Salinity Control and Drip Irrigation for Silt Soils

Final report

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Trial site in Holbeach Marsh

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1 Field lab aims

Agriculture in eastern England is facing ever increasing pressures on freshwater resources, particularly in areas near the coast where saline intrusion of water courses is set to rise in the coming century. However, for several key crops in the region, irrigation is essential not only for healthy growth, but also for control of pests and diseases. In potato crops in the silt soils of South Lincolnshire, irrigation is widely adopted as a method of scab control on tubers.

Faced with increasing uncertainty on freshwater supplies, this field lab explores the use of brackish water (slightly saline) in irrigation of Maris Piper. In doing so, the trial measured a range of key crop yield parameter, levels of scab, and also a range of soil properties. The results will help inform not only crop tolerance and scab control from different sources of irrigation water, but also highlight any potential longer-term impacts to soil that may manifest for subsequent crops.

This field lab was instigated at the request of Nene Potatoes Ltd, one of whose members also hosted the trial.

2 Background

The Grade 1 silt soils of Holbeach Marsh and surrounding area are ideally suited for potato production. However, the region is also one the driest in the UK, and the water requirements for high yielding crops of marketable potatoes with good skin finish are high. Under future climate projections we anticipate more unpredictability in rainfall events, increased saline intrusion of groundwater reserves and therefore a more vulnerable freshwater supply, which could impact on potato yields in the area. As such, local growers are keen to explore novel ways of irrigation management to reduce water usage without affecting marketable yields or soil health.

In this trial, we explore two practices:

Brackish Water Irrigation

Much of the surface water (for abstraction) in the region remains brackish for large parts of the year, and there is also a shallow saline groundwater interface. If growers could utilise slightly more brackish water for irrigation, it would reduce their reliance on freshwater. This may also have wider societal and environmental benefits - reducing pressure on a limited freshwater reserve for all uses (household, industrial and agricultural).

Although there is a large body of work on salinity tolerance of conventional crops, much of the literature stems from trials conducted in more arid and semi-arid parts of the world. As such, there is limited data available for looking at the salinity tolerance of typical UK potato varies in UK soils and climatic conditions. However, we do know that introducing some degree of salinity into soils can have negative impacts on soil quality. This trial will investigate the effect of brackish water irrigation on Maris Piper yield and soil quality.

Trickle/Drip Irrigation

Trickle irrigation can be a much more efficient use of water than overhead delivery on silt soils. It could also avoid the problems of delivery into the ridge in hydrophobic soils and leaf scorch from a brackish application. In this trial we will apply brackish water treatments via drip irrigation, and compare with an adjacent overhead delivery system.

3 Methodology and data collection

To explore the impact of both higher levels of salinity in water, and the impact of trickle vs overhead irrigation, the trial consists of five plots in a field of Maris Piper:

- **Plot A**: Trickle irrigation with brackish water (high) (4000 ppm)
- **Plot B:** Trickle irrigation with reservoir water (950 ppm)
- **Plot C:** Trickle irrigation with (low) brackish water (2000 ppm)
- **Plot D:** No Irrigation
- **Plot E:** Overhead Irrigation with reservoir water (950 ppm)

The levels of salinity of each irrigation were decided based on available resource and know past trials. ~950 ppm represents similar salinity to reservoir water in the area at the time of sampling, and would represent a practical option for growers. 2000 and 4000 ppm represents higher threshold of salinity, although much less than local surface waters (6000 ppm recorded on 14 May 2020).

These plots have been installed in a subsection of a field of Maris Piper planted in Spring 2020, hosted by G H Hoyles. Much of the field was irrigated by overhead boom, which provides us our **Treatment 4.** A small section at the south end of the field has been installed with 3 No isolated trickle systems which connect to IBC units containing our selected water treatment. One further plot has no irrigation attached. A sketch of the trial plot set up can be seen in **Figure 1**.

