Saltwater Farming

Farmers all around the world are faced with advancing salinization. Adapting crops and farming systems is now a crucial task for agricultural science. Reusing water, getting plants accustomed to salt, and new varieties offer prospects of success. 'We are getting more and more requests for research on irrigation with brackish water.' **TEXT** ARNO VAN 'T HOOG

ILLUSTRATIONS IEN VAN LAANEN & SCHWANDT INFOGRAPHICS

Given optimal water, nutrients, light and temperature, modern varieties of wheat, potatoes and rice do exactly what the farmer expects them to do. But fewer and fewer food crops get to grow under optimal conditions these days, says Gerard van der Linden, head of the Abiotic Stress research group in the Plant Breeding department at Wageningen UR.

More and more agricultural regions face water shortages and year after year there is more salt in the soil because irrigation water and fertilizer leave behind small quantities of salt after evaporation. The agricultural area exposed to this kind of salinization is growing worldwide by an estimated 250 to 500 hectares per year. And in low-lying delta regions there is additional salinization due to rising sea levels and falling volumes of water being brought down by rivers. 'For many years we have bred food crops for high production. Now we shall have to put more effort into improving their stress tolerance,' says Van der Linden.

Salt in the soil causes two kinds of stress in plants. The first is osmotic stress caused by a shortage of water. Osmosis is the movement of molecules in the direction of the place with the highest salt concentration. Even if the soil is saturated, if there is a lot of salt in the water, the plant experiences the effects of drought. 'With more salt in the ground it is much harder for plant roots to extract water from the soil. Whereas that water is badly needed for transporting various substances in the plant, as well as for keeping its cells firm.'

Plants could simply restore the balance between the salt concentrations inside and those outside by absorbing more salt. But this creates a second kind of stress: sodium – the main ingredient of kitchen salt – is highly poisonous to the plant, explains Van der Linden. 'Sodium takes the place of potassium in the plant, preventing various proteins from working properly. This disrupts photosynthesis and other important processes.'

LOWER YIELDS

The combination of a water shortage and the toxic effect of salt mean that salinization quickly leads to slower growth and lower yields of food crops. But plants are not all equally sensitive: some crops can cope better than others with salt in the soil, explains Greet Blom, who researches silt farming systems at Plant Research International.

In a report she published in the middle of last year, there are several graphs showing how fast the yields of different agricultural crops fall as concentrations of salt in the soil rise. Rice is much more sensitive than wheat or barley. At a concentration equivalent to six grams of kitchen salt per litre, rice refuses to grow, whereas barley and wheat continue to do so, albeit with a 40 percent lower yield. Only at a salt concentration of around 15 grams per litre do wheat and barley give up the battle. To put this in perspective: chicken stock contains 5 to 6 grams of salt per litre; seawater contains an average of 35 grams per litre.

'Those, at least, are the data on salt sensitivity that are known from the literature,' comments Blom. 'At a guess you could end up with higher salt concentrations, by forcing plants to adapt.' Exposure to salt initially leads to stress and delayed growth, but if plants are able to adapt, they may then be able to tolerate those salt concentrations.

One method of forcing plants to adapt is partial root zone irrigation, says Blom. Instead of watering the whole plant at a go, in turns one half of the plant gets slightly salty water and the other does not. Agricultural researchers are also testing this system as a way of getting plants accustomed to water shortages, by exposing half the plant at a time to drought. 'It appears that plants react to this kind of mild stress by activating their hormone system. That gets various physiological mechanisms going, which can lead to adaptation. I find that a very interesting strategy to work out further.'

According to Blom, it is important not to try to fight salinization but to develop farming systems in which production is still possible with slightly saline water and soils. 'We are getting more and more requests from abroad for research on irrigation with brackish water.' One possibility is to avoid watering from above, because many crops are extra sensitive to salt on their leaves. Another strategy is mulching: creating a layer of straw or leaves which reduces evaporation and with it salinization, as well as insulating the soil from high temperatures.

