Integrated "in soil" desalination and irrigation – promising preliminary results in Turkana

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1 Background

Crop farming, livestock and afforestation in many of the Arid and Semi-Arid Lands (ASAL) parts of Kenya depend on water from underground resources that is often saline. ('brackish water'). This salinity is a serious issue not just for human health through direct consumption of water, but also for animal health and crop growth and development. Saline water reduces the yield and quality of many crops including maize, a staple diet in Kenya, and irrigation with saline water also degrades the quality of the soil overtime ('soil salinization').

Therefore, as part of a wider project on "Enhanced Food Security and Afforestation through Novel Approaches to Irrigation", our research team focused on developing improved or novel irrigation methods that allowed the use of saline water to grow crops and tree saplings, with applications in Kenya and other similar Arid and Semi-Arid Land (ASAL) regions of the world.

This short report focuses on the part of the project that investigated simultaneous desalination and irrigation directly in the soil. New techniques including vapour-fed SAP irrigation were developed and tested that provided water to plant roots while preventing contact of the salinity with the soil. They relied on in-situ vapourization in the soil, and could be more effective in preserving the soil than direct irrigation using brackish water. Other, more conventional techniques were also tested to improve the survivability of tree saplings. We found that

- Vapour-fed SAP irrigation from pitcher bottles significantly improved yields of dual-use sorghum compared with other techniques.
- Even without SAP, vapour-fed irrigation from pitchers ('condensation irrigation') was effective for slow growing tree species, a remarkable result. The survival and growth rates of Mango, Guava and Acacia saplings were similar to those with direct watering.
- When using direct watering, the survivability of tree saplings significantly improved when SAP were incorporated in the soil, though this would not prevent salinization.

2 Methods

Following an original method devised at Edinburgh University, Super Absorbent Polymers (SAPs) buried in soil captured the moisture and condensate that was produced by the

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evaporation of brackish water. The water was held in impervious containers that had opening in the headspace. The containers were buried in the warm soil of Turkana with their tops exposed to sunlight.

Anecdotal observation supported the suggestion that evaporation losses were significant in the conventional buried pitcher irrigation method. The combination of suitably modified pitchers (which are glazed in the bottom half where the water is placed, to prevent saline water from seeping into the soil) and SAPs in the soil (placed near the openings of the pitchers in the headspace above the water) could provide integrated desalination and irrigation to plant roots while preventing salinization of the soil. The pitchers could also be made from plastic bottles with holes near the top. Figure 1 illustrates the concept.