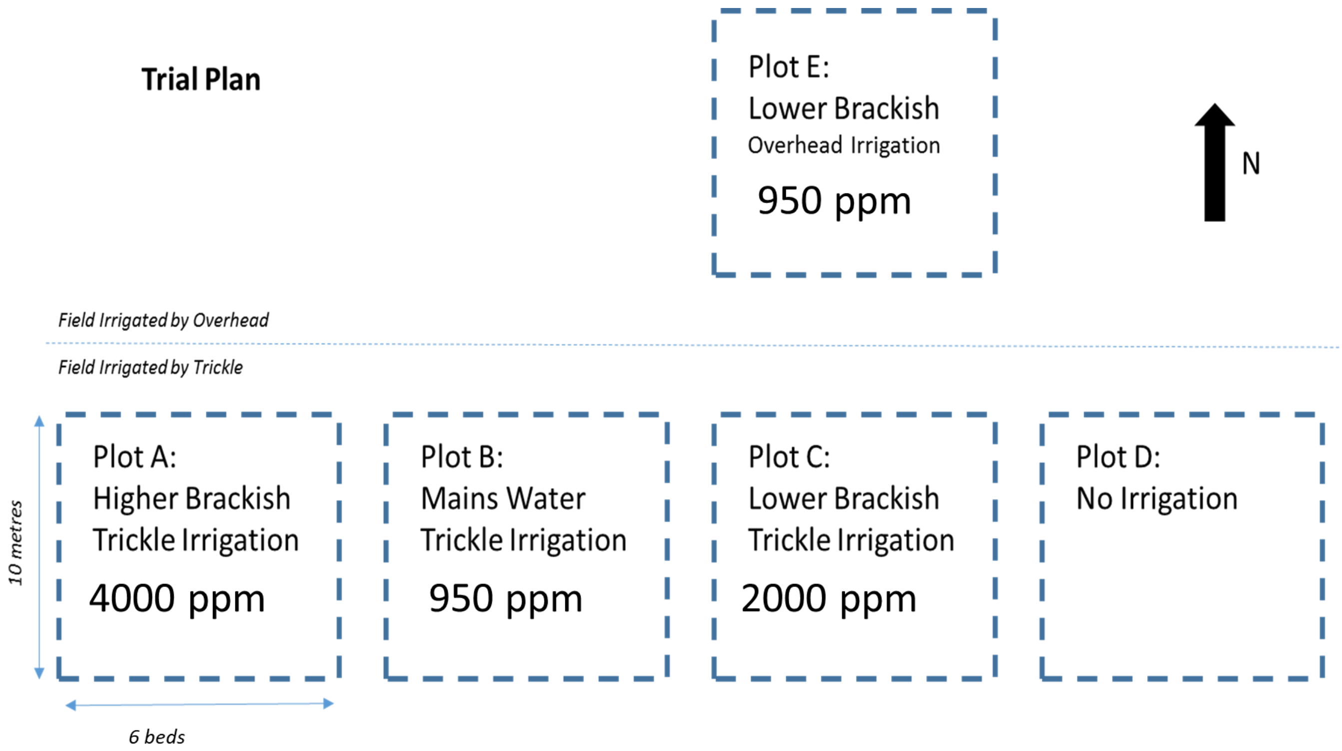


Figure 1: *Plan of Trial*

Soil Moisture probes (Soil Moisture Sense) were installed in Plot A, Plot C and Plot D in order to monitor moisture dynamics and inform irrigation scheduling. Baseline soil samples were taken (University of Lincoln) from two depths: 0-20cm and 50-70cm to assess soil quality pre-saline irrigation in topsoil and subsoil. The first irrigation event occurred on the 14th May 2020. IBC's were filled/diluted with the corresponding salinity levels and linked up to each individual plot by Andrew Howseman (Howseman Agriculture). Water samples from each IBC were also taken for analysis alongside the soil samples.

Figure 2: IBC connections to each plot

Figure 3: View of the field inc. soil moisture probe

Samplings and assessments

Crop Assessment

Crop Assessment was conducted by John Keer. Five replicate plots (3.0m row) per treatment were dug to provide data on tuber yield, tuber size distribution and tuber quality. The yield plots were marked out when the crop was at the rosette growth stage (20.05.2020). Early marking out was undertaken to ensure a similar number and size of plants per plot, to minimise the inherent yield variation in potato crops.
Haulm vigour was assessed as percentage groundcover on the following dates:

20.05.2020 rosette
29.05.2020 meeting in rows
04.06.2020 meeting in rows
11.06.2020 early flower
26.06.2020 full flower
02.07.2020 post flowering

Haulm vigour was assessed for each of five replicate plots per treatment, previously marked out for later yield/quality assessment.
Once the plots were lifted, tubers were immediately washed and graded into <45mm, 45-65mm, 65-85mm and >85mm size fractions. Tubers were also assessed for skin blemish disease as overall percentage of tuber area affected by Common scab and Black dot. "Skin brightness" was assessed using an arbitrary scale of 1- 10.

Soil Assessment

To track soil salinity and **chemical** changes throughout the trial, representative samples of topsoil (0-20cm) and subsoil (40-60cm) from each of the plots were taken in May 2020, July

2020, August 2020 and March 2021 and analysed for Exchangeable Sodium Percentage in Lancrop Laboratories. These time intervals represent before, during, after irrigation, with a final sampling in the spring in the following crop to assess any remaining salts.

As an assessment for **soil biological activity,** Soil Respiration Rates were measured with a portable InfraRed Gas Analyser in all plots in July and August 2020.

To assess **soil physical properties,** soil penetrometer readings were taken at the end of the trial (August 2020) and in the following crop (March 2021). Soil infiltration rates were measured in August 2020, but were unable to be measured in March 2021 due to heavy rainfall at time of sampling.

4 Results and discussions

The effect of water salinity and irrigation water delivery method on haulm vigour

Haulm vigour, assessed as percentage crop groundcover, was little affected by salinity level of the irrigation water or type of irrigation delivery (Fig. 4) No significant (P=0.05) haulm vigour differences were observed between treatments on assessment dates: 20.05.2020, 29.05.2020, 11.06.2020 and 02.07.2020.