FISH AND DATE PALMS

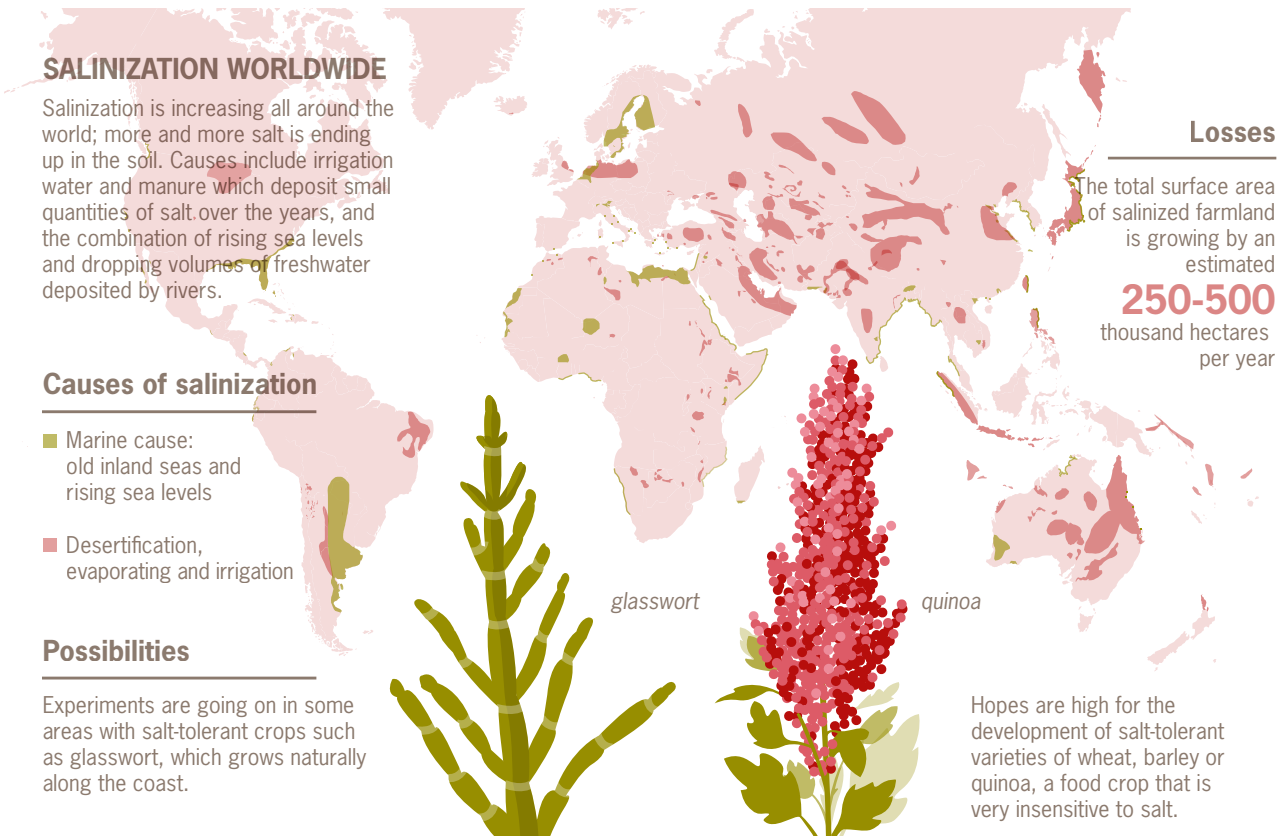
In desert areas such as Egypt, research is going on into the use of brackish groundwater for a combination of agriculture and >

'Through the exposure to salt, diseases get more of a chance'

fish farming. Some species of fish such as tilapia thrive in brackish water, and the idea is to use waste water from fish farms to irrigate date palms, sugar cane and other crops which are not so sensitive to salt. There are already several companies in Egypt which combine farming tilapia with producing wheat, fruit and horticultural crops. Moreover, there are some major investments ahead in the use of brackish groundwater, according to an Alterra report that came out in May last year. The report was positive about the feasibility of this in Egypt as long as a few legal and technical hurdles are removed.

