AERES UNIVERSITY OF APPLIED SCIENCES

The influence of salinisation and ploughing on the vegetative growth of winter wheat (*Triticum aestivum* 'Extase')

BSc. thesis

Rowan Schreijer
Senior student Applied Biology
Aeres University of Applied Sciences

The influence of salinisation and ploughing on the vegetative growth of winter wheat (*Triticum aestivum* 'Extase')

BSc. thesis

Requested by:
Examination committee
Aeres University of Applied Sciences

University coach:
B. Knegt
Lecturer at Aeres University of Applied Sciences

In cooperation with:
SPNA Agroresearch

Author:
R.M. Schreijer 3025372
Senior student Applied Biology
Aeres University of Applied Sciences

Cover picture: Paswan (n.d.)

Munnekezijl, June 2021

Preface

Here, before you, lies the final research paper that I have written in relation to my current study. I am a fourth-year student of the Applied Biology programme and have written this as a graduation paper for the degree course of Aeres University of Applied Sciences.

I have tried to incorporate all the knowledge I have gained during my study into this final report. It involves an analysis of the influence of salination and ploughing on the vegetative growth of winter wheat. It turned out to be quite a challenge to carry out this research independently, but I am very satisfied with the achieved results.

I would like to take this opportunity to thank a number of people. First of all, I would like to thank Carina Rietema for making the trial location available and for all the important advice. Secondly, I would like to thank my graduation lecturer Bram Knegt, whose advice and help with the statistical analyses have been extremely valuable for the delivery of this report. Finally, I would like to thank all the people involved from SPNA and the lecturers of the past years for all their knowledge, advice and the incredibly beautiful experience. The knowledge I have gained during my training has become meaningful for my further career.

I have now come to the end of this preface, so all that remains for me now is to wish you a pleasant time in reading this report.

With kind regards,

Rowan Schreijer
Senior student Applied Biology
Aeres University of Applied Science

Munnekezijl, June 2021

Table of contents

Index

Abstract

English abstract
Climate change can be described as both a natural and an artificial process that affects all life on earth. One of its consequences is the rising of sea levels which can cause problems in coastal areas, such as increasing the pressure of saline groundwater. Due to this increased pressure, this saline seepage water can rise to the surface, causing salinisation of the soil in question. This has direct impacts in nature, but it affects agricultural land as well. Salinisation of the soil causes a loss of soil structure and soil fertility, and these soils are often dehydrated. In addition, plants find it more difficult to root on these soils and can suffer from osmotic and ionic stress. Until now, it was still unknown whether ploughing could be a method of reducing the negative effects of salinisation. In addition, breeding salt tolerant wheat crops is considered difficult because this involves a polygenetic trait for which not much phenotypic selection methods are available. Therefore, this research focuses on which vegetative growth differences are visible in saline soils and to what extent ploughing has an effect on this. This study was carried out on two types of wheat parcels, where one of which was ploughed. Half of each parcel was then salinated with saline seepage water through drip irrigation, and the other half was irrigated with fresh surface water. The variables germination, plant length, leaf area, damage, condition and root architecture were then examined over a 13-week period. The results showed that ploughing and salinisation had an interactive effect on the variables germination, plant length, damage and condition. Ploughing always seemed to have a negative effect on germination, but also limited the effects of salinisation in the other variables. In the treatments where salinisation was applied, the plants were significantly higher, had less damage and an improved condition. This was probably caused by an increased quantity of strigolactones, which these plants release in response to salt stress. These hormones contribute positively to apical dominance and salt tolerance. It can therefore be concluded that ploughing and salinisation have an interactive effect on germination, plant length, damage and condition during the vegetative growth of Triticum aestivum 'Extase'.

Dutch abstract

Klimaatverandering is tegenwoordig zowel een natuurlijk als kunstmatig proces dat al het leven op aarde beïnvloed. Zo is één van de gevolgen de stijging van de zeespiegel die voor problemen kan zorgen in gebieden langs de kust, zoals het verhogen van de druk van zout grondwater. Door de verhoogde druk kan dit zoute grondwater stijgen waardoor de bodem in kwestie verzilt. Dit heeft directe gevolgen in de natuur, maar ook op agrarische gronden. Verzilting van de bodem zorgt voor een verlies van bodemstructuur en bodemvruchtbaarheid, en ook zijn deze gronden vaak uitgedroogd. Daarnaast kunnen planten lastiger op de gronden bewortelen en kunnen zij leiden aan osmotische en ionische stress. Tot voorheen was het nog onbekend of ploegen een methode kon zijn om de negatieve gevolgen van verzilting te beperken. Daarnaast is het veredelen van zouttolerante tarwegewassen erg lastig omdat het hierbij gaat om een polygenetische eigenschap waarbij nog weinig fenotypische selectiemethoden bekend zijn. Daarom focust dit onderzoek zich op welke vegetatieve groeiverschillen zichtbaar zijn in verzilte bodems en in welke mate ploegen hierop een effect heeft. Dit onderzoek is uitgevoerd op twee type tarwepercelen, hierbij is een perceel geploegd en de ander niet. De helft van ieder tarweperceel is vervolgens verzilt met zout kwelwater middels een druppelirrigatiesysteem en de andere helft werd geïrrigeerd met zoet oppervlakte water. Vervolgens is in een periode van 13 weken gekeken naar de variabelen ontkieming, plantlengte, bladoppervlak, schade, conditie en wortelarchitectuur. Uit de resultaten is gebleken dat ploegen en verzilting een interacterend effect hebben op de variabelen ontkieming, plantlengte, schade en conditie. Ploegen leek hierbij altijd de ontkieming negatief aan te tasten, maar daarnaast wel de effecten van verzilting in de andere variabelen te beperken. In de behandelingen waar verzilting werd toegepast waren de planten significant hoger, hadden minder schade en een verbeterde conditie. Dit werd waarschijnlijk veroorzaakt door een verhoogde hoeveelheid strigolactonen, die deze planten als reactie op zoutstress afgeven. Deze hormonen dragen positief bij aan apicale dominantie en zouttolerantie. Hierdoor kan worden geconcludeerd dat ploegen en verzilting een interactief effect op de kieming, de plantlengte, de schade en de conditie tijdens de vegetatieve groei van *Triticum aestivum* 'Extase'.

1. Introduction

Climate change can be described as a natural process that affects all living organisms on earth. Climate is formed by the chemistry and physics of the Earth's atmosphere, as well as the natural processes that take place on Earth. Natural climate change is a rather slow process and is caused by chemical changes in the Earth's atmosphere due to the greenhouse effect. This effect is caused by increasing and decreasing of greenhouse gasses (water (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3)) (Hardy, 2003). These gasses emit and absorb radiant energy and reflect this back to Earth which contributes to global warming (Cassia, Nocioni, Correa-Aragunde, & Lamattina, 2018). In natural climate change, these greenhouse gasses are produced by Earth's natural cycles which create warmer and colder periods. Natural climate changes are small and take thousands to even millions of years to develop (Hardy, 2003). Most organisms on Earth can adapt to such subtle changes through evolution (Campbell *et al.*, 2018). Over the past 150 to 200 years, however, humans began to influence this natural cycle by adding more greenhouse gasses to the Earth's atmosphere as a consequence of new technologies which emitted more greenhouse gasses. This caused the Earth to warm up at a much faster scale, which has led to drastic effects on health, environment and economy (Hardy, 2003).

One of the effects of artificial climate change is the rising of the sea level, which has negative consequences for the people that live in most coastal lands. For example, in the Netherlands, most coastal areas have high concentrations (>10.000 mg/l) of salts in groundwater (see figure 1.1). Because of this rising sea level, the pressure of saline seepage water increases, making the soil saltier (Daliakopoulos *et al.*, 2016). Seepage is water that is present and stored underground and can rise to the surface due to increasing pressure or a reduction in rainfall. In the Netherlands, most groundwater is brackish to saline. The rising of this water therefore directly salinates the soil in question (Stichting Toegepast Onderzoek Waterbeheer, n.d.). This is already causing problems in nature, but it is even more problematic for agricultural lands (Daliakopoulos *et al.*, 2016). Most cultivated plants grow poorly on saline soil, rendering salinisation a challenge for both breeders and growers, who are currently looking for more salt tolerant varieties or innovative ways to overcome salinisation. Consequently, more research into the effects of salinisation on both soil and plants is needed (Zhu, 2001).

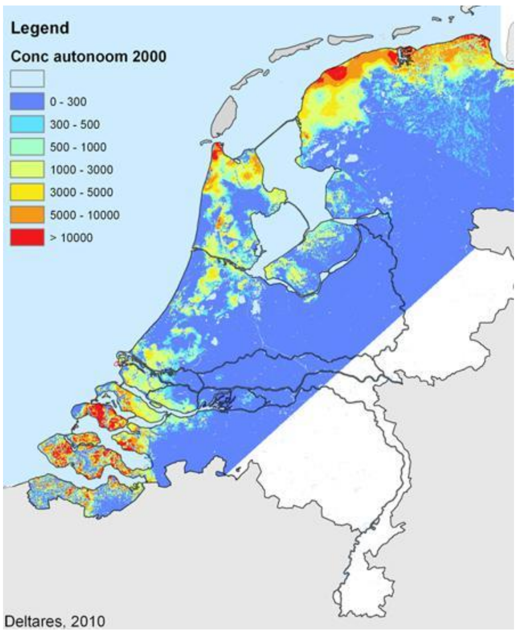

Figure 1.1: Salt concentrations in mg/l present in Dutch soils (Deltares, 2010)

1.1 Effects of salinisation on agricultural lands

As mentioned before, soil salinisation is a major problem for most agricultural lands, due to the fact that most cultivated plants do not grow well on saline soils. Salinisation can have many different causes that can be classified as salinisation due to natural causes and salinisation caused by humans. Natural salinisation occurs by chemical or physical transport of salt in rain or ground water, carried by wind or accumulation of seawater. Artificial salinisation is often caused by insufficient use of fertilisation, irrigation or drainage of the soil. Fertilisation adds nutrients to the soil, which can accumulate if used improperly, making the soil more saline. Irrigation water is often saltier because it is one of the ways in which plants can be fertilised, and salinisation can occur as a result of residual irrigation water on the land. Finally, drainage can also contribute to salinisation because residual salts can remain in the soil, after the groundwater is pumped away. (Daliakopoulos *et al.*, 2016)

Salinisation can have many different effects on the soil, based on the soil type. In clay grounds, degradation of the structure of clay particles is possible due to the replacement of calcium (Ca^{2+}) and magnesium (Mg^{2+}) cations with sodium (Na^{+}). This leads to the weakening of bonds between soil particles and increases the chance of erosion (Daliakopoulos *et al.*, 2016). It also makes the soil less suitable for plants to grow on, as Na^{+} is considered to be toxic for plants in extreme concentrations (Tester & Davenport, 2003). The soil can become dehydrated, crusted and sometimes even structureless due to the disappearing of natural aggregations. Crusted grounds limit the possibility of rooting, making it harder for seedlings to root. Saline soils are often susceptible to tunnel erosion as well. Tunnel erosion is when the small clay particles move towards each other and collect in the cracks caused by dehydration of the soil. This results in the obstruction of the pores that are present in the ground and a decrease of hydraulic conductivity. This means that water has a harder time penetrating the soil because of its high compactness, making it more difficult to rehydrate the dry soil. In addition, it is known that saline soils are often less fertile, because of the reduction in available nutrient ions when sodium and chlorine are present in high quantities in the soil. This can in turn reduce the biomass production of the plants growing on these types of soils (Daliakopoulos *et al.*, 2016).

There are various ways in which farmers themselves can limit the appearance of salinisation on their land. This can be done, for example, by reducing the use of fertilisers, irrigation and drainage, and adapting the use of these systems in a way that is suitable for the type of land and the characteristics of the soil. These are preventive ways to reduce salinisation to some extent. The major effect of salinisation on agricultural lands, however, is dehydration (Daliakopoulos *et al.*, 2016). One way to restore soil moisture is to enrich the soil with more organic matter, as organic matter increases the moisture holding capacity of the soil (Bot & Benites, 2005). Ploughing could help to increase the organic matter in the soil, as this involves mixing organic matter found on the land, such as green manures, weeds or crop residues from previous years, evenly with the soil in question. In ploughing the upper layer of the soil is turned upside down and mixed. This makes it easier for plants to root, brings the fertile parts of the ground to the surface and could even help to control weeds (The Editors of Encyclopaedia Britannica, 2020). Ploughing may thus reduce some of the negative effects of salinisation, but in literature only one research has been found that addresses the influence of ploughing on salinisation. This study, of Libus, Mauer, & Vavříček from 2010, did not show evidence of ploughing having an effect on salinisation. However, this study only examined possible differences in the soil and focused on natural vegetation on a natural soil type. Research into the effect of ploughing on salinisation on agricultural lands is still lacking. Besides this, ploughing could also have negative effects on the soil. Wang *et al*. showed in 2014 that ploughing could disrupt soil structure and moisture stability, and that no-tillage cultivation systems actually decreased the salinity concentration in the soil (Wang *et al*., 2014). It is currently unclear whether ploughing can be a method of limiting the effects of salinisation, as both positive and negative effects can be found in the literature regarding this subject. More research on this subject is therefore of evident importance as salinisation of soil is becoming an increasing problem in agriculture.

1.2 Effects of salinisation on plants

Salt stress is a common phenomenon on saline soils. It occurs when the salinity of the soils becomes toxic and is the main consequence of salinisation for plants. Currently, about 5.7 million hectares (ha) of land worldwide are affected by salinisation and this is likely to increase to 17 million ha by 2050. Rooting and germination is harder for plants on saline soils as the ground dries out due to salinisation. In addition, salinisation has direct effects on the plant's development and can be described as a combination of osmotic stress and ionic stress. (Isayenkov, 2012)

Osmotic stress is caused by the accumulation of sodium (Na^+) and chlorine (Cl^-) in the groundwater. Plants use osmosis for their water absorption. The plant stores certain salts, to have an osmotic potential that is higher than in its environment. This results in water uptake from the environment, as water always moves towards the highest concentration of solutes. Due to the accumulation of the previously mentioned ions, the osmotic value of the soil moisture changes. This results in a reduced water uptake by plants because the osmotic potential is now higher in the soil than in the plant itself, and plants may consequently suffer from dehydration. This phenomenon is called osmotic stress. (Isayenkov, 2012)

Ionic stress is caused by the high absorption of, in particular, Na^+ and Cl^-, via non-specific ion channels in the membrane of root cells. When these ions are present in high quantities inside the plant, they have a strong influence on various processes. First of all, these ions cause an imbalance in the mineral homeostasis because they replace calcium (Ca^+) and potassium (K^+). Both calcium and potassium control important processes in the plant such as stomatal movement, turgor, membrane potential and adaptive stress responses. By replacing these ions with Na^+ and Cl^-, the degree to which these processes are controlled is significantly reduced, leading to a decreased growth. In addition, ionic stress disrupts biochemical activity and inhibits enzyme activity. (Isayenkov, 2012)

Plants can react differently to salt stress. Some plant species, so-called halophytes, are adapted to a saline environment and can therefore cope well with osmotic and ionic stress without suffering any deterioration in their development. These plants often have built-in organs that actively excrete excess salt (Glenn, Brown, & Blumwald, 1999). Examples of halophytic crops are barley (*Hordeum vulgare*), quinoa (*Chenopodium quinoa*) and wild rice (*Zizania aquatica*) (Biosalinity Awareness Project, n.d.). Unfortunately for growers, most cultivated crops are glycophytic, which are known to be quite sensitive to salt stress. Salinisation severely impacts growth of carrots (*Daucus carota* sp.), onions (*Allium cepa*) and different types of beans, for example (Isayenkov, 2012).

Within these glycophytic crops, however, some varieties express tolerance to salt stress, due to genetic differences. Breeders can use this variation to select for salt tolerant varieties and possibly cross these with varieties that have commercially important traits in order to get a high yielding, salt tolerant cultivar (Isayenkov, 2012). Salt tolerance refers to a plant that can germinate, is not inhibited in its development and can reproduce in a saline environment (Jana, 1993). Breeding crops for salt tolerance, however, is a difficult process. It is a polygenetic trait, which means that several genes determine the level of tolerance, and these are often recessive. Also, for most crops it is still unknown which genes underlie any possible salt tolerance (Shannon, 1985). This makes genetic selection methods mostly infeasible. It would therefore be better to use phenotypic selection methods, but salt stress symptoms are very general, and similar to other stresses (Shannon, 1985). Due to this generality of stress symptoms, selecting the plants that show the least stress symptoms is not very precise. Salt tolerance is thus considered to be a difficult trait to breed. In order to implement an efficient breeding program and to select salt tolerant plants at an early stage, insight into phenotypic plant responses to salt stress is crucial (Isayenkov, 2012).

According to Isayenkov (2012), both halophytes and glycophytes often use comparable strategies to deal with salt stress, albeit to different degrees. The first strategy is to selectively take up calcium and potassium from the environment instead of sodium and chlorine. Another strategy is to store the toxic ions in different parts of the plant, such as in xylem- or phloem vessels, secreting organs or in the vacuole (Isayenkov, 2012). The last strategy that plants employ is to actively change their growth through halotropism. Halotropism can be described as a phenomenon in which a plant grows its roots away from a saline environment, so that it absorbs less salt from the soil it stands on (Galvan-Ampudia *et* *al.*, 2013). The effects of salt stress may be visible on the phenotype of the plant. Possible symptoms are poor germination, growth inhibition, increased rate of development, apoptosis and finally death. In addition, leaves may become discoloured or deformed, and burnt damage may be present (Shahid, Zaman, & Heng, 2018). As mentioned before in paragraph 1.1, ploughing could be a means for limiting the effects of salinisation, but its efficacy in this context has thus far not been studied.

One crop that particularly suffers from salt stress these days is wheat. It is known that 69% of all wheat production worldwide has been negatively affected by salinisation (Isayenkov, 2012). The development of salt-tolerant wheat varieties is therefore an important objective. However, in order to develop these varieties, more research is needed to find out what plant responses to salt stress make the plant more tolerant.

1.3 Wheat

Wheat is one of the most widely grown crops for global consumption (Shewry, 2009). It belongs to the grasses family (*Poaceae*) under the genus *Triticum* (The Editors of Encyclopaedia Britannica, 2021). According to Shewry (2009), breeding and cultivation of wheat began probably 10.000 years ago during the Neolithic revolution when humans began to grow plants for food instead of hunting or collecting it. Prove has been found that wheat probably originates from south-eastern Turkey. The varieties used in these times were still diploid or sometimes tetraploid, while the market nowadays is being dominated by hexaploid or tetraploid varieties. Nowadays, there are essentially two types of wheat that are still being cultivated. First is durum wheat (*Triticum durum*), a tetraploid which accounts for 5% of the world market for wheat production and is mainly cultivated for products such as pasta. The second type is common wheat (*Triticum aestivum*), a hexaploid that accounts for the other 95% of the market and is grown mainly for bread. It is therefore clearly visible that common wheat has become the most important wheat crop in both economic and agricultural terms (Shewry, 2009).

Common wheat is very similar to other grasses in its characteristics. Typical properties include pointed leaves, a round and hollow stem, a ligula and inflorescence in spikelets. Wheat is pollinated by wind and produces about 2 to 3 grains per flower and there are 20 to 100 flowers per spikelet (The Editors of Encyclopaedia Britannica, 2021). Figure 1.2. shows a botanical drawing of the characteristic features of common wheat.

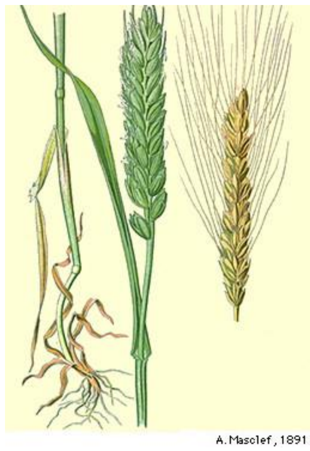

Figure 1.2: Fruit of common wheat (*T. aestivum*) (Masclef, 1891)

The two major types of common wheat are spring wheat and winter wheat, where winter wheat has the main benefit that it can grow in winter (The Editors of Encyclopaedia Britannica, 2021). Additionally, winter wheat can be used for both cereal production and as a cover crop that promotes the nutritional value of the soil (Town and Country Supply Association, 2019).

Winter wheat is usually seeded from September to February on primarily clay soils. The soil must be slightly moist (16%) and well aerated. The pH of the soil on which winter wheat is grown varies between 5 and 8. The plant grows best at temperatures of 15° to 20°C, with a vernalisation period up to 2 months between 0° and 2°C. This vernalisation period is necessary for the plant to enter its generative phase and is initiated shortly after germination. In addition, the crop has a water requirement of 50,000 litres per ha. Furthermore, winter wheat only needs to be fertilised with nitrogen (N), as the other nutrients are already available in clay soils. The recommended nitrogen fertilisation rates from 150 to 200 kg N/ha, with the amount and number of applications adapted to the development stages of the plant. (Darwinkel, 1997)

1.4 Research

The organisation SPNA agroresearch (Stichting Proefboerderijen Noordelijke Akkerbouw) is currently investigating the main effects of salinisation on various crops in collaboration with the SalFar project of the European Union (EU), which aims to examine the impact of salinisation on both plants and soils at different levels on a more realistic scale in ordinary cultivation systems (Interreg North Sea Region SalFar, n.d; C. Rietema, personal communication, 2021). SPNA agroresearch is an organisation that performs practical research into various problems within plant cultivation. It is a non-profit organisation with two experimental farms, location Ebelsheerd in Nieuw-Beerta (Groningen, the Netherlands) and location Kollumerwaard in Munnekezijl (Friesland, the Netherlands). The organisation works on the basis of project applications, but also takes the initiative to carry out research projects itself (SPNA agroresearch, n.d.). In the current project SPNA wants to investigate the effects of salinisation of agricultural soils on the most commonly grown Dutch field crops, such as potatoes, onions and wheat. 2021 is the first year of a more than four-year long study and SPNA has already prepared two ha of land for the above-mentioned project. On each ha of land, four parcels are created on which the above-mentioned crops are grown: potato (*Solanum tuberosum*), spring wheat (*Triticum aestivum*), onion (*Allium cepa*) and winter wheat (*Triticum aestivum*). All crops grow both on salinated and unsalinated, and on ploughed and unploughed clay soils (see figure 1.3). Because of the different seeding times of the crops, only the winter wheat cultivar ‘Extase’ was sown yet on the start of this research (February 2021) (C. Rietema, personal communication, 2021).