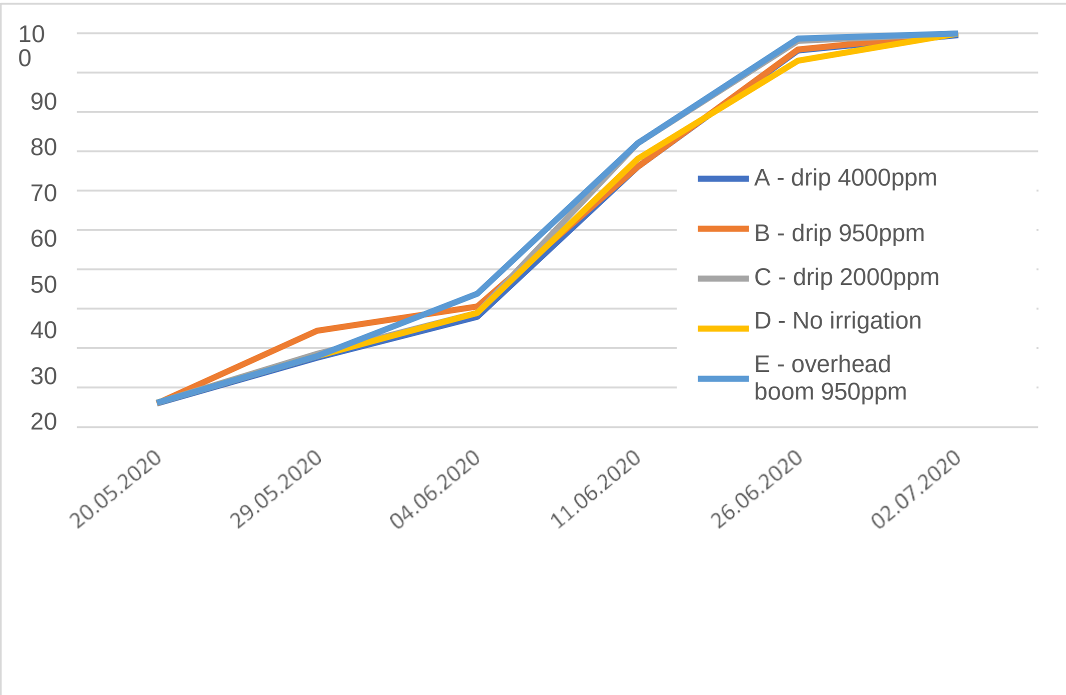


Figure 4. The effect of salinity and irrigation type on haulm vigour (% groundcover).

Overhead irrigation showed significantly (P=0.05) greater haulm vigour, temporarily, on 04.06.2020, compared with all other treatments. The unirrigated plots showed significantly (P=0.05) lower haulm vigour than all other treatments on 26.06.2020, although all treatments showed significantly (p=0.05) similar haulm vigour at the final assessment six days later. This difference could have been due to the very intermittent rainfall during the growing season.

Haulm vigour assessments indicated no significant (P=0.05) effect on the crop from any level of salinity in the trial. The haulm vigour assessments indicated that the crop was not under severe moisture stress during the 2020 growing season. The type of irrigation delivery method had no significant (P=0.05) effect on haulm vigour.

The effect of water salinity and irrigation water delivery method on potato yield and grade

Although less commercially important, the total tuber yield is the best biological measure of treatment effect. Total yield is significantly (P=0.05) similar for all treatments. The unirrigated plots showed the lowest total yield but were not significantly (P=0.05) different to the irrigated plots. The combination of high available water soil type and good regular rainfall events during July-Sept has resulted in a lack of yield response to irrigation.

