Soil and water salinization and the development of organic saline crops

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Abstract

Saline water and soils present an increasing problem for agriculture. Adaptation strategies include selection of existing crops for salt tolerance, and development of new salt-tolerant or halophyte crops. As saline areas are often located near sensitive nature conservation areas, the development of saline crops represents a challenge to sustainable and organic agriculture.

In small field plots we tested the salt tolerance of two wild plant species that have some potential as saline crops: seakale and seabeet. We also tested the crop performance of seakale, on larger field plots.

Our results show that seakale can be classified as salt-tolerant and seabeet as halophyte. In the larger field tests the performance of seakale was poor on soils saturated with (fresh) water, showing the need for adapted crop management.

We conclude that the development of new saline crops has potential. However, there is still a long way to go before these crops can be produced on a larger scale.

Introduction

Worldwide, salinization of soils and water bodies and agricultural use of and competition for scarce freshwater resources are increasing problems (Rozema & Flowers, 2008, Pimentel et al., 1997) . According to current estimates, about 7% of the global land area (including 20% of irrigated land area) is salt-affected (Figure 1A; De Vos, 2011).

In the Netherlands, large areas of the country are situated below sea level and include historical tidal zones. In these areas salt water is present in the subsoil (e.g. Post et al., 2003).

During summer droughts, the freshwater lens on top of this salt water is depleted, leading to capillary rise of salt water and damage to topsoils and crops (De Vos, 2011; Figure 1B). Furthermore, in various parts of the country near coastal areas, irrigation becomes impossible due to saltwater intrusion into surface water bodies.

In the Netherlands, current efforts of agriculture to adapt to these conditions are focusing on two main strategies: firstly to test existing crops and cultivars for their salt tolerance in order to minimize damage, and secondly to search for new, highly salt-tolerant crops in order to reclaim salinized/salt-affected areas that are already lost for agriculture. For organic and sustainable agriculture the development of saline crops presents a particular challenge, as salinized soils are often located near (coastal) nature conservation areas that are sensitive to eutrophication.

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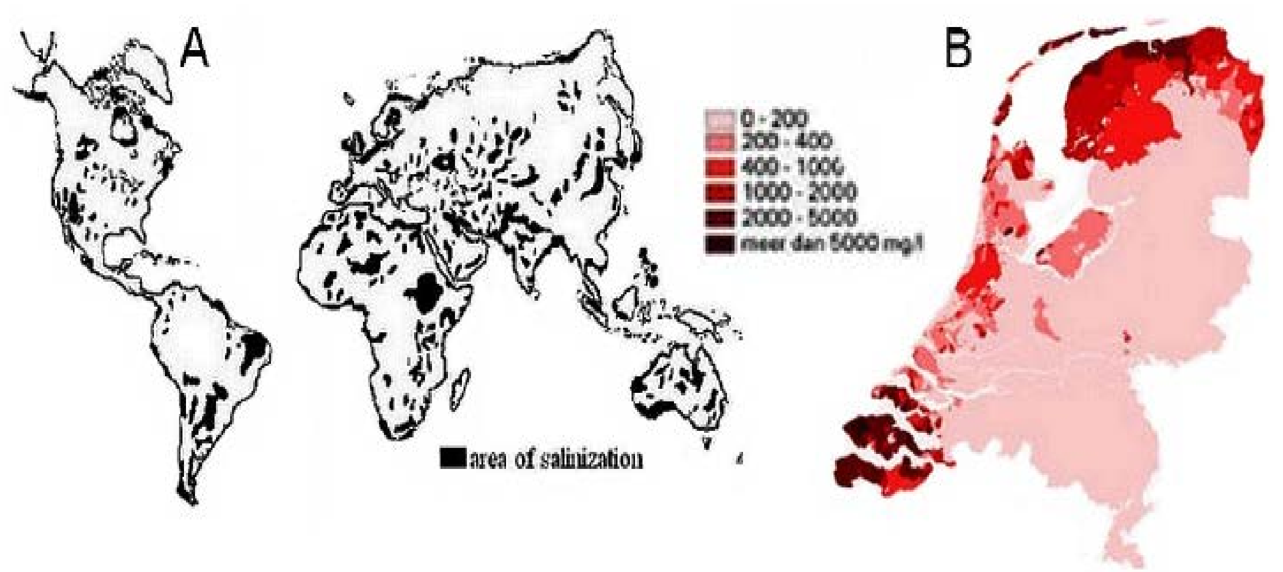

Figure 1: A: World map of soil salinization; B: Average chloride concentration (mg/L) of surface water in July during a dry year in the Netherlands. Figures adapted from De Vos (2011).

Salt tolerance in crops, whether existing or new, can be characterized by two parameters: firstly, the level of salinity above which plant damage occurs (where damage is often expressed as a decrease in yield or some growth parameter), and secondly the slope of the regression line between soil salinity and plant damage.