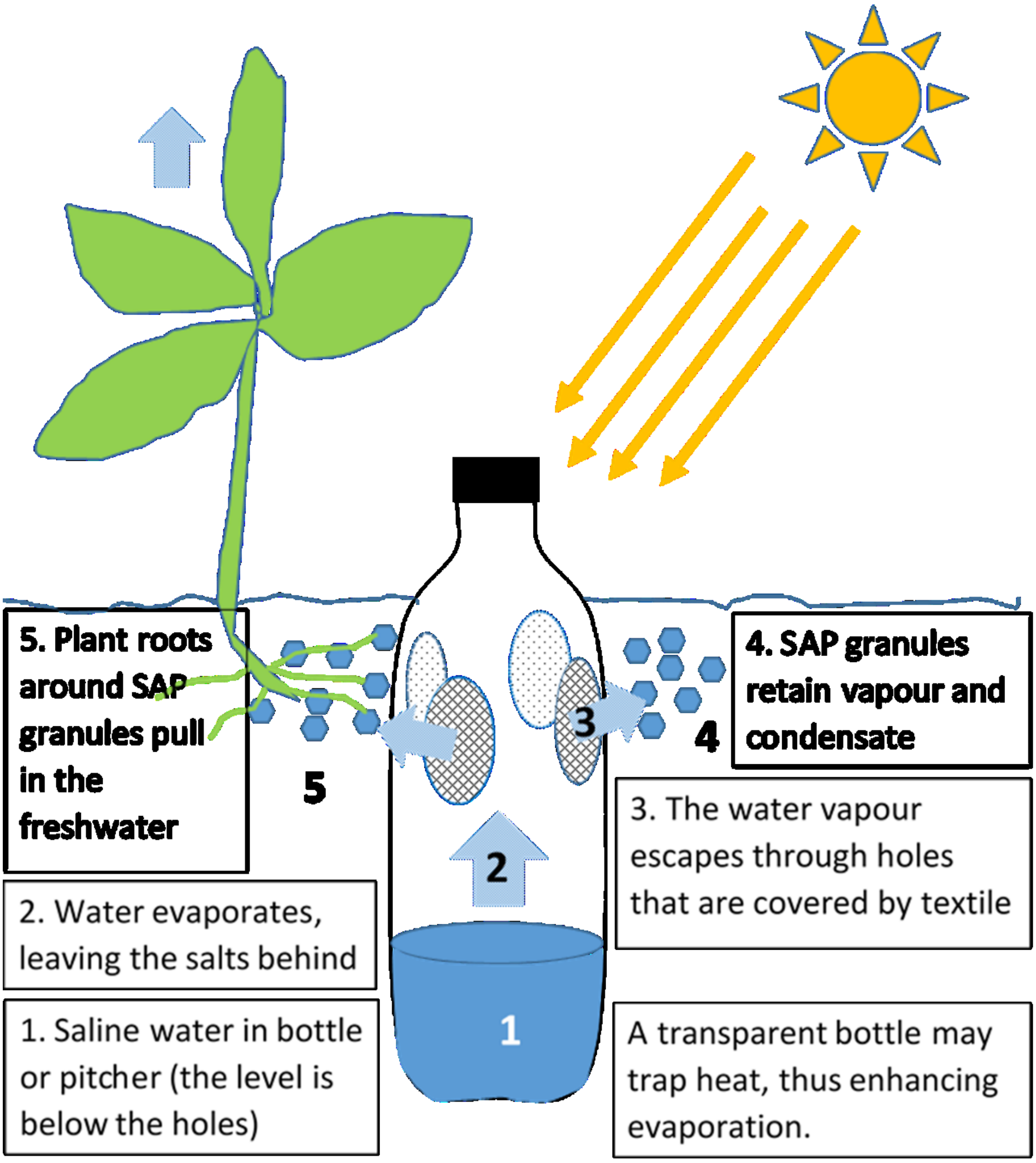

Figure 1: Tentative integrated irrigation and desalination by humidity absorption using SAPs.

SAPs are commercially available for use in horticulture in conjunction with conventional forms of watering, at a cost of around 150 KSh per kg and application rates of a few kg / ha. A typical application rate in the field is of the order of a few kilos per hectare, e.g. 5 kg/ha in the arid North of China when growing sweetcorn there.

Our novel method of using SAPs for integrated irrigation and desalination relies on the absorption rate by the SAP matching the evaporation rate from the pitcher, in which the absorptive capacity of the SAP can buffer the plant against evaporative losses from the soil. Both values were measured in Edinburgh for a common SAP (Na, K polyacrylate).

KALRO tested this method in the field using sodium polyacrylate as the SAP. The crop was dual-purpose Sorghum (variety BJ28), which was chosen specifically as it is of interest to pastoralists communities for food and fodder, and because it is also drought resistant (growing again after drought stress). The experiments were run in two sites in Lodwar, Turkana: St Teresa's pastoral centre, and Bishop Mahon Primary school farm. Five different treatments were applied, each in five replicates (each consisting of nine plants growing around 20L plastic pitchers):

- SAP;
- biochar;
- plastic mulch, i.e. sheeting;
- organic mulch;
- control (no additive or mulching).

KEFRI also tested two methods: conventional 'condensation' irrigation using plastic pitcher, as well as direct irrigation with brackish water using SAP in soil, in Nanyee in Turkana. The aim was to test tree establishments with different irrigation methods, a particularly important step in the afforestation process and in horticulture since tree saplings are much more vulnerable to drought and poor quality of soil surface than established trees. Different species of trees were planted with the following treatments:

- SAPs and direct watering (150 g SAP into the soil where tree seedlings were planted).
- Condensation (no SAP): 20-litre pitcher bottles buried adjacent to the plant.
- Condensation (no SAP): 20-litre pitcher bottles buried 1m away from the plant.
- Control (no SAP, direct watering).

After extensive site preparation (fencing, digging of '*zai'* pits and furrows, preparing the soil), planting started in August 2018 (KEFRI) and November 2018 (KALRO). Pictures of some of the field sites are shown in Figures 2, 3 and 4.