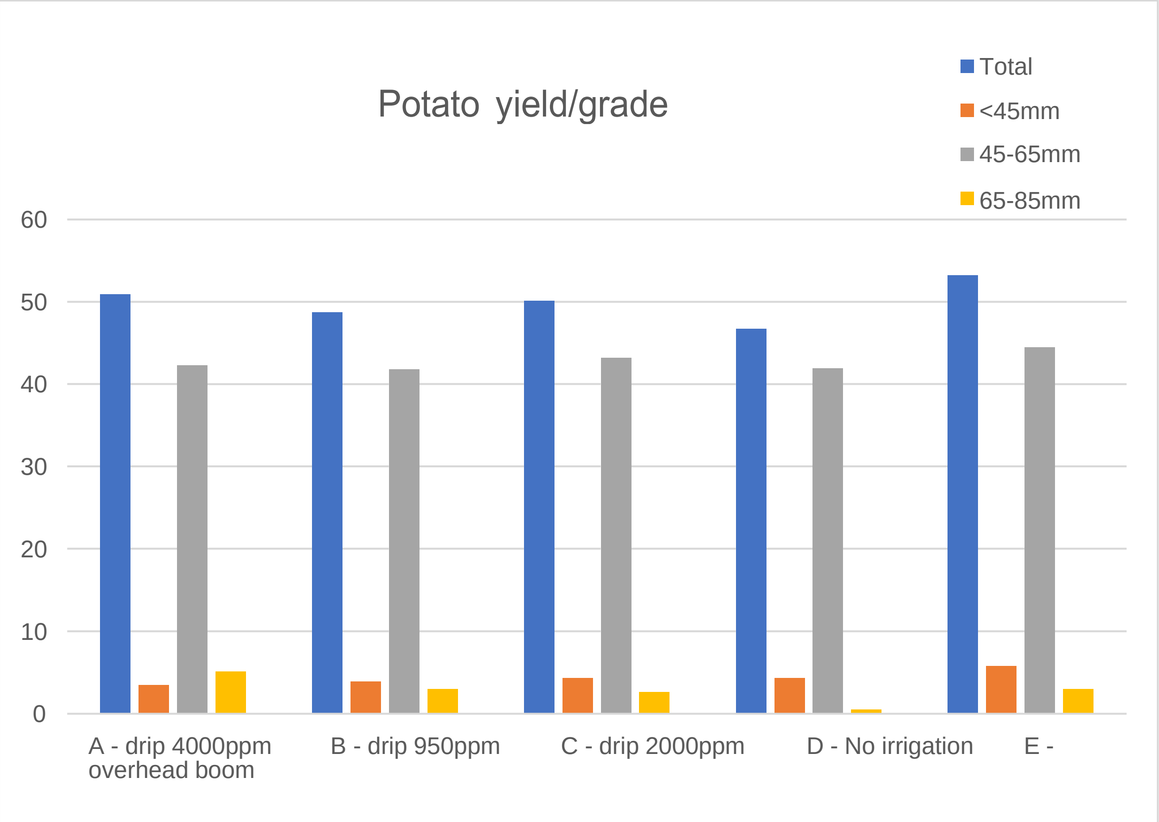


Figure 5. The effect of water salinity and irrigation delivery on potato yield and grade.

A similar pattern was found for the various size fractions assessed, with no significant (P=0.05) differences between any combination of size grade and treatment. Irrigation had not provided a bolder sample of tubers. No tubers >85mm were recorded. Importantly, the higher levels of salinity had not reduced yield or affected grade.

The effect of water salinity and irrigation water delivery method on tuber quality

The application of water demonstrated clear benefits in terms of tuber quality. Levels of Common scab have been significantly (P=0.05) reduced by irrigating water with a range of salinity levels and types of delivery. Water of all salinity levels and both methods of water delivery, all controlled Common scab equally well (P=0.05). Black dot levels were observed on tubers but no significant (P=0.05) treatment effects were recorded. Irrigation has been found to increase levels of Black dot (Managing the risk of Black dot. AHDB, 2008)

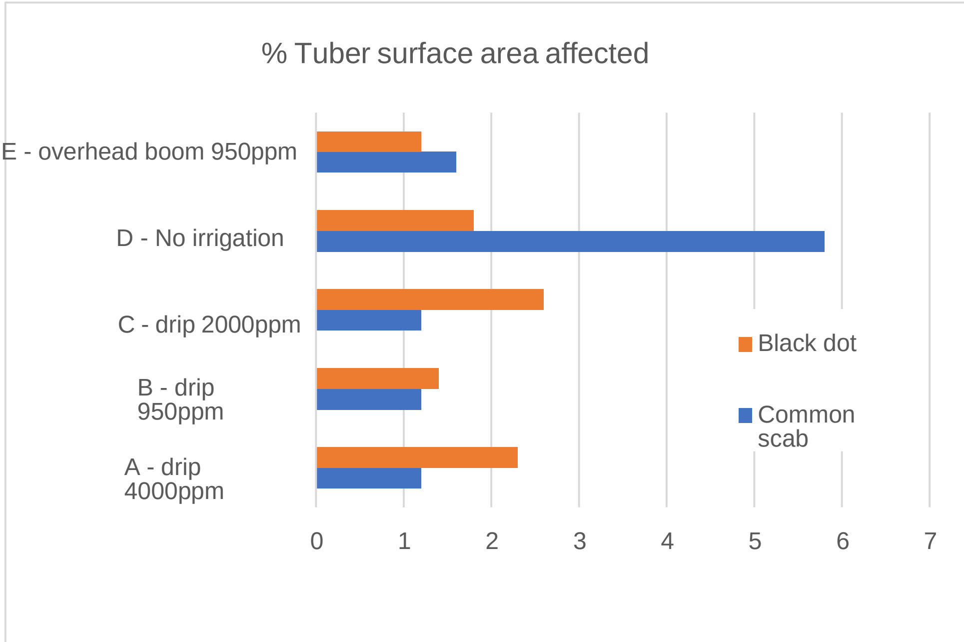


Figure 6. The effect of water salinity and irrigation delivery on tuber skin blemish diseases.