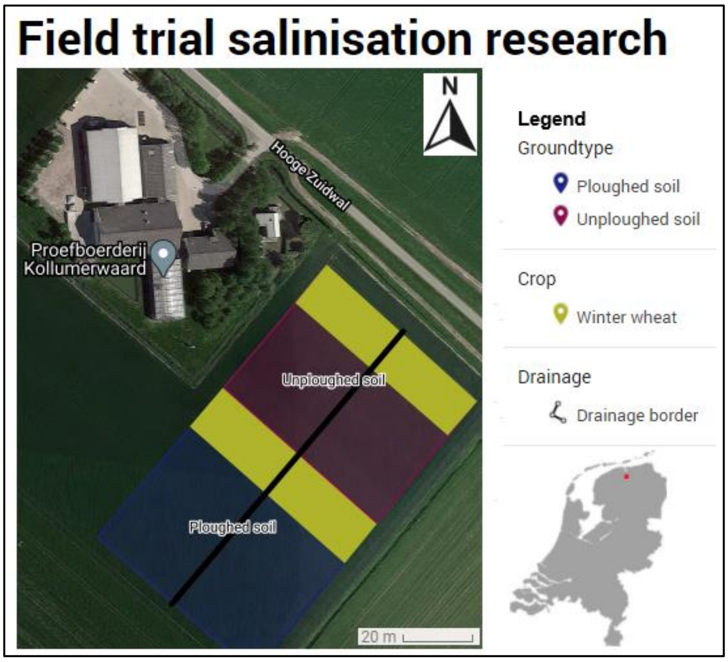

Figure 1.3: Overview of the research area, top side is salinized soil, and the bottom side is regular soil (via Google My Maps)

Salinisation is clearly causing major problems in plant cultivation and breeding. In this research, two possible directions aimed at reducing the negative effects of salinisation will be pursued. Ploughing could be a method to limit the effects of salinisation, through increasing the organic matter in the soil which contributes to an increase in soil moisture (Bot & Benites, 2005). Ploughing may disperse the salt concentration in the soil more evenly, and therefore will most likely benefit the growth of plants on this soil, when compared to plants that grow on unploughed saline soils, as the salt concentration is now diluted. However, it is still unknown whether and to what extent ploughing affects the growth of plants on saline soils and proof has been found that ploughing could disrupt soil structure, and that no-tillage cultivation systems decreases soil salinity (Wang *et al.*, 2014). Research into how ploughing would affect the growth of plants on saline soils would therefore be of great value for growers. Second, breeding salt tolerant plant cultivars is complicated due to the polygenetic nature of salt tolerance in most crops, and the difficulty of effectively selecting among tolerant and susceptible plants (Shannon, 1985). Various studies have addressed salinisation at the soil, plant physiological and plant genetic level, but practical research into differences in the phenotypical development of plants on saline soils versus plants on favourable soils is lacking, but crucial for future breeding of salt tolerant varieties. Therefore, both topics will be analysed in this research that is conducted on *Triticum aestivum* 'Extase' at the trial field of SPNA.

As mentioned above, this research investigates growth differences of winter wheat on a regular soil versus a salinated soil, and on a ploughed versus a non-ploughed soil. To keep the size of the study manageable, it was decided to focus only on the vegetative growth differences. The main research question is therefore: “How do ploughing and salinisation affect the vegetative growth of winter wheat (*Triticum aestivum* 'Extase')?”

The aim of this research is to be able to determine, by answering the main question, how vegetative growth variables change in winter wheat when it is grown in a saline environment and what influence ploughing has on this. By answering this question, advice can be given to breeders and growers. For example, breeders of winter wheat can be advised which vegetative growth properties are important for breeding salt-tolerant varieties and growers can be advised whether ploughing contributes positively or negatively to salt stress in winter wheat due to salinisation. In order to answer this research question, a number of sub-questions have been formulated as well. These sub-questions are displayed below, in an order that follows logically from a statistical perspective.

- How do salinisation and ploughing interactively affect the vegetative growth of winter wheat?
- How does ploughing affect the vegetative growth of winter wheat?
- How does salinisation affect the vegetative growth of winter wheat?

Salinisation is expected to have a major impact on the vegetative growth of winter wheat, as literature has shown that Na^+ and Cl^- in high concentrations are toxic to plants, and two thirds of all wheat grown worldwide is negatively affected by salinisation (Isayenkov, 2012). To what extent the 'Extase' wheat variety is susceptible to salt stress and which typical symptoms can be observed in this variety, was not found in literature. Ploughing could possibly ensure that the plants develop more quickly, as it increases the fertility of the soil by adding more organic matter in deeper soil layers (The Editors of Encyclopaedia Britannica, 2020). This indirectly restores soil moisture and could help to reduce dehydration (Bot & Benites, 2005). Ploughing might also negatively affect the vegetative growth of winter wheat, as ploughing can disrupt soil structure and decrease moisture stability (Wang *et al.*, 2014). There is not much information that can be found in literature when looking at the effects of ploughing on salinisation. The possible effect of ploughing on salinisation and how this relates to plant growth will therefore have to be revealed in this study.

The following chapters will describe the conducted research. Chapter 2 explains how and where this research took place and which method was used to answer the research questions. Chapter 3 presents the results of this research, after which chapter 4 analyses and evaluates these results. Finally, in chapter 5, an answer is given to the research questions and advice is given for both growers and breeders.

2. Materials and methods

The second chapter will explain where, when and how this research took place. It will also explain which statistical tests were used to analyse the found data and which measurements took place to provide an answer to the research questions.

2.1 Location and period

In the period from 8 February 2021 to 6 June 2021, a study was conducted regarding the vegetative growth differences in winter wheat on regular soil and on saline soil at location Kollumerwaard, Hoge Zuidwal 1 in Munnekezijl (see figure 1.3). Standard measurements were taken weekly on Thursdays and there were 13 measurements in total. However, a total of three destructive measurements have been conducted as well. Paragraph 2.3 further explains exactly which variables were measured. The following sub-paragraphs will now first describe how the field was prepared for carrying out this research and what the climatic conditions were.

2.1.1 Trial field

The trial field (2 ha) is shown in figure 2.1. This trial field was divided into two spaces; half of the trial field was ploughed, and the other half was not. This created two separate experimental fields (of 1 ha each) which were divided into four parcels. A different crop was grown in each parcel (potato, onion, spring wheat or winter wheat). Also, half of each parcel was irrigated with saline seepage water and the other half with fresh surface water, using Subsurface Drip Irrigation. The saline seepage water was pumped from a natural source near the trial field, and the fresh surface water came from a reservoir which was filled with both rain and tap water (C. Rietema, personal communication 2021). The EC value of the saline seepage water was 15,3 mS/cm and the EC value of the fresh surface water was 0,5 mS/cm (Eurofins, personal communication, 2021). The water characteristics of each source is displayed in table 2 of Appendix I.

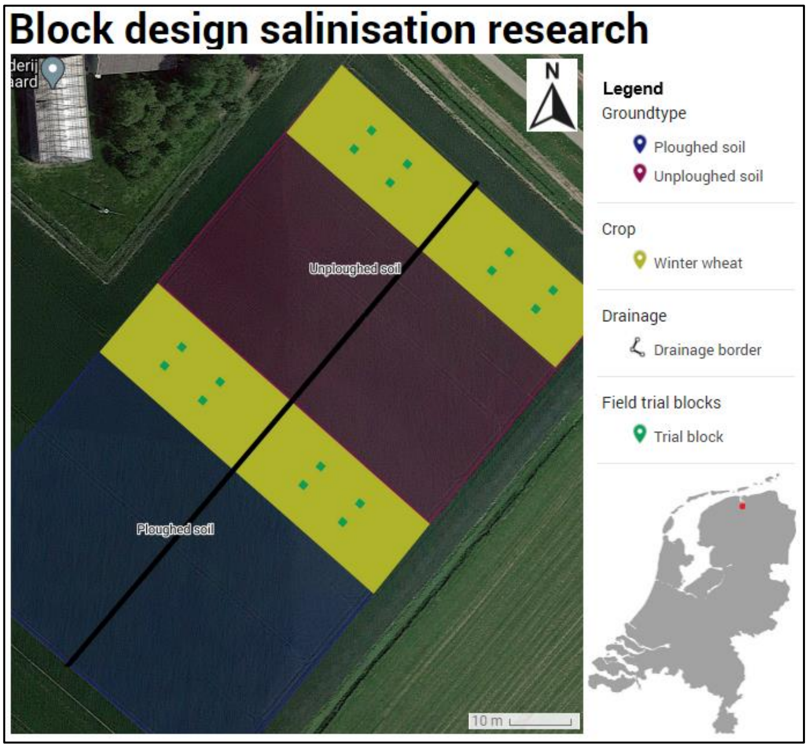

Figure 2.1: Block design salinisation field trial, top is salinized soil and bottom is regular soil (via Google My Maps)

In the parcel of winter wheat on both experimental grounds (110 m x 25,6 m on unploughed soil and 110 m x 22,4 m on ploughed soil) a block test was carried out, with four blocks in the saline part and four blocks in the regular part of the ground (see figure 2.1). The size of the blocks is about 2 metres by 2 metres, where approximately 1642 seeds have been sown. In these blocks, three plants were selected, and their growth was monitored weekly (see section 2.2). The saline soil was irrigated from November 2020 with water with the above-mentioned EC value of 15,3 mS/cm. The regular soil was irrigated for the first time in April 2021, since this soil was still sufficiently saturated with fresh water which was already present in the soil as a buffer. Underground drip irrigation (40 - 50 cm deep on ploughed soil and 30 - 40 cm deep on unploughed soil) has been applied for this. Hereby, an average of

380 litres of water is irrigated on both grounds every three hours for 5 minutes (G. Koops, personal communication 2021). The trial field is situated on a light clay/silt soil with all essential micro- and macronutrients (Eurofins, personal communication, 2020). The soil characteristics are displayed in table 1 of Appendix I.

The same sowing technique has been used on both fields. On these fields 195 kg/ha winter wheat seed of the variety 'Extase' was sown with a thousand seed weight of 40 to 55 grams. Sowing was done on 26-11-2020 on the ploughed soil and on 27-11-2020 on the unploughed soil. This means that there was a difference of one day between the sowing times. All other factors, such as fertilisation and pest and weed control are again the same on both trial fields. Both chemical and mechanical techniques are used for this purpose. First of all, each trial field was spaded and of course, only one trial field was ploughed in order to clear the weeds. Both ploughing and spading were conducted once, only before the winter wheat was sown on it. After this, chemical control of weeds, diseases and pests was carried out. The following crop protection agents were used at the following concentrations: Capri Twin (0.200 kg/ha), Pacifica Plus (0.300 kg/ha), Plant oil HF (1,000 l/ha), Trimaxx (0.250 l/ha), UPL CCC 750 (0.750 l/ha), Elatus Era (1,000 l/ha), U 46 MCPA (2,500 l/ha). These crop protection products have all been used once between February and May. Fertilisation was also applied, using the fertilisers Sulfan (420 kg/ha) and calcium ammonium nitrate (220 kg/ha), and were also used once in February and April. (C. Rietema, personal communication, 2021)

2.1.2 Climate and weather

The average climate data of location Kollumerwaard in the months that this research took place are shown in table 2.2. Climate data of 2021 were used from the weather station located near the research location.

Table 2.1: Average climate data in research location Kollumerwaard February - June (via Dacom Online)

	February	March	April	May
Temperature (mean)	1,7 °C	4,5 °C	5,1 °C	9,1 °C
Total radiation (sum)	3.446,7 J/cm²	6.361,4 J/cm²	22.506,3 J/cm²	48.034,5 J/cm²
Rainfall (sum)	30,8 mm	45,2 mm	34,4 mm	91,6 mm
Wind velocity (mean)	3,6 m/s	4,1 m/s	4,1 m/s	3,7 m/s
Relative humidity	47,5 - 87,8 %	32,2 - 97,8 %	35,2 - 97,8 %	56,1 – 97,8 %

2.2 Selection of plants for measurements

As mentioned in section 2.1, four blocks of 2 x 2 metres were created in both the regular soil and in the saline soil and this was applied in both wheat parcels. By using a block design, it is possible to compensate for gradients that are present above and below the ground, such as temperature differences, soil moisture and sunlight (Kirk, 2012). In each block, three plants were selected on which weekly above-ground measurements took place, for 13 weeks in total. When selecting these three plants, it was important that they all grew at approximately the same location in the block. For example, they were all positioned around the middle, taking border rows into account. Border rows are the plants that stand on the outside of the block and therefore often differ in growth due to the present gradients (Wang, Zhao, Wu, Gao, Yang, & Shen, 2017), which is why it was decided to only use the middle plants. In addition, when the plants were selected, a first measurement was taken to assess the condition of the plant at the beginning of the study.

Besides above-ground measurements, root measurements were also conducted in this study. For these measurements, the plants were taken at random from the block. This was done because below-ground measurements are destructive. Plants used for below-ground measurements were not taken from border rows. In addition, the plants had to be representative for the entire block by showing an average growth. Section 2.3 mentions exactly which measurements took place.

2.3 Vegetative growth measurements

A couple of measurements were needed in order to give an answer to the research questions. These measurements were conducted both above and below the surface and were needed to monitor the vegetative growth of winter wheat. Jana (1993) stated that salt tolerance refers to a plant that can germinate, is not inhibited in its development and can reproduce in a saline environment. As mentioned earlier, the generative phase has been left out of this research in order to keep it manageable. Therefore, this study focuses on measurements of germination and vegetative growth. Each measurement that took place is described below in more detail.

2.3.1 Germination

The germination success of a crop reflects the quality of the soil it grows on. As mentioned earlier, salinisation has negative effects on germination. This is caused by the fact that saline soils are often dehydrated, structureless and less fertile (Daliakopoulos *et al.*, 2016). Ploughing also has various effects on germination. Besides the fact that ploughing increases soil fertility by adding organic matter to the soil which indirectly increases soil moisture (Bot & Benites, 2005), it can also have negative effects on germination success. For example, the compactness of the soil is decreased, which can make germination more difficult (The Editors of Encyclopaedia Britannica, 2020). Because of the above-mentioned facts, germination success is an important variable for determining the influence of salinisation and ploughing.

To determine the success of germination, individual plants were counted by using a counting frame. A counting frame is a quarter-square-metre metal construction that can be placed on the land in question. This can be done once at the front of the land and once at the back, taking border rows into consideration. All plants that fall within this counting frame are then counted. After counting, the following formula was applied (C. Rietema, personal communication, 2021):

$$D_c = (\mathrm{N_{c1}} + \mathrm{N_{c2}}) \times 2$$

D_c = Crop density per m^2
N_{c1} = Number of plants in counting plot 1
N_{c2} = Number of plants in counting plot 2

The germination success could then be determined, as the sowing data was known. This could be done by applying the following formula (C. Rietema, personal communication, 2021):

$$O = \frac{\mathrm{D_c}}{\mathrm{D_s}} \times 100$$

O = Percentage developed/germinated seeds
D_s = Number of sown seeds per m^2

2.3.2 Plant length

Plant length is one of the most obvious growth factors when it comes to vegetative growth. It shows how fast a plant grows, and is negatively affected under saline conditions (Jana, 1993). Every week, the same three research plants were measured for determining plant length in centimetres. A ruler was held next to the plant at ground level to the tip of the highest leaf (apex) of the plant, to be able to read how high the plant grew in centimetres.

2.3.3 Leaf area

Leaf area is an important factor when it comes to vegetative growth. The leaf is where most of the photosynthesis in a plant takes place, and the size of the leaf can reflect the photosynthetic production of a plant. Since salinisation drastically limits plant growth (Jana, 1993), the effect of salinisation should therefore be noticeable in the growth of leaf area of plants growing on saline soils.

The total leaf area in square centimetres (cm^2) per plant was estimated using a dot chart. A dot chart is a transparent A4 sheet with a dot on every centimetre, four dots together is about 1 cm^2. By placing this transparent A4 on the leaf, the cm^2 of each leaf could be estimated by counting the dots. After knowing how many cm^2 each leaf was, it was possible to determine the total leaf area per plant. This method was performed on all leaves of the three research plants per block. By repeating this every week, the average vegetative growth in leaf area could be registered.

2.3.4 Damage

In order to be able to determine whether the plants are damaged by the type of treatment (ploughing and/or salinisation), it was decided to quantify the damage present on the plant every week. For this purpose, a scale of 1 to 10 has been used, where 1 stands for no damage present (0%) and 10 stands for severely damaged (>75%). The scale that was used for these assessments is shown in Appendix II. The three research plants per block have been assessed weekly using this method. Since salt damage can be very similar to other types of damage, it was decided not to make any distinction between them; all damage was assessed when the plants were evaluated.

2.3.5 Condition

The condition of the plant is a subjective assessment, in which the plant is judged on the overall impression it shows when it comes to growth. The size of the plant, the presence of damage and whether the plant is upright or hanging down are all examined. (C. Rietema, personal communication, 2021). Both the individual research plants and the entire block were tested weekly for their state. A grading of 1 to 10 was applied, where 1 indicates a poor condition and 10 indicates a perfect condition. The scales of these scores are shown in Appendix II.

2.3.6 Root architecture

The way in which the plant root grows can help to understand how a plant deals with stress situations. For instance, the plant may choose to put more energy into apical root growth, which often happens when there is no saline gradient present in the ground. Alternatively, the plant may choose to put more energy into lateral root growth, which happens when there actually is a saline gradient present (Julkowska et al., 2014). Halotropism is also a phenomenon often observed in plants undergoing salt stress, whereby the root moves away from the saline environment (Galvan-Ampudia et al., 2013).

Root growth thus is an important factor when it comes to growing in a saline environment. A disadvantage of root measurements is that they are destructive; the plant is often damaged in the process and will often not survive the measurement. For this reason, it was decided to measure the roots only three times, in the beginning, middle and end of this research. The lateral root growth (from the longest root on the left to the longest root on the right) and the longest apical root were thereby measured in centimetres. In order to do this, one random plant per block was used, which had to be representative for the entire block.

2.4 Data analysis

In order to answer the research questions, the effects of salinisation, ploughing and the possible interaction of ploughing and salinisation must be evaluated. To achieve this, it was decided to apply two types of statistical tests. The 'Mixed Model ANOVA' test was used for all vegetative growth variables (plant length, leaf area, damage, condition, and apical/lateral root length). This was chosen because it fits with the obtained data, since this involves weekly measurements. Furthermore, the Chi-square test for independence was used for determining the possible association between the different treatments on germination. This test was used for germination, because the result of this variable is based on only one measurement. Both methods will be discussed briefly below.

Mixed model ANOVA:

An ANOVA test compares mean values of two or more groups and determines whether statistically detectable differences exist between the groups (Statistics Solutions, n.d.). The ANOVA test can be applied in various ways, including the 'Mixed model ANOVA', which takes the variables that are based on multiple observations into account. It also considers within-subjects, which means that this test assumes that different conditions are applied to the different groups. This test can be used to find the possible relationship between the dependent (the plant) and the independent (the treatment) variable, and also distinguishes fixed effects (ploughing yes or no × salinated yes or no) and random effects (block + time in weeks) (Laerd Statistics, n.d.). The test can be carried out in various programs, including SPSS. This program determines the chance of finding the observed variables when the null hypothesis is correct, with a significance value (p-value). For the successful demonstration of a significant relationship, the p should be lower than the alpha (Statistics Solutions, n.d.). For this study, the standard alpha value of 0,05 is used with the null hypothesis that there are no detectable differences between the treatments and therefore no significant relationship between the dependent and independent variable exists.

Chi-square test for independence

The Chi-square test for independence is a statistical test that can be used to determine a possible relationship between two (independent) groups. The test can be performed in programs such as MS Excel. It compares observed data with expected data. The expected data must first be calculated by applying the following formula (Frost, n.d.):

$$Expected\ data = \frac{(Row\ total\ \times Column\ total)}{Sample\ size}$$

When the expected data is calculated, the Chi-square test can be performed by using the next formula (Frost, n.d.):

$$X^2\ = \sum \frac{(Observed - Expected)^2}{Expected}$$

When the above-mentioned formula is applied, the result of this comparison must be verified with the critical Chi-square value. If this outcome surpasses the critical Chi-square value at an alpha of 0,05, it can be described as a significant effect. This means that the null hypothesis can be rejected (Frost, n.d.). The null hypothesis formulated in this study is that no association between germination and the different treatments exists.

After performing the above-mentioned statistical tests, graphs were produced showing the average weekly development of the variables per treatment. By comparing the results of the statistical tests with these graphs, it was possible to determine the potential (interactive) effects of the treatments.

3. Results

In order to answer the research questions, all observed data had to be analysed using statistics. The Chi-square test for independence was used for determining association between the treatment groups and germination, and a Mixed Model ANOVA test was conducted for determining any possible (interactive) effects of the treatments per growth variable. All analyses per variable can be found below in order of the research questions. By doing so, first will be determined whether there is an interactive effect between the treatments, when this is not the case, each treatment is individually analysed. (Non)Significant data is displayed as follows: p= <0,05 = *, p= <0,01 = **, p= >0,05 = n.s. (not significant). Finally, a graph is produced to explain the possible (interacting) effects. The complete dataset can be found in Appendix III, and the full output of the statistic tests from SPSS can be found in Appendix IV.

3.1 Germination

The Chi-square test for independence was used for determining possible associations between the treatments on germination. Crop density per square meter was used for the Chi-square test for independence, that was conducted using MS Excel. Figure 3.1 shows a p-value of 2,37273E-07 (df = 1, p = 0,000**). The impact size of unploughed/unsalinated soil was the highest (1,51), and the lowest impact size was found in ploughed/unsalinated soil (0,60). Figure 3.2 displays germination success per treatment. Most plants germinated on unploughed soil, where unploughed/unsalinated scored the highest germination success with 61,0%. The lowest germination was visible on ploughed/unsalinated soil, with a germination success of 24,4%.

