URBAN AND RURAL APPLICATIONS

FOR THE

SALINITY TOLERANCE

OF ORNAMENTAL TREES AND SHRUBS

IN SOUTHERN ALBERTA

by

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THE FACULTY OF ENVIRONMENTAL DESIGN

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ABSTRACT

Urban and Rural Applications for the Salinity Tolerance of Ornamental Trees and Shrubs in Southern Alberta
by
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Completed in partial fulfilment of the requirements for the degree of Master of Environmental Design in the Faculty of Environmental Design
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The goals of this Master's Degree Project were to study the nature of saline soils and amendment techniques useful in dealing with the problem; to study the growth and survival of 28 types of trees and shrubs; to correlate this information to increasing amounts of soil salinity; and to examine the applications and economic benefits associated with this information.

Soil salinization is a widespread and growing problem, both in Western Canada's prairies and on a worldwide basis. It has been estimated to affect .75 million hectares of land in Alberta alone and can lead to decreases in crop production of 25 to 50 percent and even to irreversible desertification. One solution to the problem of soil salinity is the use of salt tolerant species on affected areas.

Starting in the summer of 1989, 28 species of ornamental trees and shrubs were tested. They were grown at a site near Brooks, Alberta that exhibited a wide range of naturally occurring soil salinity. The trees were planted randomly, with the same amount in each of five zones ranging from low to high salinity. Data were gathered for soil salinity and for plant growth and survival. The results show a continuum which represents the relative speed of growth, salinity tolerance and hardiness of the 28 types of trees and shrubs. These results were used to calculate an overall ranking value which reflects the three characteristics in equal proportions. One type, the Russian olive, was outstanding, showing rapid growth combined with a high degree of salinity tolerance and a high rate of survival. Other types that performed exceptionally well were Brooks poplar, acute leaf willow, northwest poplar and caragana. The scots pine and bur oak were the poorest overall. For these two, the small size of the transplant materials was indicated in the substandard results.

The results of the field study can be applied to both the urban and rural environment and may also have implications for the creation of related consulting businesses. Urban applications examined in this study are salted roadway boulevards, visual and sound barriers, landscaping and wildlife habitat creation. Rural applications, which are examined, are shelterbelts and land reclamation projects.

KEY WORDS

Soil Salinity, Salinity Tolerance, Trees, Shrubs, Deicing Salts, Visual Barriers, Sound Barriers, Landscaping, Shelterbelts, Reclamation

CHAPTER 1 INTRODUCTION

1.1 PROJECT RATIONALE

Globally, there are 20 million hectares of land that are too saline to produce economic crop yields and more become less productive every year (Rhoades 1987 p. 118). Soil salinity problems are present in nearly all irrigated areas of the world and, in the case of dryland salinity, they also occur on unirrigated crop and range lands. Large salinity problems are usually confined to arid or semi-arid regions (25% of the earth's surface) that do not have sufficient rainfall to wash salts from the plant root zone (Poljakoff-Mayber 1975, p. 25). According to Brown (1989, p. 26), "the productivity of one third of irrigated land is being affected by severe waterlogging and salinity". Not only does soil salinization adversely affect productivity it also directly causes desertification, which brings implications of starvation (Brown 1989, p. 26). Soil salinization is an important issue worldwide and is of particular interest in the dry irrigated lands of southern Alberta.

Techniques have been developed which combat soil salinity, with varying degrees of success. Many of these require large amounts of materials and specialized equipment, all of which may be prohibitively expensive. In Alberta drainage tiles have been installed at great expense (Toogood 1989, p. 29). The use of saline tolerant crops is inexpensive, allows for continued production of an affected area and results in favourable changes to the soil structure.

1.2 PROJECT BACKGROUND

Southern Alberta has naturally occurring soil salinity which has often been exacerbated by poor soil management practices. This situation can be detrimental to ornamental trees and shrubs in both urban and rural communities. The Landscape and Nursery Trades Association (LANTA) estimates that $40 million are spent every year in Alberta on nursery crops, one half of which are for trees and woody shrubs. An additional 2.5 million trees (worth $2.5 million) are distributed each year through Alberta Agriculture's shelterbelt program. There are a number of parties who have an economic or social interest in which species of trees are best suited to Southern Alberta's soil conditions. These individuals may be farmers and ranchers, landscape architects, home-owners, tree nursery operators or members in all levels of government involved with parks, local beautification or agriculture.

1.3 GOALS AND OBJECTIVES

The goals of this project are to determine the salinity tolerance of ornamental trees and shrubs and to explore the applications as they apply to techniques of landscape management in both rural and urban environments.

The objectives for this project are:

1. to study the nature of soil salinity and techniques for its amendment,
2. to correlate growth and survival of 28 types of trees and shrubs to soil salinity in field trials and
3. to review applications and economic benefits of the results.

CHAPTER 2 LITERATURE REVIEW

2.1 INTRODUCTION

As was discussed in Chapter 1, soil salinity is an issue that continues to grow in importance on both irrigated and unirrigated croplands, which are usually arid or semi-arid. In Alberta, approximately 1.2 million hectares of dryland are affected by saline seepage, reducing crop yield by 25% on average (Toogood 1989, p. 28). Saline soil is most common on Alberta's grassland region (Toogood 1989, p. 28). Figure 2.1 shows the location of Alberta's solonetzic soils.

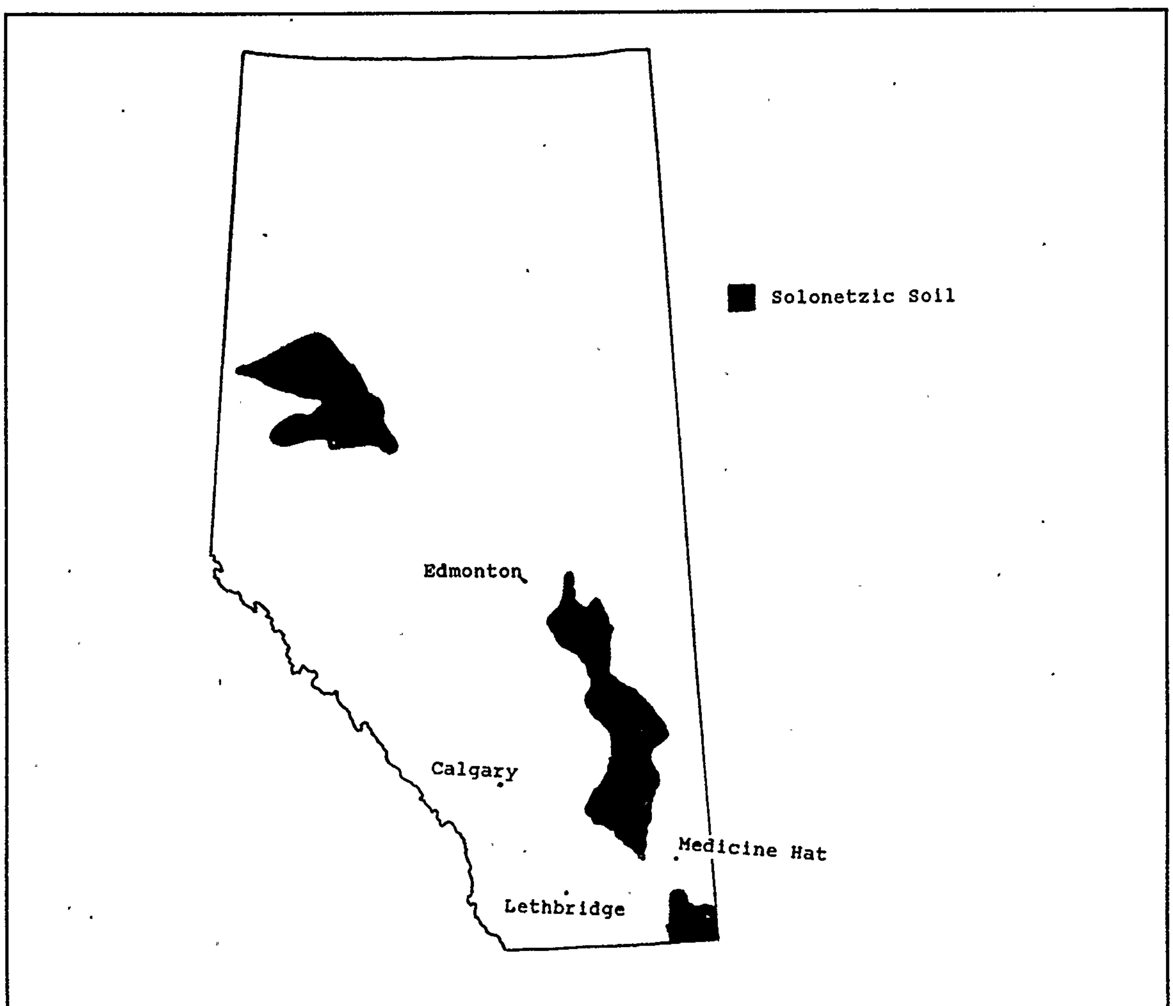


Figure 2.1: Alberta's Solonetzic Soils (Adapted from Toogood 1989, p. 8)

Saline soils are not exclusively of the solonetzic soil order. The chernozemic and luvisolic soil orders also have solonetzic subgroups (Agriculture Canada 1977, pp. 33-39).

The field study for this project was conducted near Brooks, Alberta, within the area of solonetzic soils and within the Eastern Irrigation District (Figure 2.2). This is of importance because leaking irrigation systems and overuse of irrigation can create or exacerbate problems with soil salinity. This will be discussed in greater detail in the following section.

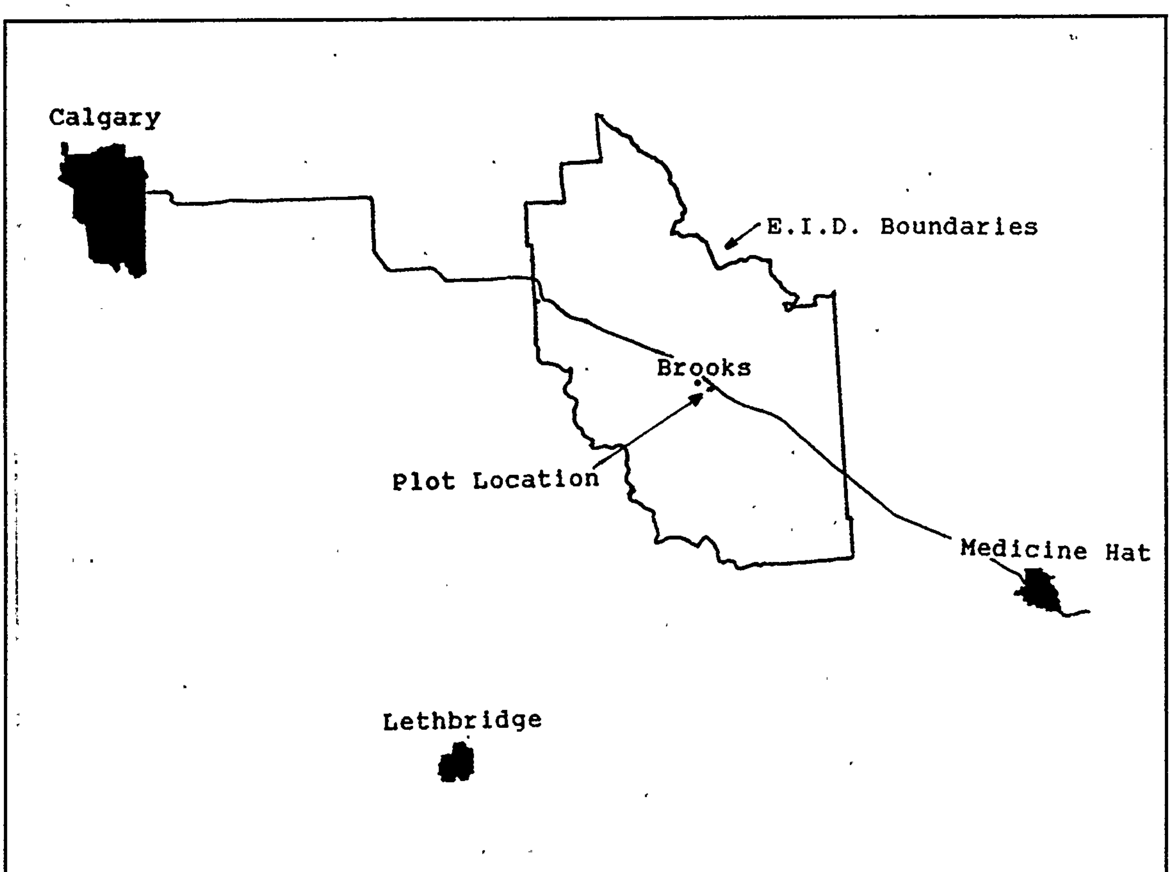


Figure 2.2: Eastern Irrigation District (Modified from Toogood 1989, p. 13)

2.2 SOIL SALINITY

2.2.1 The Classification of Solonetzic Soils

Originally solonetzic soils were considered to be soils that were saline or alkaline. Since 1977 Agriculture Canada (1977, p. 109) has defined the solonetzic order of soil as mineral soils, which are well to imperfectly drained and have distinctive physical and chemical horizon features. Solonetzic soils are formed under a cover of grasses and forbes, with the possibility of some tree cover. Solonetzic soils make up 0.8% of Canada, 45% of which is under cultivation.

Two processes important to the formation of solonetzic soils are salinization and alkalinization which are, respectively, the prerequisite and the prime cause for the development of solonetzic soils. Salinization by alkaline salts may originate internally (saline parent material) or externally (saturation with saline water). At the same time, desalinization is occurring through leaching within the soil. This combination of salinization and desalinization is a dynamic process. The process of alkalinization (solonization) results in the deflocculation of clays in the soil. Conversely dealkalinization (solodization) entails the removal of alkali bases and the formation of a hard acidic surface layer (Agriculture Canada 1977, p. 109). On the western glaciated plains, salts are produced by weathering of glacial sediments exposed to the atmosphere. Leaching is limited by the semi-arid climate and the low permeability of clays and clayey tills, therefore the soil salts stay in place and are localized to discharge zones of shallow aquifers (van der Kamp 1992).

The order of solonetzic soils is broken down into three great groups; solonetz, solodized solonetz and solod. Soil classification is based on a continuum of dynamic soil processes. At the great group level, the only break that should be recognized is the point in the solodization process (Agriculture Canada 1977, p. 111). Subgroup separation is based primarily on the colour of the surface horizon, which may be related to vegetation cover and regional climate (Figure 2.3). Solonetzic soils are most commonly associated with brown, dark brown and black chernozems (Agriculture Canada 1977, p. 111). The field work for this project took place on soil that is predominantly brown chernozemic and solonetzic (Toogood 1989, pp. 8-9).

Order		Solonetzic Soils	
Great Groups	Solonetz	Solodized Solonetz	Solod
Sub Groups	Brown Black Grey Alkaline Gleyed	Brown Black Grey Gleyed	Brown Black Grey Gleyed

Figure 2.3: Solonetzic Soil Order (Adapted from Agriculture Canada 1977, p. 111)

2.2.2 The Nature of Saline Soils

Halomorphic soils are a suborder of soil which is formed under imperfect drainage in arid regions and is subdivided into soil groups such as saline and sodic (Brady 1974, p. 396). A saline soil is one in which soluble salts have accumulated in sufficient quantity to adversely affect growth (Harpstead 1988, p. 118). Saline soils are predominant in southern Alberta and have an excess of soluble salts such as the chlorides and sulphates of sodium, calcium and magnesium (Brady 1974, p. 397). It is important to note that not all saline soils are solonetzic, just as all solonetzic soils are not saline. A sodic soil is one that contains enough sodium for the clay particles to become highly dispersed so that yields are adversely affected (Harpstead 1988, p. 118). Table 2.1 (Brady 1974, pp. 396-399) summarizes the electrical conductivity (EC), sodium content and acidity of three categories of halomorphic soils.

Table 2.1: Halomorphic Soils

Category	EC (dS/m)	%[Na+]	pH
Saline	>4	<15	<8.5
Saline-sodic	>4	>15	<8.5
Sodic	<4	>>15	>10

There are generally four components to soil. In a silt loam surface soil in good condition for plant growth, they are in the following proportions, by volume (Brady 1974, p. 13):

Table 2.2: Components of Soil by Volume

Mineral Materials	45%
Organic Matter	5%
Water	20 - 30%
Air	20 - 30%

In saline soils the ratio of soil components becomes altered. This may be a direct result of salinization, where soil compaction leads to a decline in the amount of air and water present in the soil. The alteration of soil components may also be an indirect result of salinization, where the impenetrability of the soil decreases plant growth and therefore the amount of organic matter in the soil.

There are a number of terms that can be used to characterize saline soils by the amount of soluble salts present. Solute potential is a term used to describe the amount of soluble materials (such as salts) found in the soil solution. The solute potential of a soil affects the semipermeable membranes found in the soil. One semipermeable membrane is the air-water interface, another type is the root cell walls. The osmotic behaviour that occurs at the root cell wall is a result of the solute potential of the soil and is one characteristic of saline soils that affects plant "comfort" (Hanks 1980, p. 51).

The soluble salts present in a soil can be distinguished further,usually emphasizing the sodium ions. One measure is the soluble sodium percentage (SSP), which describes the proportion of sodium in a soil solution. Another measure is called the sodium adsorption ratio (SAR), which provides a value for the predicted rate of sodium adsorption to the soil. A similar measure is the exchangeable sodium percentage (ESP), which defines the extent to which the adsorption complex of a soil is occupied by sodium. The formulas for each of these are provided in the glossary.

Solonetz soils have some characteristics that affect their agricultural productivity as well as their suitability to construction. Those characteristics that produce management problems for the farmer are (Toogood 1978, pp. 19-20):

1. Hard, compact B horizon which limits water, air and root penetration.
2. High salt content of the subsoil produces osmotic pressure on roots.
3. The soil horizon is slowly to very slowly permeable to water.
4. The surface horizon is low in organic matter and forms crusts which affects emergence.
5. The chemical composition of these soils adversely affect the uptake of nutrients, particularly nitrogen.
6. Low soil pH may adversely affect sensitive crops (alfalfa).
7. Good soil management is difficult due to extreme variability in the soil over short distances.

2.2.3 Sources of Soil Salinity

Soil salinity can occur naturally or be due to human activity (Harpstead 1988, p. 118). According to Brady (1974), soil salinity pollution from human activity is primarily agricultural in origin. The process of salinization may begin with the conversion of native rangelands to agricultural production. The diversity of vegetation on native prairie ensures a demand for water throughout the entire growing season and soil profile. The water requirements of a monoculture are temporally specific. This allows for an elevation of the water table in times of low demand (Revel 1985, p. 100). A rising water table brings with it salts from deep within the soil. On dry farmed prairies, "development of salinity is almost completely due to the transport of the naturally occurring salts in the near-surface soil layers by capillary soil moisture flow" (Stolte 1992). The results of an examination of a road-side borrow pit showed that nearby soil salinization was not a result of deicing salts but "due to raised ground water table and resulting lateral and vertical flows of soil water" (Hammermeister 1992).