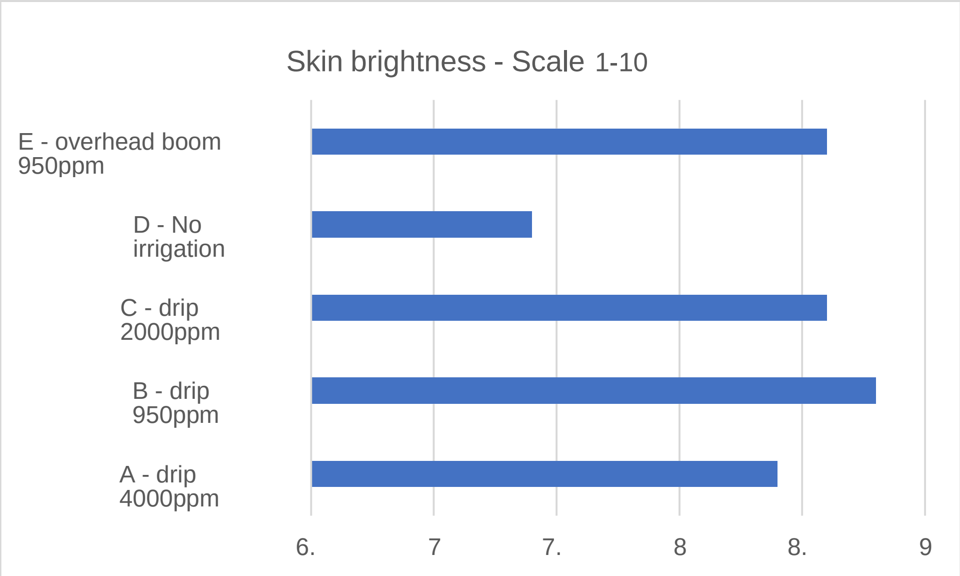


Figure 7, The effect of water salinity and irrigation delivery on tuber "skin brightness".

"Skin brightness" is difficult to quantify but by using an arbitrary scale of 1-10, with 10 being a perfect skin finish and 1 being unacceptable to the pre-pack market, significant (P=0.05) improvement from all irrigation treatments was found when compared to the unirrigated plots. Level of salinity and water delivery method did not significantly (P=0.05) affect "skin brightness".

Pictures of the effect of some treatments on tuber quality are shown in the plates below.

Plate 1. Treatment A – drip 4000ppm

Plate 2. Treatment B – drip 950ppm

Plate 3. Treatment C – drip 2000ppm

Plate 4. Treatment D – No irrigation

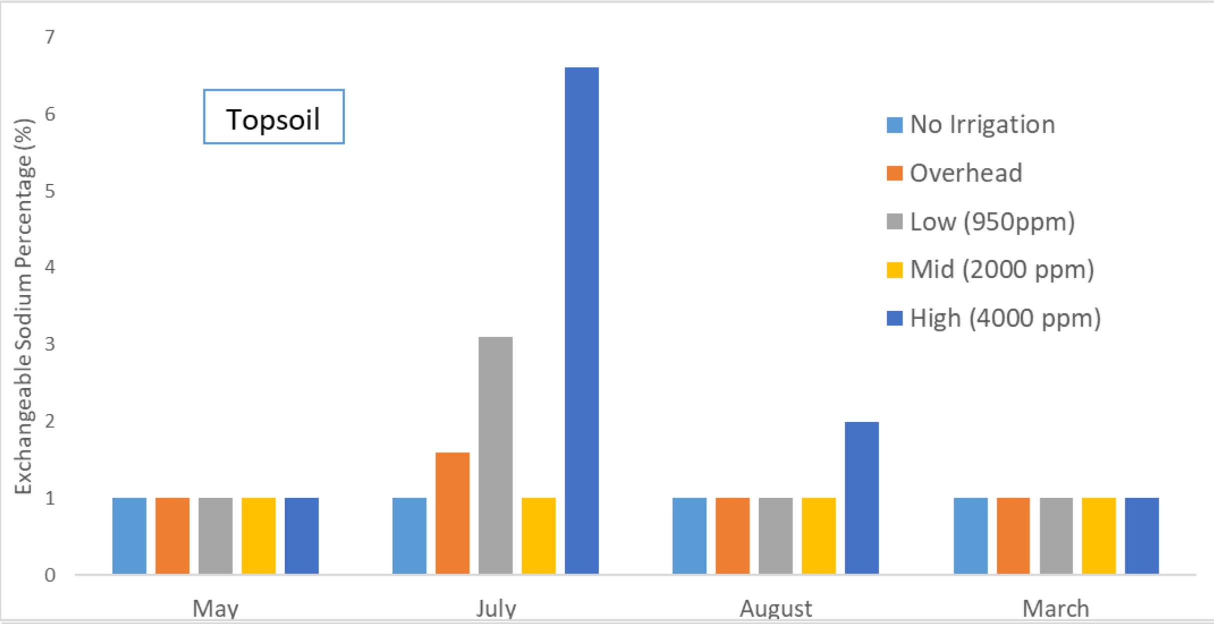
Plate 5. Treatment D – No irrigation (close-up)

Plate 6. Treatment E – Overhead boom 950ppm

Soil Measurements

Soil Sodium Levels

Exchangeable Sodium Percentage (ESP), represents the amount of sodium on soil colloids in relation to other, less damaging, cations. As such, it is a good indicator of too much sodium in a system. Figure 8 shows ESP values in Topsoil and Subsoil from pre-irrigation (May 2020) to the next year crop (March 2021). From base values of 1% pre-irrigation (May), Figure 8 shows that a sodium peak in topsoil samples is seen in July, after several weeks of brackish irrigation in the highest salinity plots. We also see a slight rise in the lower salinity plots. However, by the end of the trial, and into the next year's crop, we found that sodium levels in the topsoil have dropped back to normal, suggesting that any sodium applied from the brackish irrigation is no longer in the areas we sampled from. Furthermore, levels of sodium in the subsoil remain low throughout the trial, indicating no sodium risk at depth.