More detail on the method used for sorghum field trial can be found in Appendix 1. More detail on the method used for trials involving tree saplings can be found in Appendix 2.

Figure 2: KALRO testing site for sorghum using brackish water at St Teresa's Parish Centre in Lodwar. The bottles corresponding to the design in Fig. 2 are clearly visible.

Figure 3: Dual-purpose Sorghum variety (BJ28) growing in St Teresa site, with innovative vapour-fed SAP irrigation.

Figure 4: Measuring the root collar diameter of *Moringa oleifera*

3 Results

3.1 Growth performance of dual-purpose Sorghum

This subsection is a brief summary of some of the results from Appendix 1.

A field trial using dual-purpose Sorghum variety (BJ28) experiment was carried out at two sites. Figure 5 compares the mean heights of the plants for the different treatments.

The figure suggests that the vapour-fed SAP technique (rows S) can perform better than other techniques, with the advantage of avoiding bringing salts to the root zone in the soil.

Statistical analysis over the 30 days of the experiment (Duncan's Multiple Range Test) confirmed that the SAP treatment performed significantly better than the others:

- **The SAP treatment performed 15% better than the next best performing treatment (which was organic mulch).** There was a greater than 95% chance that this was not due to chance, i.e. 95 % likelihood or 5 % significance level.
- **The SAP treatment performed 34% better than the control** (95 % likelihood).
- **The organic mulch came second, 18% better than the control** (95% likelihood).

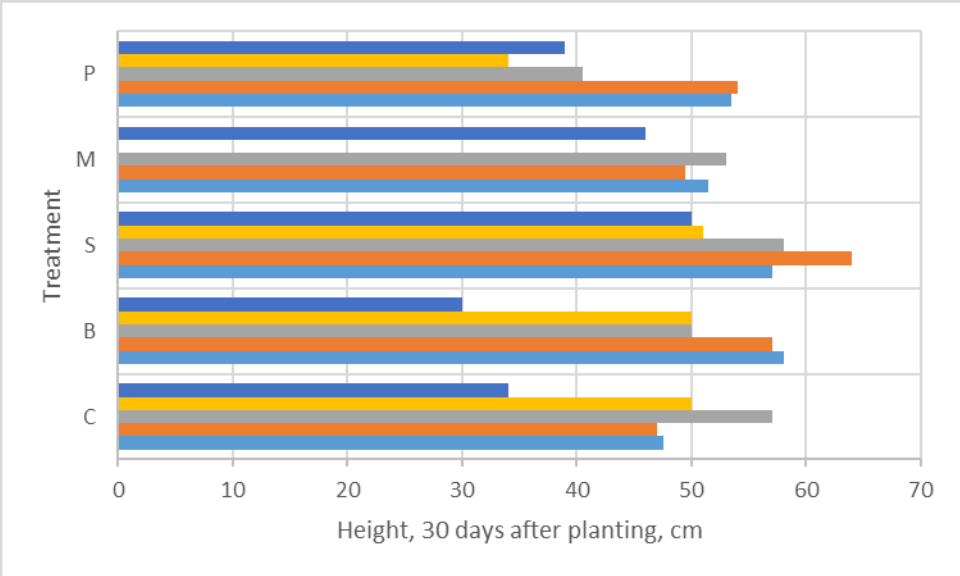

Figure 5: Results for Sorghum growth in St Teresa, 30 days after planting / onset of treatment. Treatments were P (plastic mulch), M (Organic mulch), S (SAP), B (Biochar) and C (control). For each treatment, 5 replicates were available (5 bars of different colours).

Figure 6 below shows the sorghum flowering fairly early after planting. While this could suggest water stress, local pastoralists were hoping that it would mean more frequent crops. Unfortunately, locusts destroyed the crop before we could measure the yields!

Figure 6: Sorghum at flowering stage at the St Teresa's test site.

3.2 Growth performance of tree species under different irrigation technologies

This subsection is a brief summary of some of the results from Appendix 2.

Figure 7a) shows the survival rates of four tree species under study at Nanyee, Turkana County after three months of transplanting and using different irrigation technologies: SAPs with direct watering; condensation irrigation with pitcher bottles, adjacent to plants; the same, but with plants 1 m away from the pitcher bottles; and control (direct watering, no SAP), as previously described in section 2.