Soil salinity can also result from salt-laden irrigation water or poor drainage on irrigated soil (Russell 1961, p. 598). Leaky canals and irrigation systems and over irrigation may also increase the area of a naturally occurring saline soil (Warren 1987, p. 7). The source of salts in naturally saline soils is usually the ground water (Russell 1961, p. 598). Salts are deposited into ground water by the weathering of upstream rock formations and by passing through salt deposits prior to arrival at the destination. Less frequently, saline soils result from flooding by sea water (Russell 1961, p. 598). Boyko (1966, p. 28) lists nine factors that affect the salinity of inland areas. These factors affect the amount of leaching and evaporation, drainage patterns, movement of salts, uniformity of salt deposits and need for irrigation (Boyko 1966, p. 28). They are:

1. precipitation,
2. proximity to drainage channels,
3. nature of the soil,
4. vegetation,
5. slope of the ground
6. depth of the soil water table,
7. depth of the salt deposit,
8. water inflow into the region and
9. temperature.

2.2.4 Techniques for Reclaiming Saline Soils

As with all reclamation projects, the reclamation of saline soils requires careful pre-planning. There is a danger that attempts to reclaim saline soils may result in increased soil impermeability and this possibility must be kept in mind throughout all phases of reclamation. "Soils containing much exchangeable sodium, or free sodium carbonate, will deflocculate and become quite impermeable to water if wetted with pure water, or with rain, whereas if they contain much soluble salts, or the irrigation water has a high salinity, they may remain flocculated and permeable" (Russell 1961, p. 615). The future land use of the saline soil to be reclaimed is an important factor to be considered when choosing amendments or amending procedures (Toogood 1978, p. 70). Other factors that must also be considered are the time allowed for the soil melioration process and economic feasibility of particular amendments under the specific soil conditions, topography and drainage at the site (Toogood 1978, p. 82).

The general goals of reclamation of saline soils should be to reduce the soluble salts, reduce the sodium concentrations, neutralize the soil pH and break up the impermeable subsurface soils (Warren 1987, p. 7). Warren (1987, p. 8) notes that reduction of salts may be facilitated by:

1. increased permeability through improved soil structure,
2. increased water volumes for leaching of permeable soil,
3. improved drainage to lower the ground water table and allow leaching, and
4. decreased evapotranspiration and water table through favourable vegetation management practices.

One solution for controlling the spread of saline soils is to control the quality of irrigation water. This can be accomplished through public policies regarding use and through the promotion of responsible farming practices, which will ensure efficient irrigation practices and adequate soil drainage. Once drainage is ensured, replacement of some of the exchangeable sodium with calcium can begin (Russell 1961, p. 615).

Saline soils can be treated by leaching with water to carry the salts below the root zone (Harpstead 1988, p. 118). The water table must be kept at least 3 meters below the surface so that roots will not be able to carry soluble salts closer to the surface (Russell 1961, p. 609). Irrigation water will bring more salts with it so the amounts must be minimized and existing salts must be removed (Russell 1961, p. 607). For sodic soils the application of gypsum ($CaSO_4 * 2H_2O$) prior to leaching is one solution. If calcium carbonate is already present in the soil, sulphur may be added (Harpstead 1988, p. 119).

Warren (1987, pp. 9-22) describes and evaluates the feasibility of four approaches to the reclamation of saline soils: chemical, physical, biological and hydro-technical. For utility, they have been condensed to three, by placing the hydro-technical approach under the heading of physical approaches.

The goal of the chemical approach is to replace the available sodium ions with calcium ions (Na^+ with Ca^{2+}). This may be done by the addition of chemicals which replace the sodium in the soil with calcium or those which provide an abundance of the deficient ions to the plant materials present in the soil (Warren 1987, p. 9). Based on the low cost and wide availability, gypsum seems to be the most cost-effective and commonly used chemical for the reclamation of saline soils (Warren 1987, pp. 10-13). Gypsum is only feasible to use on soils with a high SAR and small amounts of gypsum. Most saline and saline sodic soils in southern Alberta are saturated with gypsum (McKenzie 1991, pers. comm.).

Warren (1987, pp. 10-13) suggests the following list of chemical soil amendments which work to decrease soil salinity.

1. Calcium chloride ($CaCl_2$)
2. Calcium Sulphate (gypsum, $CaSO_4 * 2H_2O$)
3. Lime (which contains several Ca^{2+} products)
4. Calcium Mobilizing Amendments (H_2SO_4, HCl, S and sulphates of iron or aluminum)
5. Soil Conditioners (heavy soil stabilizers)
6. Fertilizers (correct unbalanced nutrient status)

Warren's second approach is a physical one (1987, pp.13-16). These techniques are generally large scale alterations to the structure of the problem soils. They are briefly described below. All of these techniques are expensive, requiring the use of specialized equipment or large amounts of materials. The first three are useful on solonetzic soils.

1. Deep ploughing (35-150 cm) breaks up impermeable layers and mixes undesirable surface soil with Ca^{2+} rich subsoil.
2. Subsoiling breaks up the impermeable layers without disturbing the soil horizon.
3. Profile inversion is multistaged ploughing followed by leaching. The end result is mixing of the subsurface soils without disruption of the surface layer.
4. Sanding involves the mixing of sand into the impermeable saline soil.
5. Digosage involves the mixing of soil which is high in lime or gypsum into the saline soil.
6. Earth filling is the removal and disposal of contaminated soil, which is then replaced by fertile topsoil.
7. Hydro-technical approaches involve the installation of irrigation and sub-surface drainage systems. They may also involve such techniques as land levelling and irrigation water quality control.

The biological approach includes the application of both living and nonliving plant material to saline soils (Warren 1987, pp. 16-18). They are beneficial in a number of ways.

1. Mulches consisting of non-saline plant material or manure can be placed on saline soil and can reduce surface evaporation and encourage water infiltration on soils with low permeability.
2. Plants are highly beneficial to saline soils through improved water infiltration and soil stabilization. This technique will be discussed further in the following sections.

2.2.5 Management of Saline Soils

Brady (1974, pp. 400-402) presents three categories of management methods of saline soils: eradication, conversion and control.

Eradication can be accomplished by such techniques as drainage tiles, leaching or a combination of the two. Leaching or flushing involves the heavy application of water so that the salts in the soil become soluble and are leached down and drained away. The water used for flushing should be free of silt and salts,especially sodium(Brady 1974, p. 400). In order for flushing to be successful, the soil must be permeable and well levelled (Russell 1961, p. 611). The most thorough method of eradication is a combination of drainage tiles and leaching. Eradication is best used on saline soils but is possible for other soil types if the water used is high in salts but low in sodium, otherwise it may increase the alkalinity (Brady 1974, p. 401). The higher the salinity, the lower the monovalent:bivalent (Na^+:Ca^{2+}) ratio must be kept (Russell 1961, p. 613).

Conversion is the method by which one ion is replaced by another to form a compound which is more readily leachable. One technique is to replace the monovalent sodium ion by a bivalent calcium ion as shown by the following reactions.

$$Na_2CO_3 + CaSO_4 = CaCO_3 + Na_2SO_4$$

$$\text{Na-micelle-Na} + CaSO_4 = \text{Ca-micelle} + Na_2SO_4$$

These reactions are promoted by the addition of gypsum, which should be cultivated or disced into the soil, not ploughed. The soil surface should be kept moist to speed the reaction and the process should be supplemented by leaching to remove the leachable Na_2SO_4. Another technique is the addition of sulphur which oxidizes to sulphuric acid, converts the sodium salt, reduces the alkalinity and eradicates the carbonate(CO_3^{2-}). This technique is especially suited to soils where a carbonate is abundant and it must be followed by flushing to remove the leachable salt Na_2SO_4. The process is described by the following reactions (Brady 1974,p.401).

$$Na_2CO_3 + H_2SO_4 = CO_2 + H_2O + Na_2SO_4$$

$$\text{Na-micelle-Na} + H_2SO_4 = \text{H-micelle-H} + Na_2SO_4$$

The third method described by Brady (1974, p. 401) is control. One technique is the retardation of evaporation which saves moisture and slows upward translocation of salts to the plant root zone. There are no cheap methods of accomplishing this however frequent light irrigations are useful. Irrigating just prior to and following planting will help to push down salts until the plants are established. The rooting action of salt resistant crops is exceptionally useful for improving the sodic soil's physical condition. Manure may temporarily alleviate surface alkali until a crop can be established (Brady 1974, p. 402). Care must be taken to use only manure which is low in salts.

Alberta Agriculture recommends four specific dryland farming practices which may help to alleviate saline soils. These are (Toogood 1989, p. 29):

1. minimizing summer fallowing,
2. planting deep rooted crops,
3. applying barnyard manure and
4. using salt tolerant crops.

2.2.6 Conclusions

Soil salinization is a widespread global problem, which continues to grow. Soil salinity may be treated by prevention, restraint and reclamation. There are a number of reclamation techniques,chemical, physical and biological, which are useful for soils high in soluble salts.

Of the biological reclamation techniques, the use of salt tolerant plants is an important one. While some information exists about the use of salt tolerant crops, more research is required on the salinity tolerance of trees and shrubs, particularly in southern Alberta.

2.3 SALINITY TOLERANCE OF ORNAMENTAL TREES AND SHRUBS

2.3.1 Plant Responses to Salinity

An increase in salinity reduces the size of the plant and the organs may be affected proportionally (Boyko 1966, p. 36). It is useful for the farm manager to be able to recognize the signs of a plant's reaction to salinity and differentiate these from responses to other adverse conditions (Russell 1961, p. 606). The types of natural vegetation that are present on an area may be an indicator of the soil's salt content (Boyko 1966, p. 31). For example, a number of weeds which are more salt tolerant than crops indicate the presence of salts in the soil (Toogood 1989, p. 28).

A plant's tolerance to salts may vary and may manifest itself indifferent ways. For example, a plant may show poor growth (yield) or poor quality (inedibility) (Russell 1961, p. 606). Boyko (1966, p. 36) has suggested that for certain plants, temporary or permanent soil salinization may raise the plant's vitality by producing increased resistance to drought and disease. Unfortunately, most of the research regarding the salinity tolerance of plants has been carried out on maritime halophytes and very few studies have been made upon salt desert plants (Poljakoff-Mayber 1975, p. 9).

Brady (1974, p. 399) explains that sodic soils are detrimental to plants by the:

1. caustic influence of high alkalinity,
2. toxicity of anions (ex. bicarbonate), and
3. effects of the $Na+$ ion on plant metabolism and nutrition.

Plasmolysis is one result that a saline soil has on plant material. Plasmolysis is the shrinking of the protoplasmic lining of the plant cell when it comes in contact with the salt solution, due to the osmotic movement of water (Brady 1974, p. 399). The concentration of salts at which a particular plant succumbs depends upon the:

1. nature of the salt,
2. nature of the species,
3. nature of the individual plant and
4. other adverse physiological conditions of the soil.

The capacity of a species to withstand soil salinity depends upon its physiological constitution, stage of growth and rooting habits (Brady 1974, p. 399). There are a variety of effects of salinity upon germination, but with increasing age there is usually an increased tolerance to salinity (Boyko 1966, p. 36). In general, if a particular plant is not saline sensitive it will still show a linear decline of 10% yield for each 1 atmosphere increase in osmotic pressure (Russell 1961, p. 604). This decline is due to the plant's inability to take up water so these crops require frequent irrigation (Russell 1961, p. 605).

There are also other means by which soil salinity may affect plant growth. Dispersed soil is easily waterlogged, which inhibits root respiration and plant growth. The presence of some ions may also reduce the amount of energy available for normal metabolic processes and inhibit the metabolic activities of the cell protoplasm (Boyko 1966, p. 37). Ions found in a saline soil may be harmful to the plant in both high and low concentrations. For example, a high concentration of sodium will decrease the availability of calcium and produce a calcium deficiency, which may decrease yields up to 20% and may go unnoticed by the producer (Russell 1961, p. 603). Salinity deprives the soil of trace elements, due to ion exchange, much more than crop removal does (Boyko 1966, p. 37). Low concentrations of soluble borates are directly toxic to plant material. At a high pH, low concentrations of sodium carbonate will cause many nutrients to become unavailable and will cause the soil structure to become unstable. Unstable soil structure will produce low water permeability, poor aeration and unworkable tilth (Russell 1961, p. 603).

2.3.2 Saline Tolerant Plants

"Under some circumstances it may not be feasible to reduce the salt content of soils to permit the growth of sensitive crops. The alternative is to select crops which are tolerant to salt" (Donahue 1965, p. 251). Some of these plants will improve soil conditions while others (halophytes) will actually remove salts from the soils

(Warren 1987, p. 18). Producers have expressed a desire to use saline tolerant crops as a means of dealing with soil salinity (McNeely 1992: Smith 1992).

Since "there is no known way of neutralizing the effects of soluble salts in the soil on crop growth" (Toogood 1989, p. 29), Vander Pluym (1983, p. 173) recommends the planting of salt tolerant crops as a control for dryland saline seepage in the North West Great Plains Region. Evapotranspiration will be lowered and the amount of snow trapped due to stubble will increase (Vander Pluym 1983, p. 176). The rooting action of plants physically breaks up the soil, thereby improving permeability and leaching. Deep rooting crops such as alfalfa and sweet clover are useful. In addition, the roots of plants will remove moisture throughout the entire soil profile, which reduces the ground water table, minimizes surface evaporation and promotes leaching of soluble salts. If the plant material is allowed to remain on the soil surface as green manure, its decomposition will also be beneficial to the saline soil. The plant material will encourage soil organisms, which in turn stabilize the soil aggregates. Decomposition of green manure releases CO_2, which increases the solubility of calcium carbonate in the soil. This process will:

1. decrease salinity due to dilution,
2. decrease the Na^+ concentration due to leaching, and
3. improve overall plant nutrition (Warren 1987, p. 17).

Halophytes such as Atriplex spp. and Kochia spp. help to remove salt from the soil but they must be harvested to prevent the re-entry of salts into the soil, which results in a net loss of organic matter. The crop may be used as livestock feed but the resulting manure will also be too salty for application to the problem soil (Warren 1987, p. 17).

2.3.3 Previous Studies

The planting of salt tolerant trees and shrubs may be beneficial to saline soils through their root action and as shelterbelts. Shelterbelts help to decrease the velocity of winds on a given area which in turn decreases erosion and the rate of surface evaporation.

Carter (1980) experimented with the salinity tolerance of Siberian larch in both a greenhouse and field setting. It was found that, for Siberian larch, higher soil salinities could be tolerated in the greenhouse than in the field. This was due to increased moisture stress that may occur in the field. Siberian larch was found to be very slightly salt tolerant. Another greenhouse experiment (Werkhoven 1966) concluded that deciduous trees are more salt tolerant than coniferous ones, and that salinity tolerance is markedly improved with increased soil moisture. Hardy BBT Limited (1989, pp. 253-394) examined 35 types of trees and shrubs for their suitability to particular reclamation projects in Alberta. Each was ranked on a six-point scale of tolerance to salinity. Of the 35, none ranked as having very high or high tolerance and only 10 had medium tolerance to soil salinity (Hardy BBT Limited 1989, p. 255). It is apparent that further research into trees with a high degree of salt tolerance is necessary in Alberta. Monk (1962) indicated that the growth habits of trees and shrubs "and the fact that they are not subject to annual harvesting may mean that even so-called tolerant species will be susceptible to cumulative effects over a period of years". For this reason, it is desirable to study the salinity tolerance of ornamental trees and shrubs over several years.

2.4 METHODS OF MEASURING SOIL SALINITY

"The management and need for reclamation of saline soils are evaluated from measurements of concentrations of soluble salts" (Rhoades 1982). Various techniques are available to measure soil salinity, but many of them are expensive and time consuming. The EM38 salinity meter, which measures soil salt content based on the principles of electro-magnetic conduction, has proven to be both a quick and reliable method. Presently, there are no practical methods of determining the individual solute concentrations of a soil immediately in the field. However, the EM38 is capable of producing *in situ* measurements of soil salinity and is recommended for monitoring soil salinity changes with time and for large field or project situations (Rhoades 1982). The EM38 salinity meter can also be "extremely useful for detecting salinity when visual soil and plant indicators are not present" (Eilers 1984). The following is an overview of some of the techniques used for measuring soil salinity (McKenzie 1989, pp. 1-3). For convenience, they have been placed into three categories; those which require soil samples, those which are inserted into the soil and those which work by means of remote sensing.

2.4.1 Methods Requiring Soil Samples

1. Saturated Paste Extract

This technique is the most common and is the standard method to which all other techniques are compared. A known quantity of air-dried soil is saturated with water and left undisturbed for several hours. The liquid extract is then drawn off and the conductivity of this solution is measured and corrected for temperature to a standard of 25°C.

2. 1:2 Soil-Water Extract

A simpler method is the 1:2 soil-water extract. One part air-dried soil is mixed with two parts distilled water in a test tube. The mixture is shaken for about one-half hour, and then analyzed with an electrical conductivity meter. The resulting value of electrical conductivity (EC) can then be converted to a paste extract equivalent using standard correction factors.

2.4.2 Methods Requiring Insertion into the Soil

1. Martek Soil Conductivity and Temperature System

Four electrodes are placed in the soil in a straight line. A constant current is passed through the outer probes (transmitter and receiver), and the potential current flow is measured by the inner probes (sensors). The meter corrects its measure of current flow to 25°C, which in turn is directly proportional to electrical conductivity and can be converted to a paste extract equivalent. Because current flow is affected by soil moisture, measurements should be taken near field capacity.

A. Vertical Sensor

This technique is designed for taking discrete measurements of soil conductivity. In this case, the four electrodes are fixed to a plastic cylinder that is placed in the soil. The vertical sensor measures soil conductivity in 15 cm increments.

B. Horizontal Sensor

The horizontal sensor is designed for taking an average conductivity reading on large volumes of soil. The depth and volume of soil being measured is increased by increasing the distances between the probes.

2.4.3 Methods Using Remote Sensing

1. Satellite and Air Photos

The theory of this technique is based on the idea that saline soils generally have high reflectivity, due to the large amounts of sodium salts close to the soil's surface. This method can be particularly unreliable on agricultural lands because recent ploughing of a saline soil will cause it to appear darker than it normally would. The costs of acquiring the necessary photographs and satellite images can be high and this technique requires ground truthing to verify results.

2. Vegetation Analysis

As discussed earlier, the presence of saline tolerant plants may be an indication of highly saline soils. This technique must be accompanied by soil analysis to verify assumptions.

3. Inductive Electromagnetic Soil Conductivity Meter

The EM38 electrical conductivity meter is portable and self-contained. It has a dipole transmitter at one end and a receiver at the other end, 1 m away. The transmitter emits a primary electromagnetic field into the soil. The current flow through the soil is proportional to the soil's electrical conductivity. The receiver measures the electromagnetic field, which has been induced by the current flow through the soil, and produces an output reading that has a linear relationship to the soil's electrical conductivity (EC). Formulae have been developed which convert the raw EM38 readings to paste extract equivalents by correcting for soil temperature, moisture and texture (McKenzie 1987).