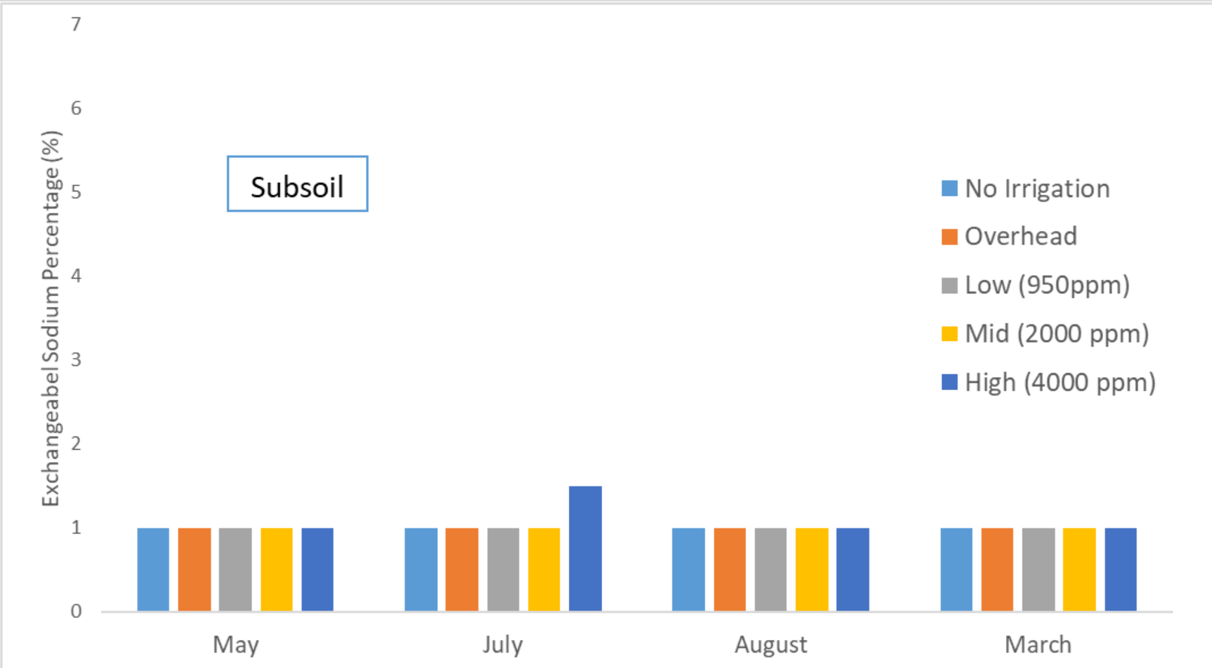


Figure 8. ESP levels in topsoil and subsoil throughout the trial

Soil Physical Properties

Penetrometer readings from the three trickle plots (950ppm, 2000 ppm and 4000ppm) were taken in August 2020 and March 2021 and are shown in Figure 9. Penetrometer readings show that the highest salinity plot, 4000 ppm tended to have higher penetration resistance at depth greater than 35cm compared to some of the other plots. Soil Infiltration rates were measured in August 2020 at the end of the trial, with the lowest salinity plot tending to show highest levels of infiltration, although this was not found to be significantly different (Figure 10).