In the Netherlands, silt farming is already under way on a small scale, for the cultivation of glasswort for instance (see box). That is primarily a culinary specialty rather than an energy-rich food crop for mass consumption. For that purpose, a leading role in silt farming may be reserved for quinoa, a crop that has gained enormous popularity among Western consumers as an alternative to rice and potatoes. 'Quinoa is very exceptional,' explains Van der Linden. 'It is one of the few food crops that are extremely insensitive to salt. At concentrations of 15 grams per litre, this plant still does fine. There are even varieties that grow in seawater. Quinoa may well become the new staple crop.'

Van der Linden and his colleague Robert van Loo are doing research on the salt tolerance of quinoa. Exactly how the plant manages it is not entirely clear. The crop has developed a range of mechanisms for limiting the



consequences of osmotic stress and for removing toxic sodium from the sensitive parts of the plant. Quinoa stores sodium in the vacuoles of the leaves. Vacuoles form the cell's central water reservoir. Sodium there cannot do any more damage and the rest of the cell carries on functioning normally.

KEEPING SODIUM AT BAY

Insight into the mechanisms at work in quinoa can help improve other agricultural crops. There has already been progress in the field of plant-breeding, says Van der Linden. In Australia, for instance, a new wheat variety has been introduced which grows better on the naturally saline farmland there. 'Australian researchers found a gene called HKT in wild wheat varieties, which ensures that the plant keeps sodium at bay in the roots. That hereditary characteristic was then bred into a commercial wheat variety, bringing about yields that were 25 percent higher.'

Cross-breeding with HKT varieties which make plants more salt-tolerant is a fruitful strategy, thinks Van der Linden. He is studying the HKT gene in barley varieties with a view to making it possible to breed for greater salt tolerance. In Asian research on breeding rice, the same strategy produced a new variety that does better in low-lying delta areas such as Bangladesh, where frequent flooding leaves salt behind in the soil.

Described like this, it may sound as though the problem of salt tolerance in agriculture is already largely solved, but that is not the case, says Van der Linden. 'There is no holy grail that will solve all the problems once you can find it. And it is never just about one characteristic; it is a question of the total picture of stress tolerance, growth, yield, disease resistance and taste characteristics. Take the tomato for instance: if you grow tomatoes in slightly more saline conditions, they become much more vulnerable to mildew. Through the stress of exposure to salt, diseases get more of a chance.' Salt also affects the taste of the tomato, and you never know what the consumer will think of that. 'In short, that is the big challenge for plant breeders,' says Van der Linden. 'How do you improve stress tolerance in combination with all those other characteristics?' ■

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GLASSWORT IN THE PADDIES

It is not only in dry regions that salt causes trouble for farmers. Salinization can also hamper crop farming on low-lying land behind the dikes of coasts and deltas. A few dozen farmers in the Netherlands have made a virtue of a necessity by starting to grow glasswort. This is a decidedly salt-loving plant which grows wild along the banks of the Oosterschelde estuary and the Wadden sea coast. 'The market for glasswort is small,' says Greet Blom, who did research on cultivation systems and their economic feasibility in the context of the Zeeuwse Tong project. 'It is mainly popular in up-market restaurants.' The cultivation system resembles that of a rice paddy: diked fields in which the salt water levels can be raised at lowered at will. It is a very labour-intensive crop, says Blom. Salt-loving weeds grow like wildfire and weeding has to be done by hand because weed killer would get straight into the groundwater.

The farmer can easily spend 40,000 euros on labour per hectare of glasswort. When you add other investments – especially in seed – the costs go up to 89,000 euros per hectare. This means the crop needs to fetch a hefty price per kilo. It is currently managing to do so but the margin is small and the competition with imported glasswort is fierce.

GLOBAL FORUM FOR INNOVATIONS IN AGRICULTURE

Gerard van der Linden and Greet Blom will be speaking about saltwater agriculture in March at the Global Forum for Innovations in Agriculture (GFIA) in Abu Dhabi. The conference deals with innovations in the field of climate smart agriculture, food losses, urban farming and water. Wageningen will be represented by Louise Fresco and about 10 other researchers in various fields.
www.innovationsinagriculture.com