In our study, we measured the salt tolerance of two wild plant species that have potential as saline crops, seakale (Crambe maritima) and seabeet (Beta vulgaris subsp. Maritima), in small field plots at different salinity levels. Secondly, we tested the performance of seakale grown on a larger scale as an agricultural crop.

Material and methods

At a unique experimental field facility of an organically managed farm in the north of the Netherlands, we grew seakale and seabeet at 4 levels of salinity, applying saline waterby drip irrigation during the growing season. Salinity levels (measured as EC in saturated soil paste) were around 0 dS/m, 12 dS/m, 20 dS/m and 35 dS/m, and plot size was 1.25 by 1.25 m, with 4 replicate plots for each treatment. At various times during the 2013 growing season, we conducted non-destructive and destructive measurements, including plant height measurements on 31 July as presented in Figure 2.

In a second experiment, performed in 2011 and 2012, seakale was grown in larger field plots (1.2 x 15 m), with saltwater spray or sweetwater spray to simulate coastal conditions, and different levels of manure application (0, 70 and 100 kg N per ha applied as organic pellets, with and without compost, four replicates per treatment, data not shown), to test its performance as an agricultural crop. All plots were located an organic farm and managed organically. Plant numbers were counted at 52, 71 and 112 days after planting (DAP). The whole season had high rainfall, and 25 May and 13 June, soil moisture content was measured by sampling the top 10 cm of the soil and drying the samples in a stove at 70oC for 48 hours.

Results

Our field tests showed that seakale can be classified as salt-tolerant: up to an EC of 10 dS/m (during the entire growing season), seakale plants performed reasonably well (Figure 2). At higher salinity levels average plant height decreased, but the slope of this effect was relatively shallow, compared to the slope of salt-sensitive crops (Figure 2). Seabeet performed even better: this species did not show any damage (or even performed better than at 0 dS/m) up to ECs of 20 dS/m. At higher salinity levels only a slight decrease in growth performance was observed.

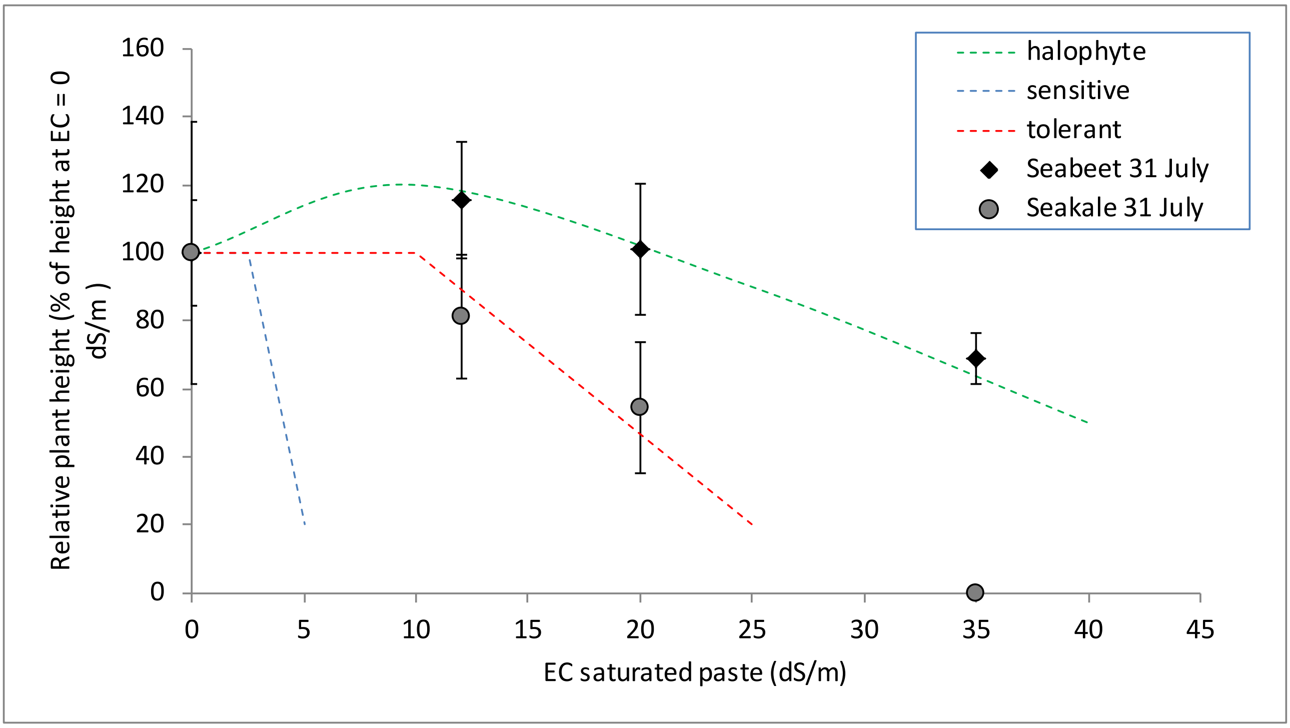

Figure 2. Relative plant height of seakale and seabeet at different soil salinity levels, as measured on 31 July 2013. The dotted lines are the theoretical curves for salt-sensitive , salt-tolerant and halophyte plants (after De Vos, 2011). Error bars indicate standard error of the mean. Seawater around the Netherlands ranges in salinity from ~30 to 55 dS/m.