	Observed data				Impact Size		
	Ploughed	Unploughed	*Total*			Observed data	Impact (O/M)
Salinated	150	162	*312*		ploughed/unsalinated	100	0,60
Unsalinated	100	250	*350*		Ploughed/salinated	150	0,91
Total	*250*	*412*	*662*		Unploughed/unsalinated	250	1,51
					Unploughed/salinated	162	0,98
					Mean	166	
	Expected data				Significance		
	Ploughed	Unploughed	*Total*		Test quantity: ∑(O-E)^2/E		
Salinated	117,8247734	194,1752266	*312*		26,7028326		
Unsalinated	132,1752266	217,8247734	*350*		P-value:		
Total	*250*	*412*	*662*		2,37273E-07		

Figure 3.1: Chi-square output results MS Excel

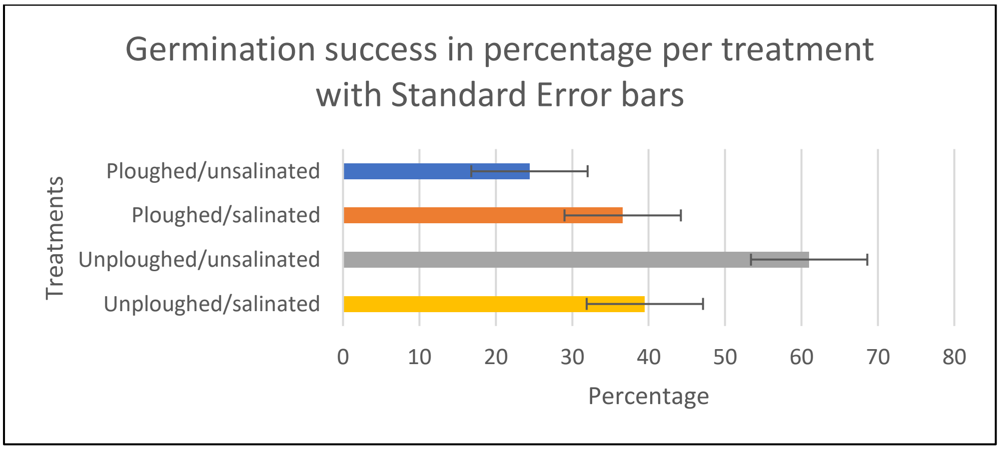

Figure 3.2: Germination success per treatment

3.2 Plant length

Figure 3.3 shows the output of the Mixed model ANOVA test by SPSS. This test showed a significant value for the interactive effect of both treatments (df = 1, p = 0,003**) and for salinisation (df = 1, p = 0,009**). Ploughing did not show any significance (df = 1, p = 0,782 n.s.). The weekly growth in plant length per treatment is displayed in figure 3.4. Since an interactive effect is found, it was decided to show all treatment groups in one graph. This graph shows the highest growth in unploughed/salinated soil, and the lowest growth can be seen in unploughed/unsalinated soil.

Fixed Effects

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	284,924	4742,884	,000
Ploughing	1	284,924	,077	,782
Salinisation	1	284,924	6,997	,009
Ploughing * Salinisation	1	284,924	9,178	,003

a. Dependent Variable: Plant_length.

Figure 3.3: SPSS output: Mixed Model ANOVA for determining (interactive) effects of treatments on plant length

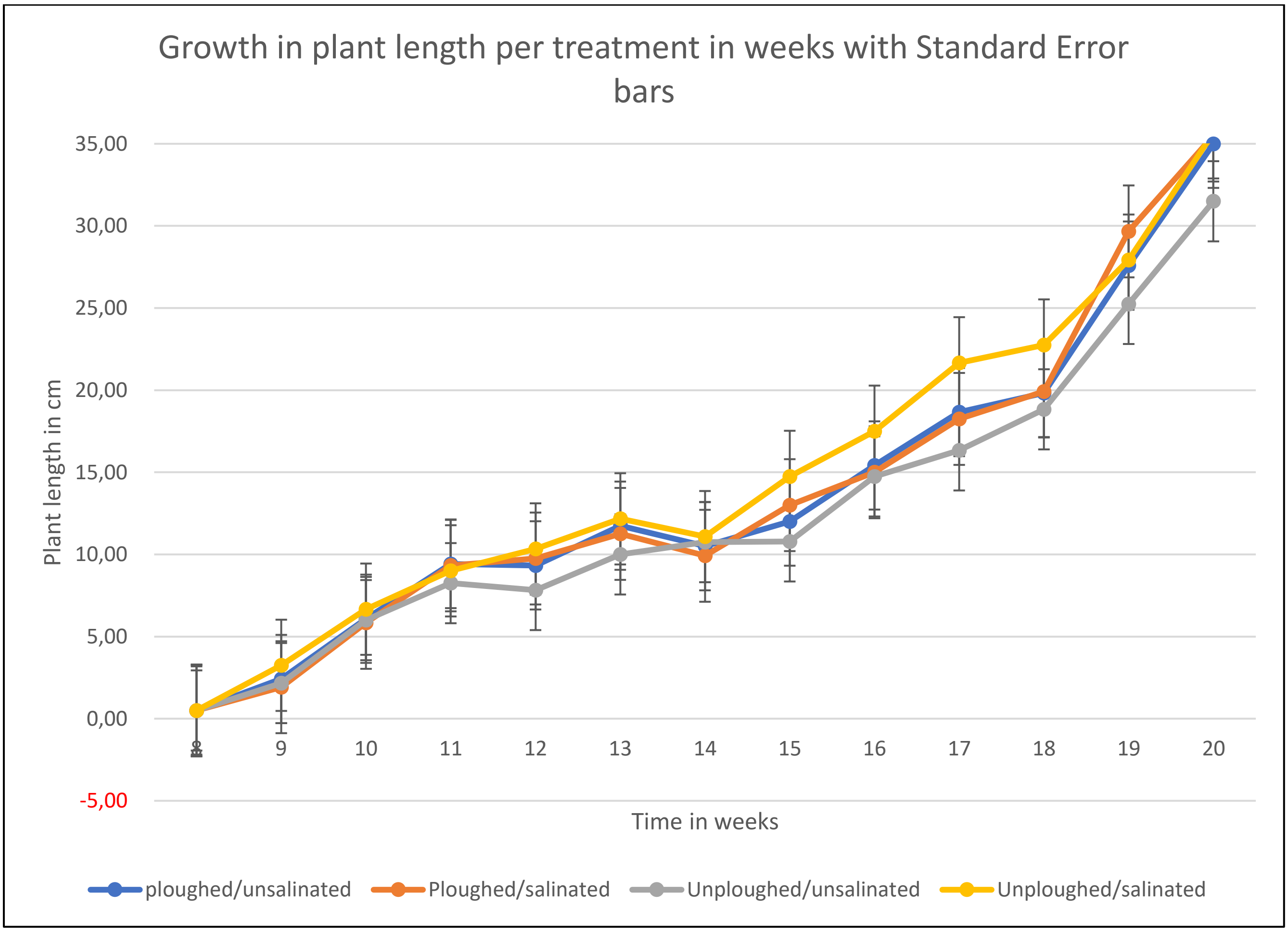

Figure 3.4: The vegetative growth in plant length of the research plants per treatment

3.3 Leaf Area

Leaf area was the only variable that was not normally distributed, and therefore had to be transformed into logarithmic data in order to fulfil the requirement for the data to be normally distributed. No significant value came out of the Mixed Model ANOVA test by SPSS, for both the interaction of the treatments (df = 1, p= 0,225 n.s.), as the treatments individually (df = 1, p = 0,613 n.s for ploughing, and df = 1, p = 0,406 n.s. for salinisation). This can be seen in figure 3.5, displaying the SPSS output. As no effects were found by the statistical test, it was decided to make a graph showing each type of treatment separately in figure 3.6. This graph showed an exponential growth in all treatments with minor differences. Unploughed/salinated soil showed the highest growth in weeks 8 to 18 but was then surpassed by both ploughed/unsalinated and ploughed/salinated soil types. The unploughed/unsalinated treatment showed the lowest growth in leaf area.

Fixed Effects

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	127,771	7431,149	,000
Ploughing	1	127,771	,258	,613
Salinisation	1	127,771	,695	,406
Ploughing * Salinisation	1	127,771	1,485	,225

a. Dependent Variable: Leaf_Area_LOG.

Figure 3.5: SPSS output: Mixed Model ANOVA for determining (interactive) effects of treatments on leaf area

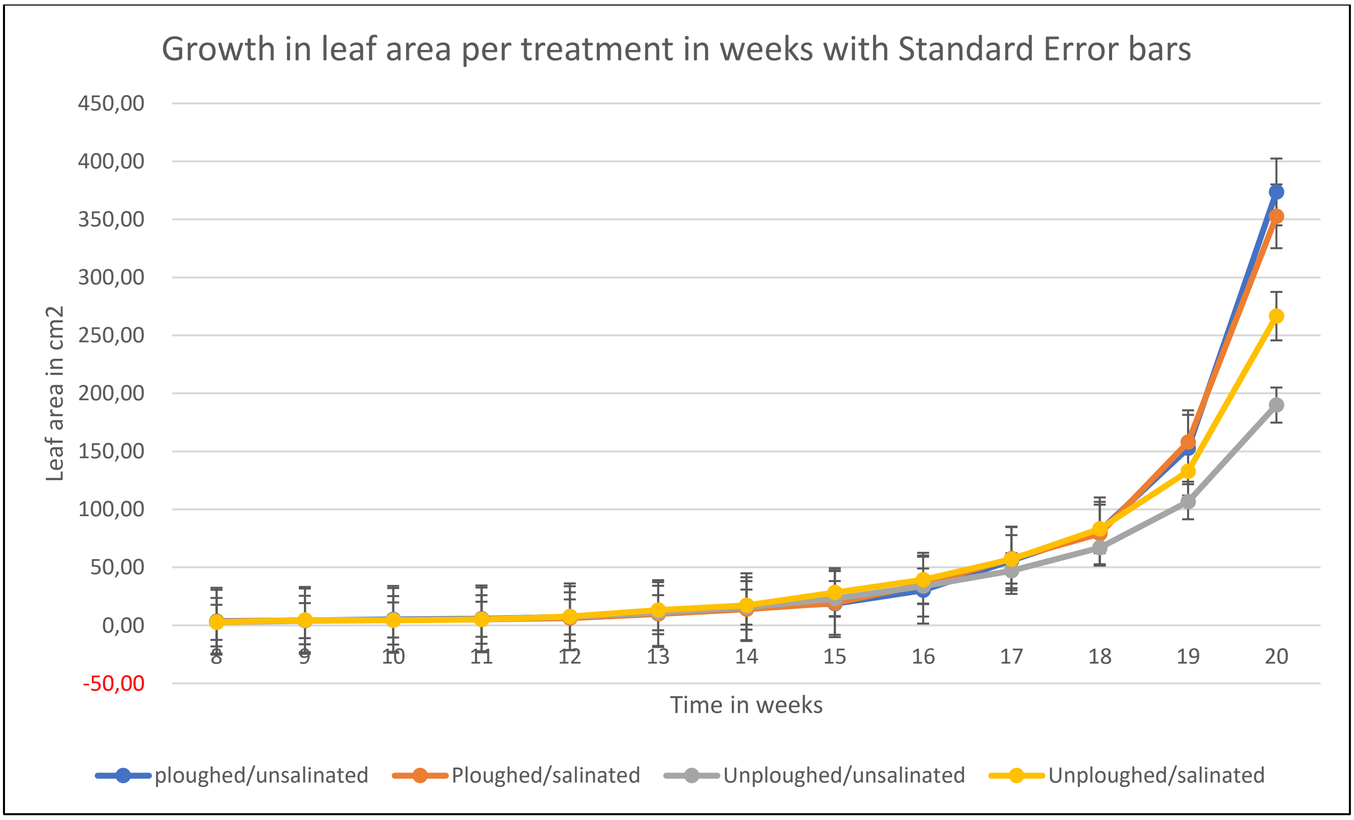

Figure 3.6: The vegetative growth in leaf area of the research plants per treatment

3.4 Damage

A significant value of df = 1, p = 0,001** came out of the Mixed Model ANOVA test, when looking at the interaction between salinisation and ploughing on plant damage. Both ploughing (df = 1, p= 0,000**) and salinisation (df = 1, p = 0,026*) scored a significant value as well (see figure 3.7). The amount of damage has been scored by using the classification system, described in Appendix II. Since an interactive effect has been found, all treatment groups were separated in one graph. The means of weekly damage on the twelve research plants per treatment is therefore visualised in figure 3.8. The overall least amount of damage can be seen on unploughed/salinated soil on weeks 9 to 16, and most of the damage was visible in week 11 to 20 on unsalinated/unploughed soil. The ploughed treatments stayed most of the time in between the other two treatments.

Fixed Effects

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	303,832	3345,372	,000
Ploughing	1	303,832	16,383	,000
Salinisation	1	303,832	4,999	,026
Ploughing * Salinisation	1	303,832	12,192	,001

a. Dependent Variable: Damage.

Figure 3.7: SPSS output: Mixed Model ANOVA for determining (interactive) effects of treatments on plant damage

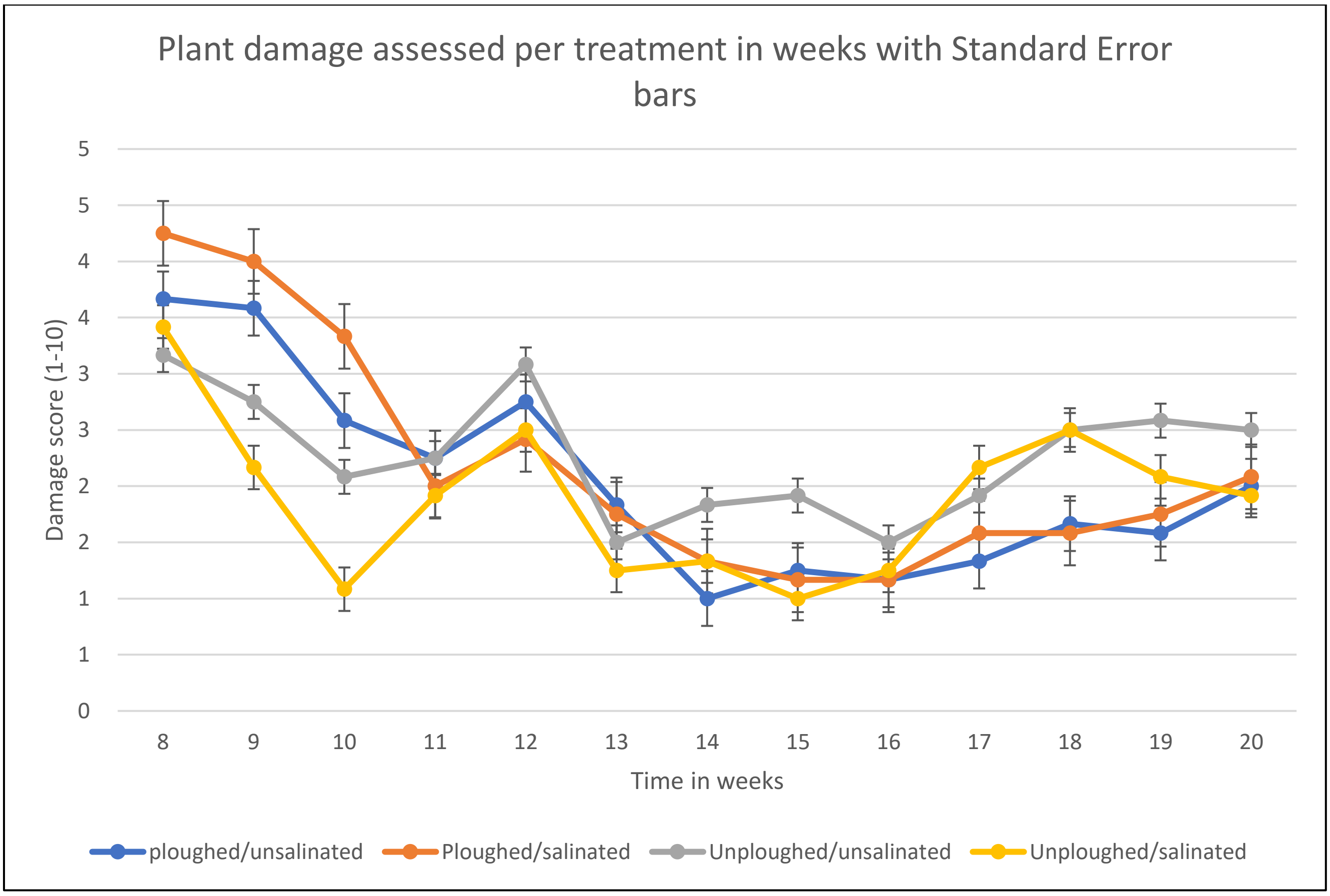

Figure 3.8: The amount of damage on vegetative plant parts of the research plants per treatment

3.5 Condition
The Mixed Model ANOVA test showed again a significant value for the interaction between the treatments on the measured variable (df = 1, p = 0,000**). Ploughing did not show a significant effect (df = 1, p = 0,109 n.s.), but salinisation did (df = 1, p = 0,000**) (see figure 3.9). A classification system was again used for determining individual plant condition and the general expression of each plant (see Appendix II). Since an interaction between the treatment groups is found, it was decided to show all treatment groups separately in one graph. Means of the condition score had been calculated per treatment and is displayed in figure 3.10. The condition was quite consistent in all treatment groups, and only minor differences between the treatment groups can be seen. The highest condition was scored, most of the times, in unploughed/salinated soil, and the lowest condition was scored mostly in unploughed/unsalinated soil. The ploughed treatments stayed again most of the time in between the other two treatments.

Fixed Effects

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	412,252	66300,671	,000
Ploughing	1	412,252	2,585	,109
Salinisation	1	412,252	18,136	,000
Ploughing * Salinisation	1	412,252	23,798	,000

a. Dependent Variable: Condition.

Figure 3.9: SPSS output: Mixed Model ANOVA for determining (interactive) effects of treatments on plant condition

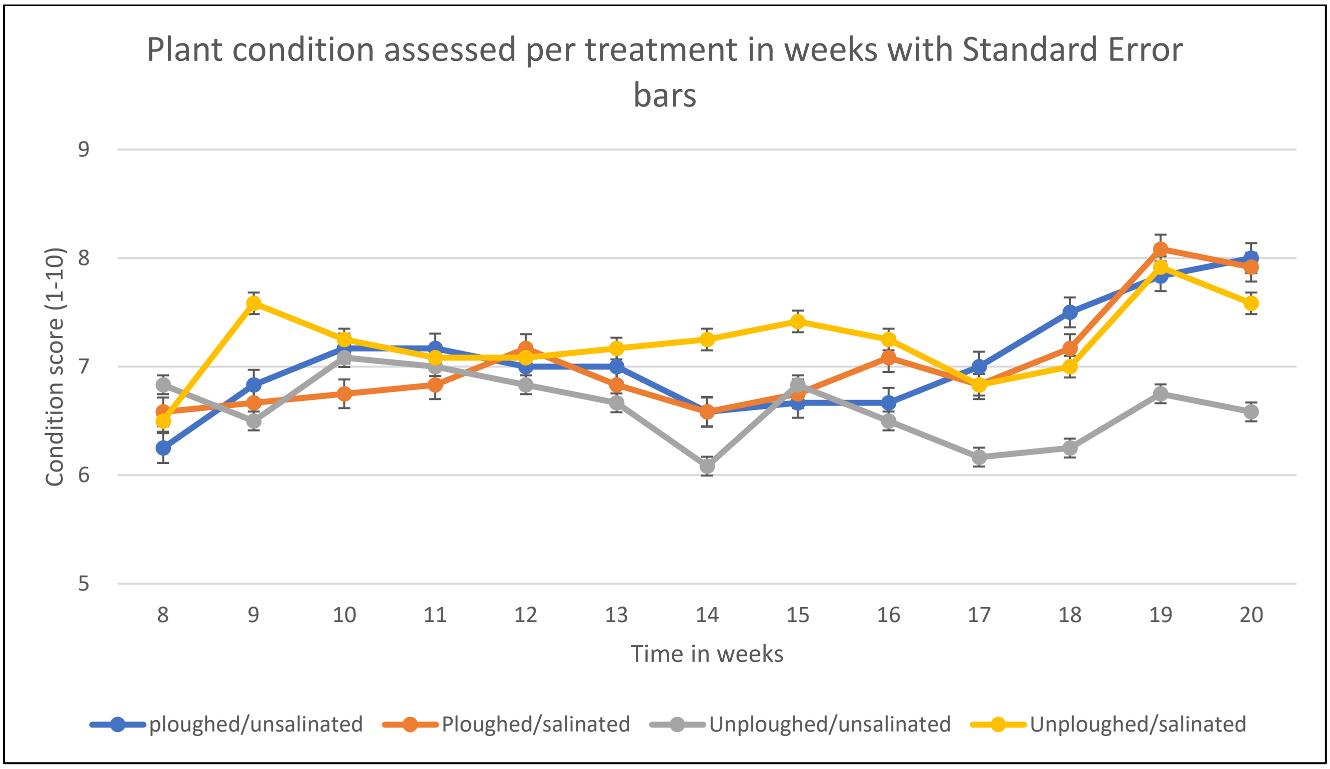

Figure 3.10: The weekly plant condition of the research plants per treatment

3.6 Root architecture

When looking at the outcome of the Mixed Model ANOVA tests, no significant value is found for both the interaction between the treatments as the treatments themselves on affecting apical or lateral root length (see figure 3.11 for apical root length and 3.12 for lateral root length). Apical root length scored df = 1, p = 0,892 n.s. on interactive effects, df = 1, p = 0,792 n.s on ploughing, and df = 1, p = 0,961 n.s on salinisation. Lateral root length scored df = 1, p = 0,407 n.s. for the interactive effect of ploughing and salinisation, df = 1, p = 0,128 n.s. for ploughing, and df = 1, p = 0,598 n.s. for salinisation. Since no effects emerged from the statistical test, it was decided to present each treatment separately in a graph. The length of both apical and lateral roots was measured three times during this study. Means of the twelve research plants per treatment have been calculated to show the root growth in weeks. The results are visualised in figure 3.13 and 3.14, where 3.13 shows the results of the apical root length measurements, and 3.14 shows the results of lateral root length measurements. There are only subtle differences between the treatment groups visible, when looking at the apical root growth, and these subtle differences are not consistent either. Lateral root growth does differ much between the treatment groups, but these differences are also inconsistent.