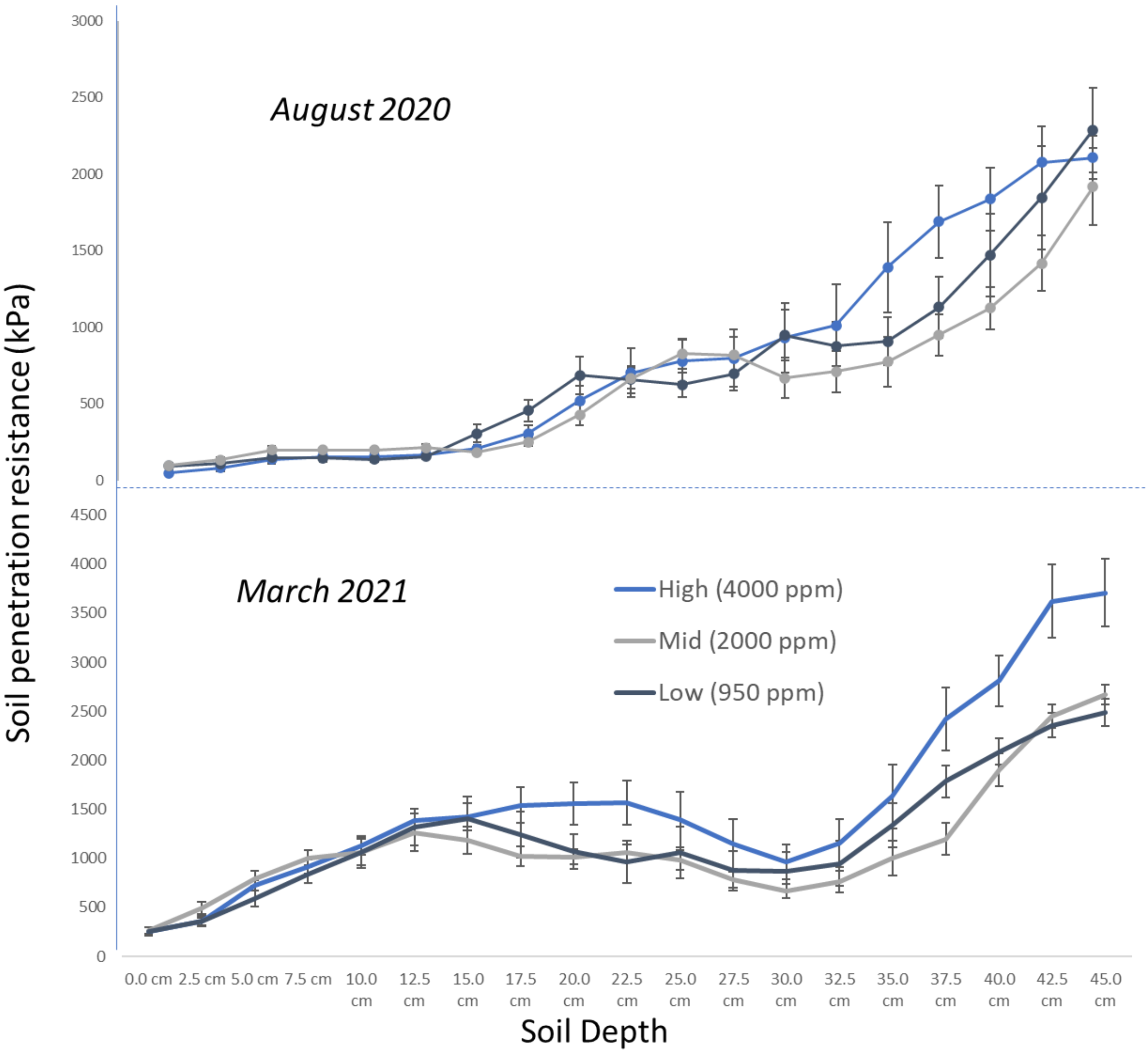


Figure 9: Soil penetration resistance in the three brackish irrigated plots, measured in August 2020 and March 2021.

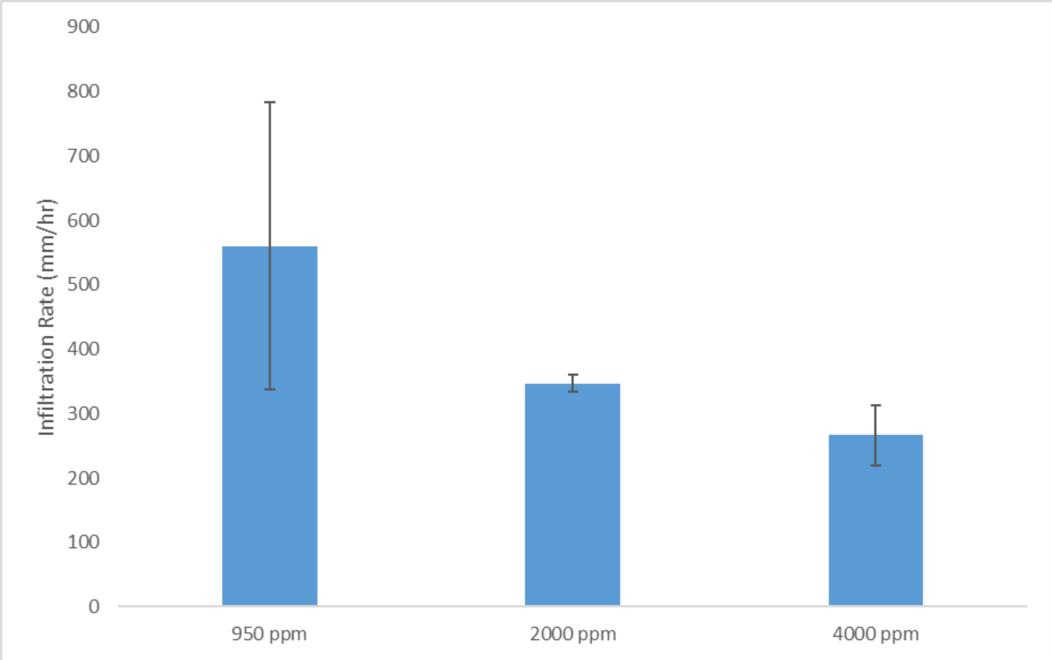


Figure 10. Soil Infiltration Rates

Soil Respiration Rates

At two dates in July and August, soil respiration rates were measured beneath the canopy with a portable Infrared gas analyser (IRGA) (Figure 11). The IRGA measures the release of carbon dioxide from the soil surface over a period of time, which can be used as an indicator for soil biological activity in the plot. (Figure 12). Although Respiration rates differed between July and August, likely on account of changes in environmental conditions (moisture, warmth), there was no significant difference found between treatments

Figure 11. Portable IRGA device and Soil Respiration chamber placed at soil surface.