Generally, trees grown under SAP treatment had higher survival rates (69% overall) compared to the control (44%). The finding that direct incorporation of SAP in the soil combined with watering as usual improves survivability of saplings is consistent with literature, but was tested here for the first time in Turkana.

Adjacent vapour-feeding pitchers overall performed slightly worse than the control (37.5%) when considering all species, but they were markedly better for certain species (Mango and Guava) at 50% compared with 25% for the control (same figures for both species).

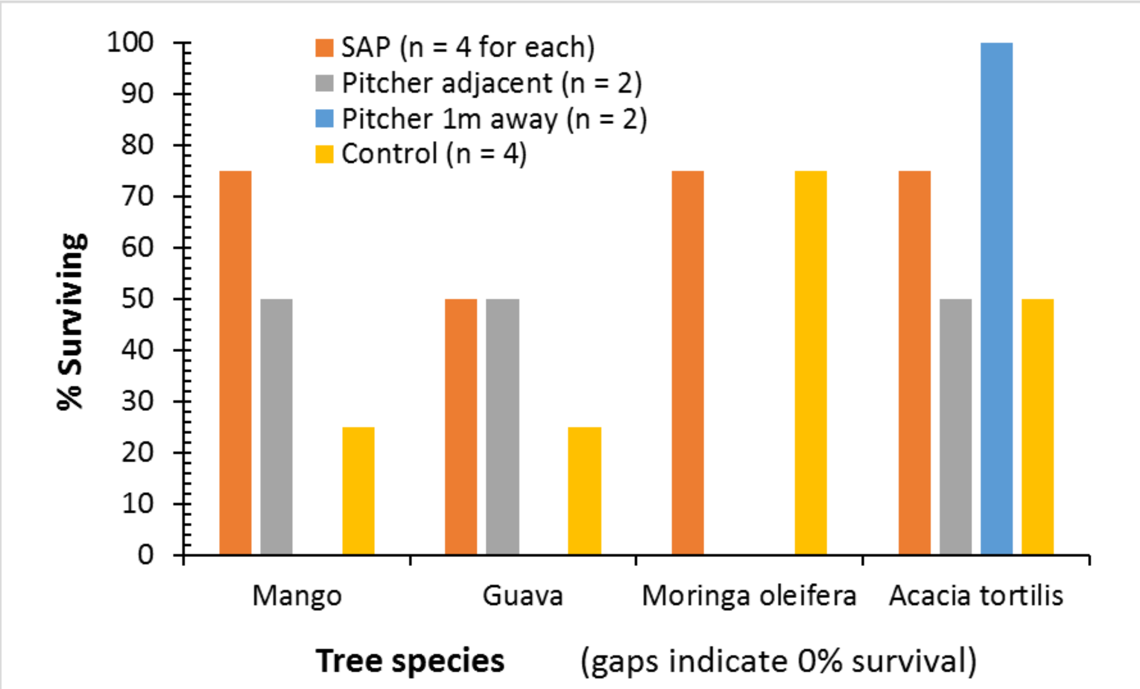

Figure 7 a): Survival rates of saplings of tree species under study at Nanyee after three months of transplanting ('pitcher' here refers only to plants that were adjacent to bottles).

When considering growth rates for Mango and Guava, adjacent vapour-feeding pitchers produced results that were comparable to the control, at 36% for Mango and 50% for Guava with adjacent vapour-feeding pitcher after three months compared with 56% for Mango and 30% for Guava with the Control treatment. **This result in itself is remarkable and promising.** Figure 7 b) compares the growth of Mango, Guava, as well as *Acacia tortilis* for these two techniques. Again, *Acacia tortilis* enjoyed comparable growth under vapour-feeding pitcher irrigation as it did with direct watering.