CHAPTER 3 METHODS

3.1 INTRODUCTION

The physical research required for the project began during the summer of 1989 and continued through the summers of 1990 and 1991. The first two growing seasons (1989 and 1990) were considered to be the establishment period for the trees and woody shrubs. The growth data which was statistically analyzed for this project was gathered during the third growing season (1991). The field research for this project was conducted at the Alberta Special Crops and Horticultural Research Center (ASCHRC) with funding through Farming for the Future.

3.2 SPECIES TO BE EXAMINED

The species that were examined for this project were selected by R. McKenzie and H. Mathers. This was a selection of ornamental trees and shrubs commonly grown in Alberta, both native and non-native. Table 3.1 lists the common and corresponding scientific names of the 28 types of trees and shrubs used. The common names followed by an asterisk are those which had 50 specimens planted. The others had 30 specimens planted.

Table 3.1: Species to be Examined

Green Ash*	*Fraxinus Pensylvanica*
Mountain Ash	*Sorbus americana*
Paper Birch*	*Betula papyrifera*
Sea Buckthorn*	*Hippophae rhamnoides*
Caragana	*Caragana arborescens*
Nanking Cherry*	*Prunus tomentosa*
Columbia Crab	*Malus x columbiana*
Dogwood*	*Cornus sericea*
Hawthorn	*Crataegus curus-galli*
Prince of Wales Juniper	*Juniperus horizontalis* "Prince of Wales"
Siberian Larch*	*Larix sibirica*
Common Lilac	*Syringa vulgaris*
Villosa Lilac	*Syringa villosa*
Mayday*	*Prunus padus commutata*
Amur Maple*	*Acer ginalla*
Manitoba Maple	*Acer negundo*
Bur Oak*	*Quercus macrocarpa*
Russian Olive*	*Elaeagnus angustifolia*
Scots Pine*	*Pinus sylvestris*
Brooks Poplar*	*Populus* x "Brooks"
Northwest Poplar	*Populus* x "Northwest"
Potentilla	*Potentilla fruticosa*
Saskatoon	*Amelanchier alnifolia*
Siberian Salt Tree*	*Halmodendrum halodendrum*
Colorado Spruce*	*Picea pungens*
White Spruce	*Picea glauca*
Acute Leaf Willow	*Salix acutifolia*
Laurel Leaf Willow*	*Salix pentandrum*

3.3 SITE SELECTION

3.3.1 Plot Location Selection

The selection of the site was based upon land availability and the variation of naturally occurring salinity present. A site for the experimental plot was selected at the ASCHRC's McLeod Farm (Figure 3.1). The soil of the area is predominantly brown chernozemic and solonetzic (Toogood 1989, pp. 8-9). The site exhibited EC's (electrical conductivities) ranging from 1.7 to 11.8 dS/m over the top 1.2 m of soil. In order to take advantage of the full range of salinities in the area, three separate plots were chosen on the site. Plot A showed the lowest amounts of salinity. Plot B exhibited medium to high salinities and Plot C the highest salinities (Figure 3.2).

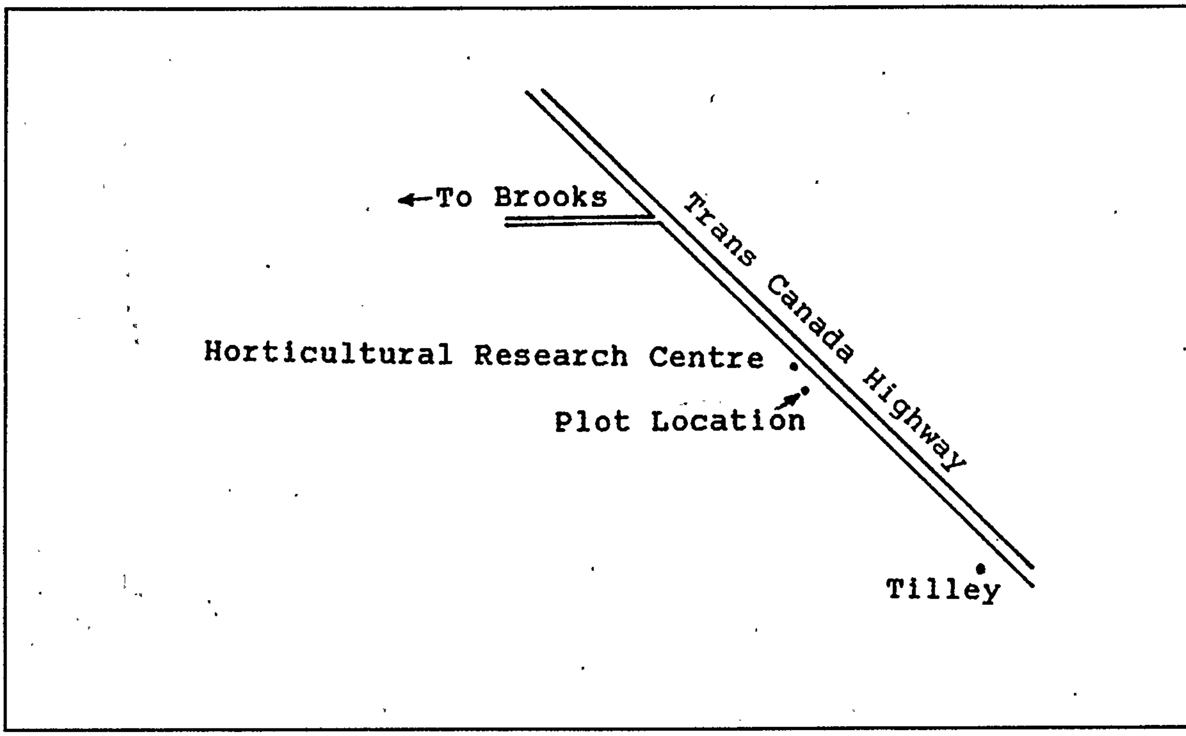


Figure 3.1: Plot Location

3.3.2 Specimen Site Selection

A grid of 5 m X 2 m was established within the plot, where each node indicated a potential site for a tree or shrub. Salinity levels were recorded with an EM38 salinity meter at each point on the plotted grid. The resulting data were then categorized into five salinity zones. Each zone was assigned an equal number of sites within it.

The parameters for the zone categories are shown in Table 3.2.

Table 3.2: Salinity Zone Parameters (dS/m)

Type	Limits	Mean
Low	1.7 - 4.0	3.2
Medium/Low	4.1 - 5.1	4.6
Medium	5.4 - 6.9	6.1
Medium/High	7.3 - 8.8	8.1
High	8.9 - 11.8	9.7

The positions for each type of tree or shrub were then assigned by random selection, based on equal numbers of each species of tree within each salinity zone. For some types of trees and shrubs, only 30 specimens were required, six in each zone. Other types were to be used for other experiments. For these, a total of 50 specimens were planted, ten within each zone.

3.3.3 Position Numbering Scheme

To simplify site selection, a number was assigned to each potential site. For each plot, numbering begins in the northeast corner of the plot. Consecutive numbers run in ascending order from east to west, along the row. For plot A, the rows are 50 sites long. They are 75 sites long for plot B and 12 for plot C, creating a total of 1298 potential sites, not all to be used. Refer to Figures 3.3 and 3.4 for clarification.

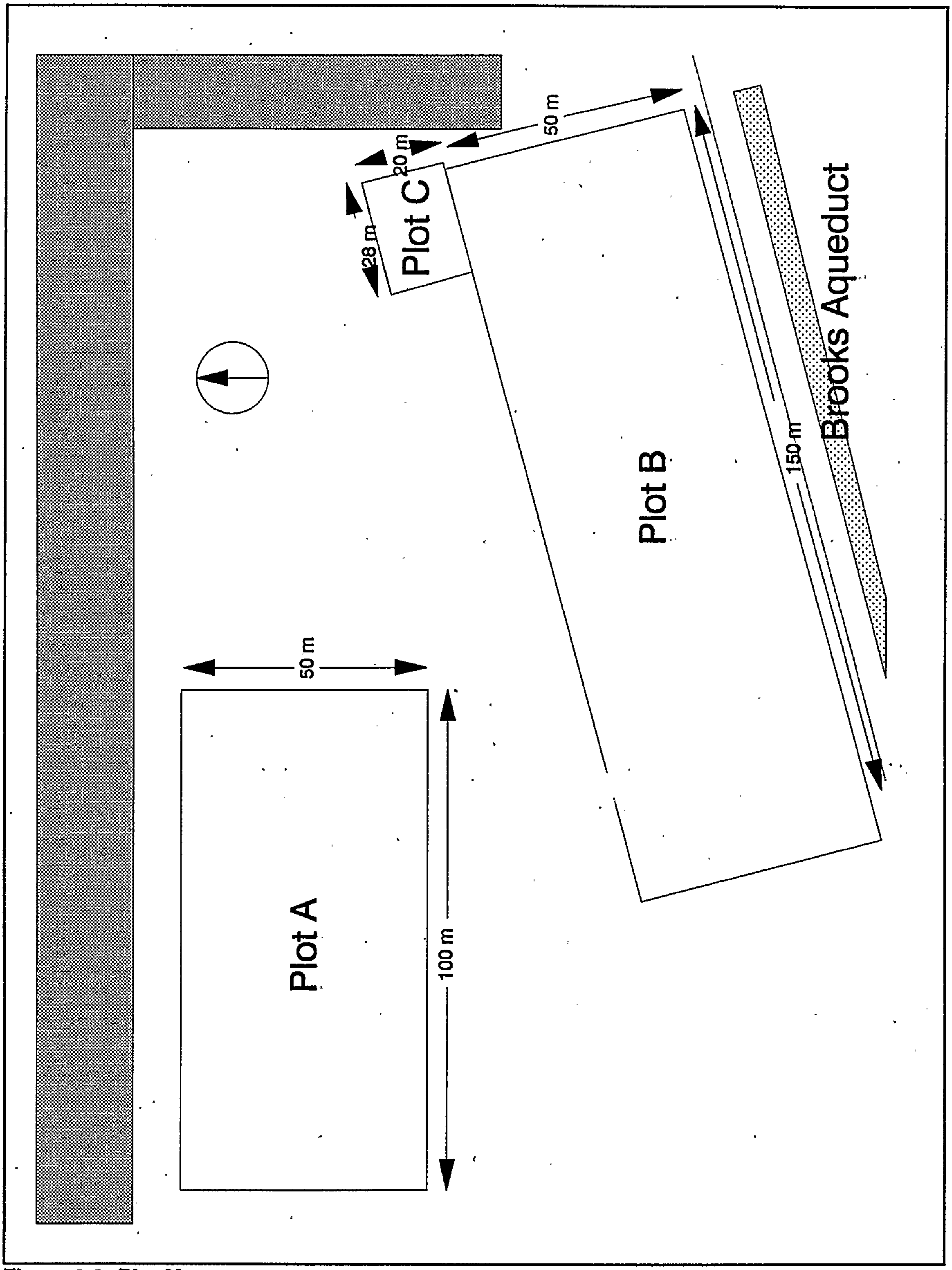


Figure 3.2: Plot Map

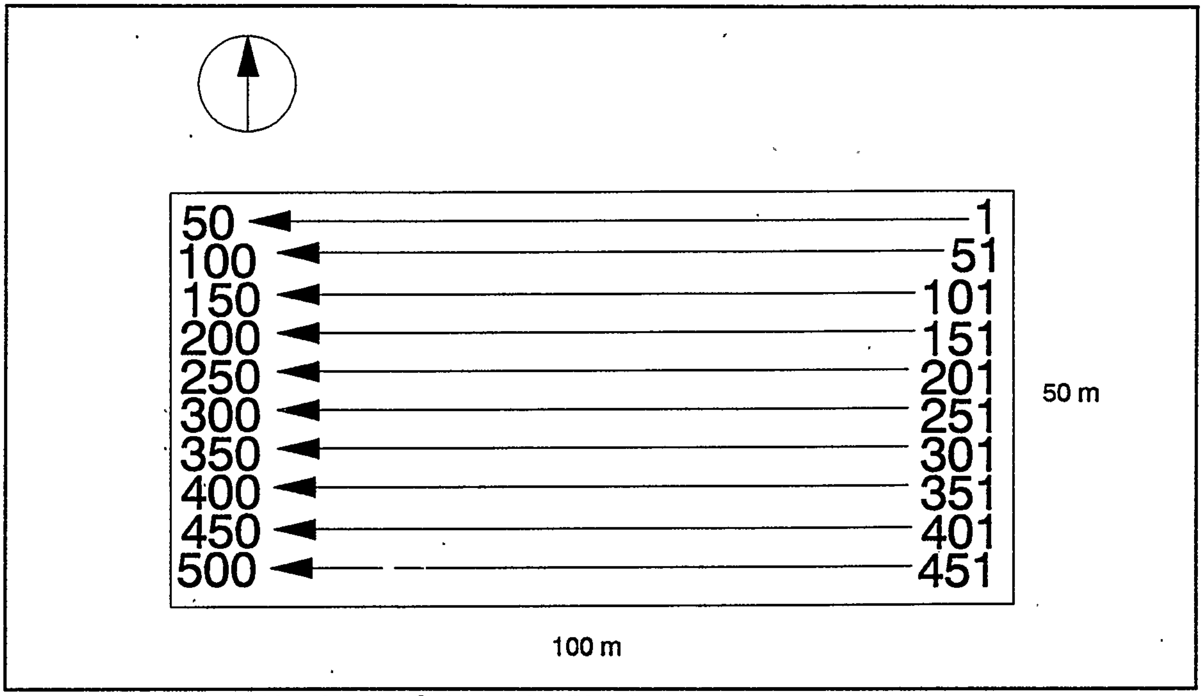


Figure 3.3: Position Numbering Scheme for Plot A

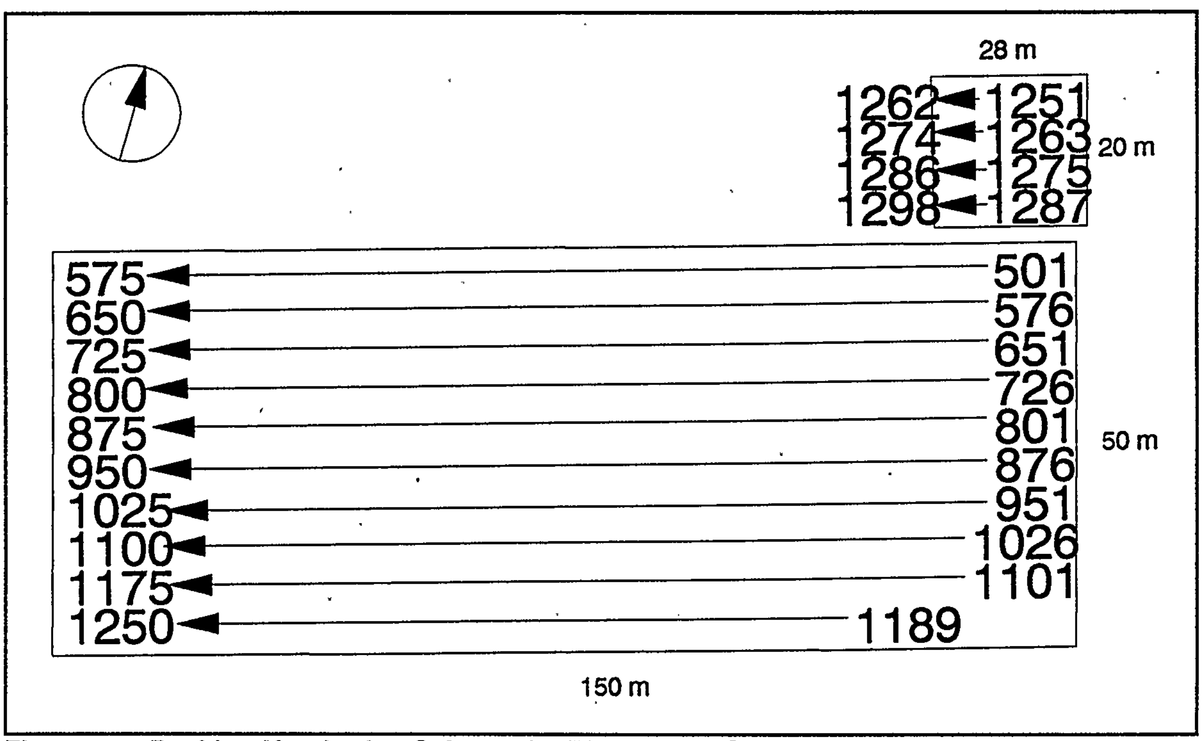


Figure 3.4: Position Numbering Scheme for Plots B and C

3.3 PLANTING AND MAINTENANCE

The trees were then planted so that all of the samples for each species were planted on approximately the same day under similar circumstances. Twenty seven of the species were planted in 1989 (Table 3.2). The Siberian salt trees were unavailable in 1989, so were seeded into pots in 1989 and kept in a greenhouse until they were planted in 1990.

The same procedure was used to plant each tree. An adequately sized hole was dug and approximately 20 mL of ammonium phosphate fertilizer (11-51-0) was placed in the bottom. The fertilizer was covered with a 1 cm layer of soil and then the specimen was placed into the hole. The hole was refilled with soil, which was compacted by stepping around the tree. A dyke of approximately 50 cm in diameter was built around the tree and filled with water. Three initial measurements were taken for each specimen; height, maximum width (largest horizontal measurement) and minimum width (smallest horizontal measurement, usually at the base).

During each growing season, the trees were irrigated and monitored for disease. Throughout the first two summer seasons, dead specimens were replaced as their condition was discovered. The final replacement of dead plants was conducted in the spring of 1991.

3.4 DATA COLLECTION

3.4.1 Soil Salinity Measurements

Soil salinity measurements were recorded for two depth ranges using the EM38 salinity meter. Readings were taken in the horizontal mode, producing an average salinity for the top 0.6 m of soil and in the vertical mode, producing an average for the top 1.2 m of soil. These measurements were taken three times each summer. A "Tandy 1000" laptop computer was used in the field to record salinity measurements directly from the EM38. The EM38 data was then transferred to a personal computer, where it was corrected for soil moisture, temperature and texture to calculate the soil salinity as a paste extract equivalent. This information was stored in Lotus 1-2-3 files.

Salinity readings were compiled with "Geosoft" software to create salinity maps for the plot sites. The following salinity maps are based on readings taken in the vertical mode (0 - 1.2 m) during September of 1991.

In July of 1990 eight core samples, which represented the range of salinities, were taken and analysed for pH, nitrogen (N) content and phosphorous (P) content. For the top 60 cm of the soil, pH ranged between 7.3 and 8.3 and was consistent throughout the range of salinities. N content ranged between 43 and 91 ppm and P between 37 and 55 ppm. These amounts increased with increasing soil salinity.

