends on the efficiency of the irrigation system used, and as a result of the low efficiency of irrigation uses large amounts of seawater not to allow the depletion of water until it reaches the wilt point between the irrigation because in this case the concentration of salt will be very high in the region. The soil moisture should be kept close to the field capacity at any time. This means that the efficiency of each soil should be as high as possible.

### **3.4 Use of salt-loving plants as feed for animals**

Halophyte plants are known to be a traditional source of animal feed, although some of the problems that accompany it include high concentrations of salts, low energy content, and low animal palatability compared with traditional fodder. For the cultivation of halophytes to be economically viable, their performance should be higher or at least equal to the traditional feed. Many studies have shown that, given the lack of adequate animal feeds, especially in desert conditions, certain varieties have been successfully cultivated and can be used as feed substitutes [54, 55].

It is important to keep in mind that if halophytes are used as feed, animals may need to increase the consumption of drinking water, and feed consumption per unit may increase in animal weight as a result of increased metal content in halophytes. The carcass fed to the ingredients of a diet containing halophytes is equal to that fed on traditional feeds. One of the most common halophytes studied and used is a *Salicornia* cultivar. The results of the University of Arizona on sheep showed that *Salicornia* (seeds and market) can be used, as well as the cut as an alternative to the processed barley or the cotton seed. *Salicornia* is cultivated to produce oil and straw seeds. Oil can be extracted from the seed age. Organic materials that are free of salts can be used in animal feed. Oil can also be used as a high energy source in animal feed, especially poultry. Mansour et al. [44] found that subsurface drip irrigation systems may increase water use efficiency due to reduced soil and plant surface evaporation and because only the root zone or the partial root zone is irrigated as opposed to sprinkler irrigation where the entire field area is wetted. Besides this physiological dimension, several studies have been conducted for development of irrigation systems for salinity management with drip irrigation using saline water [32]. According to [20], the DI permits a uniform and frequent application of water and a direct feeding of the plant at the root zone level, leading to an increase of yield and saving water [36]. According to [47], DI improves tomato yield and reduces leaf burn (browning). However, this system may result in localized accumulation of salts at the soil surface [72] due to increased evaporation. According to [39], salt accumulates on the soil surface before migrating and reaches the root zone when DI irrigation is used. Subsurface drip irrigation has been developed to improve salinity management and water use efficiency. According to [54], SDI decreases the accumulation of salts at the root zone level of plants, producing an improved yield and fruit quality.

## **4. Discussion**

Electrolysis is mainly used to desalinate half-saline groundwater. Electrolysis usually occurs because the salt is dissolved in water, which decomposes into

electrons (electrically charged particles) of sodium and chloride. Sodium ions carry a positive electrical charge and chloride ions carry a negative electrical charge. A wide chamber divided into several cells is used in electrolysis by means of thin plastic sheets called membranes. Two types of membranes are used, one of which allows only positive ions to pass through and the other passes only negative ions. There is a positive electrode in one of the terminal chambers and on the other end a negative electrode [19].

The freezing process depends on the established fact that ice crystals formed by salt water are saltfree. The most important disadvantages of this method are the problems caused by the transfer and purification of snow, and the most important advantages are reducing the deposition and corrosion as they are operating at relatively low temperatures [12–15].

The process of desalination is divided into two ways: direct freezing and indirect freezing in order to reduce costs and accelerate the provision of a larger volume of water needed, with the increasing need to exploit new sources of water to bridge the huge gap between supply and demand, to meet the need for development, and to meet population growth.

The matter of how to settle the desalination industry in the Arab world, especially in Egypt, was a target for the 11th Conference on Water Desalination, hosted by Cairo for the first time under the patronage of the Prime Minister [20–23]. About 400 Arab and international experts in water field and the organization of the Ministry of Housing represented by the Holding Company for Water and Drainage, in addition to the Saudi Arabia government, attended the event.

The conference, which was held under the slogan “Localization of the Desalination Industry in the Arab World”, came under the attention of seawater as a source that can be exploited to obtain water through desalination processes to fill part of the water gap.

In recent years, the need for desalination technology in many Arab countries, notably Saudi Arabia and the Gulf States, has succeeded in developing policies and administrative and technical systems that have made a successful and distinctive experience. Other Arab countries have been stranded for various reasons, despite their maritime coasts, due to the difficulty of obtaining appropriate technology and high costs, and the absence of culture adequate appropriateness [24–26].

Mansour et al. [46], the conference’s general secretary, stressed that water saving is one of the biggest challenges facing the Arab region, especially Egypt. It is suffering from a shortage of about 28 billion cubic meters annually, as well as rapid population growth, which requires additional new water resources, which led to the use of three new resources: desalination, reuse of wastewater, and groundwater. He added that it is necessary for all Arab countries to search for unconventional water resources under geographical determinants, including that most of the sources of rivers exist in non-Arab countries, as well as groundwater, as they are shared with other countries. He explained that the conference was prepared by a number of important international and Arab bodies, including Saudi Arabia, which produces about 1.60 billion cubic meters of water annually based on desalination technology and has considerable experience in this field, pointing out that the conference aims to benefit from these experiences for an institutional mechanism for cooperation with them and to promote the desalination industry in Egypt.