Fixed Effects

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	28,104	754,662	,000
Ploughing	1	28,104	,071	,792
Salinisation	1	28,104	,002	,961
Ploughing * Salinisation	1	28,104	,019	,892

a. Dependent Variable: Apical_root_length.

Figure 3.11: SPSS output: Mixed Model ANOVA for determining (interactive) effects of treatments on apical root length

Fixed Effects

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	33,500	444,572	,000
Ploughing	1	33,500	2,442	,128
Salinisation	1	33,500	,283	,598
Ploughing * Salinisation	1	33,500	,706	,407

a. Dependent Variable: Lateral_root_length.

Figure 3.12:SPSS output: Mixed Model ANOVA for determining (interactive) effects of treatments on lateral root length

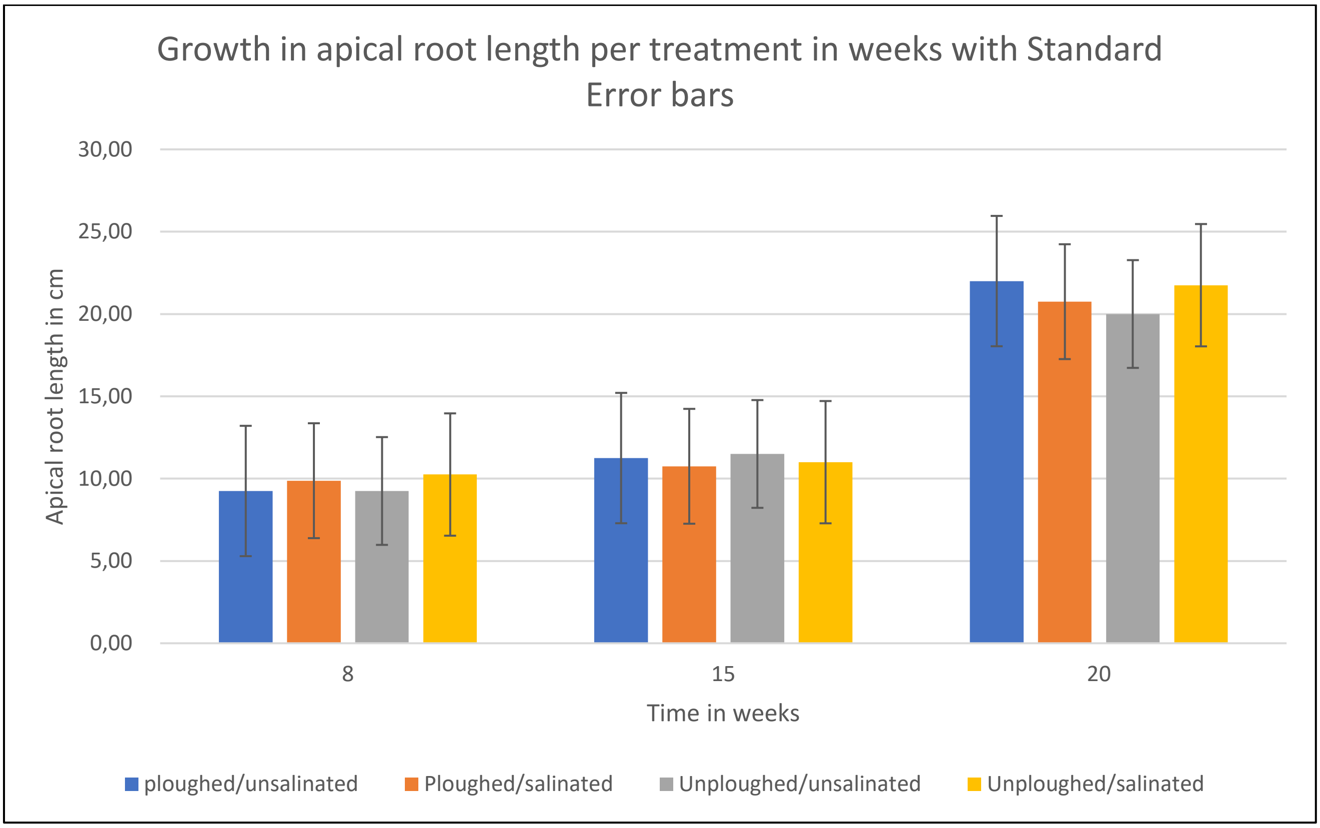

Figure 3.13: The vegetative growth in apical root length of the research plants per treatment

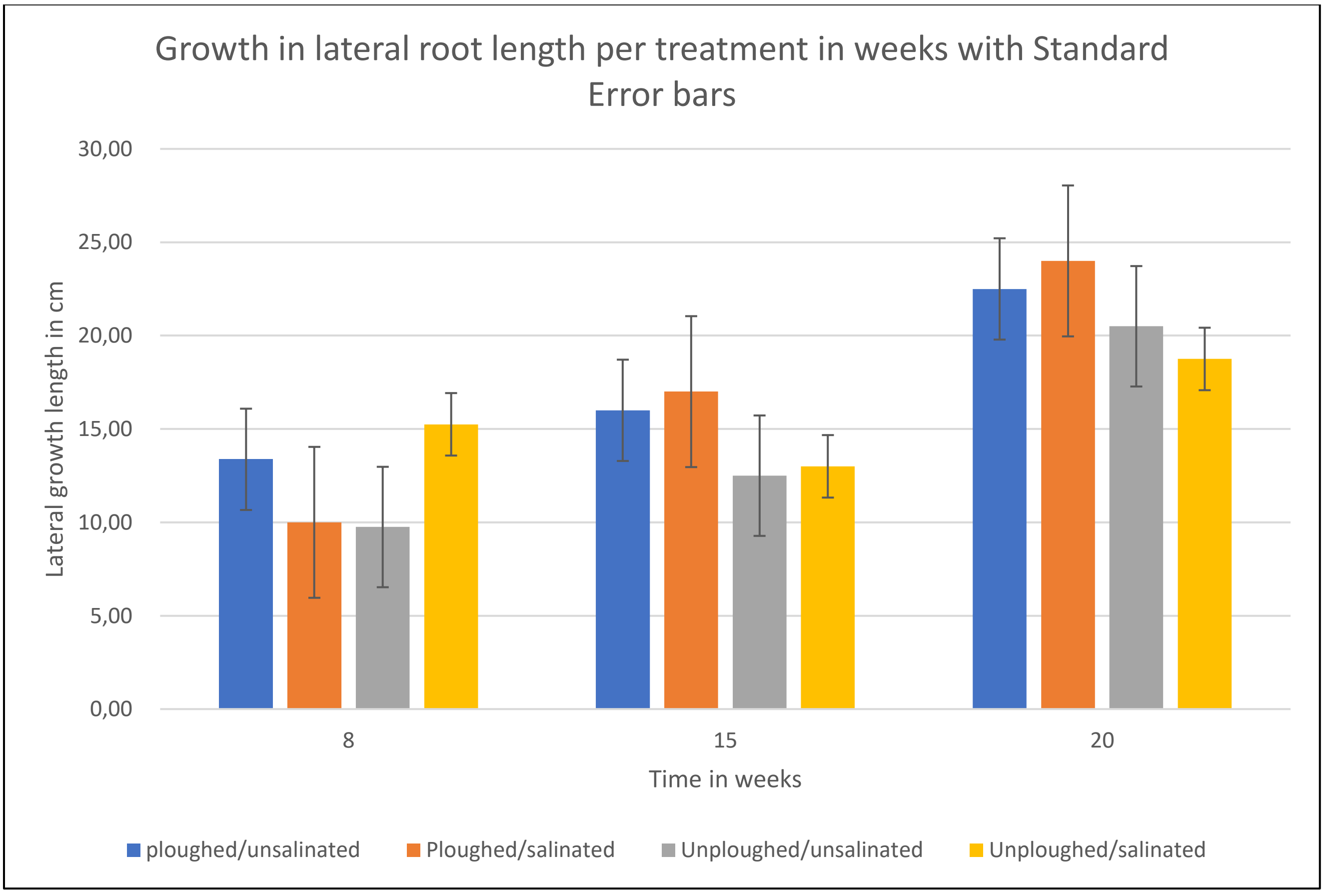

Figure 3.14: The vegetative growth in lateral root length of the research plants per treatment

4. Discussion

In section 4, the obtained results will be explained and interpreted. In addition, the used methodology will be critically examined, and points of improvement will be given for a possible repeat or follow-up study. The interpretation of the obtained results can be used by breeders of salt-tolerant wheat varieties for choosing phenotypic selection criteria and provide information to wheat growers growing on saline soils.

4.1 interpretation of the obtained results

In the analysis conducted in SPSS and MS Excel, only four growth variables showed an interactive effect of the treatments, and all other variables showed no individual or interactive treatment effects. The interpretation of these results will be discussed below per variable in order of the research questions.

4.1.1 Germination

The Chi-square test for independence shows a significant value of df = 1, p = 0,000** (see figure 3.1). Since the p-value is lower than the standard alpha value of 0,05, the null hypothesis can be rejected. This means that there is an association between the treatments on the level of germination. When looking at figure 3.2 it became clear that most plants germinated on unploughed/unsalinated soil, and the least number of plants germinated on ploughed/unsalinated soil. Both ploughed/salinated and unploughed/salinated showed comparable amounts of germination with only a difference of 2,9% (12 plants). This outcome provides insight on the influence of ploughing and salinisation on germination success.

First, ploughing seems to interact with salinisation when looking at germination success, because neither salinisation nor ploughing show consistent differences in the rate of germination when this was applied to the soil in question. This means that both treatments influence the level of germination. Ploughing seems to drastically decrease the germination of winter wheat growing on unsalinated soil types. When ploughing was applied, a decrease of 36,6% in germination success was visualised. This can be logically explained by the fact that ploughing disrupts soil structure (Wang *et al*., 2014). By disrupting soil structure, plants such as winter wheat may find it harder to germinate, since seeds need direct contact with (moist) soil in order to germinate properly (Campbell *et al.*, 2018). When the soil was salinated, ploughing only seems to have minor effects on germination, since only a decrease of 2,9% was visible. This means that ploughing majorly affects the level of germination when no salinisation is present in the ground. The effect of salinisation on germination did not show a clear decrease or increase when it was applied. On unploughed soil, salinisation shows a decrease in germination of 21,5%. However, on ploughed soil the presence of salinisation shows an increase of 12,2% on the level of germination. This means that the effect of salinisation on germination depends on whether or not ploughing is applied. Why salinisation shows an increase on germination on ploughed grounds can not be explained in literature. This is likely caused by other environmental factors that differed in the trail field.

4.1.2 Plant length

The Mixed model ANOVA test shows a significant value of df = 1, p = 0,003** for the interactive effect of both treatments on plant length (see figure 3.3). The p-value is therefore lower that the standard alpha value of 0,05, meaning that the null hypothesis can be rejected. This means that there is an interactive effect of ploughing and salinisation that influences the plant length. Therefore, the treatments cannot be analysed separately because both treatments will always interact with each other. The graph in figure 3.4 showed minor differences between the treatment groups, and only two-to-five-centimetre differences can be seen. However, the graph clearly shows the highest growth, most of the times, in unploughed/salinated soil and the lowest in unploughed/unsalinated soil. The other two treatments (ploughed/salinated and ploughed/unsalinated) showed a quite similar growth and stayed in between the growth of the other two treatments. This means two things:

- The effect of ploughing does not simply mean that plants will grow bigger or smaller, because the difference with the unploughed treatments depended on whether or not those treatments were salinated. The ploughed treatments were smaller than the unploughed/salinated treatment but were bigger than the unploughed/unsalinated treatment. Therefore, the combination of ploughing and whether or not salinisation is applied will influence the growth in plant length.
- The effect of salinisation does not simply mean that the plants will grow bigger or smaller, since the difference in growth depended on whether or not ploughing was applied in the treatments. In most cases, the biggest plant length was visible in the treatment unploughed/salinated. However, the ploughed/salinated treatment showed most of the times the same growth as the ploughed/unsalinated treatment did. Therefore, the combination of salinisation and whether or not ploughing is applied will influence the growth in plant length.

In the introduction, a number of expectations were mentioned regarding this research. Ploughing was expected to possibly enhance the plant's development, as it increases the fertility of the soil by adding more organic matter in deeper soil layers (The Editors of Encyclopaedia Britannica, 2020). Increasing soil fertility would indirectly restore soil moisture and could therefore help to reduce the dehydration effect of salinisation (Bot & Benites, 2005). Besides this, Wang *et al*. (2014) found that ploughing disrupts soil structure and moisture stability, and that no-tillage cultivation systems actually decrease the salinity concentration in the soil. This made it unclear whether or not ploughing would have positive or negative effects on plants growing on salinized soil. When looking at the outcome of this research, it became clear that when no salinisation was applied ploughing would benefit the plant's length. This is in line with the mentioned expectations as ploughing was expected to enhance the plant's development. However, when salinisation was applied on unploughed soil, salinisation tends to have major impact on the plant's growth, as plants would show a higher growth in unploughed/salinated than in unploughed/unsalinated soil types. When salinisation was applied in ploughed soils, only minor differences can be seen, as ploughed/salinated and ploughed/unsalinated showed similar growth. This means that when winter wheat grows in saline conditions, ploughing could decrease the effects of salinisation on plant length. This is in line with the expectation that ploughing may dilute the salt concentration in the soil, by dispersing the salts more evenly when this method was applied. However, this has not been proved by literature and another logical explanation has not been found.

Another expectation was that salinisation was expected to have major influence on the vegetative growth of winter wheat and literature showed that plants who suffer from salinisation show a decreased growth (Isayenkov, 2012). Since no differences in plant length were visible on ploughed/salinated and ploughed/unsalinated soil types, and since the highest growth was visible in unploughed/salinated soil, it can be mentioned that this expectation did not came out of this research. There was no sign of a decreased growth in the salinated treatments, and in one of the treatments (unploughed/salinated) a higher growth was visible. However, higher plant growth of plants growing on salinated soils does not mean that the plants do not suffer from salt stress. As a reaction on salt stress, plants could release a group of hormones called strigolactones which regulates abiotic stresses like salinisation by changing the vegetative growth (Saeed, Naseem, & Ali, 2017). Ling *et al.* (2020) found that rice seedlings that were subjected to salinisation in combination with synthetic strigolactone GR24 had indeed a higher tolerance against salt stress and showed an increased plant length. This could mean that the increase of plant length might be a reaction of the plant to cope with salt stress conditions.

4.1.3 Leaf area

No significant value came out of the Mixed Model ANOVA test when looking at the effect of the treatments on leaf area. Neither the interaction between the treatments (df = 1, p= 0,225 n.s.) as the individual effect of ploughing (df = 1, p = 0,613 n.s), and salinisation (df = 1, p = 0,406 n.s.) showed a significant effect (see figure 3.5). Therefore the null hypothesis cannot be rejected, meaning that there is no (interactive) treatment effect on the growth in leaf area of winter wheat. Even though figure 3.6 shows quite some similarities with plant length (see figure 3.5). The highest leaf area was, most of the times, found on unploughed/salinated soil and the lowest leaf area was found in unploughed/unsalinated soil. The ploughed treatments stayed in between the other two treatments for weeks 8 to 18 and surpassed the unploughed/salinated treatment on week 18. All treatment groups showed quite the same exponential growth in leaf area and only minor differences are visible. Since no effect is proven by statistics, it became sure that ploughing and salinisation do not, interactively or individually, affect the growth in leaf area of winter wheat. This means that differences visible in figure 3.6 are based on other environmental factors, present on the different trial fields of this research.

Ploughing was expected to benefit the vegetative growth as it increases the fertility of the soil (The Editors of Encyclopaedia Britannica, 2020). Figure 3.6 does show the highest amount of leaf area on ploughed soils in week 18 to 20, which could mean that this expectation is correct. Then again, unploughed/salinated soil showed the highest growth in leaf area in weeks 8 to 18, which in turn contradicts this expectation. Since this could not be proven by statistics, it remains unsure if ploughing has this beneficial effect on winter wheat.

Salinisation was expected to decrease the vegetative growth of winter wheat (Isayenkov, 2012). The salinated treatments showed a slightly decreased growth on ploughed soils, but a major increase on unploughed soils in growth of leaf area. This could mean that plants growing on saline soils develop quicker in leaf area and contradicts with the abovementioned expectation. The reason for developing larger leaves on salinated soils could be the same reason as why plant length was larger in salinated treatments. As mentioned before, plants can react differently on salt stress and could release a group of hormones called strigolactones, which helps the plant to cope with salt stress. This hormone also tends to make the plant and its leaves bigger (Saeed, Naseem, & Ali, 2017). Of course, since no significant value came out of the Mixed Model ANOVA test, it remains unsure if this effect is caused by salinisation.

4.1.4 Damage

A significant value of df = 1, p = 0,001** came out of the Mixed Model ANOVA test when looking at the interactive effect of salinisation and ploughing on present damage (see figure 3.7). Since this p-value is lower than the standard alpha value of 0,05, the null hypothesis can be rejected. This means that both ploughing and salinisation interactively affects the present damage seen on winter wheat. Because an interactive effect was found, the treatments could not be analysed individually, since the treatments will always interact with each other. Figure 3.8 shows the weekly amount of damage present on winter wheat. This damage differs only slightly between the treatment groups and is not consistent. Most of the times, the highest amount of damage can be seen on unploughed/unsalinated soil and the lowest amount on unploughed/salinated soil. The other two treatments stayed in between unploughed/salinated and unploughed/unsalinated treatments for weeks 11 to 16 and show the least amount of damage from weeks 16 to 19. This means the following things:

- The effect of ploughing does not simply mean that plants will show more or less damage, because the difference with the unploughed treatments depended on whether or not those treatments were salinated. When ploughing is conducted on unsalinated soil, it decreases the present amount of damage, since ploughed/unsalinated scored a lesser degree of damage than unploughed/unsalinated did. Ploughing on salinated soil seems to decrease the effects of salinisation, as ploughed/salinated showed a similar amount of damage as ploughed/unsalinated, and when no ploughing was conducted big differences were visible between the salinated treatments. Therefore, the combination of ploughing and whether or not salinisation is applied will influence the present amount of damage on winter wheat.
- The effect of salinisation does not simply mean that the plants will show more or less damage, since the difference in damage depended on whether or not ploughing was applied in the treatments. In most cases, unploughed/salinated scored a lesser degree of damage than unploughed/unsalinated did. However, on ploughed soil the ploughed/salinated treatment showed most of the times somewhat the same amount of damage as the ploughed/unsalinated treatment. Therefore, the combination of salinisation and whether or not ploughing is applied will influence the present amount of damage.

In the introduction it remained unsure whether ploughing would have positive or negative effects on damage caused by salinisation. When looking at the outcome of this study, ploughing on saline soils seems to decrease the effect of salinisation on plant damage. No explanation about this phenomenon have been found in literature, as the interactive effects of ploughing and salinisation have not been described before. A logical explanation could be that ploughing mixed the salt concentration in the soil, causing the seedlings to root in a saline condition, which could have caused the earlier and a higher degree of damage in the beginning of the experiment, visible in ploughed soil. It also explains the sudden increase of damage present in unploughed/salinated soil in week 16. This could have been the week that the roots of these plants were able to extract water from the saline part of the ground because this sudden increase is not visible in the ploughed treatments. Salinisation was expected to increase damage as extreme concentrations of Na^+ and C^{l-} are toxic to plants (Tester & Davenport, 2003). This did not emerge clearly from this study, as the non-salinated treatments showed a higher degree of damage than the salinated treatments did. The reason for this is probably the same reason as why plants were higher in salinated soil types. As a rection to salt stress, plants can release a group of hormones called strigolactones, which helps the plant to cope with the saline conditions (Saeed, Naseem, & Ali, 2017). As these plants were more capable of coping with salt stress, they presumably showed less damage.

4.1.5 Condition

The Mixed Model ANOVA test shows again a significant value for the interaction between the treatments on the measured variable (df = 1, p = 0,000**) (see figure 3.9). This means that the null hypothesis can be rejected and that salinisation and ploughing interactively affects plant condition. Figure 3.10 shows that, in general, no major differences are visible. Nevertheless, unploughed/salinated almost always scored the highest value for condition and unploughed/unsalinated almost always scored the lowest value. The other two treatments (ploughed/salinated and ploughed/unsalinated) scored similar values and mostly stayed between the lines of the other two treatments. This means that:

- The effect of ploughing does not simply mean that plants will show a better or worse condition, because the difference with the unploughed treatments depended on whether or not those treatments were salinated. When ploughing is conducted on unsalinated soil, it increases the plant's condition, since ploughed/unsalinated scored a higher value for condition than unploughed/unsalinated did. Ploughing on salinated soil seems to decrease the effects of salinisation, as ploughed/salinated showed a similar condition as ploughed/unsalinated, and when no ploughing was conducted big differences were visible between the salinated treatments. Therefore, the combination of ploughing and whether or not salinisation is applied will influence the plant's condition.
- The effect of salinisation does not simply mean that the plants will show a better or worse condition, since the difference in condition depended on whether or not ploughing was applied in the treatments. In most cases, unploughed/salinated scored a higher value for condition than unploughed/unsalinated did. However, on ploughed soil the ploughed/salinated treatment showed most of the times somewhat the same condition as the ploughed/unsalinated treatment. Therefore, the combination of salinisation and whether or not ploughing is applied will influence plant condition.