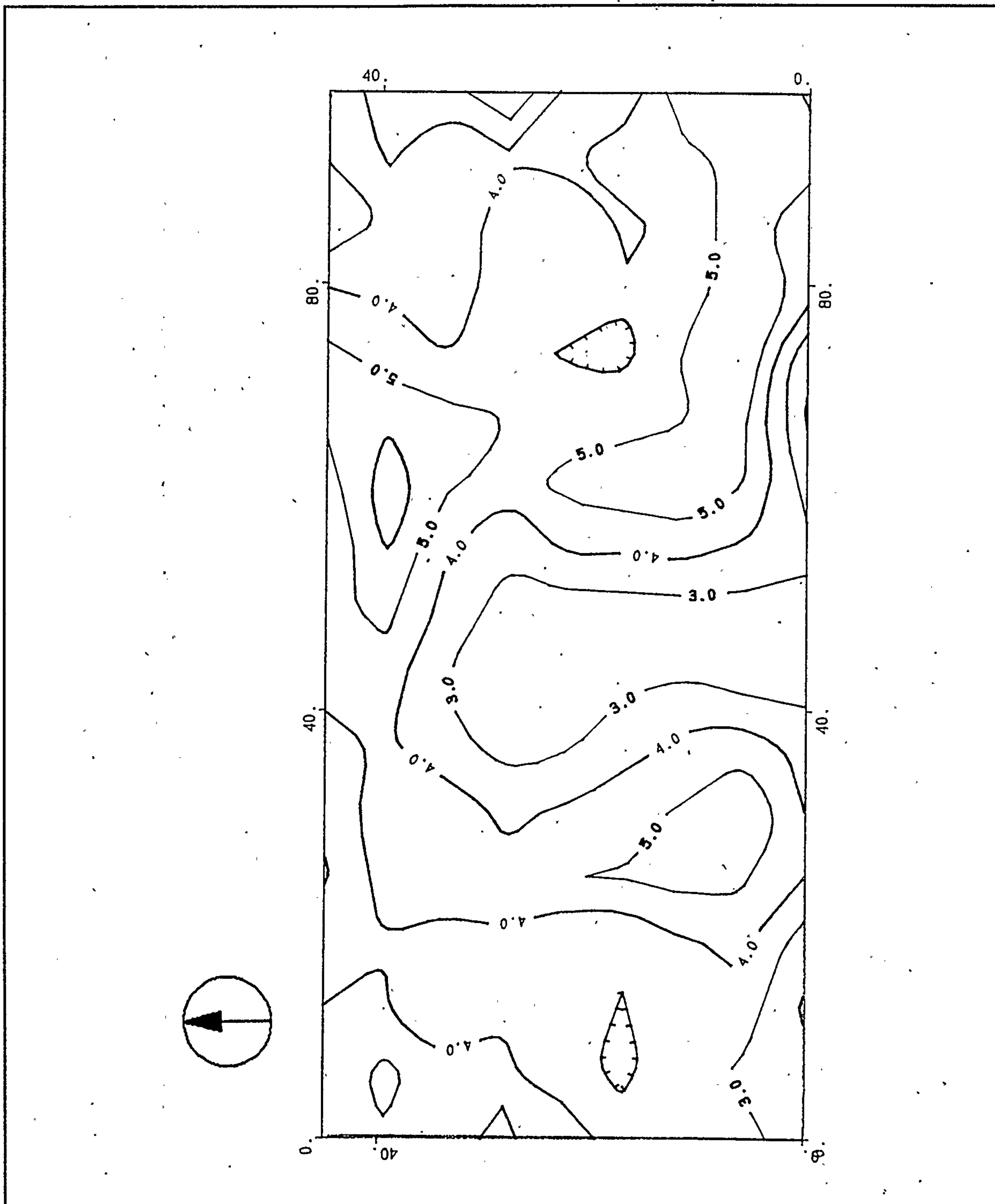


Figure 3.5: Salinity Map of Plot A
(Axis values are in meters, map values in dS/m)

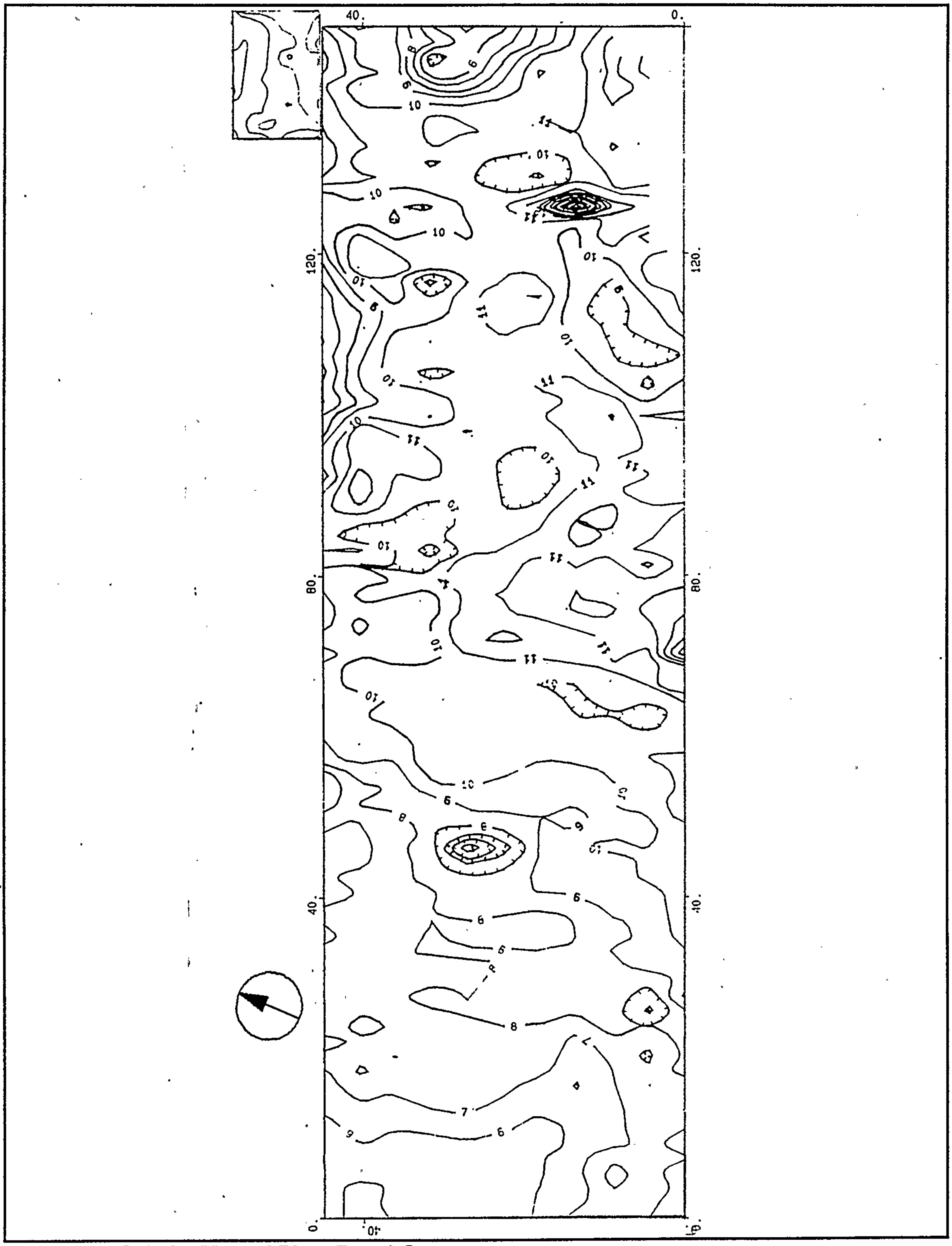


Figure 3.6: Salinity Map of Plots B and C
(Axis values are in meters, map values in dS/m)

3.4.2 Measurements of Growth

The three growth measurements were used to calculate a growth index value for each tree, based on the formula;

$$\text{Growth Index} = \frac{\text{height} + \dfrac{\text{maximum width} + \text{minimum width}}{2}}{2}$$

The growth index measurements were taken at the beginning and end of each growing season. To calculate a measure of annual change in growth index, the year's first growth index was subtracted from the year's final growth index. For trees that died, the growth index measurements of the replacement tree were taken at the time of replanting.

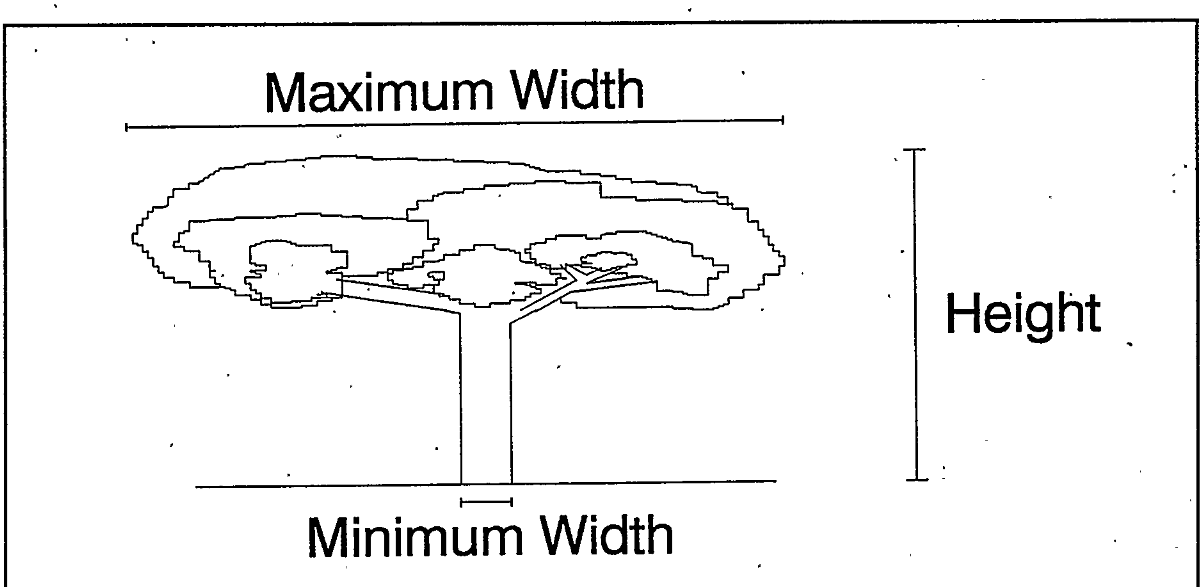


Figure 3.7: Growth Index Measurements

A value, referred to as the normalized change in growth index, was calculated for the data, using;

$$\textit{Normalized G.I.} = \frac{1991 \textit{ Change in G.I.}}{\textit{Largest } 1991 \textit{ Change In G.I. for the Species}}$$

The result is a range of data with highest value of 1 and all others a measure of the individual tree or shrub's growth as it compares to the highest change in growth index for that variety. This calculation was used to eliminate unfair comparisons between naturally fast and naturally slow growing species.

3.4.3 Measurements of Mortality

Specimen mortality was monitored throughout the three years. Dead trees were replaced as they were discovered, and their type and location were recorded. At the end of the third growing season (1991), this information was summarized for all of the trees and each of their five salinity zones. To allow valid comparison between varieties having different numbers of specimens, total percent mortality was calculated for each salinity zone.

$$\%\ Mortality = \frac{\text{Sum of Mortality for the Salinity Zone}}{\text{Total Number of Specimens for that Variety}} \times 100$$

Because more than one replant was possible per site, it was possible for the percent mortality to exceed one hundred percent. This, however, did not occur.

Percent survival was also used for some data analysis.

$$\%\ Survival = 100\% - \%\ Mortality$$

CHAPTER 4 RESULTS AND DISCUSSION

4.1 INTRODUCTION

Information was amassed over the three year period and has been stored on computer disc in Lotus 1-2-3 files. For each specimen the following information was retained;

- species name
- location
- salinity zone
- number and date of replants
- horizontal salinity (nine values)
- vertical salinity (nine values)
- annual increase in growth index (three values)

Because the specimens have had only three growing seasons in the field, the horizontal (0.00-0.60 m) salinity was used for statistical analysis. With the exception of a few fast growing varieties, most have not had a chance for root growth to exceed this depth. Because the first two growing seasons showed such a high overall mortality rate due to difficulties in establishment, it was decided to use only the 1991 growth data and its corresponding salinity data. Mortality has been calculated as a cumulative value for the three years.

4.2 RAW DATA

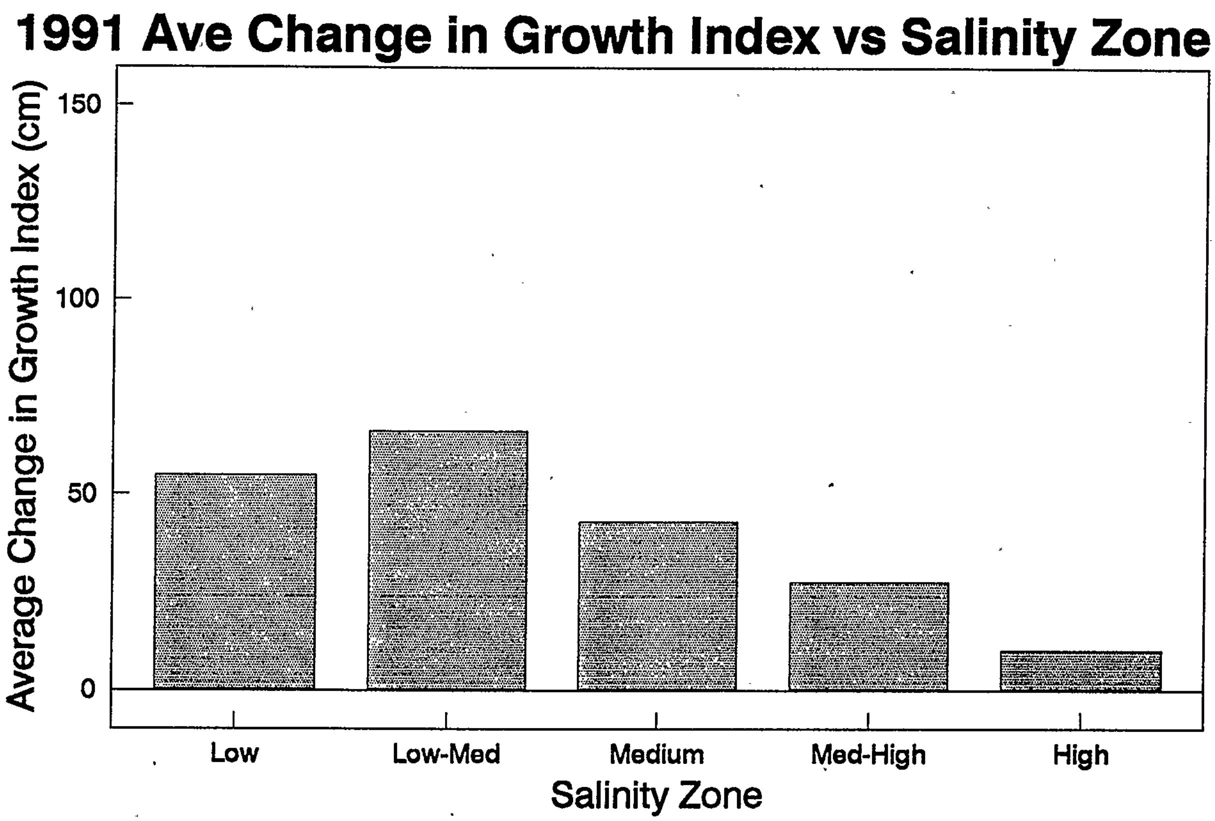
4.2.1 Results

Some of the data are presented in tabular form in Appendix A. For each type of tree or shrub, there is a chart containing the following information for each specimen;

- common name
- site number
- original vertical salinity (dS/m)
- 1991 horizontal salinity (dS/m)
- 1991 change in growth index (cm)
- 1991 normalized change in growth index
- average (1989-1991) horizontal salinity (dS/m)
- total (1989-1991) replants per site

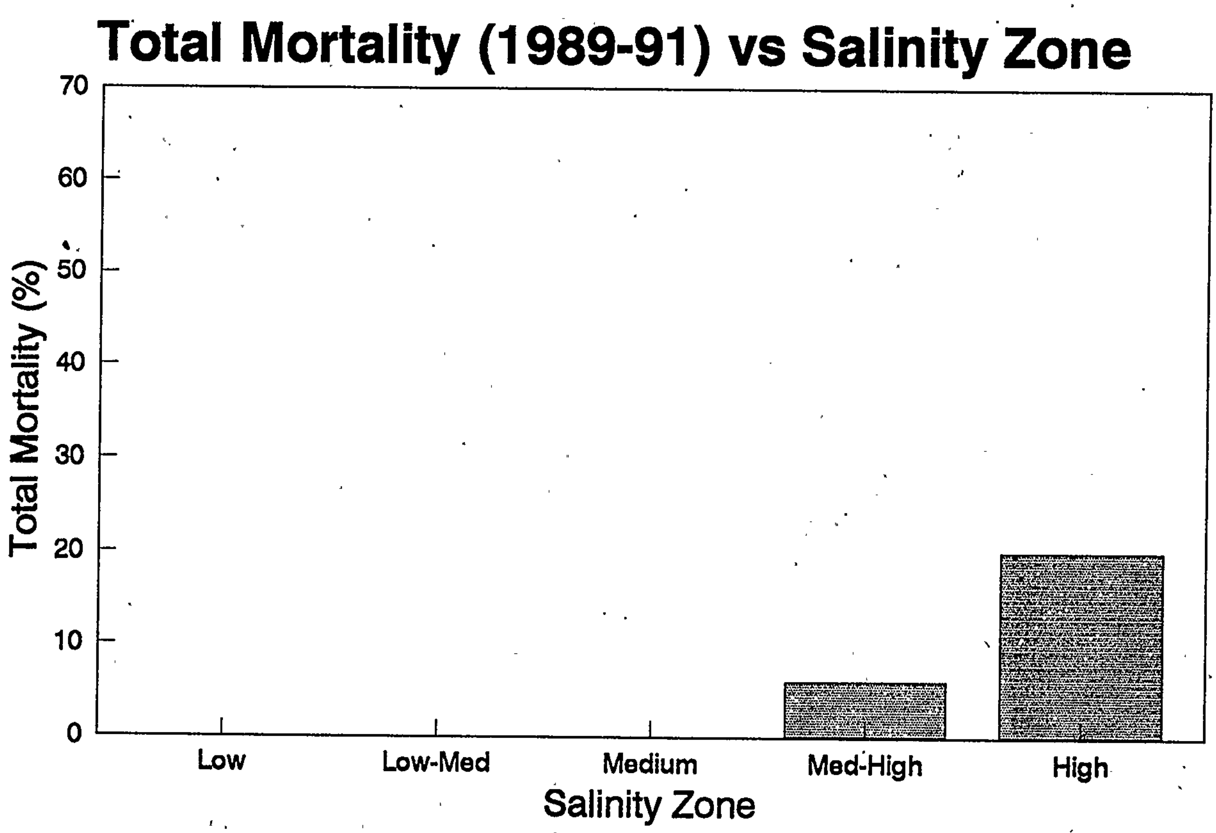
The same information is summarized in graph form on the following pages. On facing pages are two bar graphs corresponding to the data for each tree type. The first of these charts depicts 1991 growth as a function of salinity. Within each variety, for each of the five zones, an average change in growth index was calculated. This gives a visual representation of each type of tree's hardiness to salinity. The right hand bar graph depicts the total percent mortality as a function of salinity. This graph depicts the tolerance to salinity within the variety.