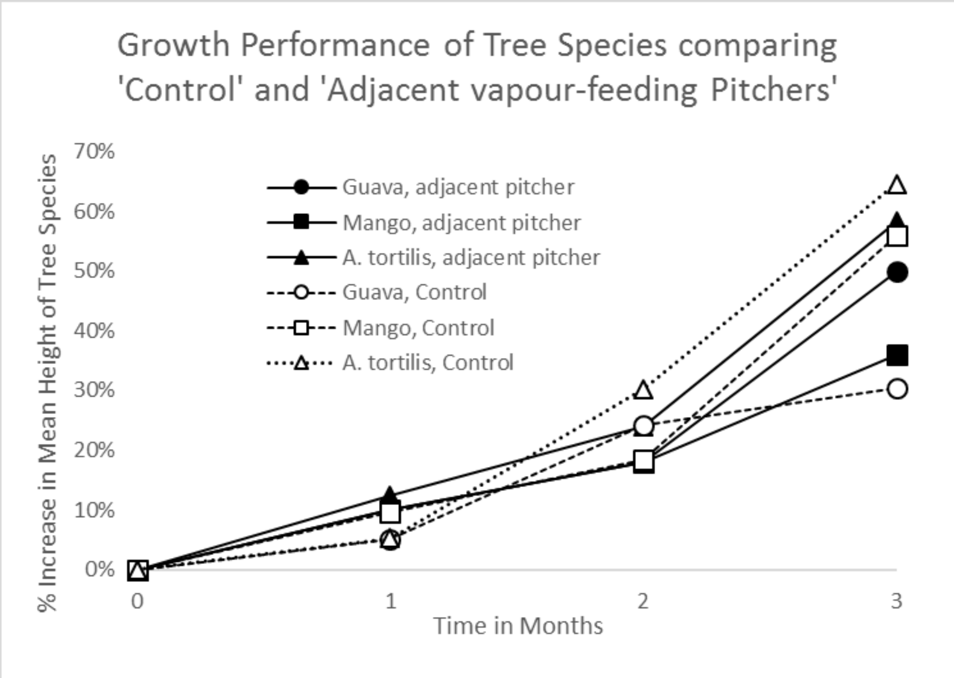

Figure 7b): Growth of Guava, Mango and *A. tortilis* under 'Control' and under 'Adjacent, vapour-feeding Pitchers' treatments over the three months after planting.

The 1m away vapour-feeding pitchers did not perform well with les resilient species, with none of the specimen of Mango, Guava and *Moringa oleifera* surviving the experiment.

4 Conclusion and future work

The results from our experiments looked very promising, with significantly better performance of crops and trees that were treated with SAP than with the control, and benefits found for grass seed germination rates (not reported here) and dual-purpose sorghum.

To our knowledge, the combination of condensation irrigation and SAP has been demonstrated here for the first time, achieving plant height that was 35% better than simple condensation irrigation after 30 days for dual purpose Sorghum. The use of organic mulch gave an 18% better result. It is suggested that the experiment be repeated with the combination of both SAP and organic mulch, and to full maturation of the crop, which unfortunately was interrupted by a locust attack on this occasion.

On its own, condensation irrigation also already significantly improved survivability of saplings, a result which suggest using this simple and economical technique in the reforestation effort in the ASAL regions of Kenya where only brackish water is available, and in other similar regions in the world. In fact, growth rates of slow growing species like Mango, Guava and Acacia were comparable to those achieved with direct watering.

It is worth noting that soil chemical quality will matter much. On another site where the soil was much more degraded (electrical conductivity was at the threshold for which a soil would be classified saline), there were no significant differences between techniques and growth was significantly more reduced. Therefore, soil characteristics including soil sodicity, salinity and pH must be addressed too.

Substantial improvements to the technique could be brought by

- Ensuring minimum shading of the transparent pitcher bottles for increased vapourization rates (care with placing plants on the North and South sides of the bottles since we are on or near the Equator; and leaving the East and West sides unshaded by plants).

- Cutting the openings in the bottle with an upper lip hanging over the lower edge, so that condensation would drip out of the bottle. This prevent the condensate from dripping back into the brackish water. Alternatively, or in addition to this, the bottles could be cut and refashioned so as to present inverted tunnels on the inside.of them that would direct the condensate to the openings.

- Using SAP made in the country from agricultural waste and sunlight rather than petrochemicals, in an attempt to cut costs and improve sustainability.

- Following the growth of the dual purpose sorghum right through to grain and harvest (this was prevented by an attack of locust).

- Comparing the effectiveness of the method on different sites with different soils, e.g. riverine vs. non riverine.

- Combining techniques together to maximise benefits and yields, e.g. vapour-feeding pitchers, SAPs, mulching and microcatchments.

We are now seeking partners and funding to conduct further work in these areas. Appendix 3 provides an example of a possible mini-project designed to investigate these approaches that was costed at US $ 20,000

Acknowledgements:

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