Similar expectations were formulated in the introduction regarding condition when compared to damage. For example, it was not entirely clear whether ploughing would improve the condition of plants on a saline soil, and it was expected that salinisation would negatively affect the condition. The results show that ploughing on unsalinated soil increases the condition of plants. Ploughing also decreased the effect of salinisation, as only minor differences were visible in the salinated treatments on ploughed soil and major differences between the salinated treatments were visible in unploughed soil. This could be caused by the fact that ploughing uniforms the soil by mixing it, allowing the plants to grow more uniform as well. In addition, salinisation seems to have had a positive effect on the condition, as the salinated treatments often received the highest condition scores. Most likely this is caused by the fact that the plants on the saline soils also had a higher plant length and showed less damage (see paragraph 4.1.2 and 4.1.4), which is why they often received better scores. Paragraph 4.1.2 clearly mentioned that plants suffering from salt stress could release a group of hormones called strigolactones. These hormones tend to make the plant bigger as well and helps the plant to cope with salinisation, which in turn will make the plant show less damage (Saeed, Naseem, & Ali, 2017).

4.1.6 Root architecture

No significant treatment effects were found in the measurements of apical and lateral root length. Apical root length scored df = 1, p = 0,892 n.s. on interactive effects, df = 1, p = 0,792 n.s on ploughing, and df = 1, p = 0,961 n.s on salinisation (see figure 3.11). Lateral root length scored df = 1, p = 0,407 n.s. for the interactive effect of ploughing and salinisation, df = 1, p = 0,128 n.s. for ploughing, and df = 1, p = 0,598 n.s. for salinisation (see figure 3.12). All of these p-values surpassed the alpha of 0,05, which means the null hypothesis for both apical and lateral root length cannot be rejected. This means that no individual or interactive treatment effects cause differences in apical or lateral root length of winter wheat. Not much can be said from the graphs analysed for these variables. The apical roots grew very uniformly in all treatment groups and any differences were not consistent (see Figure 3.13). The lateral roots did show noticeable differences between treatments, but again, these differences were also inconsistent (see figure 3.14). Therefore, this study showed that neither salinisation nor ploughing nor the interaction between ploughing and salinisation affect the apical or lateral root growth of winter wheat.

This does not strike with the expectations mentioned in the introduction. Ploughing was expected to make it easier for plants to root (The Editors of Encyclopaedia Britannica, 2020), and salinisation was expected to change the way the roots grew horizontally and/or vertically (Julkowska et al., 2014). The reason why this is not emerged from this study is probably related to the approached method. Since the plants had to be excavated from the soil, there was a chance that roots might break. Therefore, it cannot be completely guaranteed that the roots of the measured plants were in fact longer, shorter, wider or narrower. Paragraph 4.2 will discuss this in more detail.

4.2 Evaluation

In general, it can be said that this experiment has been successful. Clear results have emerged that can be of real value to growers who grow on saline soils and to breeders of salt-tolerant winter wheat varieties. However, there are also a number of issues that could be considered in a possible next study or repeat study, regarding this subject.

The first matter to be addressed, regarding this research, is the extent to which all environmental factors were equal on the trial fields. Of course, it cannot be guaranteed that all factors, except for the chosen treatments, were equal on each trial field. The randomised block design was used to compensate for this effect, but of course there will always be external factors that influence the experiment in question. Therefore, it would probably be better to carry out a trial like this in a closed greenhouse environment. Although a closed greenhouse environment is very different from the real cultivation situation, environmental factors are easier to control.

In addition, the method for applying the treatments will be discussed. In order to make the soil saline, drip irrigation was chosen, with water being the medium by which the salts were added to the soil. Because of that, the plants that stood on a non-saline soil were offered less water, as they were only irrigated with fresh water when the water buffer in the soil was too low. The difference in water supply may have influenced the results of this research. Therefore, it is recommended to keep the methods of applying the treatments as similar as possible in a repeat or follow-up study.

Finally, human activity is a crucial factor during a research like this. Observations such as determining the leaf area are not suitable for when the plant reaches a later stage of growth. Winter wheat will start to sprout at a certain point, and it has been found very difficult to measure all the individual leaves at that time. There is also the chance that leaves are counted twice or being bypassed. Furthermore, an observation such as condition is quite subjective and will be judged differently when determined by another individual. The root measurements were also susceptible for human intervention, as the method used to excavate the roots determines the length and width. It is better for measurements such as root measurements to use methods that do not damage the plant in question. Therefore, the advice is to choose the measurements carefully, perhaps per growing stage.

5. Conclusion and advise

In this last chapter, the research questions will be answered, and a conclusion will be given. Based on the outcome of this research, advice will be given to growers and breeders of winter wheat on saline soils.

5.1 Answers to the research questions

At the beginning of this study, three sub questions were formulated to answer the final research question. Now that the results are known and have been interpreted, all research questions can now be answered. The goal of this study was to determine how vegetative growth variables change in winter wheat when it is grown in a saline environment and what influence ploughing has on this. By answering this question, advice can be given to breeders and growers. Below, the research questions are answered one by one and together they provide the conclusion of this research.

- <u>How do salinisation and ploughing interactively affect the vegetative growth of winter wheat?</u>
  Ploughing and salinisation interactively affect the following variables in winter wheat: germination, plant length, damage and condition. The results indicate that both treatments have an effect on the abovementioned variables in winter wheat, the extent to which these treatments are applied determines the final effect. When looking at germination, it can be concluded that germination of the winter wheat variety ‘Extase’ is negatively affected by ploughing, since ploughing on both salinated and unsalinated grounds significantly decreased the number of germinated plants. Salinisation does not show a clear increase or decrease in germination when this treatment is applied.

  In most cases, the combination of no ploughing and salinisation led to longer plant lengths, less damage and an improved condition. On the other hand, the combination of no ploughing and no salinisation led to the shortest plant length, more damage and a lower condition. The increased plant length and reduced damage on saline soils was probably caused by the way the plants coped with the saline conditions. As a response to salt stress, plants can release strigolactones that make them more tolerant to the negative effects of salt stress and promote apical dominance. Since these plants were taller and showed less damage, they automatically received a higher rating on condition. Ploughing seems to decrease the effects of salinisation, as ploughing decreased the differences between the unsalinated and salinated treatment groups in all variables where a significant interactive effect was found. However, it should be realised that this is a new study that needs to be repeated more often to provide more certainty regarding this subject.

- <u>How does ploughing affect the vegetative growth of winter wheat?</u>
  The study showed that ploughing had no individual effects on the selected variables and will always interact with salinisation. Germination, plant length, damage and condition were all significantly influenced by the interaction of both ploughing and salinisation. Ploughing showed a significant reduction in germination rate when applied to unsalinated soils. On saline soils there was also a slight reduction in germination, but this was likely to be negligible. This would indicate that ploughing on saline soils has little or no effect on germination rates but will always decrease the number of germinated plants.

In addition, it can be concluded that the difference between the salinated treatments on unploughed soils, plant length, damage and condition, were clearly visible. In contrast, on ploughed soils almost no differences in the abovementioned variables were noticeable and may therefore indicate that ploughing limits the effects of salinisation to some extent. However, it should be realised that this is a new study that needs to be repeated more often to provide more certainty regarding this subject.

- <u>How does salinisation affect the vegetative growth of winter wheat?</u>
  The study showed that salinisation had no individual effects on the selected variables and will always interact with ploughing. Germination, plant length, damage and condition were all significantly influenced by the interaction of both salinisation and ploughing. Salinisation showed no clear effect on germination, and its influence therefore depends entirely on whether or not ploughing has been used. In ploughed soils, salinisation showed an increase in germination success, whereas a decrease in germination success was seen in unploughed soils.

  In addition, salinisation on unploughed soil almost always contributed to increased plant length, reduced damage, and a better condition. This conclusion does not seem logical, but it is understandable. The increased plant length is probably caused by the way in which the plant has dealt with the present salt stress. Literature research has shown that strigolactones play a role in this. A possibly increased value of strigolactones present in the plant enables it to cope better with the present salt stress and will therefore show less damage and promote apical dominance. Because the plants were significantly higher on these saline soils and showed less damage, they probably received a higher condition rating as well. However, it must be concluded that this statement is only based on an expectation, as the amount of strigolactones present in the plant has not been tested in this research.

  At last, salinisation on ploughed soil consistently showed similar numbers to ploughed soil where salinisation did not occur, while major differences between the salinated treatments were visible on unploughed soil. This was visible in all significant variables (plant length, damage and condition). This would suggest that salinisation has less of an effect on ploughed soils. However, it should be realised that this is a relatively new type of research, and it is the first year that it has been conducted. In order to gain a better understanding of the interacting role of salinisation and ploughing, it is important to continue this research and to monitor the chosen crop through different growth stages.

- <u>How do ploughing and salinisation affect the vegetative growth of winter wheat (*Triticum aestivum* 'Extase')?</u>
  Ploughing and salinisation interactively affect the vegetative growth of the winter wheat variety ‘Extase’. Germination is negatively influenced by ploughing and the influence of salinisation on germination depends on whether or not ploughing was conducted; on ploughed soils an increase in germination was seen when salinisation was present, whereas on unploughed soils a decrease was seen when salinisation was present. Besides this, ploughing seems to limit the effects of salinisation to a certain extent, since there were no or hardly any visible differences in plant length, damage and condition when the salinated treatments were compared to unsalinated treatments. Since these differences were clearly present in unploughed soils, it can be concluded that ploughing seems to restrict the effects of salinisation. Lastly, salinisation seems to have contributed to increased plant length, reduced damage

and an improved condition in the winter wheat variety 'Extase'. This is probably due to the fact that these plants released strigolactones that positively influenced apical dominance and stress tolerance. However, this cannot be said with certainty, as the concentration of strigolactones present in the plant has not been determined in this study. If such a concentration is present, it can be concluded that 'Extase' is a salt-tolerant winter wheat variety, but this was not found in the literature either. All other growth variables, such as leaf area and root structure, showed no significant (interacting) effects of the treatments. Therefore, ploughing and salinisation interactively affect germination, plant length, damage and condition during the vegetative growth of *Triticum aestivum* 'Extase'.

5.2 Advise

Now the conclusion is presented, advice can be given to the target group of this research. The results of this research can be of evident importance to breeders of salt-tolerant wheat crops and growers on saline soils, as it provides innovative insight into the interaction of ploughing and salinisation, as well as the phenotypic growth differences caused by salinisation. Below, advice is given to both growers and breeders of winter wheat. In addition, it is advised to include all the discussion points in paragraph 4.2 in a possible repeat or follow-up study.

<u>Advise for growers of winter wheat on saline soils:</u>
Based on the results of this study, it is recommended that ploughing is used on saline soils when growing winter wheat. This advice is applicable in short-term, as ploughing can be applied before the beginning of cultivation. Ploughing has significantly reduced the effects of salinisation, which is assumed to be beneficial for the crop in question. This is because ploughing interacts with salinisation, and this interaction leads to a limitation of the salinisation effects. However, it should be noted that ploughing also had negative effects in this study. For example, it drastically reduced germination. The grower should therefore consider whether or not ploughing is profitable enough, and a decision seems to have to be made between a higher germination with more salinisation effects, or a lower germination with a reduced salinisation effect. In addition, the wheat variety 'Extase' seems to be very salt tolerant as it responded positively to saline conditions. The short-term advice is to use this variety on saline conditions. However, this cannot be said with certainty, as this is based on an expectation. No further proof was found that ‘Extase’ is indeed a salt tolerant variety.

<u>Advise for breeders of salt tolerant winter wheat varieties:</u>
The results of this study showed that a higher plant length in winter wheat significantly leads to a higher tolerance of salt stress. Plants with a higher plant length suffered less damage in this study and received the highest condition scores. Literature research has shown that the hormone group strigolactones play a major role in this. These hormones not only help the plant to cope better with salt stress, but also contribute to apical dominance. This means that plant length can be a good phenotypic characteristic in the selection of salt-tolerant plants and forms the advice on short-term perspectives. In addition, the gene responsible for strigolactone expression could be identified, which could be the basis for a future breeding plan for salt tolerant wheat crops and forms the advice on long-term perspectives. However, it must be stated that the differences in plant length were rather small and only 2-to-5-centimetre differences were visible. Finally, the variety used in this research, 'Extase', seems to be salt tolerant and could therefore be a suitable crossing parent in future breeding plans for both short-term and long-term perspectives. However, this cannot be said with certainty since the strigolactone content in the plants were not investigated in this research and is based on an expectation. More research on this subject is therefore highly recommended on short term as well.

Literature

- Biosalinity Awareness Project. (n.d.). *Listing of Halophytes & Salt-Tolerant Plants*. Retrieved 19 April 2021, from http://www.biosalinity.org/salt-tolerant_plants.htm

- Bot, A., & Benites, J. (2005). *The importance of soil organic matter: Key to drought-resistant soil and sustained food production* (No. 80). Rome, Italy: Food and Agriculture Organization of the United Nations.

- Campbell, N. A., Reece, J. B., Urry, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., & Jackson, R. B. (2018). *Biology: a global approach*. New York, USA: Pearson.

- Cassia, R., Nocioni, M., Correa-Aragunde, N., & Lamattina, L. (2018). Climate change and the impact of greenhouse gasses: CO2 and NO, friends and foes of plant oxidative stress. *Frontiers in plant science*, *9*, 273, 1-11. https://doi.org/10.3389/fpls.2018.00273

- Daliakopoulos, I. N., Tsanis, I. K., Koutroulis, A., Kourgialas, N. N., Varouchakis, A. E., Karatzas, G. P., & Ritsema, C. J. (2016). The threat of soil salinity: A European scale review. *Science of the Total Environment*, *573*, 727-739. https://doi.org/10.1016/j.scitotenv.2016.08.177

- Darwinkel, A. (1997). *Teelthandleiding wintertarwe*. Retrieved 23 April 2021, from https://library.wur.nl/ebooks/VWA/GKN/1699304.pdf

- Deltares. (2010). *Brackish seepage* [Illustration]. Retrieved 25 May 2021 from https://www.stowa.nl/deltafacts/zoetwatervoorziening/delta-facts-english-versions/brackish-seepage

- Frost, J. (n.d.). *How the Chi-Squared Test of Independence Works*. Retrieved 25 May 2021, from https://statisticsbyjim.com/hypothesis-testing/chi-squared-independence/#:%7E:text=To%20calculate%20the%20chi%2Dsquared,resulting%20value%20is%20%CF%872.

- Galvan-Ampudia, C. S., Julkowska, M. M., Darwish, E., Gandullo, J., Korver, R. A., Brunoud, G., ... & Testerink, C. (2013). Halotropism is a response of plant roots to avoid a saline environment. *Current Biology*, *23*(20), 2044-2050. https://doi.org/10.1016/j.cub.2013.08.042

- Glenn, E. P., Brown, J. J., & Blumwald, E. (1999). Salt tolerance and crop potential of halophytes. *Critical reviews in plant sciences*, *18*(2), 227-255. https://doi.org/10.1080/07352689991309207

- Hardy, J. T. (2003). *Climate change: causes, effects, and solutions*. Bellingham, USA: John Wiley & Sons.

- Interreg North Sea Region SalFar. (n.d.). *SalFar, Interreg VB North Sea Region Programme*. Retrieved 19 April 2021, from https://northsearegion.eu/salfar/

- Isayenkov, S. V. (2012). Physiological and molecular aspects of salt stress in plants. *Cytology and Genetics*, *46*(5), 302-318. https://doi.org/10.3103/S0095452712050040

- Jana, S. (1993). A practical approach to improving salinity tolerance in winter cereals. In H. Lieth & A. A. Masoom (Eds.) *Towards the rational use of high salinity tolerant plants* (pp. 35-44). Dordrecht, the Netherlands: Springer. https://doi.org/10.1007/978-94-011-1860-6_4

- Julkowska, M. M., Hoefsloot, H. C., Mol, S., Feron, R., de Boer, G. J., Haring, M. A., & Testerink, C. (2014). Capturing Arabidopsis root architecture dynamics with ROOT-FIT reveals diversity in responses to salinity. *Plant Physiology*, *166*(3), 1387-1402. https://doi.org/10.1104/pp.114.248963

- Kirk, R. E. (2012). Experimental design. In I. B. Weiner (Ed.), *Handbook of Psychology, Second Edition* (pp. 3-33). Hoboken, USA: John Wiley & Sons. https://doi.org/10.1002/9781118133880.hop202001

- Laerd Statistics. (n.d.). *Mixed ANOVA using SPSS Statistics*. Retrieved 10 March 2021, from https://statistics.laerd.com/spss-tutorials/mixed-anova-using-spss-statistics.php#:%7E:text=However%2C%20the%20fundamental%20difference%20is,%22between%2Dsubjects%22%20factor.

- Libus, J., Mauer, O., & Vavříček, D. (2010). Soil preparation by ploughing in the floodplain forest and its influence on vegetation and primary soil characteristics. *Journal of Forest Science*, *56*(4), 183-196. https://doi.org/10.17221/46/2009-JFS

- Ling, F., Su, Q., Jiang, H., Cui, J., He, X., Wu, Z., ... & Zhao, Y. (2020). Effects of strigolactone on photosynthetic and physiological characteristics in salt-stressed rice seedlings. *Scientific reports*, *10*(1), 1-8. https://doi.org/10.1038/s41598-020-63352-6

- Masclef, A. (1891). *Triticum aestivum 2.tif (vergroot)* [Illustration]. Retrieved 25 May 2021 from http://www.soortenbank.nl/soorten.php?soortengroep=flora_nl_v2&menuentry=soorten&id=735&tab=multimedia

- Paswan, R. V. (n.d.). *Transparent Wheat - Espigas De Trigo Clipart Png, Png Download* [Picture]. Retrieved 25 May 2021 from https://www.vhv.rs/viewpic/wJwimR_transparent-wheat-espigas-de-trigo-clipart-png-png/

- Saeed, W., Naseem, S., & Ali, Z. (2017). Strigolactones biosynthesis and their role in abiotic stress resilience in plants: a critical review. *Frontiers in Plant Science*, *8*, 1487, 1-13. https://doi.org/10.3389/fpls.2017.01487

- Shahid, S. A., Zaman, M., & Heng, L. (2018). Introduction to soil salinity, sodicity and diagnostics techniques. In M. Zaman, S. A. Shahid, & L. Heng (Eds.), *Guideline for salinity assessment, mitigation and adaptation using nuclear and related techniques* (pp. 1-42). Cham, Switzerland: Springer. https://doi.org/10.1007/978-3-319-96190-3_1

- Shannon, M. C. (1985). Principles and strategies in breeding for higher salt tolerance. In D. Pasternak & A. San Pietro (Eds.), *Biosalinity in Action: Bioproduction with Saline Water* (pp. 227-241). Dordrecht, the Netherlands: Springer. https://doi.org/10.1007/978-94-009-5111-2_15

- Shewry, P. R. (2009). Wheat. *Journal of experimental botany*, *60*(6), 1537-1553. https://doi.org/10.1093/jxb/erp058

- SPNA agroresearch. (n.d.). *Proefbedrijven*. Retrieved 10 February 2021, from https://www.spna.nl/spna/proefbedrijven/

- Statistics Solutions. (n.d.). *Conduct and Interpret a Repeated Measures ANOVA*. Retrieved 10 March 2021, from https://www.statisticssolutions.com/free-resources/directory-of-statistical-analyses/repeated-measures-anova/

- Stichting Toegepast Onderzoek Waterbeheer. (n.d.). *Brackish seepage*. Retrieved 25 May 2021, from https://www.stowa.nl/deltafacts/zoetwatervoorziening/delta-facts-english-versions/brackish-seepage

- Tester, M., & Davenport, R. (2003). Na+ tolerance and Na+ transport in higher plants. *Annals of botany*, *91*(5), 503-527. https://doi.org/10.1093/aob/mcg058

- The Editors of Encyclopaedia Britannica. (2020, June 10). *Plow*. Retrieved 1 March 2021, from https://www.britannica.com/technology/plow

- The Editors of Encyclopaedia Britannica. (2021, January 28). *Wheat*. Retrieved 4 March 2021, from https://www.britannica.com/plant/wheat

- Wang, Q., Lu, C., Li, H., He, J., Sarker, K. K., Rasaily, R. G., ... & Mchugh, A. D. J. (2014). The effects of no-tillage with subsoiling on soil properties and maize yield: 12-Year experiment on alkaline soils of Northeast China. *Soil and Tillage Research*, *137*, 43-49. https://doi.org/10.1016/j.still.2013.11.006

- Wang, Z., Zhao, X., Wu, P., Gao, Y., Yang, Q., & Shen, Y. (2017). Border row effects on light interception in wheat/maize strip intercropping systems. *Field Crops Research*, *214*, 1-13. https://doi.org/10.1016/j.fcr.2017.08.017

- Zhu, J. K. (2001). Plant salt tolerance. *Trends in plant science*, *6*(2), 66-71. https://doi.org/10.1016/S1360-1385(00)01838-0

Appendix

All the important information that contributed to this study can be found here. This information consists of the used measurement scales, dataset and other information that can be consulted.

Appendix I: Soil and water properties

Both the soil and irrigated water have been tested by official research lab; Eurofins in Wageningen, the Netherlands. The test results are displayed below.

Soil properties:

Both the chemical and physical characteristics of the soil are shown in table 1.

Table 1: Soil characteristics from Eurofins soil analysis (11-02-2020) (Eurofins, personal communication, 2020).