For ease of comparison between varieties, the y axis was kept the same for all types, on each graph. The parameters of the salinity zones are outlined in table 3.1. The salinity values, which are referred to, are from vertical EM38 readings and represent an average salinity over the top 1.20 m of the soil horizon.

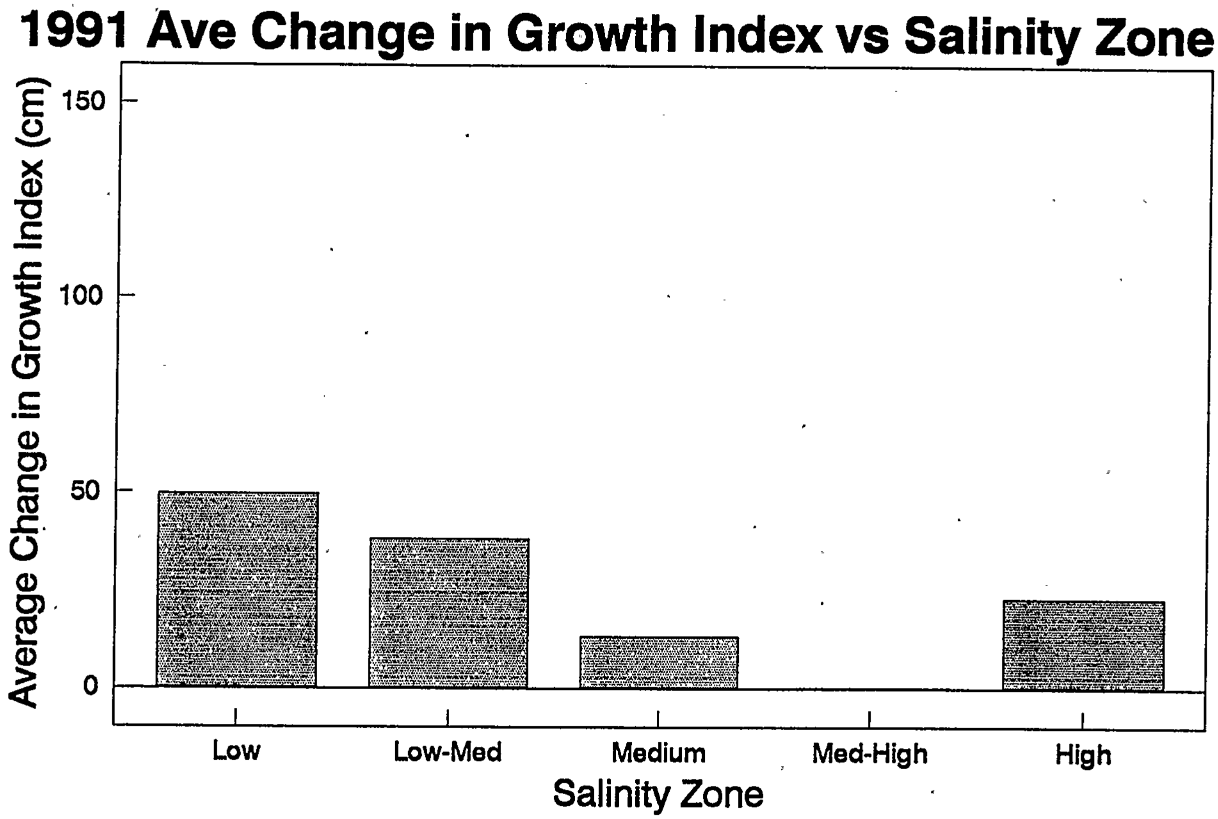


The bar graph for green ash, with growth as a function of salinity, shows that increasing salinity results in an overall decline in growth. The "Low-Medium" salinity zone has a greater amount of growth than the "Low" salinity zone. Since saline soils usually have a high water table, they are wetter than non-saline soils. If water is a factor limiting growth, the trees may show greater growth on slightly saline soils. The "Medium" salinity zone (5.4-6.9 dS/m) is the point at which the benefits of greater amounts of water are overcome by the adverse effects of salinity and growth begins to decline. This graph demonstrates that, for green ash, growth is adversely affected by moderate to high levels of salinity. One experiment showed green ash

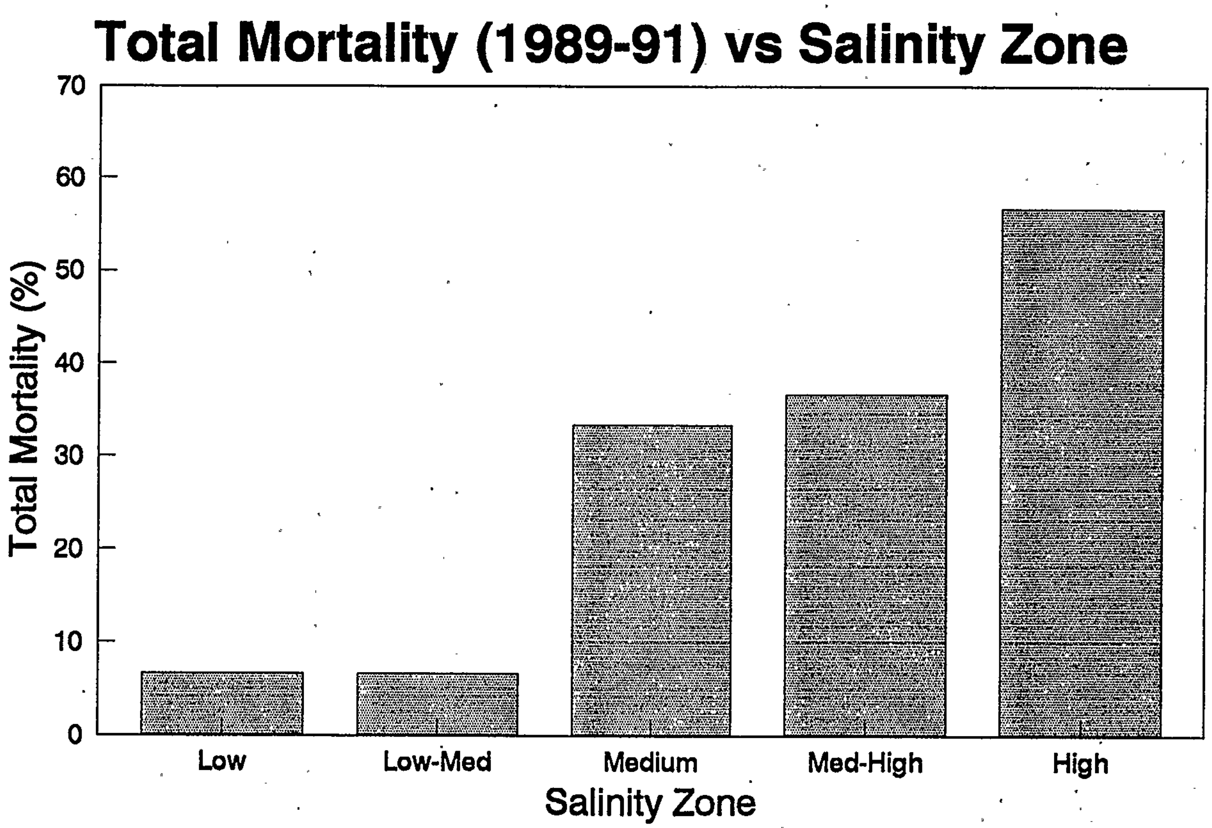
GREEN ASH



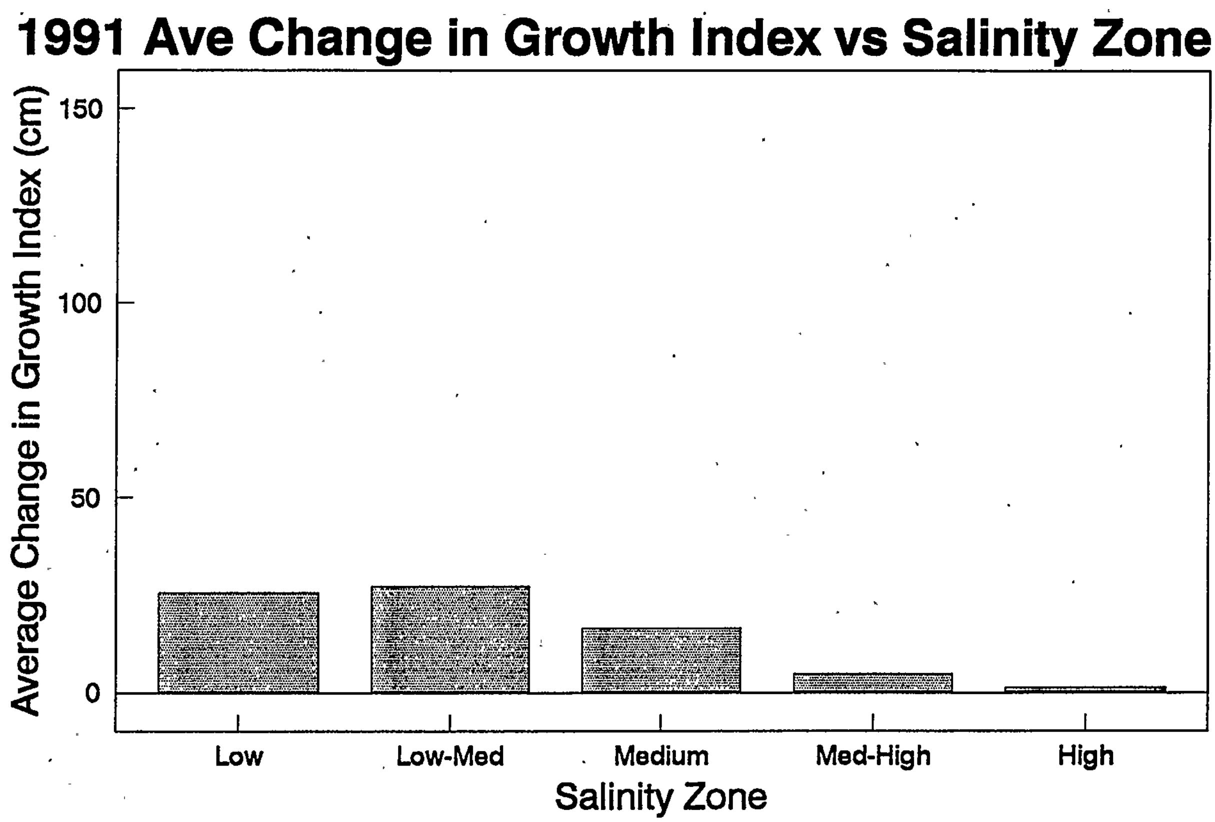
as having a higher rate of growth on all salt treated specimens than on the control (Monk 1962). Another study rated green ash as being somewhat salt tolerant (Monk 1961). The graph depicting total percent mortality as a function of salinity zone indicates that there were no deaths of green ash over the first three salinity zones (1.7-6.9 dS/m). There is an increasing mortality rate over the highest two salinity zones, although this rate is still small in comparison to many other types of trees and shrubs. It may be concluded from these graphs that the green ash is capable of surviving moderate to high levels of salinity, even though growth is reduced.



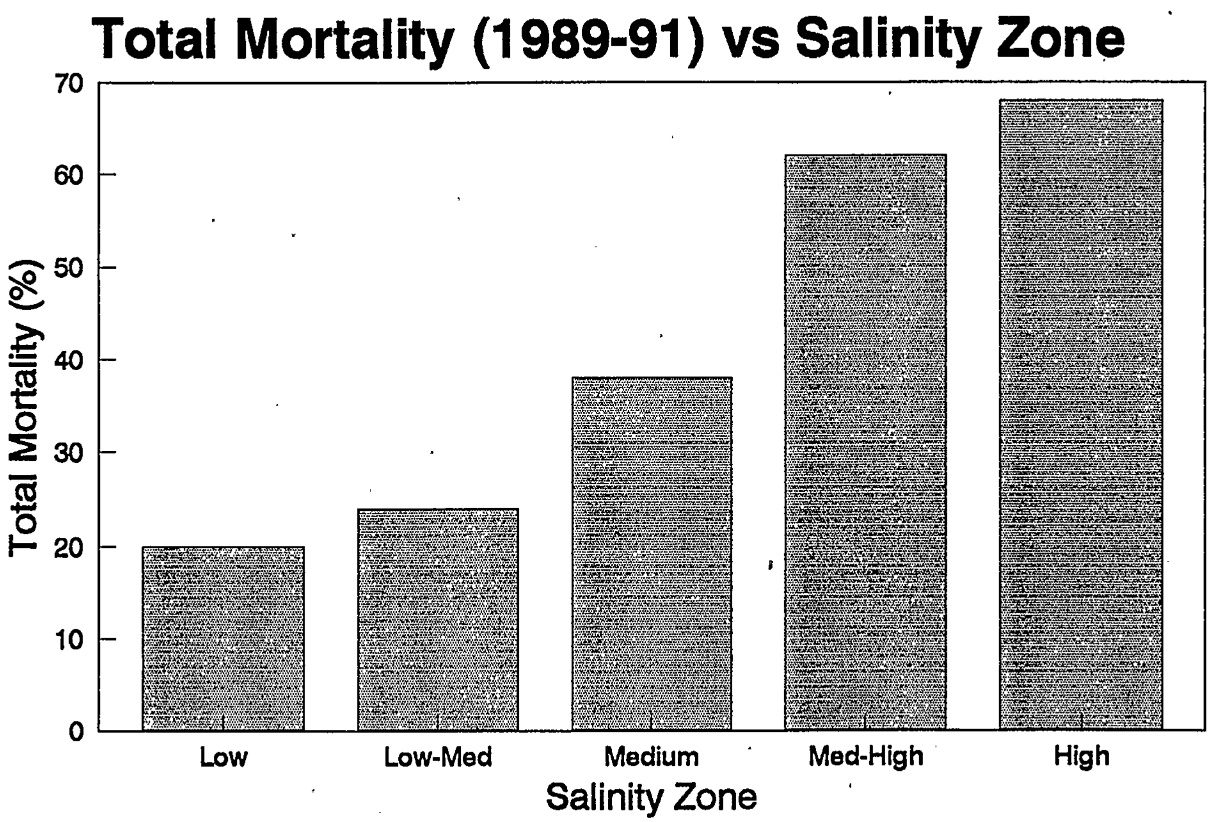
For mountain ash, the above graph shows a general decline in growth with increasing soil salinity. At the "Medium-High" salinity zone, growth is reduced to zero, but increases slightly at the "High" salinity zone. This slight increase in growth may be due to the large number of replants required at this salinity zone. Fresh potted stock may have continued to grow before it succumbed to the salinity present in the surrounding soil.



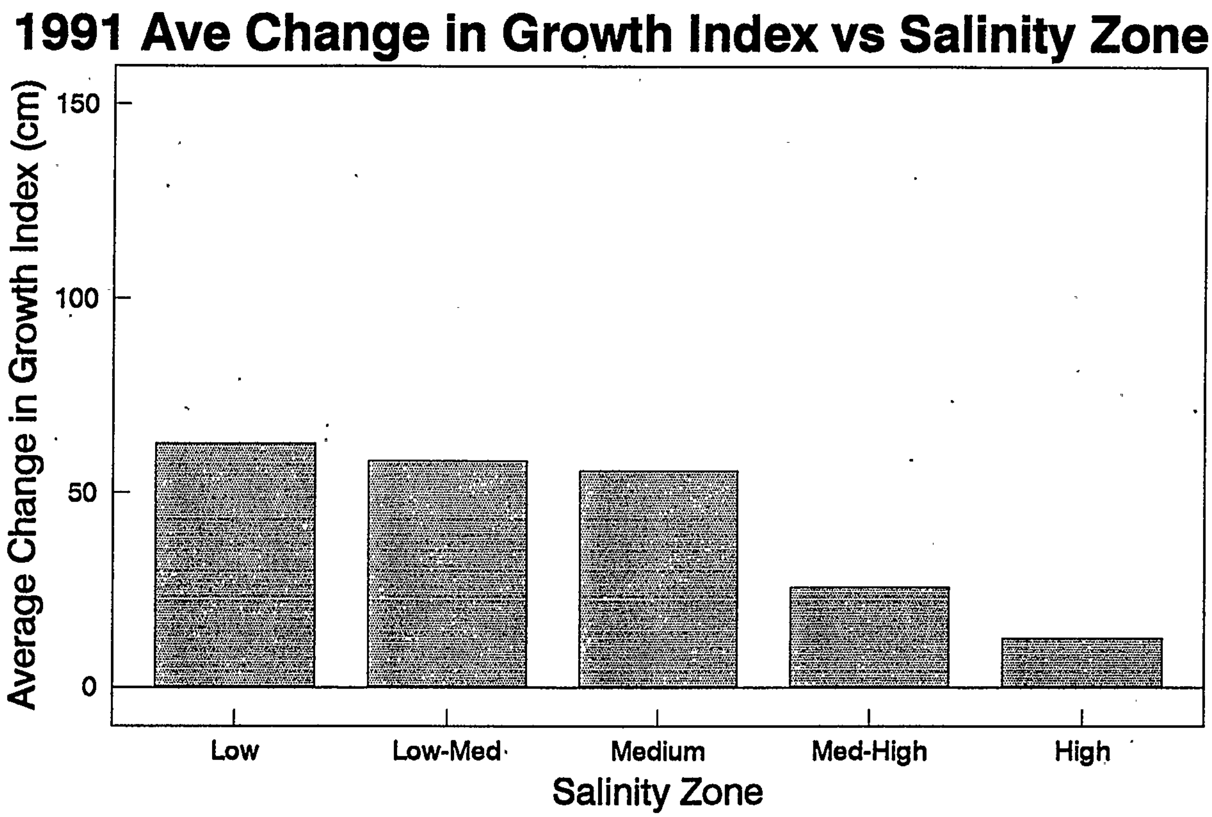
The graph which depicts the mortality for the green ash as a function of salinity shows that mortality increases with increasing salinity. There is a marked increase in mortality between the "Low-Medium" and the "Medium" salinity zones. Relative to other varieties of trees, the mountain ash has large rates of mortality. This graph indicates that the mountain ash is affected by even small amounts of soil salinity and that it suffers high rates of mortality.