Testing the crop performance of seakale in larger field plots showed surprising new problems: in the second year we tested this species (2012), a large number of plants died (Figure 3A) or showed very slow growth (3B), even though general growing conditions seemed to be good. Salt or manure treatments did not show a clear effect on plant performance. Both plant number and plant height were negatively correlated to soil saturation with fresh water during periods of heavy rainfall (e.g. the first two weeks of June, 2012). The occurring plant death seems to be associated with a disease that needs yet to be identified. There are indications that this disease is caused by a complex of fungi and occurs under specific environmental conditions (saturation of the soil with fresh water);

Discussion and conclusions

Our first results show that there are prospects for the development of new saline crops. For example seakale was shown to be quite salt-tolerant; this species could be grown in many salt-affected areas in the Netherlands. Seabeet showed to be a real halophyte. At 35 dS/m, almost as saline as seawater north of the Netherlands, seabeet showed a decrease in plant height of only about 30%, whereas it meant a certain death for most other tested plants (including most weeds).

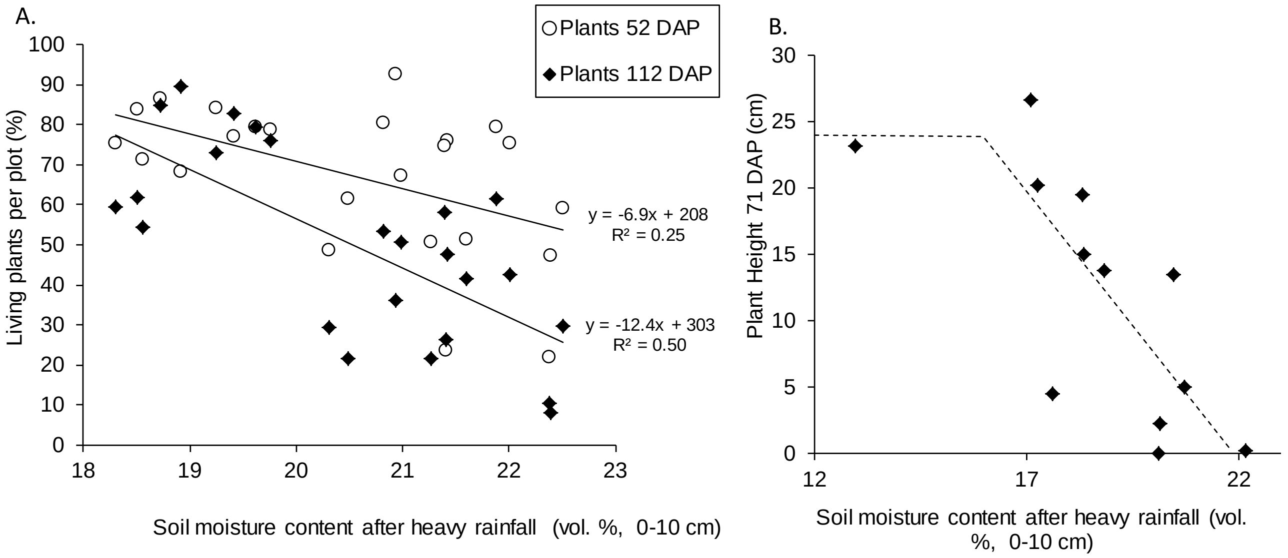

Figure 3. The performance of Seakale as an organically grown crop. Left: Correlation between plant number and soil moisture content (significant with p=0.012 at 52 DAP and p<0.001 at 112 DAP). Right: Correlation between plant height and soil moisture content. The dotted line indicates the theoretical relation, significant above 16% soil moisture (p=0.011).

Secondly, our results show that there is still a long way to go between identifying salt-tolerant and halophytic wild plants, and achieving stable crop production with these species. We selected seakale for the larger-scale field tests because there already is a market for seakale, and on a small scale it has been grown for some years already. The massive plant death observed in 2012, also observed by growers some years ago, is an example of the risks associated with growing new crop species.

In conclusion, the development of saline crops has potential, but still some problems have to be overcome. As saline areas are often located near vulnerable coastal nature areas, the production of saline crops presents a particular challenge for organic and sustainable agriculture. Some wild species, such as Salicornia, are already being produced organically on a commercial scale, but for other potentially suitable species, there is still a long way to go.

Acknowledgements

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