Saline soil		
Chemical elements	**Unity**	**Result**
Nitrogen (N)	kg N/ha	4.840
Sulphur (S)	kg S/ha	1.695
Phosphorus (P)	kg P/ha	725
Potassium (K)	kg K/ha	545
Calcium (Ca)	kg Ca/ha	9.165
Magnesium (Mg)	kg Mg/ha	360
Sodium (Na)	kg Na/ha	75
Chlorine (Cl)	kg Cl/ha	< 13
Silicon (Si)	g Si/ha	241.630
Iron (Fe)	g Fe/ha	< 6.150
Zinc (Zn)	g Zn/ha	360
Manganese (Mn)	g Mn/ha	< 760
Copper (Cu)	g Cu/ha	90
Cobalt (Co)	g Co/ha	< 10
Boron (B)	g B/ha	1.330
Molybdenum (Mo)	g Mo/ha	30
Selenium (Se)	g Se/ha	16
Physical elements	**Unity**	**Result**
C/N ratio		13
Acidity (pH)	pH	7,1
Organic tissue	%	3,2
Clay (<2 µm)	%	19
Silt (2-50 µm)	%	36
Sand (>50 µm)	%	35
Sludge (>16 µm)	%	30
Regular soil		
Chemical elements	**Unity**	**Result**
Nitrogen (N)	kg N/ha	4.350
Sulphur (S)	kg S/ha	2.435
Phosphorus (P)	kg P/ha	590
Potassium (K)	kg K/ha	530
Calcium (Ca)	kg Ca/ha	8.770
Magnesium (Mg)	kg Mg/ha	250
Sodium (Na)	kg Na/ha	80
Chlorine (Cl)	kg Cl/ha	< 13
Silicon (Si)	g Si/ha	192.050
Iron (Fe)	g Fe/ha	< 6.260

Zinc (Zn)	g Zn/ha	< 310
Manganese (Mn)	g Mn/ha	920
Copper (Cu)	g Cu/ha	115
Cobalt (Co)	g Co/ha	< 10
Boron (B)	g B/ha	1.140
Molybdenum (Mo)	g Mo/ha	50
Selenium (Se)	g Se/ha	17
Physical elements	**Unity**	**Result**
C/N ratio		11
Acidity (pH)	pH	7,4
Organic tissue	%	2,6
Clay (<2 µm)	%	18
Silt (2-50 µm)	%	32
Sand (>50 µm)	%	40
Sludge (>16 µm)	%	28

<u>Water properties</u>

Both the chemical and physical characteristics of the water are shown in table 2.

Table 2: Water characteristics from Eurofins water analysis (23-03-2021) (Eurofins, personal communication, 2021).

Saline seepage water		
Chemical elements	**Unity**	**Result**
Ammonium (NH_4)	mmol/l	0,5
Potassium (K)	mmol/l	2,1
Sodium (Na)	mmol/l	130,3
Calcium (Ca)	mmol/l	7,9
Magnesium (Mg)	mmol/l	14,5
Nitrate (NO_3)	mmol/l	0,1
Chlorine (Cl)	mmol/l	118,7
Sulphur (S)	mmol/l	1,3
Bicarbonate (HCO_3)	mmol/l	21,9
Phosphorus (P)	mmol/l	0,05
Iron (Fe)	µmol/l	0,6
Manganese (Mn)	µmol/l	1,7
Zinc (Zn)	µmol/l	<0,1
Boron (B)	µmol/l	74
Copper (Cu)	µmol/l	<0,1
Molybdenum (Mo)	µmol/l	<0,1
Silicon (Si)	mmol/l	0,26
Physical elements	**Unity**	**Result**
Electro Conductivity (EC)	mS/cm	15,3
Acidity (pH)	pH	7,5
Fresh surface water		
Chemical elements	**Unity**	**Result**
Ammonium (NH_4)	mmol/l	<0,1
Potassium (K)	mmol/l	<0,1
Sodium (Na)	mmol/l	1,2
Calcium (Ca)	mmol/l	0,9
Magnesium (Mg)	mmol/l	0,3
Nitrate (NO_3)	mmol/l	<0,1
Chlorine (Cl)	mmol/l	2,1

Sulphur (S)	mmol/l	<0,1
Bicarbonate (HCO_3)	mmol/l	1,8
Phosphorus (P)	mmol/l	<0,04
Iron (Fe)	µmol/l	0,2
Manganese (Mn)	µmol/l	<0,1
Zinc (Zn)	µmol/l	0,4
Boron (B)	µmol/l	2,8
Copper (Cu)	µmol/l	<0,1
Molybdenum (Mo)	µmol/l	<0,1
Silicon (Si)	mmol/l	0,24
Physical elements	**Unity**	**Result**
Electro Conductivity (EC)	mS/cm	0,5
Acidity (pH)	pH	8,0

Appendix II: Measurement scales

Two scales have been used in this research. One was used to determine the state of a plant and one was used for determining the damage that was present on the plant (see section 2.3). Both scales are shown below.

<u>Scale for determining condition:</u>

1. <u>Poor condition:</u>
   >20% smaller than average size, majorly/completely damaged, hanging down (combination of all)
2. <u>Poor condition:</u>
   >20% smaller than average size, majorly/completely damaged, hanging down (combination of 2)
3. <u>Bad condition:</u>
   20% smaller than average size, damaged, hanging down (combination of all)
4. <u>Bad condition:</u>
   20% smaller than average size, damaged, hanging down (combination of 2)
5. <u>Average condition:</u>
   average size, minor damage, upright/hanging down (combination of 2)
6. <u>Average condition:</u>
   average size, minor damage, upright/hanging down (combination of all)
7. <u>Good condition:</u>
   20% bigger than average size, minor/no damage, upright (combination of all)
8. <u>Great condition:</u>
   20% bigger than average size, no damage, upright (combination of 2)
9. <u>Great condition:</u>
   >20% bigger than average size, no damage, upright (combination of 2)
10. <u>Perfect condition:</u>
    >20% bigger than average size, no damage, upright (combination of all)

<u>Scale for determining damage:</u>

1. No damage present (0%)
2. 5% damage
3. 10% damage
4. 20% damage
5. Minor damage present (25 – 30%)
6. 40% damage
7. 50% damage
8. 60% damage
9. 70% damage
10. Major damage present (>75%)

Appendix III: Used dataset

The used dataset can be found below.

Sample_block	Plant	Ploughing	Salinisation	Week	Plant_length	Leaf_area	Damage	Condition	Apical_root_length	Lateral_root_length	Sown_Seeds	Plant_count	Germinated_plants	Germination_succes
KA1	KA1.1	yes	no	8	0,50	6,00	2	6	8,00	13,00				
KA1	KA1.2	yes	no	8	0,50	4,00	1	7						
KA1	KA1.3	yes	no	8	0,50	4,00	4	7						
KA2	KA2.1	yes	no	8	0,50	4,00	4	6	11,50	15,00				
KA2	KA2.2	yes	no	8	0,50	3,00	4	6						
KA2	KA2.3	yes	no	8	0,50	4,00	3	6						
KA3	KA3.1	yes	no	8	0,50	3,00	5	7	10,00	12,50				
KA3	KA3.2	yes	no	8	0,50	3,00	4	6						
KA3	KA3.3	yes	no	8	0,50	3,00	4	6						
KA4	KA4.1	yes	no	8	0,50	2,00	7	6	7,50	13,00				
KA4	KA4.2	yes	no	8	0,50	3,00	2	6						
KA4	KA4.3	yes	no	8	0,50	4,00	4	6						
KB1	KB1.1	yes	yes	8	0,50	4,00	4	7	13,00	10,00				
KB1	KB1.2	yes	yes	8	0,50	2,00	4	7						
KB1	KB1.3	yes	yes	8	0,50	4,00	7	5						
KB2	KB2.1	yes	yes	8	0,50	3,00	4	6	9,00	8,00				
KB2	KB2.2	yes	yes	8	0,50	3,00	4	6						
KB2	KB2.3	yes	yes	8	0,50	2,00	7	6						
KB3	KB3.1	yes	yes	8	0,50	3,00	4	7	8,50	11,00				
KB3	KB3.2	yes	yes	8	0,50	3,00	4	7						
KB3	KB3.3	yes	yes	8	0,50	4,00	1	8						
KB4	KB4.1	yes	yes	8	0,50	4,00	4	8	9,00	11,00				
KB4	KB4.2	yes	yes	8	0,50	3,00	4	6						
KB4	KB4.3	yes	yes	8	0,50	3,00	4	6						
NKA1	NKA1.1	no	no	8	0,50	1,00	1	6	13,00	10,00				
NKA1	NKA1.2	no	no	8	0,50	2,00	2	7						
NKA1	NKA1.3	no	no	8	0,50	2,00	2	7						
NKA2	NKA2.1	no	no	8	0,50	3,00	5	7	9,00	15,00				
NKA2	NKA2.2	no	no	8	0,50	2,00	3	5						
NKA2	NKA2.3	no	no	8	0,50	3,00	4	7						
NKA3	NKA3.1	no	no	8	0,50	2,00	5	7	8,00	7,00				
NKA3	NKA3.2	no	no	8	0,50	4,00	5	7						
NKA3	NKA3.3	no	no	8	0,50	3,00	4	7						
NKA4	NKA4.1	no	no	8	0,50	3,00	4	7	7,00	7,00				
NKA4	NKA4.2	no	no	8	0,50	3,00	1	8						
NKA4	NKA4.3	no	no	8	0,50	3,00	2	7						
NKB1	NKB1.1	no	yes	8	0,50	3,00	7	5	7,00	11,00				
NKB1	NKB1.2	no	yes	8	0,50	3,00	5	6						
NKB1	NKB1.3	no	yes	8	0,50	3,00	4	7						
NKB2	NKB2.1	no	yes	8	0,50	2,00	2	7	12,00	13,00				
NKB2	NKB2.2	no	yes	8	0,50	3,00	5	6						
NKB2	NKB2.3	no	yes	8	0,50	3,00	1	8						
NKB3	NKB3.1	no	yes	8	0,50	4,00	5	6	13,00	23,50				
NKB3	NKB3.2	no	yes	8	0,50	1,00	1	7						
NKB3	NKB3.3	no	yes	8	0,50	2,00	2	7						
NKB4	NKB4.1	no	yes	8	0,50	3,00	5	7	9,00	13,50				
NKB4	NKB4.2	no	yes	8	0,50	3,00	1	6						
NKB4	NKB4.3	no	yes	8	0,50	3,00	3	6						

Sample_block	Plant	Ploughing	Salinisation	Week	Plant_length	Leaf_area	Damage	Condition	Apical_root_length	Lateral_root_length	Sown_Seeds	Plant_count	Germinated_plants	Germination_succes
KA1	KA1.1	yes	no	9	4,00	5,00	4	8						
KA1	KA1.2	yes	no	9	6,00	6,00	1	7						
KA1	KA1.3	yes	no	9	2,00	5,00	4	7						
KA2	KA2.1	yes	no	9	2,00	2,00	2	7						
KA2	KA2.2	yes	no	9	2,00	5,00	2	7						
KA2	KA2.3	yes	no	9	5,00	4,00	2	7						
KA3	KA3.1	yes	no	9	3,00	5,00	4	7						
KA3	KA3.2	yes	no	9	1,00	4,00	5	6						
KA3	KA3.3	yes	no	9	1,00	4,00	5	7						
KA4	KA4.1	yes	no	9	1,00	4,00	5	6						
KA4	KA4.2	yes	no	9	1,00	5,00	2	6						
KA4	KA4.3	yes	no	9	1,00	3,00	7	7						
KB1	KB1.1	yes	yes	9	1,00	4,00	5	7						
KB1	KB1.2	yes	yes	9	1,00	4,00	4	5						
KB1	KB1.3	yes	yes	9	2,00	4,00	4	6						
KB2	KB2.1	yes	yes	9	2,00	5,00	5	7						
KB2	KB2.2	yes	yes	9	2,00	4,00	4	7						
KB2	KB2.3	yes	yes	9	1,00	3,00	7	6						
KB3	KB3.1	yes	yes	9	2,00	4,00	2	6						
KB3	KB3.2	yes	yes	9	3,00	5,00	3	8						
KB3	KB3.3	yes	yes	9	1,00	5,00	1	8						
KB4	KB4.1	yes	yes	9	4,00	5,00	4	8						
KB4	KB4.2	yes	yes	9	2,00	4,00	4	6						
KB4	KB4.3	yes	yes	9	2,00	5,00	5	6						
NKA1	NKA1.1	no	no	9	5,00	4,00	1	6						
NKA1	NKA1.2	no	no	9	2,00	3,00	2	6						
NKA1	NKA1.3	no	no	9	1,00	2,00	1	6						
NKA2	NKA2.1	no	no	9	1,00	4,00	5	7						
NKA2	NKA2.2	no	no	9	1,00	4,00	5	7						
NKA2	NKA2.3	no	no	9	1,00	6,00	4	6						
NKA3	NKA3.1	no	no	9	1,00	2,00	7	6						
NKA3	NKA3.2	no	no	9	2,00	4,00	1	8						
NKA3	NKA3.3	no	no	9	1,00	4,00	1	7						
NKA4	NKA4.1	no	no	9	2,00	5,00	1	6						
NKA4	NKA4.2	no	no	9	5,00	6,00	4	7						
NKA4	NKA4.3	no	no	9	4,00	5,00	1	6						
NKB1	NKB1.1	no	yes	9	1,00	4,00	3	8						
NKB1	NKB1.2	no	yes	9	1,00	4,00	4	7						
NKB1	NKB1.3	no	yes	9	6,00	6,00	2	9						
NKB2	NKB2.1	no	yes	9	3,00	4,00	1	7						
NKB2	NKB2.2	no	yes	9	2,00	6,00	4	8						
NKB2	NKB2.3	no	yes	9	6,00	6,00	1	8						
NKB3	NKB3.1	no	yes	9	6,00	5,00	4	8						
NKB3	NKB3.2	no	yes	9	1,00	3,00	1	7						
NKB3	NKB3.3	no	yes	9	1,00	3,00	1	7						
NKB4	NKB4.1	no	yes	9	6,00	5,00	2	8						
NKB4	NKB4.2	no	yes	9	2,00	4,00	1	7						
NKB4	NKB4.3	no	yes	9	4,00	5,00	2	7						

Sample_block	Plant	Ploughing	Salinisation	Week	Plant_length	Leaf_area	Damage	Condition	Apical_root_length	Lateral_root_length	Sown_Seeds	Plant_count	Germinated_plants	Germination_succes
KA1	KA1.1	yes	no	10	9,00	7,00	3	8						
KA1	KA1.2	yes	no	10	8,00	8,00	1	7						
KA1	KA1.3	yes	no	10	6,00	4,00	1	7						
KA2	KA2.1	yes	no	10	6,00	4,00	2	6						
KA2	KA2.2	yes	no	10	8,00	7,00	3	8						
KA2	KA2.3	yes	no	10	7,00	5,00	2	8						
KA3	KA3.1	yes	no	10	7,00	4,00	3	7						
KA3	KA3.2	yes	no	10	2,00	3,00	3	7						
KA3	KA3.3	yes	no	10	6,00	5,00	3	8						
KA4	KA4.1	yes	no	10	2,00	5,00	3	6						
KA4	KA4.2	yes	no	10	6,00	6,00	2	7						
KA4	KA4.3	yes	no	10	6,00	4,00	5	7						
KB1	KB1.1	yes	yes	10	4,00	4,00	3	6						
KB1	KB1.2	yes	yes	10	4,00	4,00	2	7						
KB1	KB1.3	yes	yes	10	8,00	4,00	3	7						
KB2	KB2.1	yes	yes	10	6,00	4,00	4	6						
KB2	KB2.2	yes	yes	10	6,00	4,00	5	7						
KB2	KB2.3	yes	yes	10	7,00	3,00	5	7						
KB3	KB3.1	yes	yes	10	7,00	4,00	3	7						
KB3	KB3.2	yes	yes	10	5,00	7,00	3	7						
KB3	KB3.3	yes	yes	10	3,00	7,00	1	7						
KB4	KB4.1	yes	yes	10	8,00	5,00	3	8						
KB4	KB4.2	yes	yes	10	6,00	5,00	3	7						
KB4	KB4.3	yes	yes	10	6,00	5,00	5	5						
NKA1	NKA1.1	no	no	10	8,00	5,00	1	7						
NKA1	NKA1.2	no	no	10	7,00	3,00	2	6						
NKA1	NKA1.3	no	no	10	5,00	3,00	1	7						
NKA2	NKA2.1	no	no	10	7,00	5,00	3	6						
NKA2	NKA2.2	no	no	10	5,00	5,00	3	7						
NKA2	NKA2.3	no	no	10	2,00	5,00	4	7						
NKA3	NKA3.1	no	no	10	3,00	4,00	1	7						
NKA3	NKA3.2	no	no	10	8,00	5,00	2	8						
NKA3	NKA3.3	no	no	10	8,00	6,00	1	8						
NKA4	NKA4.1	no	no	10	8,00	6,00	1	8						
NKA4	NKA4.2	no	no	10	5,00	3,00	5	7						
NKA4	NKA4.3	no	no	10	6,00	6,00	1	7						
NKB1	NKB1.1	no	yes	10	7,00	4,00	2	7						
NKB1	NKB1.2	no	yes	10	5,00	3,00	1	8						
NKB1	NKB1.3	no	yes	10	9,00	5,00	1	8						
NKB2	NKB2.1	no	yes	10	9,00	6,00	1	7						
NKB2	NKB2.2	no	yes	10	6,00	4,00	1	7						
NKB2	NKB2.3	no	yes	10	6,00	4,00	1	7						
NKB3	NKB3.1	no	yes	10	9,00	5,00	1	8						
NKB3	NKB3.2	no	yes	10	3,00	3,00	1	6						
NKB3	NKB3.3	no	yes	10	5,00	4,00	1	6						
NKB4	NKB4.1	no	yes	10	8,00	5,00	1	8						
NKB4	NKB4.2	no	yes	10	7,00	5,00	1	8						
NKB4	NKB4.3	no	yes	10	6,00	4,00	1	7						

Sample_block	Plant	Ploughing	Salinisation	Week	Plant_length	Leaf_area	Damage	Condition	Apical_root_length	Lateral_root_length	Sown_Seeds	Plant_count	Germinated_plants	Germination_succes
KA1	KA1.1	yes	no	11	11,00	6,00	3	8			410	24	100	24,4%
KA1	KA1.2	yes	no	11	6,00	6,00	1	8						
KA1	KA1.3	yes	no	11	8,00	5,00	2	7						
KA2	KA2.1	yes	no	11	12,00	6,00	1	8						
KA2	KA2.2	yes	no	11	6,00	6,00	2	7						
KA2	KA2.3	yes	no	11	10,00	5,00	2	7						
KA3	KA3.1	yes	no	11	12,00	6,00	2	7						
KA3	KA3.2	yes	no	11	8,00	4,00	3	6						
KA3	KA3.3	yes	no	11	11,00	6,00	1	7						
KA4	KA4.1	yes	no	11	8,00	6,00	4	7			410	26	100	24,4%
KA4	KA4.2	yes	no	11	11,00	6,00	1	7						
KA4	KA4.3	yes	no	11	10,00	5,00	5	7						
KB1	KB1.1	yes	yes	11	8,00	5,00	2	5			410	36	150	36,6%
KB1	KB1.2	yes	yes	11	8,00	4,00	3	6						
KB1	KB1.3	yes	yes	11	12,00	5,00	3	7						
KB2	KB2.1	yes	yes	11	9,00	4,00	3	7						
KB2	KB2.2	yes	yes	11	10,00	7,00	1	7						
KB2	KB2.3	yes	yes	11	6,00	4,00	1	7						
KB3	KB3.1	yes	yes	11	11,00	6,00	3	7						
KB3	KB3.2	yes	yes	11	9,00	5,00	2	7						
KB3	KB3.3	yes	yes	11	10,00	7,00	1	7						
KB4	KB4.1	yes	yes	11	10,00	5,00	2	8			410	39	150	36,6%
KB4	KB4.2	yes	yes	11	9,00	5,00	2	7						
KB4	KB4.3	yes	yes	11	10,00	5,00	1	7						
NKA1	NKA1.1	no	no	11	5,00	7,00	2	7			410	68	250	61,0%
NKA1	NKA1.2	no	no	11	9,00	5,00	2	7						
NKA1	NKA1.3	no	no	11	9,00	4,00	2	7						
NKA2	NKA2.1	no	no	11	10,00	6,00	3	7						
NKA2	NKA2.2	no	no	11	8,00	5,00	1	7						
NKA2	NKA2.3	no	no	11	8,00	5,00	4	7						
NKA3	NKA3.1	no	no	11	8,00	6,00	3	7						
NKA3	NKA3.2	no	no	11	12,00	6,00	3	7						
NKA3	NKA3.3	no	no	11	5,00	4,00	1	7						
NKA4	NKA4.1	no	no	11	10,00	7,00	2	7			410	57	250	61,0%
NKA4	NKA4.2	no	no	11	8,00	4,00	3	7						
NKA4	NKA4.3	no	no	11	7,00	4,00	1	7						
NKB1	NKB1.1	no	yes	11	10,00	5,00	2	8			410	39	162	39,5%
NKB1	NKB1.2	no	yes	11	7,00	5,00	3	7						
NKB1	NKB1.3	no	yes	11	12,00	7,00	1	8						
NKB2	NKB2.1	no	yes	11	11,00	6,00	2	7						
NKB2	NKB2.2	no	yes	11	9,00	5,00	2	7						
NKB2	NKB2.3	no	yes	11	6,00	6,00	1	8						
NKB3	NKB3.1	no	yes	11	11,00	5,00	3	7						
NKB3	NKB3.2	no	yes	11	5,00	3,00	3	6						
NKB3	NKB3.3	no	yes	11	8,00	3,00	1	6						
NKB4	NKB4.1	no	yes	11	9,00	5,00	1	7			410	42	162	39,5%
NKB4	NKB4.2	no	yes	11	10,00	6,00	3	7						
NKB4	NKB4.3	no	yes	11	10,00	5,00	1	7						