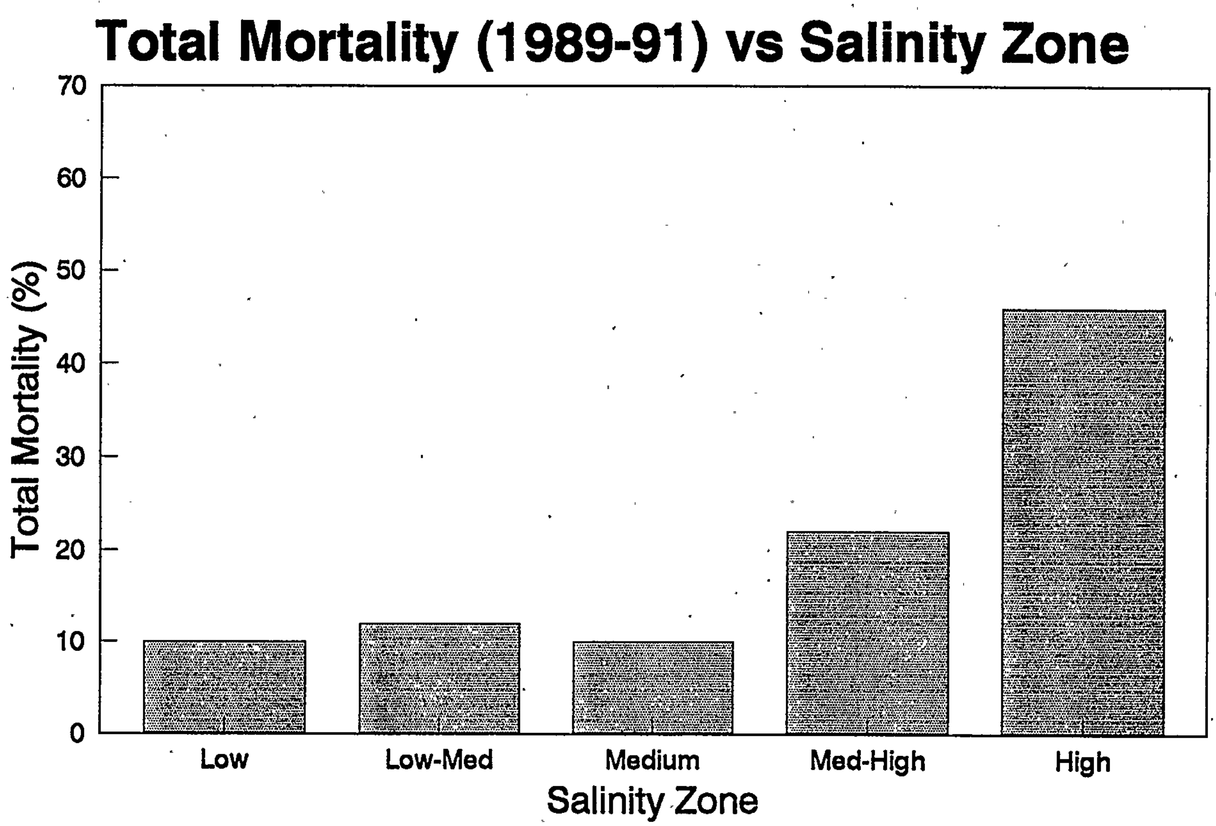
Paper birch shows extremely low amounts of growth over the full range of salinity zones. This may be a function of the small size of the transplant material used (approximately 20 cm in height) or may be an indication that this variety does not transplant well. There is an overall decline in growth as soil salinity increases. Although growth is poor overall, there is still a visible reduction in growth accompanying increasing salinity.



Paper birch demonstrates a high percentage of mortality across the spectrum of soil salinity. There is a marked increase in mortality as the salinity increases. The graphs indicate that paper birch is not salt tolerant, showing little growth and large mortality rates at even moderate levels of salinity.



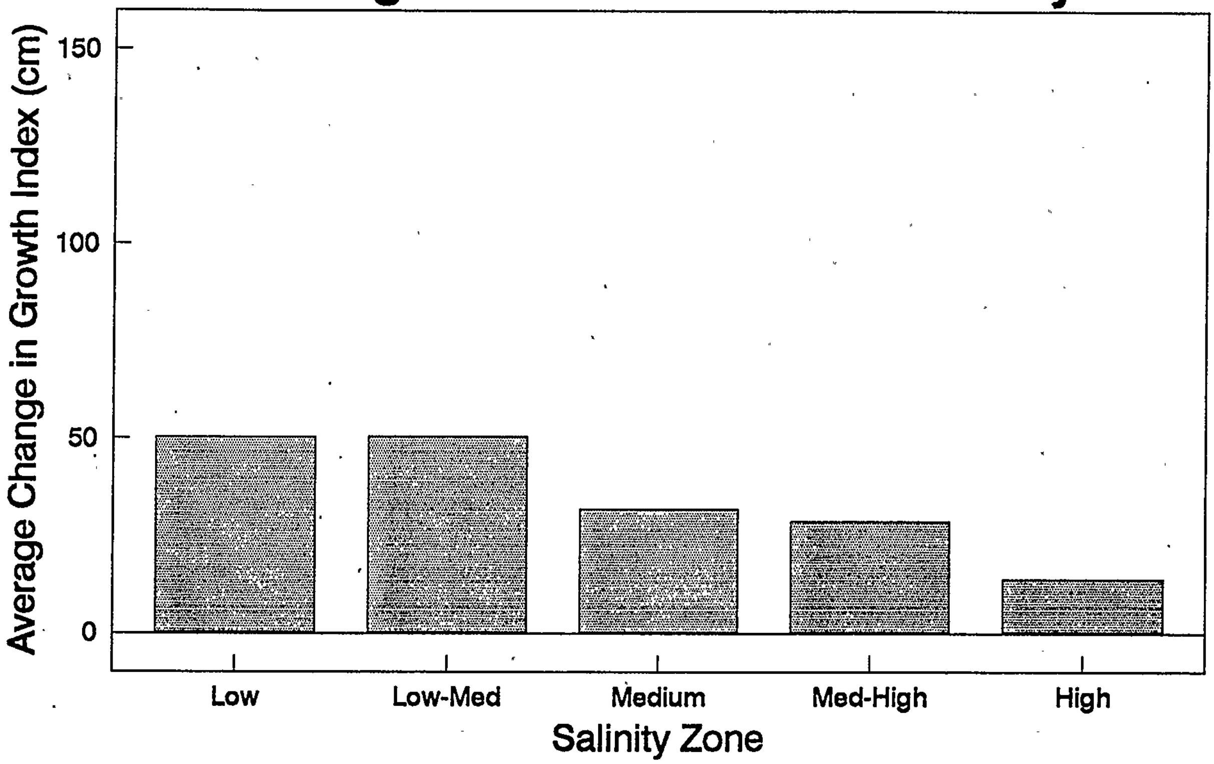
The above graph shows that for sea buckthorn growth decreases with increasing salinity. For the first three salinity zones, growth remains nearly constant and then falls for salinities greater than 7.3 dS/m. This demonstrates that sea buckthorn is capable of maintaining close to optimal growth for salinities as high as 6.9 dS/m. In comparison to the other types of trees and shrubs tested, sea buckthorn shows moderate growth.



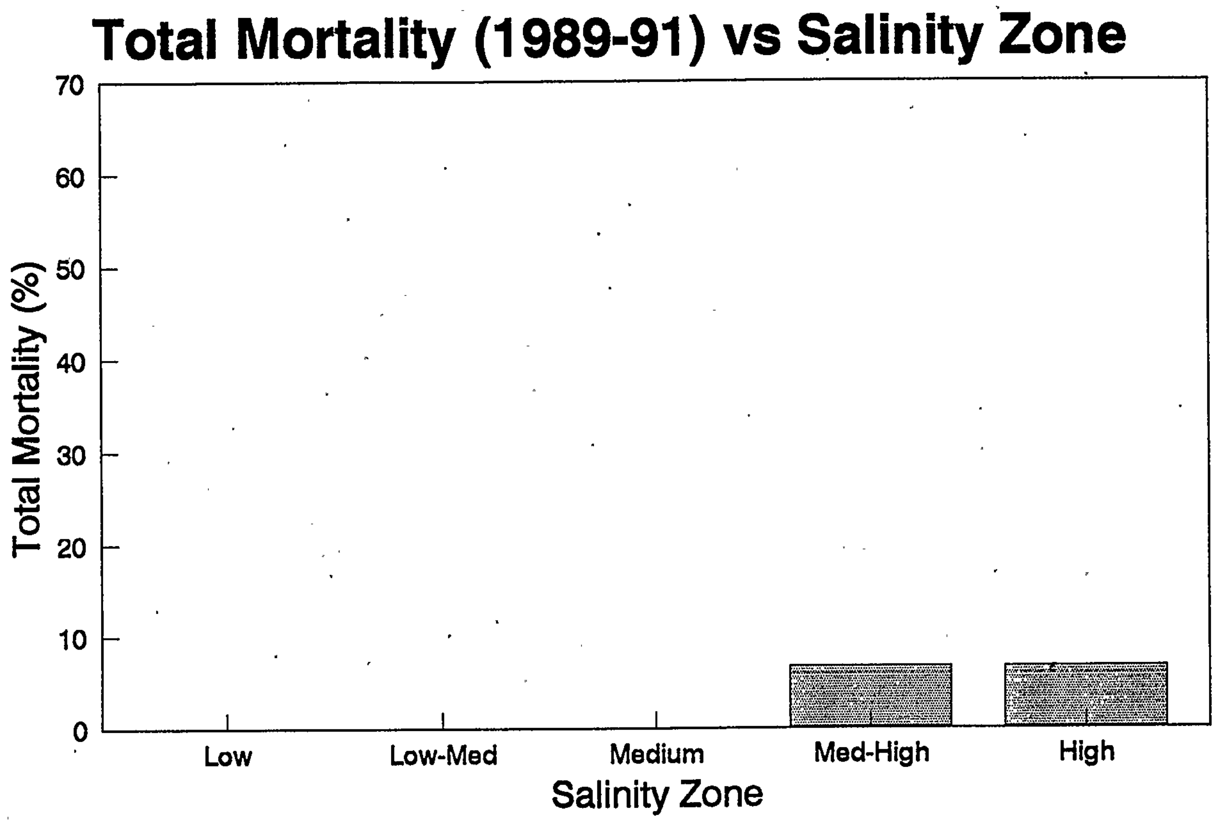
The above graph shows that the total percent mortality of sea buckthorn increases with increasing soil salinity. The information on this graph reflects that shown in the graph of growth versus salinity for sea buckthorn. The mortality rate remains nearly constant over the lowest three salinity zones and then rises over the highest two. The results of these two graphs demonstrate that sea buckthorn shows good growth and survival in soils with salt contents as high as 6.9 dS/m.

CARAGANA

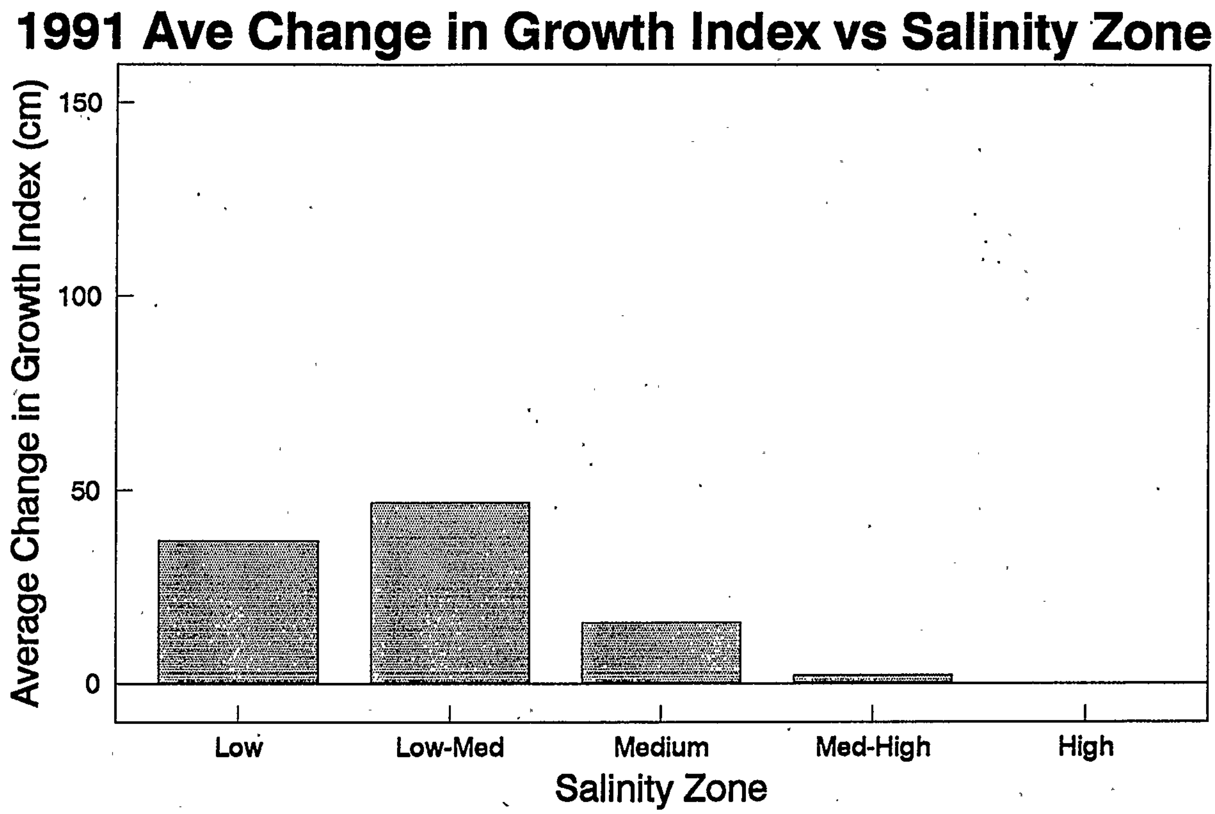
1991 Ave Change in Growth Index vs Salinity Zone



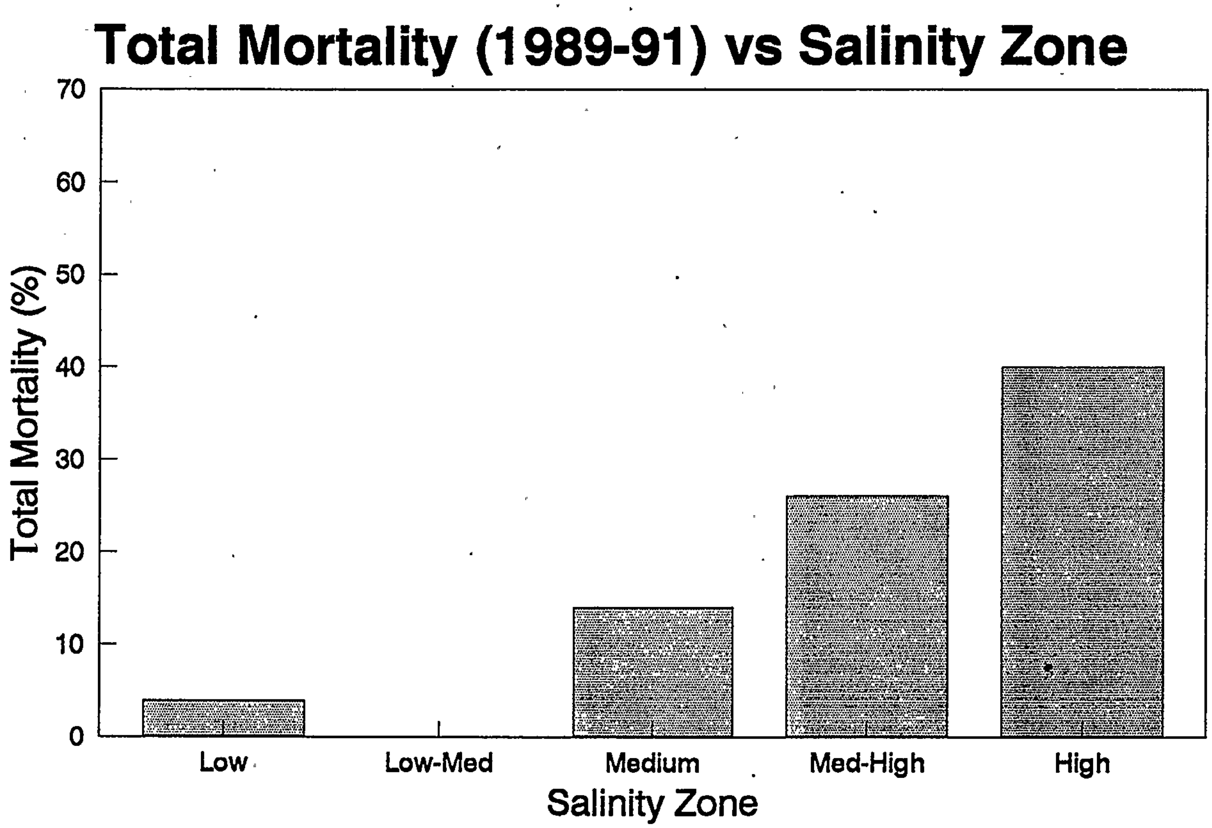
The graph of growth versus salinity for caragana shows decreasing growth with increasing salinity. The growth remains constant over the first two salinity zones and then gradually declines. The caragana retains optimal growth in soil salinities of up to 5.1 dS/m. Relative to other species tested, the caragana shows only moderate growth.



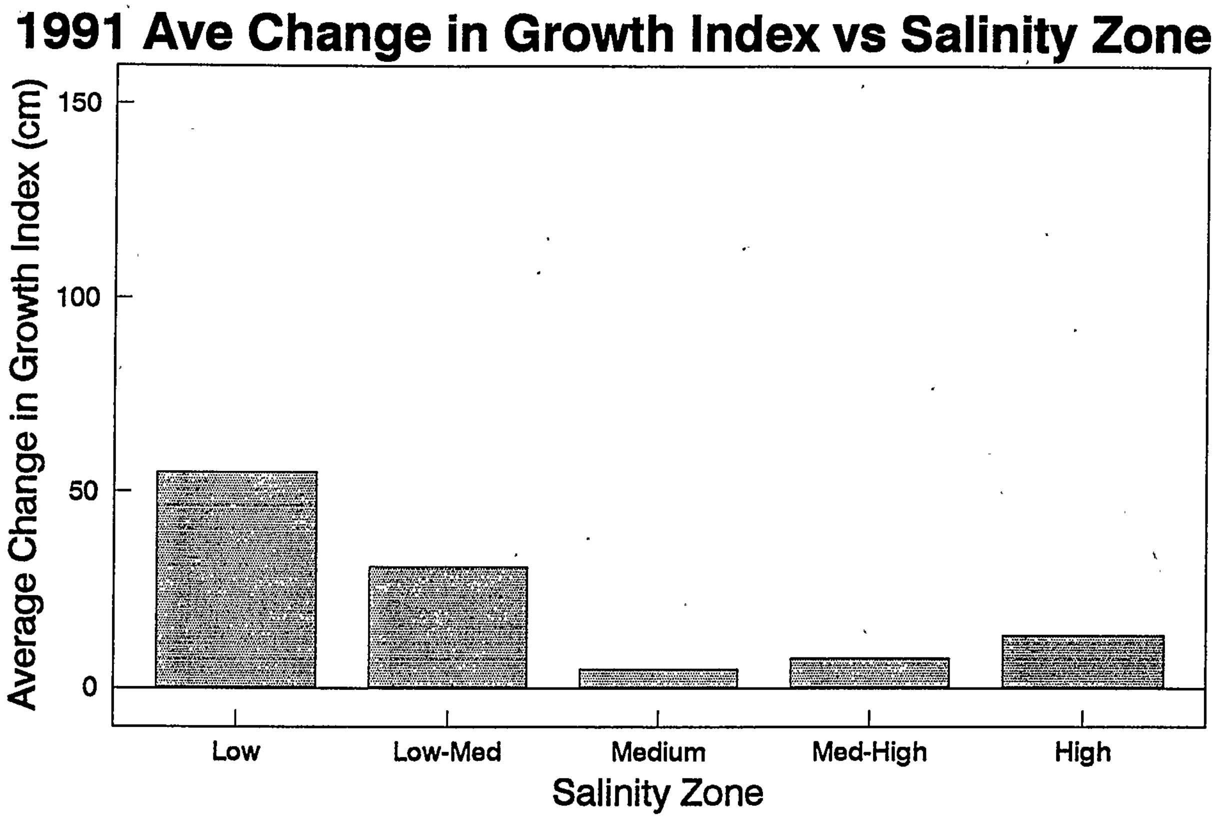
The above graph depicts the total percent mortality as a function of soil salinity, for caragana. Over the three growing seasons, there were no caraganas which required replanting in soils with salinity up to 6.9 dS/m. For the highest two salinity zones, the mortality rate increases only slightly. One study showed that, in terms of survival, the critical soil salinity for caragana was between 7 and 10 dS/m (Werkhoven 1966). In comparison to the other varieties tested, caragana demonstrates a very low mortality rate. Although its growth is modest, the caragana shows an excellent rate of survival over a broad spectrum of soil salinities.