Considering that millions of cubic meters of freshwater are being wasted annually around the world, World Bank experts have alerted to the scarcity of water day after day, and experts fear that the world will not be able to provide the necessary water. He pointed out that by 2050, the availability of water will not exceed 10% of

the available water a century ago (i.e., since 1950, most Arab countries are among the most arid regions of the earth, 15 countries are the poorest in water, and the Arab citizen will receive only 700 m<sup>3</sup> or about 80% of the water poverty limit, a thousand cubic meters per year). Zuhair stated that the desalination industry is one of the main industries in the Arab world, especially when there are 115 countries with desalination plants, but because the cost of this technology is expensive, this should stimulate us to continue scientific research to develop scientific solutions to reduce this cost.

Mansour et al. [40] state that if we take a closer look at a country with water shortages, such as Egypt, it will produce about 93 million cubic meters of desalinated water, which corresponds to the population of 93 million people in Egypt. One cubic meter per person per year, the steady increase in population far outweighs the increase in water production. “The settlement is still a controversial term,” Fawzan said. “There are countries that have achieved a high degree of production, and other countries have gone a long way in scientific research,” he said. “The resettlement of technology is still a dream that we are waiting for.”

Abdul Majeed Al Awadhi, former Head of the Electricity and Water Authority in the Kingdom of Bahrain, talked about the desalination industry in the Gulf countries, pointing out that it reached about 70% of the water production in the United Arab Emirates (UAE), Qatar, and Bahrain and 40% in Saudi Arabia and Oman with an average of 60%. He explained that with the increasing demand for water, desalinated water is expected to become the main source in all Arab countries. He pointed out that the higher the desalination plants, the lower the cost, which currently ranges between one dollar and two dollars per cubic meter, and that there is a large gap between cost and revenue, which amounts to half a dollar per cubic meter. It is necessary to reduce this gap and provide a greater role for the private sector in this regard, according to his description. All desalination methods require large amounts of energy, and power generation is expensive whether it is generated by electric methods, by burning fuel, or by nuclear power plants.

Desalination may help mainly dry areas on the coasts but give little hope to overcome the scarcity of fresh water in cities that lie offshore or on mountains. Bringing water to these cities can be more expensive than desalination [15, 16].

The high cost of desalinating water is not important in places where only sea water is available. More than 200 water desalination plants have been established in the world, most notably in Saudi Arabia, Kuwait, Australia, California, Greenland, and some countries in South America. Some of these plants are small; many of which serve military centers in isolated places or serve as wells for desert diggers, island resorts, and industrial plants [17, 18].

The world's desalination plants produce more than 3.8 billion liters of fresh water per day. This production meets a fraction of the world's freshwater needs. A large water desalination plant, such as the one in Jubail, Saudi Arabia, has been designed to produce 950 million liters of fresh water per day. One of the most pressing dilemmas for humans is how to provide for the world's food and clothing needs, and the consequent provision of adequate natural resources, especially land and water, and thus provide adequate nutrition for the growing numbers of tropical and subtropical populations within the next 30 years [3].

## **5. Conclusion**

FAO estimates the need for land resources at about 200 million hectares as new agricultural land to produce various crops. Only 93 million hectares of land can be

used for agricultural expansion. Unfortunately, much of this space is now occupied by the forests that we must preserve to maintain the ecological balance and global climate of the entire planet. We can add to this difficult problem another factor the deterioration of fertile agricultural land, either as a result of destruction or salting or pollution in most of the lands of the countries of arid and semiarid regions, which stimulates the human need to find alternative sources of water and land to grow crops and increase vegetation.

In General, the Egyptian strategy should be not only focusing on water supply management but also managing water demand. Of which, 55 billion are from the Nile River and 5.2 from groundwater, the rest from rainwater and drainage, while desalinated water does not exceed 10% of water resources. The Egyptian water strategy should include increasing the amount of desalinated water to more than 50%, especially since Egypt is in a very rich location in saltwater sources that can be utilized to the maximum extent possible. Researchers have attempted to develop varieties of some traditional crops such as wheat that are saline resistant using local selective ecotourism techniques and using genetic engineering through which saline-tolerant genes are added, but it can be said that so far these efforts have not resulted in the production of candidate seawater breeds. The maximum salinity of irrigation water in the long term, even for the most salt-tolerant crops such as date palm, is still less than 5 mm. Sea salt salinity is between 35 and 40 mm. As we know, seawater is rich in sodium chloride, one of the most harmful substances to growing plants.

The use of nonconventional water resources and the preservation of what is already available are very important rules in all countries. One of the important ideas of the last half of the twentieth century was the use of seawater, the first serious appearance of the idea after the Second World War. The use of seawater is very possible in sandy and desert environments. The sea aids in the development of saline-tolerant crops in irrigated land. This idea is an ideal solution, with 97% of the world's water being brackish water (seas and oceans), while desert lands are also widespread, accounting for 43% of the land area.

## **Acknowledgements**

The authors would like to thank the “Grassland Talents” project, Inner Mongolia (2016) 40, Xilingol Vocational College; Talented Young Scientist Program (Egypt-18-050), CHINA; and the National Research Centre, EGYPT, for the support and fund for the publishing process of this research work.

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