Sample_block	Plant	Ploughing	Salinisation	Week	Plant_length	Leaf_area	Damage	Condition	Apical_root_length	Lateral_root_length	Sown_Seeds	Plant_count	Germinated_plants	Germination_succes
KA1	KA1.1	yes	no	12	9,00	11,00	3	8						
KA1	KA1.2	yes	no	12	10,00	11,00	3	7						
KA1	KA1.3	yes	no	12	5,00	6,00	1	7						
KA2	KA2.1	yes	no	12	5,00	8,00	2	7						
KA2	KA2.2	yes	no	12	9,00	6,00	1	7						
KA2	KA2.3	yes	no	12	7,00	8,00	3	7						
KA3	KA3.1	yes	no	12	7,00	8,00	2	7						
KA3	KA3.2	yes	no	12	11,00	4,00	4	6						
KA3	KA3.3	yes	no	12	13,00	6,00	1	7						
KA4	KA4.1	yes	no	12	10,00	6,00	5	7						
KA4	KA4.2	yes	no	12	13,00	8,00	3	7						
KA4	KA4.3	yes	no	12	13,00	6,00	5	7						
KB1	KB1.1	yes	yes	12	13,00	7,00	5	7						
KB1	KB1.2	yes	yes	12	10,00	7,00	3	7						
KB1	KB1.3	yes	yes	12	8,00	7,00	4	7						
KB2	KB2.1	yes	yes	12	8,00	7,00	1	7						
KB2	KB2.2	yes	yes	12	5,00	6,00	1	7						
KB2	KB2.3	yes	yes	12	7,00	7,00	1	7						
KB3	KB3.1	yes	yes	12	10,00	4,00	4	7						
KB3	KB3.2	yes	yes	12	10,00	7,00	2	8						
KB3	KB3.3	yes	yes	12	13,00	8,00	1	7						
KB4	KB4.1	yes	yes	12	11,00	6,00	1	8						
KB4	KB4.2	yes	yes	12	11,00	6,00	3	7						
KB4	KB4.3	yes	yes	12	11,00	3,00	3	7						
NKA1	NKA1.1	no	no	12	6,00	10,00	2	7						
NKA1	NKA1.2	no	no	12	8,00	7,00	3	7						
NKA1	NKA1.3	no	no	12	6,00	6,00	3	7						
NKA2	NKA2.1	no	no	12	8,00	7,00	5	7						
NKA2	NKA2.2	no	no	12	10,00	6,00	3	7						
NKA2	NKA2.3	no	no	12	12,00	7,00	3	6						
NKA3	NKA3.1	no	no	12	10,00	6,00	2	7						
NKA3	NKA3.2	no	no	12	7,00	9,00	2	7						
NKA3	NKA3.3	no	no	12	7,00	6,00	4	6						
NKA4	NKA4.1	no	no	12	6,00	9,00	2	7						
NKA4	NKA4.2	no	no	12	4,00	5,00	1	7						
NKA4	NKA4.3	no	no	12	10,00	9,00	7	7						
NKB1	NKB1.1	no	yes	12	11,00	7,00	3	7						
NKB1	NKB1.2	no	yes	12	11,00	7,00	3	7						
NKB1	NKB1.3	no	yes	12	10,00	8,00	2	7						
NKB2	NKB2.1	no	yes	12	9,00	7,00	2	7						
NKB2	NKB2.2	no	yes	12	11,00	6,00	2	7						
NKB2	NKB2.3	no	yes	12	10,00	12,00	3	7						
NKB3	NKB3.1	no	yes	12	9,00	10,00	2	8						
NKB3	NKB3.2	no	yes	12	8,00	4,00	2	7						
NKB3	NKB3.3	no	yes	12	9,00	7,00	2	7						
NKB4	NKB4.1	no	yes	12	10,00	8,00	3	7						
NKB4	NKB4.2	no	yes	12	12,00	8,00	3	7						
NKB4	NKB4.3	no	yes	12	14,00	7,00	3	7						

Sample_block	Plant	Ploughing	Salinisation	Week	Plant_length	Leaf_area	Damage	Condition	Apical_root_length	Lateral_root_length	Sown_Seeds	Plant_count	Germinated_plants	Germination_succes
KA1	KA1.1	yes	no	13	14,00	16,00	2	7						
KA1	KA1.2	yes	no	13	15,00	12,00	2	7						
KA1	KA1.3	yes	no	13	12,00	8,00	1	7						
KA2	KA2.1	yes	no	13	12,00	10,00	1	7						
KA2	KA2.2	yes	no	13	13,00	8,00	3	7						
KA2	KA2.3	yes	no	13	14,00	10,00	1	8						
KA3	KA3.1	yes	no	13	13,00	13,00	2	7						
KA3	KA3.2	yes	no	13	8,00	5,00	3	6						
KA3	KA3.3	yes	no	13	11,00	10,00	1	7						
KA4	KA4.1	yes	no	13	8,00	9,00	3	7						
KA4	KA4.2	yes	no	13	12,00	13,00	2	7						
KA4	KA4.3	yes	no	13	9,00	8,00	1	7						
KB1	KB1.1	yes	yes	13	10,00	10,00	1	7						
KB1	KB1.2	yes	yes	13	9,00	6,00	3	7						
KB1	KB1.3	yes	yes	13	8,00	9,00	3	5						
KB2	KB2.1	yes	yes	13	12,00	10,00	1	7						
KB2	KB2.2	yes	yes	13	12,00	10,00	1	7						
KB2	KB2.3	yes	yes	13	8,00	7,00	1	7						
KB3	KB3.1	yes	yes	13	14,00	10,00	1	7						
KB3	KB3.2	yes	yes	13	13,00	11,00	3	7						
KB3	KB3.3	yes	yes	13	11,00	13,00	1	7						
KB4	KB4.1	yes	yes	13	14,00	15,00	2	7						
KB4	KB4.2	yes	yes	13	13,00	9,00	3	7						
KB4	KB4.3	yes	yes	13	11,00	7,00	1	7						
NKA1	NKA1.1	no	no	13	9,00	17,00	2	7						
NKA1	NKA1.2	no	no	13	6,00	11,00	1	7						
NKA1	NKA1.3	no	no	13	11,00	10,00	1	6						
NKA2	NKA2.1	no	no	13	13,00	14,00	2	7						
NKA2	NKA2.2	no	no	13	10,00	9,00	1	7						
NKA2	NKA2.3	no	no	13	9,00	7,00	1	7						
NKA3	NKA3.1	no	no	13	9,00	6,00	5	5						
NKA3	NKA3.2	no	no	13	13,00	10,00	1	7						
NKA3	NKA3.3	no	no	13	9,00	8,00	1	6						
NKA4	NKA4.1	no	no	13	11,00	14,00	1	7						
NKA4	NKA4.2	no	no	13	10,00	9,00	1	7						
NKA4	NKA4.3	no	no	13	10,00	16,00	1	7						
NKB1	NKB1.1	no	yes	13	12,00	13,00	2	7						
NKB1	NKB1.2	no	yes	13	11,00	10,00	1	7						
NKB1	NKB1.3	no	yes	13	9,00	21,00	2	7						
NKB2	NKB2.1	no	yes	13	16,00	15,00	1	8						
NKB2	NKB2.2	no	yes	13	11,00	10,00	1	7						
NKB2	NKB2.3	no	yes	13	14,00	18,00	1	7						
NKB3	NKB3.1	no	yes	13	13,00	18,00	1	8						
NKB3	NKB3.2	no	yes	13	13,00	11,00	1	7						
NKB3	NKB3.3	no	yes	13	11,00	10,00	1	7						
NKB4	NKB4.1	no	yes	13	10,00	11,00	1	7						
NKB4	NKB4.2	no	yes	13	14,00	12,00	2	7						
NKB4	NKB4.3	no	yes	13	12,00	10,00	1	7						

Sample_block	Plant	Ploughing	Salinisation	Week	Plant_length	Leaf_area	Damage	Condition	Apical_root_length	Lateral_root_length	Sown_Seeds	Plant_count	Germinated_plants	Germination_succes
KA1	KA1.1	yes	no	14	9,00	16,00	1	6						
KA1	KA1.2	yes	no	14	11,00	19,00	1	7						
KA1	KA1.3	yes	no	14	8,00	26,00	1	7						
KA2	KA2.1	yes	no	14	8,00	20,00	1	7						
KA2	KA2.2	yes	no	14	12,00	16,00	1	7						
KA2	KA2.3	yes	no	14	10,00	22,00	1	7						
KA3	KA3.1	yes	no	14	9,00	11,00	1	6						
KA3	KA3.2	yes	no	14	10,00	11,00	1	6						
KA3	KA3.3	yes	no	14	13,00	15,00	1	6						
KA4	KA4.1	yes	no	14	12,00	11,00	1	6						
KA4	KA4.2	yes	no	14	11,00	16,00	1	7						
KA4	KA4.3	yes	no	14	13,00	10,00	1	7						
KB1	KB1.1	yes	yes	14	12,00	11,00	1	7						
KB1	KB1.2	yes	yes	14	5,00	8,00	1	7						
KB1	KB1.3	yes	yes	14	8,00	7,00	5	4						
KB2	KB2.1	yes	yes	14	10,00	14,00	1	7						
KB2	KB2.2	yes	yes	14	15,00	21,00	1	8						
KB2	KB2.3	yes	yes	14	11,00	21,00	1	7						
KB3	KB3.1	yes	yes	14	10,00	10,00	1	6						
KB3	KB3.2	yes	yes	14	10,00	13,00	1	6						
KB3	KB3.3	yes	yes	14	10,00	19,00	1	7						
KB4	KB4.1	yes	yes	14	9,00	17,00	1	6						
KB4	KB4.2	yes	yes	14	10,00	14,00	1	7						
KB4	KB4.3	yes	yes	14	9,00	13,00	1	7						
NKA1	NKA1.1	no	no	14	14,00	20,00	1	8						
NKA1	NKA1.2	no	no	14	10,00	14,00	1	7						
NKA1	NKA1.3	no	no	14	8,00	18,00	1	6						
NKA2	NKA2.1	no	no	14	12,00	15,00	4	5						
NKA2	NKA2.2	no	no	14	7,00	13,00	1	6						
NKA2	NKA2.3	no	no	14	14,00	11,00	4	6						
NKA3	NKA3.1	no	no	14	6,00	5,00	5	4						
NKA3	NKA3.2	no	no	14	10,00	17,00	1	7						
NKA3	NKA3.3	no	no	14	11,00	15,00	1	6						
NKA4	NKA4.1	no	no	14	12,00	18,00	1	6						
NKA4	NKA4.2	no	no	14	12,00	21,00	1	6						
NKA4	NKA4.3	no	no	14	13,00	22,00	1	6						
NKB1	NKB1.1	no	yes	14	11,00	18,00	2	7						
NKB1	NKB1.2	no	yes	14	14,00	15,00	1	7						
NKB1	NKB1.3	no	yes	14	14,00	20,00	1	8						
NKB2	NKB2.1	no	yes	14	12,00	18,00	1	8						
NKB2	NKB2.2	no	yes	14	7,00	12,00	1	7						
NKB2	NKB2.3	no	yes	14	14,00	16,00	1	8						
NKB3	NKB3.1	no	yes	14	12,00	23,00	2	7						
NKB3	NKB3.2	no	yes	14	8,00	16,00	1	7						
NKB3	NKB3.3	no	yes	14	10,00	13,00	1	7						
NKB4	NKB4.1	no	yes	14	12,00	26,00	1	8						
NKB4	NKB4.2	no	yes	14	11,00	16,00	3	6						
NKB4	NKB4.3	no	yes	14	8,00	14,00	1	7						

Sample_block	Plant	Ploughing	Salinisation	Week	Plant_length	Leaf_area	Damage	Condition	Apical_root_length	Lateral_root_length	Sown_Seeds	Plant_count	Germinated_plants	Germination_succes
KA1	KA1.1	yes	no	15	14,00	25,00	1	7	13,00	21,00				
KA1	KA1.2	yes	no	15	12,00	25,00	1	7						
KA1	KA1.3	yes	no	15	12,00	30,00	1	8						
KA2	KA2.1	yes	no	15	14,00	17,00	2	7	12,00	10,00				
KA2	KA2.2	yes	no	15	8,00	22,00	1	7						
KA2	KA2.3	yes	no	15	14,00	22,00	1	7						
KA3	KA3.1	yes	no	15	13,00	12,00	1	6	9,00	16,00				
KA3	KA3.2	yes	no	15	12,00	11,00	3	6						
KA3	KA3.3	yes	no	15	15,00	17,00	1	6						
KA4	KA4.1	yes	no	15	9,00	12,00	1	7	11,00	17,00				
KA4	KA4.2	yes	no	15	12,00	19,00	1	6						
KA4	KA4.3	yes	no	15	9,00	12,00	1	6						
KB1	KB1.1	yes	yes	15	10,00	14,00	1	6	13,00	18,00				
KB1	KB1.2	yes	yes	15	10,00	12,00	1	6						
KB1	KB1.3	yes	yes	15	12,00	10,00	3	6						
KB2	KB2.1	yes	yes	15	14,00	23,00	1	7	12,00	21,00				
KB2	KB2.2	yes	yes	15	13,00	26,00	1	7						
KB2	KB2.3	yes	yes	15	10,00	26,00	1	7						
KB3	KB3.1	yes	yes	15	14,00	21,00	1	7	8,00	15,00				
KB3	KB3.2	yes	yes	15	15,00	19,00	1	7						
KB3	KB3.3	yes	yes	15	18,00	21,00	1	8						
KB4	KB4.1	yes	yes	15	13,00	25,00	1	7	10,00	14,00				
KB4	KB4.2	yes	yes	15	16,00	17,00	1	7						
KB4	KB4.3	yes	yes	15	11,00	18,00	1	6						
NKA1	NKA1.1	no	no	15	10,00	26,00	1	7	13,00	5,00				
NKA1	NKA1.2	no	no	15	14,00	17,00	1	7						
NKA1	NKA1.3	no	no	15	12,00	41,00	1	8						
NKA2	NKA2.1	no	no	15	13,00	21,00	2	7	11,00	14,00				
NKA2	NKA2.2	no	no	15	10,00	15,00	3	7						
NKA2	NKA2.3	no	no	15	10,00	14,00	1	7						
NKA3	NKA3.1	no	no	15	0,50	3,00	7	3	10,00	14,00				
NKA3	NKA3.2	no	no	15	14,00	36,00	1	8						
NKA3	NKA3.3	no	no	15	9,00	24,00	1	7						
NKA4	NKA4.1	no	no	15	14,00	22,00	2	7	12,00	17,00				
NKA4	NKA4.2	no	no	15	11,00	31,00	1	7						
NKA4	NKA4.3	no	no	15	12,00	27,00	2	7						
NKB1	NKB1.1	no	yes	15	15,00	23,00	1	8	13,00	16,00				
NKB1	NKB1.2	no	yes	15	13,00	18,00	1	7						
NKB1	NKB1.3	no	yes	15	17,00	32,00	1	8						
NKB2	NKB2.1	no	yes	15	16,00	62,00	1	8	14,00	13,00				
NKB2	NKB2.2	no	yes	15	13,00	20,00	1	7						
NKB2	NKB2.3	no	yes	15	13,00	31,00	1	7						
NKB3	NKB3.1	no	yes	15	19,00	28,00	1	8	9,00	12,00				
NKB3	NKB3.2	no	yes	15	12,00	15,00	1	6						
NKB3	NKB3.3	no	yes	15	12,00	24,00	1	7						
NKB4	NKB4.1	no	yes	15	17,00	36,00	1	8	8,00	11,00				
NKB4	NKB4.2	no	yes	15	15,00	19,00	1	7						
NKB4	NKB4.3	no	yes	15	15,00	33,00	1	8						

Sample_block	Plant	Ploughing	Salinisation	Week	Plant_length	Leaf_area	Damage	Condition	Apical_root_length	Lateral_root_length	Sown_Seeds	Plant_count	Germinated_plants	Germination_succes
KA1	KA1.1	yes	no	16	15,00	41,00	1	7						
KA1	KA1.2	yes	no	16	19,00	48,00	1	7						
KA1	KA1.3	yes	no	16	20,00	53,00	1	7						
KA2	KA2.1	yes	no	16	17,00	25,00	1	7						
KA2	KA2.2	yes	no	16	13,00	37,00	1	7						
KA2	KA2.3	yes	no	16	16,00	23,00	1	7						
KA3	KA3.1	yes	no	16	17,00	30,00	1	6						
KA3	KA3.2	yes	no	16	18,00	16,00	1	6						
KA3	KA3.3	yes	no	16	12,00	24,00	1	6						
KA4	KA4.1	yes	no	16	13,00	22,00	3	6						
KA4	KA4.2	yes	no	16	15,00	25,00	1	7						
KA4	KA4.3	yes	no	16	10,00	20,00	1	7						
KB1	KB1.1	yes	yes	16	14,00	34,00	1	7						
KB1	KB1.2	yes	yes	16	15,00	25,00	1	6						
KB1	KB1.3	yes	yes	16	10,00	28,00	1	6						
KB2	KB2.1	yes	yes	16	17,00	46,00	1	8						
KB2	KB2.2	yes	yes	16	15,00	27,00	1	7						
KB2	KB2.3	yes	yes	16	12,00	46,00	1	7						
KB3	KB3.1	yes	yes	16	18,00	28,00	1	7						
KB3	KB3.2	yes	yes	16	16,00	41,00	1	8						
KB3	KB3.3	yes	yes	16	15,00	38,00	1	8						
KB4	KB4.1	yes	yes	16	17,00	31,00	2	7						
KB4	KB4.2	yes	yes	16	18,00	25,00	2	7						
KB4	KB4.3	yes	yes	16	13,00	52,00	1	7						
NKA1	NKA1.1	no	no	16	17,00	48,00	1	8						
NKA1	NKA1.2	no	no	16	17,00	25,00	2	7						
NKA1	NKA1.3	no	no	16	15,00	36,00	1	6						
NKA2	NKA2.1	no	no	16	17,00	32,00	1	7						
NKA2	NKA2.2	no	no	16	12,00	27,00	2	7						
NKA2	NKA2.3	no	no	16	17,00	28,00	1	7						
NKA3	NKA3.1	no	no	16	8,00	7,00	3	4						
NKA3	NKA3.2	no	no	16	18,00	28,00	1	7						
NKA3	NKA3.3	no	no	16	11,00	42,00	2	6						
NKA4	NKA4.1	no	no	16	16,00	42,00	1	7						
NKA4	NKA4.2	no	no	16	11,00	43,00	1	6						
NKA4	NKA4.3	no	no	16	18,00	49,00	2	6						
NKB1	NKB1.1	no	yes	16	14,00	31,00	1	8						
NKB1	NKB1.2	no	yes	16	21,00	40,00	1	8						
NKB1	NKB1.3	no	yes	16	17,00	35,00	1	7						
NKB2	NKB2.1	no	yes	16	18,00	34,00	1	8						
NKB2	NKB2.2	no	yes	16	12,00	30,00	1	7						
NKB2	NKB2.3	no	yes	16	22,00	50,00	2	7						
NKB3	NKB3.1	no	yes	16	20,00	39,00	1	7						
NKB3	NKB3.2	no	yes	16	14,00	23,00	2	6						
NKB3	NKB3.3	no	yes	16	13,00	25,00	1	6						
NKB4	NKB4.1	no	yes	16	20,00	55,00	1	8						
NKB4	NKB4.2	no	yes	16	16,00	38,00	2	7						
NKB4	NKB4.3	no	yes	16	23,00	71,00	1	8						

Sample_block	Plant	Ploughing	Salinisation	Week	Plant_length	Leaf_area	Damage	Condition	Apical_root_length	Lateral_root_length	Sown_Seeds	Plant_count	Germinated_plants	Germination_succes
KA1	KA1.1	yes	no	17	21,00	70,00	2	7						
KA1	KA1.2	yes	no	17	19,00	63,00	1	7						
KA1	KA1.3	yes	no	17	21,00	77,00	2	7						
KA2	KA2.1	yes	no	17	20,00	51,00	1	7						
KA2	KA2.2	yes	no	17	17,00	72,00	1	8						
KA2	KA2.3	yes	no	17	20,00	35,00	2	6						
KA3	KA3.1	yes	no	17	14,00	51,00	1	7						
KA3	KA3.2	yes	no	17	17,00	54,00	1	7						
KA3	KA3.3	yes	no	17	20,00	51,00	1	7						
KA4	KA4.1	yes	no	17	18,00	38,00	2	7						
KA4	KA4.2	yes	no	17	20,00	65,00	1	7						
KA4	KA4.3	yes	no	17	17,00	44,00	1	7						
KB1	KB1.1	yes	yes	17	17,00	40,00	1	7						
KB1	KB1.2	yes	yes	17	15,00	38,00	1	5						
KB1	KB1.3	yes	yes	17	18,00	56,00	1	7						
KB2	KB2.1	yes	yes	17	17,00	76,00	2	7						
KB2	KB2.2	yes	yes	17	21,00	76,00	2	7						
KB2	KB2.3	yes	yes	17	14,00	72,00	2	7						
KB3	KB3.1	yes	yes	17	18,00	62,00	1	7						
KB3	KB3.2	yes	yes	17	17,00	84,00	1	8						
KB3	KB3.3	yes	yes	17	20,00	55,00	3	6						
KB4	KB4.1	yes	yes	17	23,00	53,00	2	7						
KB4	KB4.2	yes	yes	17	20,00	43,00	1	7						
KB4	KB4.3	yes	yes	17	19,00	37,00	2	7						
NKA1	NKA1.1	no	no	17	17,00	57,00	1	7						
NKA1	NKA1.2	no	no	17	15,00	41,00	2	7						
NKA1	NKA1.3	no	no	17	16,00	42,00	1	5						
NKA2	NKA2.1	no	no	17	16,00	47,00	2	6						
NKA2	NKA2.2	no	no	17	16,00	38,00	3	7						
NKA2	NKA2.3	no	no	17	20,00	41,00	2	6						
NKA3	NKA3.1	no	no	17	12,00	12,00	3	4						
NKA3	NKA3.2	no	no	17	18,00	41,00	1	7						
NKA3	NKA3.3	no	no	17	15,00	45,00	3	6						
NKA4	NKA4.1	no	no	17	19,00	53,00	2	6						
NKA4	NKA4.2	no	no	17	17,00	69,00	2	6						
NKA4	NKA4.3	no	no	17	15,00	80,00	1	7						
NKB1	NKB1.1	no	yes	17	19,00	43,00	2	7						
NKB1	NKB1.2	no	yes	17	21,00	52,00	1	7						
NKB1	NKB1.3	no	yes	17	20,00	60,00	2	7						
NKB2	NKB2.1	no	yes	17	20,00	62,00	2	7						
NKB2	NKB2.2	no	yes	17	23,00	44,00	1	7						
NKB2	NKB2.3	no	yes	17	25,00	76,00	2	7						
NKB3	NKB3.1	no	yes	17	23,00	58,00	3	6						
NKB3	NKB3.2	no	yes	17	20,00	40,00	3	7						
NKB3	NKB3.3	no	yes	17	17,00	30,00	3	6						
NKB4	NKB4.1	no	yes	17	24,00	80,00	3	7						
NKB4	NKB4.2	no	yes	17	23,00	48,00	2	7						
NKB4	NKB4.3	no	yes	17	25,00	90,00	2	7						