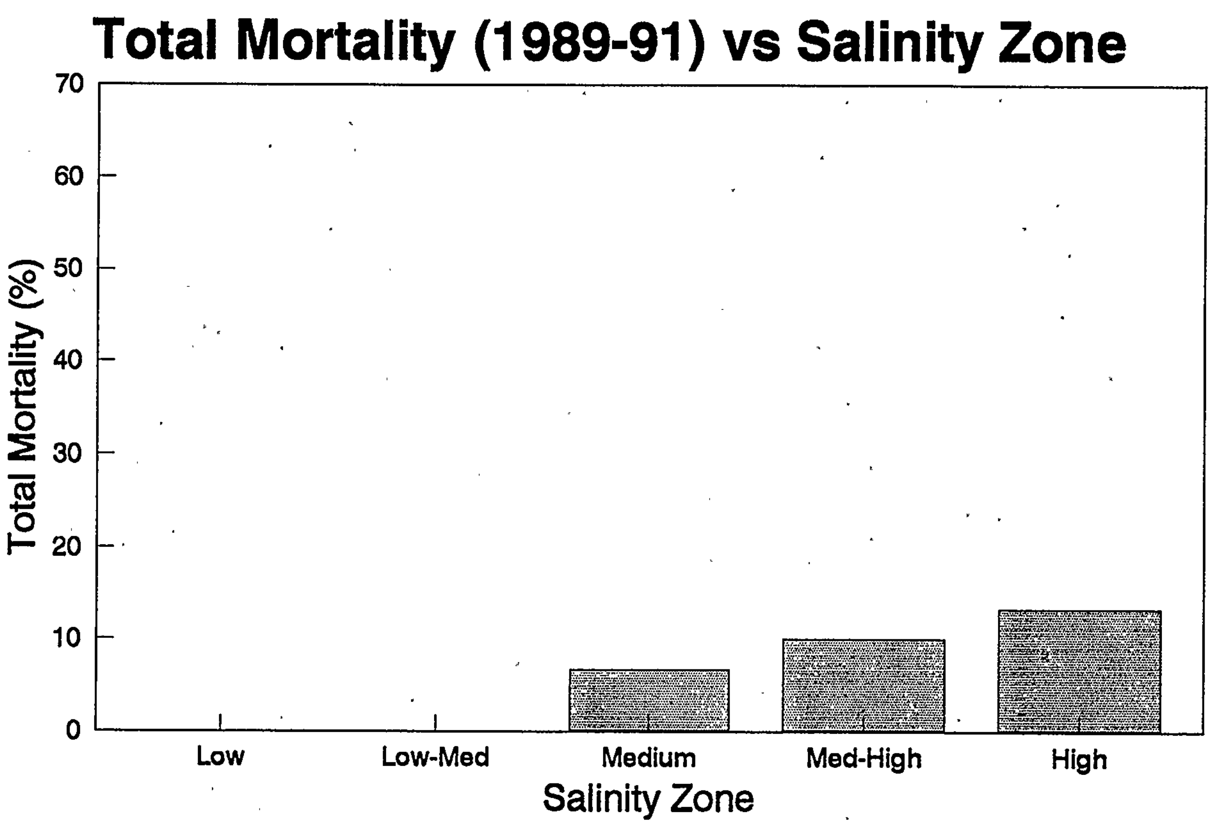
The above graph depicts the 1991 average change in growth index as a function of soil salinity for nanking cherry. It shows a modest overall growth. There is an initial increase in growth, with increasing soil salinity, followed by a decline to zero growth. The optimal growth is achieved at salinities between 4.1 and 5.1 dS/m. The growth declines quickly for soil salinities greater than 5.1 dS/m.



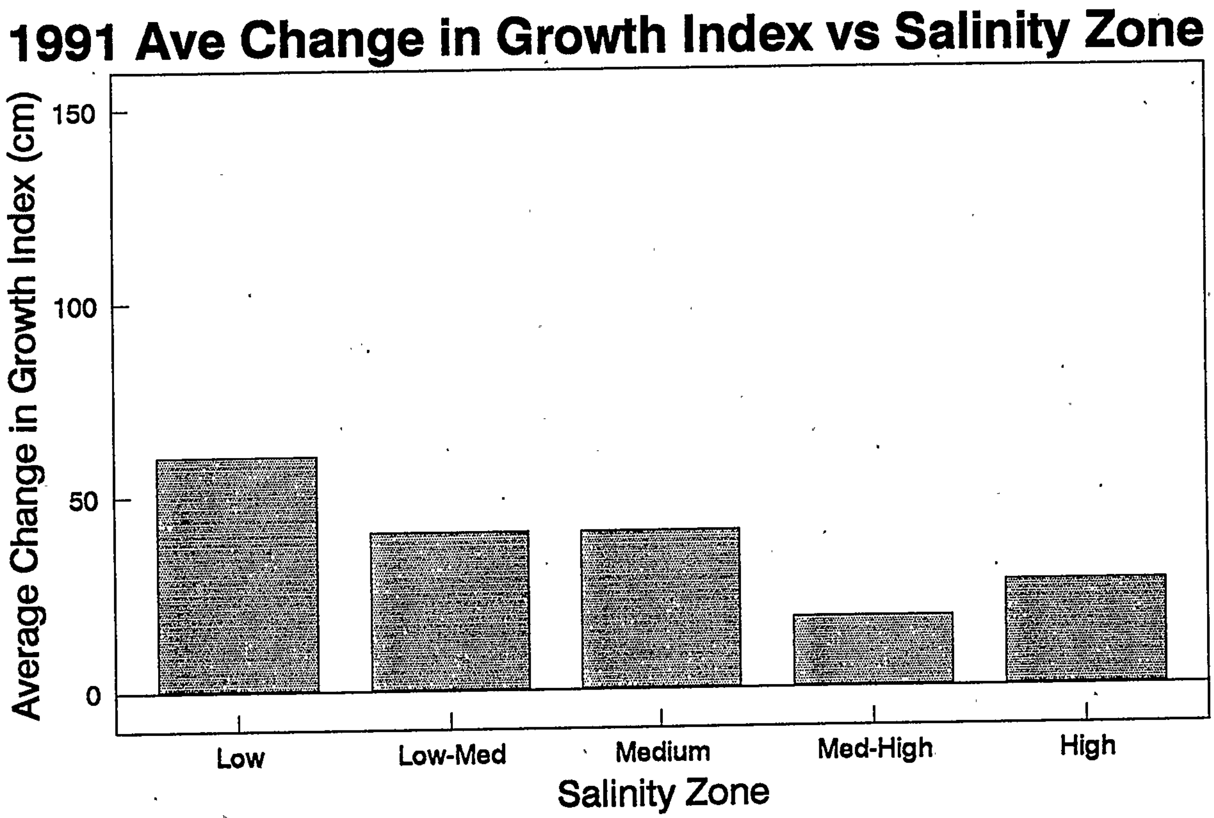
The above graph shows the three year total mortality rate of nanking cherry as a function of soil salinity zone. The information on this graph supports that on the opposite graph. There is an initial decline in percent mortality, followed by a sharp increase, with increasing salinity. Again the optimal range of soil salinities is between 4.1 and 5.1 dS/m. The "Low-Medium" salinity zone shows the best results for both growth and survival of nanking cherry. This may be due to the slightly more saline soil having greater amounts of moisture than the "Low" salinity zone.



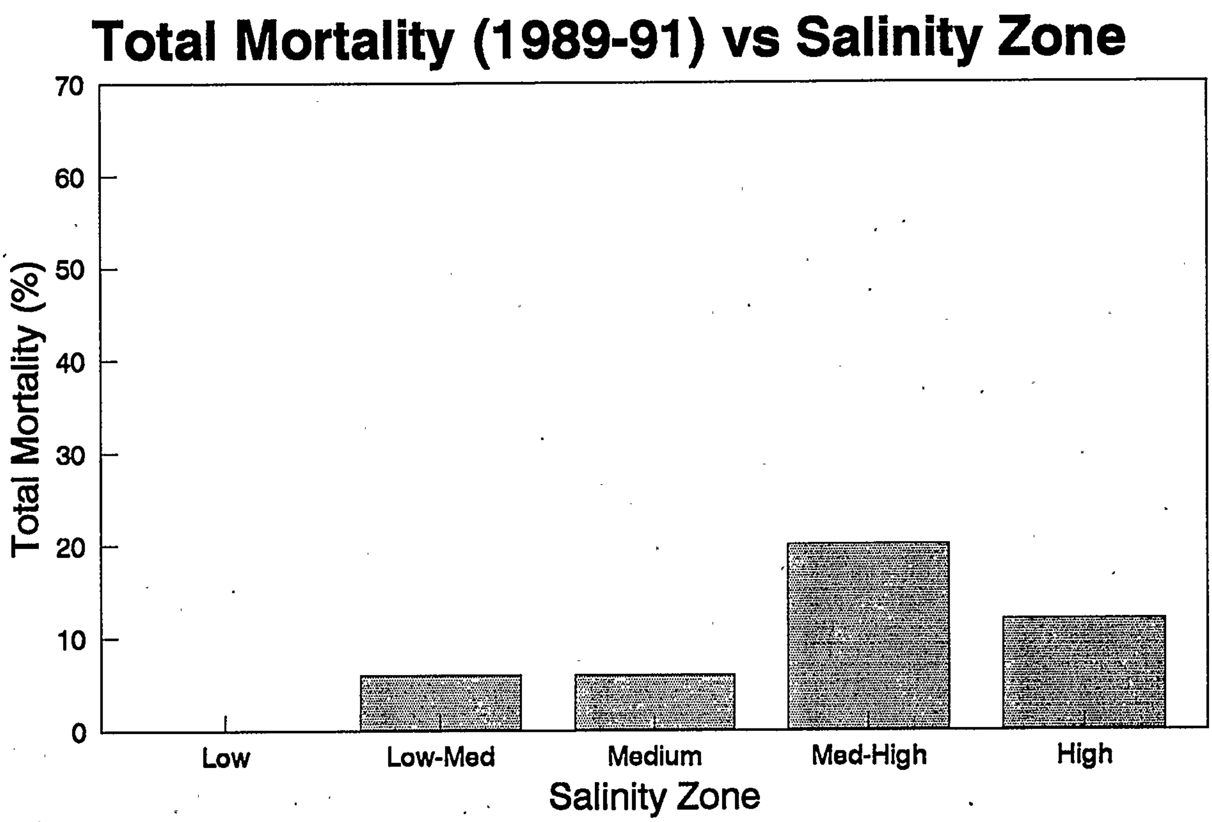
The columbia crab shows an overall decline in growth rate with increasing soil salinity. The above graph shows a decline in growth over the lowest three salinity zones, followed by a small increase in growth over the highest two salinity zones. This slight increase of growth in the highest soil salinities may be due to the increased number of replants in these two zones. The fresh potted greenhouse stock may continue to grow for a short period of time after being transplanted to the field, before it succumbs to the large amounts of salinity in the surrounding soil. The optimal growth for columbia crab was demonstrated in the "Low" (1.7 to 4.0 dS/m) salinity zone.



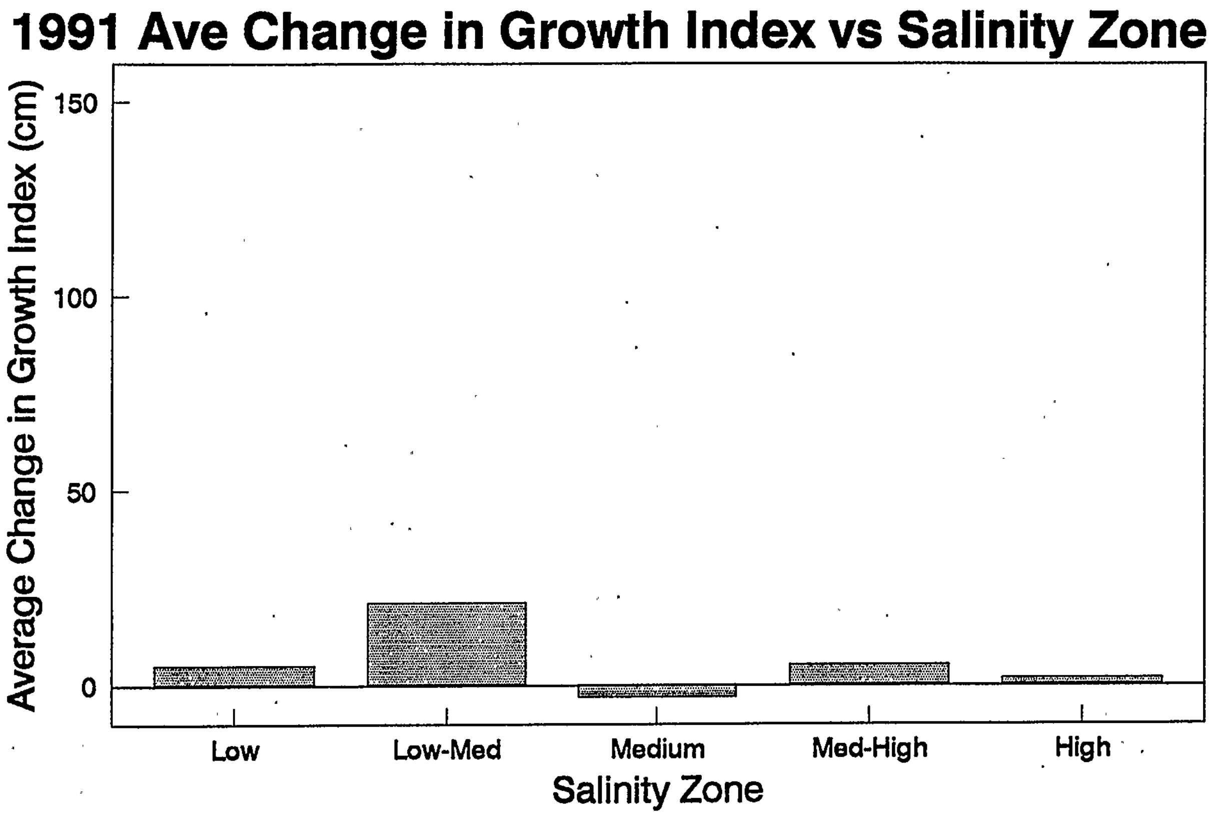
The total percent mortality for columbia crab increases with increasing soil salinity. There were no replants required for the lowest two salinity zones (1.7 to 5.1 dS/m). The mortality rate increases over the three highest salinity zones but remains low in comparison to other varieties which were tested. The columbia crab has proven to be a slow grower but resistant to death as a result of soil salinity.



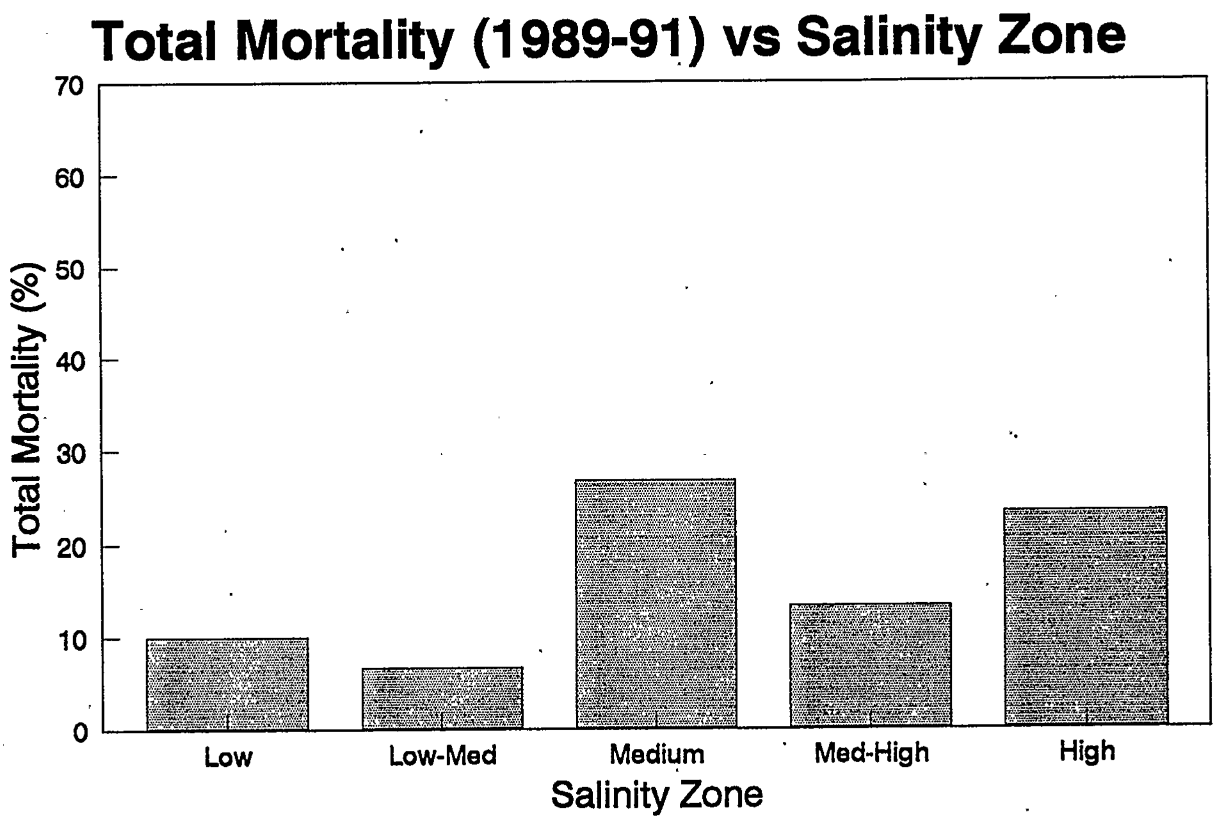
The above graph shows an overall decline in growth of dogwood, with increasing soil salinity. Dogwood has been shown to be severely affected by highway deicing salts (Lumis 1976). The optimal growth of dogwood is demonstrated in the "Low" (1.7 to 4.0 dS/m) salinity zone. The rate of growth decreases over the next three salinity zones and rises slightly over the highest salinity zone. The "Low-Medium" and "Medium" salinity zones show identical growth rates. The slight increase in growth for the "High" salinity zone may be a factor of the higher water table usually associated with saline soils. Suckering was accounted for by the measurement of minimum width.