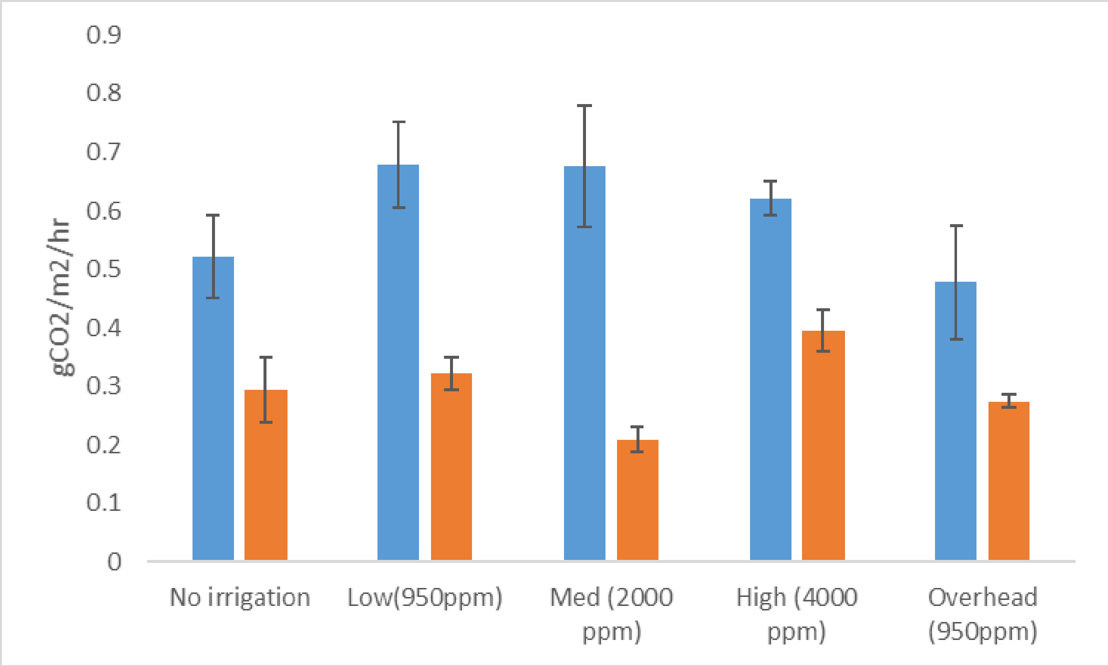


Figure 12. Results of Soil respiration measurement from each plot in July (blue) and August (orange).

5 Conclusions/Recommendations

The trial results showed that even at the maximum level of brackish water uses, there were no impacts to crop yield measures, or crucially to levels of scab. Across all treatments, it was only the non-irrigated plots which showed any indication of poorer performance, with higher levels of scab, poorer skin brightness and marginally lower total yield (although not found to be significant). All of these crop measurements indicate the potential benefits of using slightly more brackish water, in comparison to no irrigation at all, for crop performance.

However, soil measurements also need to be taken into consideration with such irrigation practice. It is critical to ensure that even if one crop, e.g. potatoes, can perform under brackish conditions, the grower has not caused any longer term impacts to the field for subsequent crops in rotation. In this trial, we assessed a range of soil measures, however it is important to note that for a one season trial we selected a suite of indicators of soil properties. A more comprehensive assessment of soil impacts would require longer term monitoring, and ideally employing more detailed assessments of soil biological properties (for example, metagenomic approaches). Nevertheless, the results of this trial give some indication that salt levels, in this case sodium, that build up in the soil under brackish irrigation scenarios are flushed out of the soil by winter rainfall, to the point that levels of exchangeable sodium (ESP) measured were down to the baseline levels in all plots in the spring sampling of the following year March 2021. Measurements of soil responses, from penetration resistance readings, infiltration readings, and soil CO2 readings did show some contrasts between plots, although none were found to be significantly different.

Recent trials on potato varieties, and other crops, in the Netherlands have shown that crops can withstand more salinity in irrigation water than first thought from original FAO data. Such trials were conducted on sandy soils, in a coastal region benefitting from winter rainfall and thus salt flushing to remove from the soils. Such results support our findings, although this study was undertaken on silt soils, rather than sands. In silt soils, we might anticipate more damage from salinity, as salts can adhere to more soil surfaces, and potentially withstand more rainfall flushing. This trial may reassure growers on silt soils that there is salt flushing potential of soils in the region.

Conclusions and Future Work

The results found that no significant crop impacts where found under our brackish irrigation treatments. Furthermore, soil salt levels had been reduced to pre-trial levels by the following spring. These results may be useful to potato growers on silt soils when faced with limited freshwater resources, or in instances of saline inundation of abstraction points, where irrigation water may become increasingly brackish. Furthermore, the results could potentially mean less demand on freshwater from agriculture, which may have wider benefits for water resources in a region projected to have increasing water resource scarcity (EA 2020).

Given that the maximum brackish level in this trial, 4000 ppm, showed no negative impact to crops, and measured salt levels reduced to pre-irrigation levels in the following spring, future trials should investigate the impacts of higher levels of salinity. As a result, in the next phase of research, the University of Lincoln are currently undertaking a fully replicated plot trial on Maris Piper with brackish water levels up to 7500 ppm as part of the EU Interreg SalFar project. These trials also aim to expand the suite of soil testing.

6 Further reading

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7 Acknowledgements

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