Sample_block	Plant	Ploughing	Salinisation	Week	Plant_length	Leaf_area	Damage	Condition	Apical_root_length	Lateral_root_length	Sown_Seeds	Plant_count	Germinated_plants	Germination_succes
KA1	KA1.1	yes	no	18	24,00	122,00	2	7						
KA1	KA1.2	yes	no	18	20,00	102,00	2	7						
KA1	KA1.3	yes	no	18	22,00	125,00	2	8						
KA2	KA2.1	yes	no	18	20,00	82,00	2	7						
KA2	KA2.2	yes	no	18	23,00	107,00	2	7						
KA2	KA2.3	yes	no	18	20,00	73,00	1	7						
KA3	KA3.1	yes	no	18	18,00	68,00	2	8						
KA3	KA3.2	yes	no	18	17,00	84,00	1	7						
KA3	KA3.3	yes	no	18	17,00	52,00	2	8						
KA4	KA4.1	yes	no	18	21,00	41,00	1	8						
KA4	KA4.2	yes	no	18	18,00	75,00	2	8						
KA4	KA4.3	yes	no	18	18,00	47,00	1	8						
KB1	KB1.1	yes	yes	18	20,00	56,00	1	8						
KB1	KB1.2	yes	yes	18	19,00	63,00	1	7						
KB1	KB1.3	yes	yes	18	17,00	69,00	2	7						
KB2	KB2.1	yes	yes	18	22,00	85,00	2	7						
KB2	KB2.2	yes	yes	18	20,00	76,00	1	7						
KB2	KB2.3	yes	yes	18	18,00	106,00	2	7						
KB3	KB3.1	yes	yes	18	25,00	78,00	1	8						
KB3	KB3.2	yes	yes	18	16,00	118,00	2	7						
KB3	KB3.3	yes	yes	18	22,00	99,00	2	7						
KB4	KB4.1	yes	yes	18	22,00	62,00	1	7						
KB4	KB4.2	yes	yes	18	20,00	66,00	2	7						
KB4	KB4.3	yes	yes	18	18,00	70,00	2	7						
NKA1	NKA1.1	no	no	18	23,00	93,00	2	7						
NKA1	NKA1.2	no	no	18	18,00	53,00	3	7						
NKA1	NKA1.3	no	no	18	15,00	81,00	1	7						
NKA2	NKA2.1	no	no	18	22,00	80,00	3	7						
NKA2	NKA2.2	no	no	18	16,00	52,00	3	7						
NKA2	NKA2.3	no	no	18	19,00	56,00	2	7						
NKA3	NKA3.1	no	no	18	18,00	17,00	1	4						
NKA3	NKA3.2	no	no	18	22,00	66,00	2	6						
NKA3	NKA3.3	no	no	18	15,00	71,00	4	4						
NKA4	NKA4.1	no	no	18	21,00	68,00	4	6						
NKA4	NKA4.2	no	no	18	17,00	84,00	3	6						
NKA4	NKA4.3	no	no	18	20,00	82,00	2	7						
NKB1	NKB1.1	no	yes	18	24,00	88,00	2	8						
NKB1	NKB1.2	no	yes	18	20,00	72,00	3	7						
NKB1	NKB1.3	no	yes	18	29,00	79,00	2	7						
NKB2	NKB2.1	no	yes	18	24,00	108,00	2	8						
NKB2	NKB2.2	no	yes	18	22,00	81,00	2	7						
NKB2	NKB2.3	no	yes	18	24,00	113,00	3	8						
NKB3	NKB3.1	no	yes	18	22,00	82,00	3	7						
NKB3	NKB3.2	no	yes	18	20,00	51,00	2	7						
NKB3	NKB3.3	no	yes	18	16,00	53,00	3	5						
NKB4	NKB4.1	no	yes	18	25,00	107,00	2	7						
NKB4	NKB4.2	no	yes	18	22,00	83,00	3	7						
NKB4	NKB4.3	no	yes	18	25,00	81,00	3	6						

Sample_block	Plant	Ploughing	Salinisation	Week	Plant_length	Leaf_area	Damage	Condition	Apical_root_length	Lateral_root_length	Sown_Seeds	Plant_count	Germinated_plants	Germination_succes
KA1	KA1.1	yes	no	19	24,00	165,00	2	8						
KA1	KA1.2	yes	no	19	28,00	229,00	2	8						
KA1	KA1.3	yes	no	19	30,00	250,00	2	8						
KA2	KA2.1	yes	no	19	29,00	135,00	1	8						
KA2	KA2.2	yes	no	19	28,00	202,00	1	8						
KA2	KA2.3	yes	no	19	28,00	105,00	1	7						
KA3	KA3.1	yes	no	19	25,00	133,00	2	8						
KA3	KA3.2	yes	no	19	24,00	137,00	2	8						
KA3	KA3.3	yes	no	19	27,00	100,00	2	8						
KA4	KA4.1	yes	no	19	29,00	100,00	1	8						
KA4	KA4.2	yes	no	19	30,00	157,00	2	7						
KA4	KA4.3	yes	no	19	29,00	119,00	1	8						
KB1	KB1.1	yes	yes	19	24,00	115,00	1	8						
KB1	KB1.2	yes	yes	19	30,00	111,00	1	8						
KB1	KB1.3	yes	yes	19	30,00	184,00	2	8						
KB2	KB2.1	yes	yes	19	30,00	180,00	2	7						
KB2	KB2.2	yes	yes	19	30,00	209,00	2	8						
KB2	KB2.3	yes	yes	19	30,00	171,00	2	8						
KB3	KB3.1	yes	yes	19	32,00	146,00	1	9						
KB3	KB3.2	yes	yes	19	32,00	195,00	2	8						
KB3	KB3.3	yes	yes	19	30,00	165,00	2	8						
KB4	KB4.1	yes	yes	19	29,00	131,00	2	9						
KB4	KB4.2	yes	yes	19	30,00	130,00	2	8						
KB4	KB4.3	yes	yes	19	29,00	158,00	2	8						
NKA1	NKA1.1	no	no	19	27,00	129,00	2	8						
NKA1	NKA1.2	no	no	19	24,00	98,00	3	7						
NKA1	NKA1.3	no	no	19	21,00	112,00	2	7						
NKA2	NKA2.1	no	no	19	24,00	97,00	4	6						
NKA2	NKA2.2	no	no	19	23,00	106,00	3	7						
NKA2	NKA2.3	no	no	19	27,00	141,00	3	7						
NKA3	NKA3.1	no	no	19	27,00	34,00	1	5						
NKA3	NKA3.2	no	no	19	30,00	94,00	3	7						
NKA3	NKA3.3	no	no	19	23,00	109,00	2	6						
NKA4	NKA4.1	no	no	19	27,00	93,00	3	7						
NKA4	NKA4.2	no	no	19	23,00	138,00	3	7						
NKA4	NKA4.3	no	no	19	27,00	128,00	2	7						
NKB1	NKB1.1	no	yes	19	29,00	112,00	2	8						
NKB1	NKB1.2	no	yes	19	29,00	109,00	2	8						
NKB1	NKB1.3	no	yes	19	32,00	164,00	2	9						
NKB2	NKB2.1	no	yes	19	30,00	177,00	2	8						
NKB2	NKB2.2	no	yes	19	30,00	153,00	2	9						
NKB2	NKB2.3	no	yes	19	27,00	183,00	2	8						
NKB3	NKB3.1	no	yes	19	29,00	136,00	2	8						
NKB3	NKB3.2	no	yes	19	24,00	77,00	3	6						
NKB3	NKB3.3	no	yes	19	24,00	94,00	2	7						
NKB4	NKB4.1	no	yes	19	29,00	180,00	2	8						
NKB4	NKB4.2	no	yes	19	22,00	101,00	2	8						
NKB4	NKB4.3	no	yes	19	30,00	108,00	2	8						

Sample_block	Plant	Ploughing	Salinisation	Week	Plant_length	Leaf_area	Damage	Condition	Apical_root_length	Lateral_root_length	Sown_Seeds	Plant_count	Germinated_plants	Germination_succes
KA1	KA1.1	yes	no	20	35,00	518,00	2	8	24,00	26,00				
KA1	KA1.2	yes	no	20	35,00	533,00	2	8						
KA1	KA1.3	yes	no	20	40,00	507,00	2	8						
KA2	KA2.1	yes	no	20	32,00	238,00	2	8	20,00	25,00				
KA2	KA2.2	yes	no	20	35,00	345,00	2	8						
KA2	KA2.3	yes	no	20	40,00	336,00	2	8						
KA3	KA3.1	yes	no	20	32,00	279,00	2	8	24,00	20,00				
KA3	KA3.2	yes	no	20	32,00	410,00	2	8						
KA3	KA3.3	yes	no	20	32,00	300,00	2	8						
KA4	KA4.1	yes	no	20	35,00	337,00	2	8	20,00	19,00				
KA4	KA4.2	yes	no	20	40,00	433,00	2	8						
KA4	KA4.3	yes	no	20	32,00	248,00	2	8						
KB1	KB1.1	yes	yes	20	32,00	325,00	2	8	25,00	30,00				
KB1	KB1.2	yes	yes	20	32,00	328,00	1	9						
KB1	KB1.3	yes	yes	20	35,00	416,00	2	8						
KB2	KB2.1	yes	yes	20	35,00	457,00	2	8	20,00	20,00				
KB2	KB2.2	yes	yes	20	35,00	263,00	2	8						
KB2	KB2.3	yes	yes	20	35,00	460,00	2	8						
KB3	KB3.1	yes	yes	20	32,00	269,00	3	7	18,00	24,00				
KB3	KB3.2	yes	yes	20	40,00	457,00	2	8						
KB3	KB3.3	yes	yes	20	40,00	481,00	2	8						
KB4	KB4.1	yes	yes	20	35,00	187,00	3	7	20,00	22,00				
KB4	KB4.2	yes	yes	20	40,00	323,00	2	8						
KB4	KB4.3	yes	yes	20	35,00	266,00	2	8						
NKA1	NKA1.1	no	no	20	35,00	241,00	3	7	18,00	20,00				
NKA1	NKA1.2	no	no	20	30,00	187,00	3	7						
NKA1	NKA1.3	no	no	20	30,00	167,00	2	6						
NKA2	NKA2.1	no	no	20	30,00	181,00	3	7	20,00	20,00				
NKA2	NKA2.2	no	no	20	30,00	184,00	2	6						
NKA2	NKA2.3	no	no	20	32,00	284,00	3	7						
NKA3	NKA3.1	no	no	20	30,00	46,00	3	5	20,00	22,00				
NKA3	NKA3.2	no	no	20	35,00	126,00	2	6						
NKA3	NKA3.3	no	no	20	32,00	200,00	2	7						
NKA4	NKA4.1	no	no	20	32,00	156,00	3	7	22,00	20,00				
NKA4	NKA4.2	no	no	20	30,00	252,00	2	7						
NKA4	NKA4.3	no	no	20	32,00	255,00	2	7						
NKB1	NKB1.1	no	yes	20	32,00	221,00	2	7	20,00	15,00				
NKB1	NKB1.2	no	yes	20	35,00	188,00	2	7						
NKB1	NKB1.3	no	yes	20	40,00	267,00	2	8						
NKB2	NKB2.1	no	yes	20	40,00	278,00	2	8	24,00	20,00				
NKB2	NKB2.2	no	yes	20	40,00	282,00	2	8						
NKB2	NKB2.3	no	yes	20	40,00	343,00	2	8						
NKB3	NKB3.1	no	yes	20	35,00	266,00	2	7	20,00	18,00				
NKB3	NKB3.2	no	yes	20	30,00	202,00	2	6						
NKB3	NKB3.3	no	yes	20	32,00	253,00	2	7						
NKB4	NKB4.1	no	yes	20	35,00	240,00	2	8	23,00	22,00				
NKB4	NKB4.2	no	yes	20	34,00	332,00	1	9						
NKB4	NKB4.3	no	yes	20	35,00	327,00	2	8						

Appendix IV: SPSS Output
The output from the Mixed Model ANOVA tests is per variable given below.

Plant length:

Mixed Model Analysis

Model Dimension[a]

		Number of Levels	Covariance Structure	Number of Parameters	Subject Variables	Number of Subjects
Fixed Effects	Intercept	1		1		
	Ploughing	2		1		
	Salinisation	2		1		
	Ploughing * Salinisation	4		1		
Repeated Effects	Week	13	Diagonal	13	Sample_block * Plant	48
Total		22		17		

a. Dependent Variable: Plant_length.

Information Criteria[a]

-2 Restricted Log Likelihood	3980,092
Akaike's Information Criterion (AIC)	4006,092
Hurvich and Tsai's Criterion (AICC)	4006,693
Bozdogan's Criterion (CAIC)	4076,678
Schwarz's Bayesian Criterion (BIC)	4063,678

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Plant_length.

Fixed Effects

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	284,924	4742,884	,000
Ploughing	1	284,924	,077	,782
Salinisation	1	284,924	6,997	,009
Ploughing * Salinisation	1	284,924	9,178	,003

a. Dependent Variable: Plant_length.

Covariance Parameters

Estimates of Covariance Parameters[a]

Parameter		Estimate	Std. Error
Repeated Measures	Var: [Week=8]	98,518488	20,624766
	Var: [Week=9]	66,274132	14,016849
	Var: [Week=10]	21,802240	4,867733
	Var: [Week=11]	5,865013	1,377403
	Var: [Week=12]	6,452798	1,414696
	Var: [Week=13]	4,957334	1,097210
	Var: [Week=14]	5,478656	1,140053
	Var: [Week=15]	12,810741	2,832910
	Var: [Week=16]	37,411749	8,019995
	Var: [Week=17]	76,137056	16,022493
	Var: [Week=18]	106,504378	22,223406
	Var: [Week=19]	303,310929	62,416761
	Var: [Week=20]	586,468368	120,222752

a. Dependent Variable: Plant_length.

Leaf area:

Mixed Model Analysis

Model Dimension[a]

		Number of Levels	Covariance Structure	Number of Parameters	Subject Variables	Number of Subjects
Fixed Effects	Intercept	1		1		
	Ploughing	2		1		
	Salinisation	2		1		
	Ploughing * Salinisation	4		1		
Repeated Effects	Week	13	Diagonal	13	Sample_block * Plant	48
Total		22		17		

a. Dependent Variable: Leaf_Area_LOG.

Information Criteria[a]

-2 Restricted Log Likelihood	742,262
Akaike's Information Criterion (AIC)	768,262
Hurvich and Tsai's Criterion (AICC)	768,863
Bozdogan's Criterion (CAIC)	838,849
Schwarz's Bayesian Criterion (BIC)	825,849

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Leaf_Area_LOG.

Fixed Effects

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	127,771	7431,149	,000
Ploughing	1	127,771	,258	,613
Salinisation	1	127,771	,695	,406
Ploughing * Salinisation	1	127,771	1,485	,225

a. Dependent Variable: Leaf_Area_LOG.

Covariance Parameters

Estimates of Covariance Parameters[a]

Parameter		Estimate	Std. Error
Repeated Measures	Var: [Week=8]	,102897	,023111
	Var: [Week=9]	,029646	,007315
	Var: [Week=10]	,019805	,005025
	Var: [Week=11]	,008792	,002153
	Var: [Week=12]	,021297	,005320
	Var: [Week=13]	,093592	,021207
	Var: [Week=14]	,204735	,044124
	Var: [Week=15]	,357085	,075231
	Var: [Week=16]	,613300	,127677
	Var: [Week=17]	,956080	,197689
	Var: [Week=18]	1,279936	,263823
	Var: [Week=19]	1,896256	,389631
	Var: [Week=20]	2,889677	,592410

a. Dependent Variable: Leaf_Area_LOG.

Damage:

Mixed Model Analysis

Model Dimension[a]

		Number of Levels	Covariance Structure	Number of Parameters	Subject Variables	Number of Subjects
Fixed Effects	Intercept	1		1		
	Ploughing	2		1		
	Salinisation	2		1		
	Ploughing * Salinisation	4		1		
Repeated Effects	Week	13	Diagonal	13	Sample_block * Plant	48
Total		22		17		

a. Dependent Variable: Damage.

Information Criteria[a]

-2 Restricted Log Likelihood	1823,233
Akaike's Information Criterion (AIC)	1849,233
Hurvich and Tsai's Criterion (AICC)	1849,834
Bozdogan's Criterion (CAIC)	1919,820
Schwarz's Bayesian Criterion (BIC)	1906,820

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Damage.

Fixed Effects

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	303,832	3345,372	,000
Ploughing	1	303,832	16,383	,000
Salinisation	1	303,832	4,999	,026
Ploughing * Salinisation	1	303,832	12,192	,001

a. Dependent Variable: Damage.

Covariance Parameters

Estimates of Covariance Parameters[a]

Parameter		Estimate	Std. Error
Repeated Measures	Var: [Week=8]	5,707844	1,173729
	Var: [Week=9]	4,748309	,975957
	Var: [Week=10]	1,963882	,406980
	Var: [Week=11]	1,015525	,208210
	Var: [Week=12]	2,192241	,451778
	Var: [Week=13]	,990954	,205893
	Var: [Week=14]	1,279434	,265345
	Var: [Week=15]	1,266062	,263339
	Var: [Week=16]	,722836	,157472
	Var: [Week=17]	,540000	,113319
	Var: [Week=18]	,539691	,113195
	Var: [Week=19]	,320033	,067162
	Var: [Week=20]	,187646	,041833

a. Dependent Variable: Damage.

Condition:

Mixed Model Analysis

Model Dimension[a]

		Number of Levels	Covariance Structure	Number of Parameters	Subject Variables	Number of Subjects
Fixed Effects	Intercept	1		1		
	Ploughing	2		1		
	Salinisation	2		1		
	Ploughing * Salinisation	4		1		
Repeated Effects	Week	13	Diagonal	13	Sample_block * Plant	48
Total		22		17		

a. Dependent Variable: Condition.

Information Criteria[a]

-2 Restricted Log Likelihood	1392,882
Akaike's Information Criterion (AIC)	1418,882
Hurvich and Tsai's Criterion (AICC)	1419,483
Bozdogan's Criterion (CAIC)	1489,468
Schwarz's Bayesian Criterion (BIC)	1476,468

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Condition.

Fixed Effects

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	412,252	66300,671	,000
Ploughing	1	412,252	2,585	,109
Salinisation	1	412,252	18,136	,000
Ploughing * Salinisation	1	412,252	23,798	,000

a. Dependent Variable: Condition.

Covariance Parameters

Estimates of Covariance Parameters[a]

Parameter		Estimate	Std. Error
Repeated Measures	Var: [Week=8]	,813964	,169336
	Var: [Week=9]	,595046	,122619
	Var: [Week=10]	,545974	,112336
	Var: [Week=11]	,338902	,070092
	Var: [Week=12]	,148564	,031210
	Var: [Week=13]	,259902	,053313
	Var: [Week=14]	,790058	,163182
	Var: [Week=15]	,728161	,149396
	Var: [Week=16]	,564722	,115894
	Var: [Week=17]	,500378	,103746
	Var: [Week=18]	,679660	,140078
	Var: [Week=19]	,968143	,202775
	Var: [Week=20]	,800944	,168631

a. Dependent Variable: Condition.

Apical root length:

Mixed Model Analysis

Model Dimension[a]

		Number of Levels	Covariance Structure	Number of Parameters	Subject Variables	Number of Subjects
Fixed Effects	Intercept	1		1		
	Ploughing	2		1		
	Salinisation	2		1		
	Ploughing * Salinisation	4		1		
Repeated Effects	Week	3	Diagonal	3	Sample_block	16
Total		12		7		

a. Dependent Variable: Apical_root_length.

Information Criteria[a]

-2 Restricted Log Likelihood	254,585
Akaike's Information Criterion (AIC)	260,585
Hurvich and Tsai's Criterion (AICC)	261,185
Bozdogan's Criterion (CAIC)	268,938
Schwarz's Bayesian Criterion (BIC)	265,938

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Apical_root_length.

Fixed Effects

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	28,104	754,662	,000
Ploughing	1	28,104	,071	,792
Salinisation	1	28,104	,002	,961
Ploughing * Salinisation	1	28,104	,019	,892

a. Dependent Variable: Apical_root_length.

Covariance Parameters

Estimates of Covariance Parameters[a]

Parameter		Estimate	Std. Error
Repeated Measures	Var: [Week=8]	6,161954	2,473830
	Var: [Week=15]	4,230368	1,618410
	Var: [Week=20]	112,680597	40,918294

a. Dependent Variable: Apical_root_length.

Lateral root length:

Mixed Model Analysis

Model Dimension[a]

		Number of Levels	Covariance Structure	Number of Parameters	Subject Variables	Number of Subjects
Fixed Effects	Intercept	1		1		
	Ploughing	2		1		
	Salinisation	2		1		
	Ploughing * Salinisation	4		1		
Repeated Effects	Week	3	Diagonal	3	Sample_block	16
Total		12		7		

a. Dependent Variable: Lateral_root_length.

Information Criteria[a]

-2 Restricted Log Likelihood	280,206
Akaike's Information Criterion (AIC)	286,206
Hurvich and Tsai's Criterion (AICC)	286,806
Bozdogan's Criterion (CAIC)	294,558
Schwarz's Bayesian Criterion (BIC)	291,558

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Lateral_root_length.

Fixed Effects

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	33,500	444,572	,000
Ploughing	1	33,500	2,442	,128
Salinisation	1	33,500	,283	,598
Ploughing * Salinisation	1	33,500	,706	,407

a. Dependent Variable: Lateral_root_length.

Covariance Parameters

Estimates of Covariance Parameters[a]

Parameter		Estimate	Std. Error
Repeated Measures	Var: [Week=8]	22,656764	10,844969
	Var: [Week=15]	14,749169	5,690232
	Var: [Week=20]	58,100655	24,901687

a. Dependent Variable: Lateral_root_length.