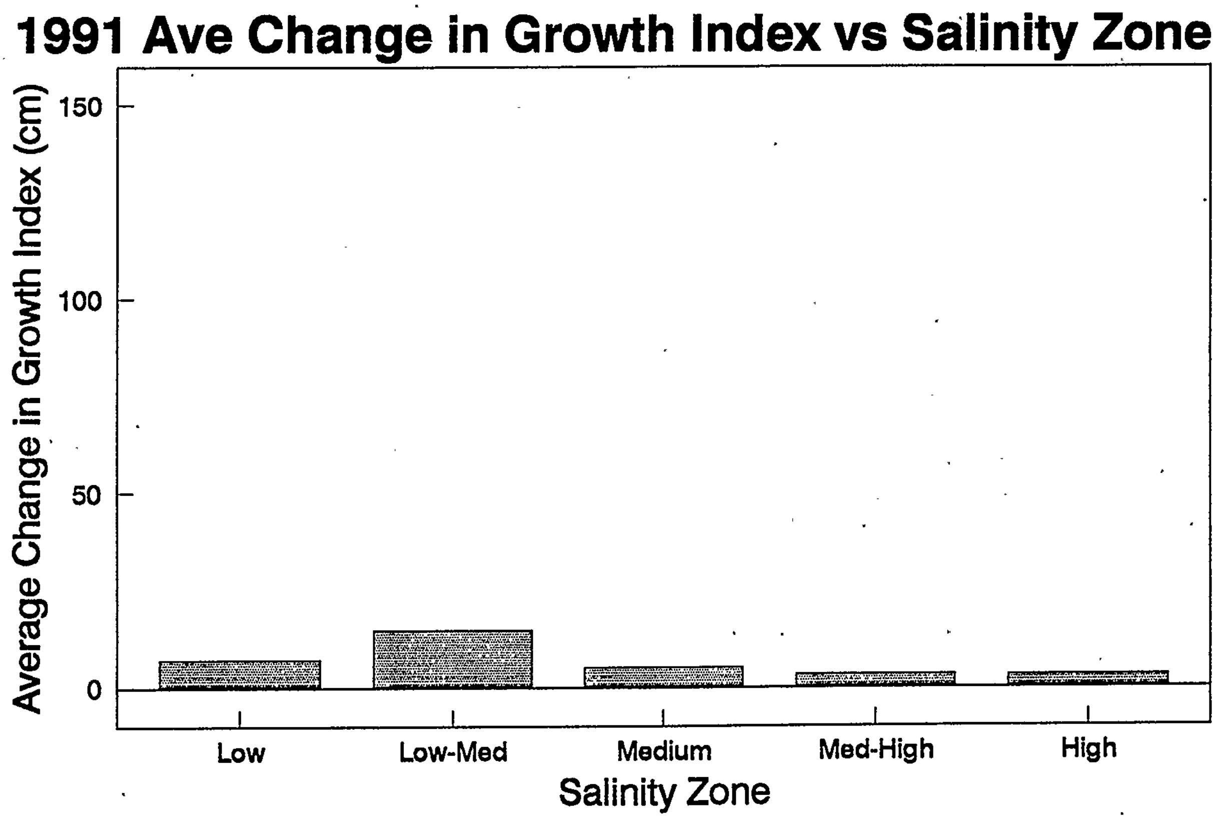
The above graph, which depicts mortality as a function of soil salinity for dogwood, has an overall increase in mortality with increasing salinity. The mortality rate is zero for the lowest salinity zone. The next two salinity zones have identical, small rates of mortality. These two zones also had identical growth rates, indicating that soil salinities in the range of 4.1 and 6.9 dS/m have a uniform effect on dogwood. The mortality rate then increases for the "Medium-High" zone and decreases slightly for the "High" zone. This unusual behaviour was also exhibited in the growth rate for the same salinity zone. It may again be attributed to the higher water table often associated with saline soils.



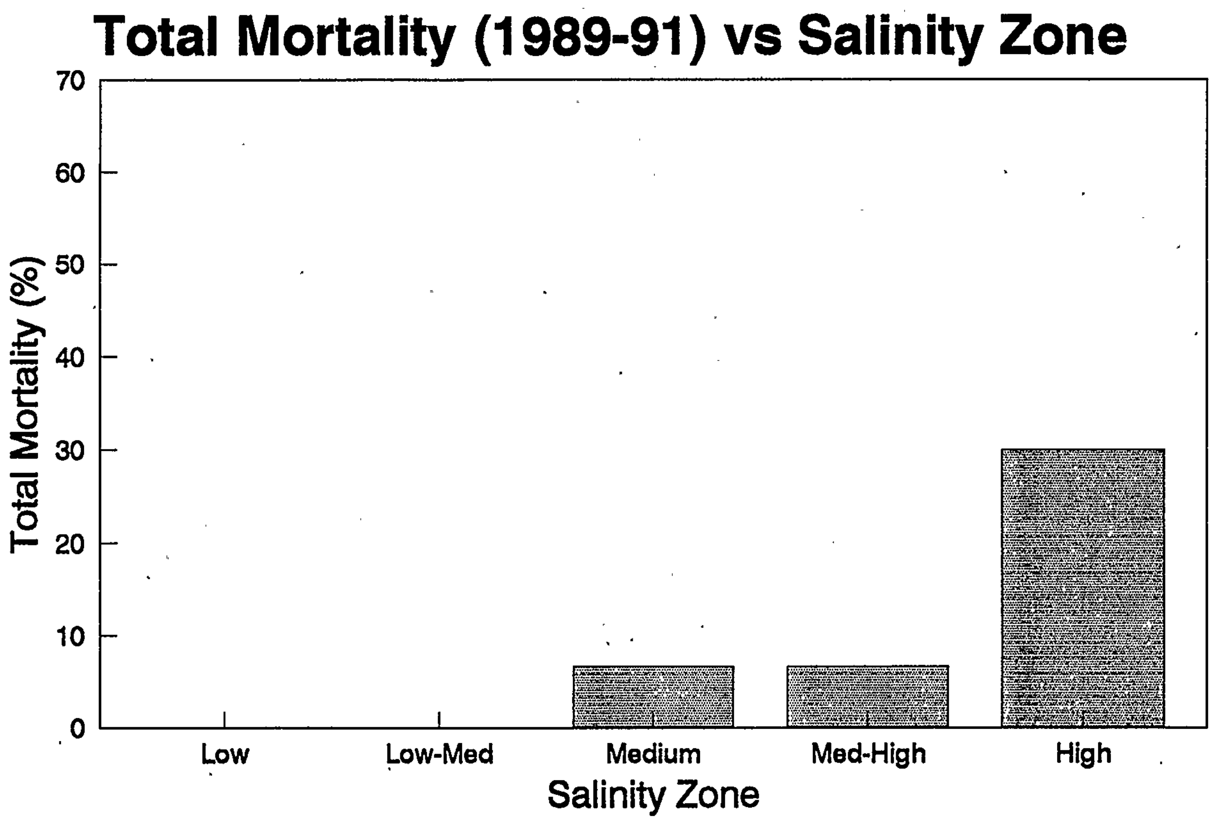
The above graph shows a very slow overall rate of growth for hawthorn. The optimal growth rate occurred in the "Low-Medium" zone. All other salinity zones showed tiny amounts of growth. The negative value for growth found in the "Medium" salinity zone indicates that, for that zone, more die back than growth of the specimens occurred.



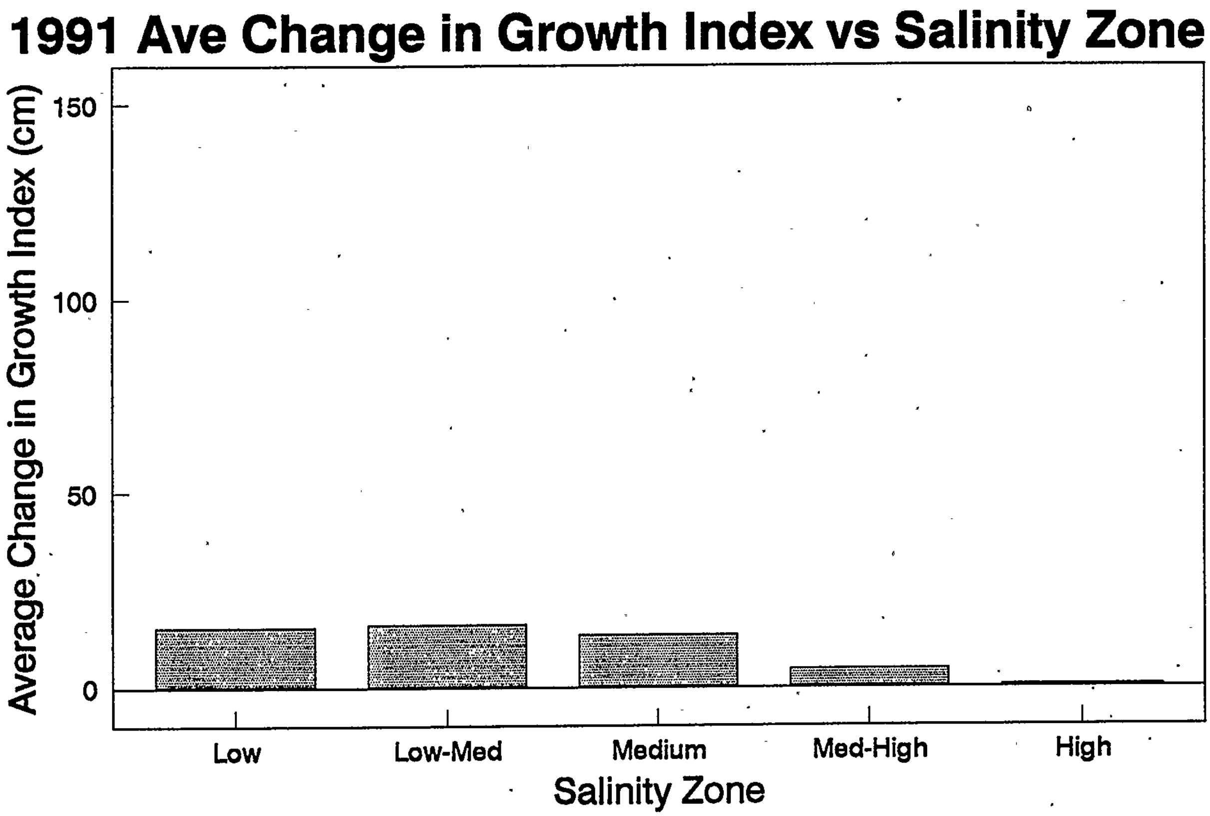
The graph of mortality as a function of salinity shows moderate overall rates of mortality for hawthorn. The graph is uneven and inconsistent. As with growth, the optimal rate for mortality was demonstrated in the "Low-Medium" salinity zone and the poorest rate for mortality was found in the "Medium" salinity zone. One conclusion that may be drawn from these graphs is that hawthorn is slow growing with unpredictable survival rates, and is therefore not recommended for planting in southeast Alberta.



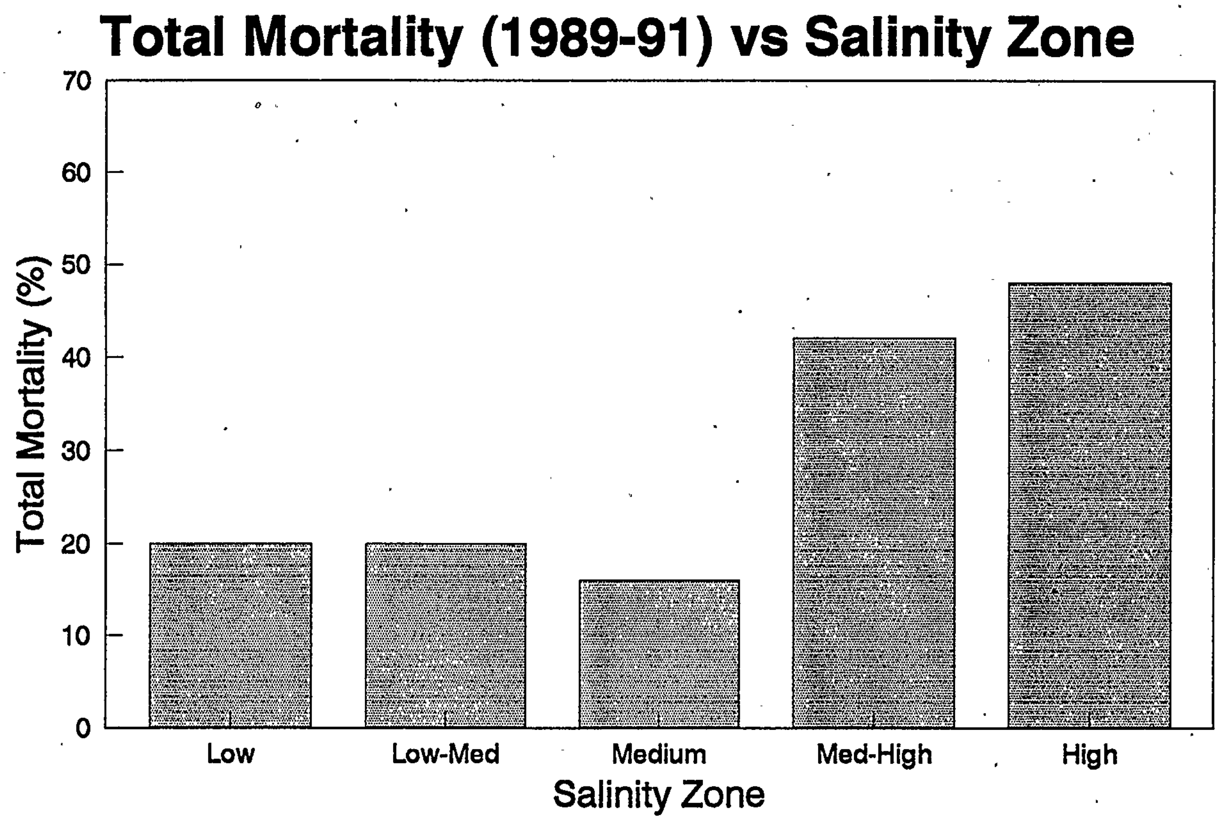
The above graph shows the Prince of Wales juniper has a slow overall rate of growth, as compared to the other species tested. Although growth is slow, the graph demonstrates that growth does decrease with increasing salinity. The optimal growth is found in the "Low-Medium" salinity zone. The initial increase in growth may be attributed to greater amounts of moisture usually associated with greater soil salt content.



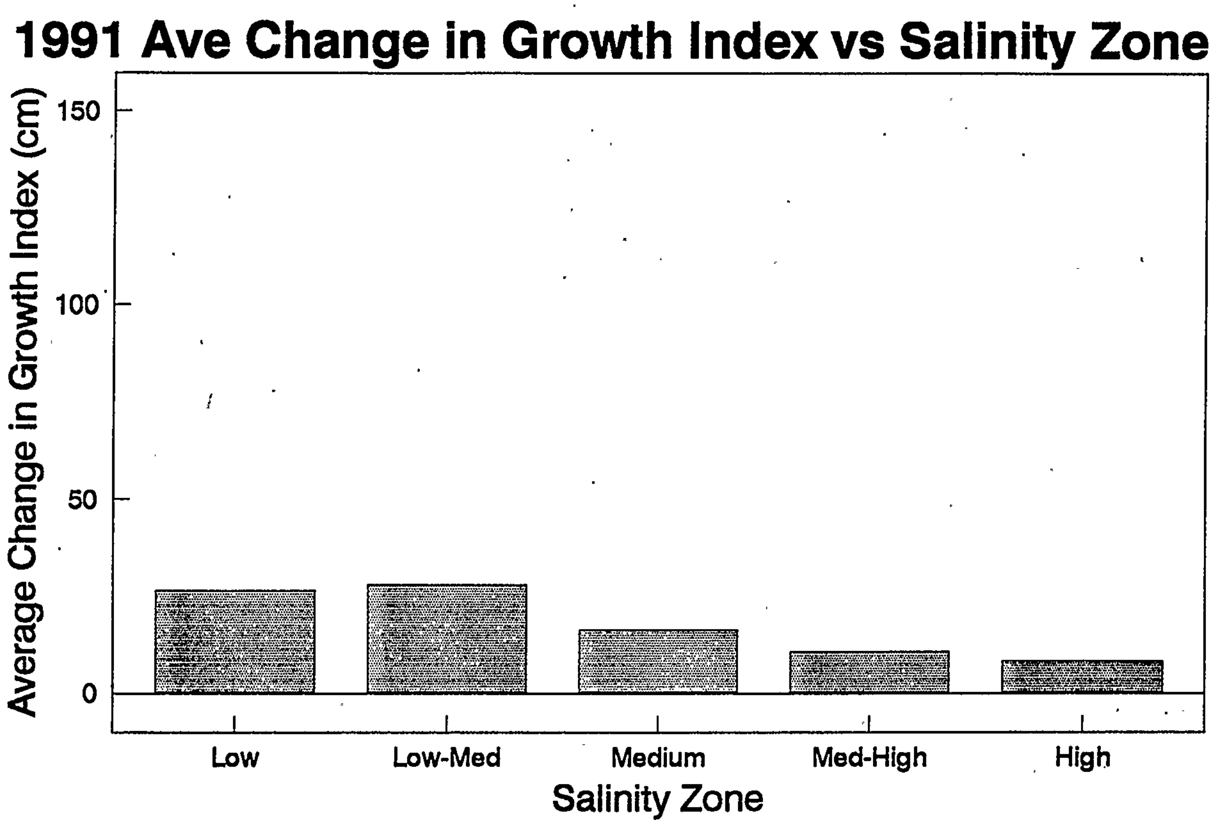
The above graph depicts the total mortality of the Prince of Wales junipers, as a function of soil salinity zone. The two lowest levels of soil salinity (1.7 to 5.1 dS/m) have zero percent mortality over the three year period. This rate increases slightly over the next two zones and then escalates for the highest salinity zone. The information on these two graphs shows that the Prince of Wales juniper is a slow grower but is capable of surviving well in all but the highest quantities of soil salinity.



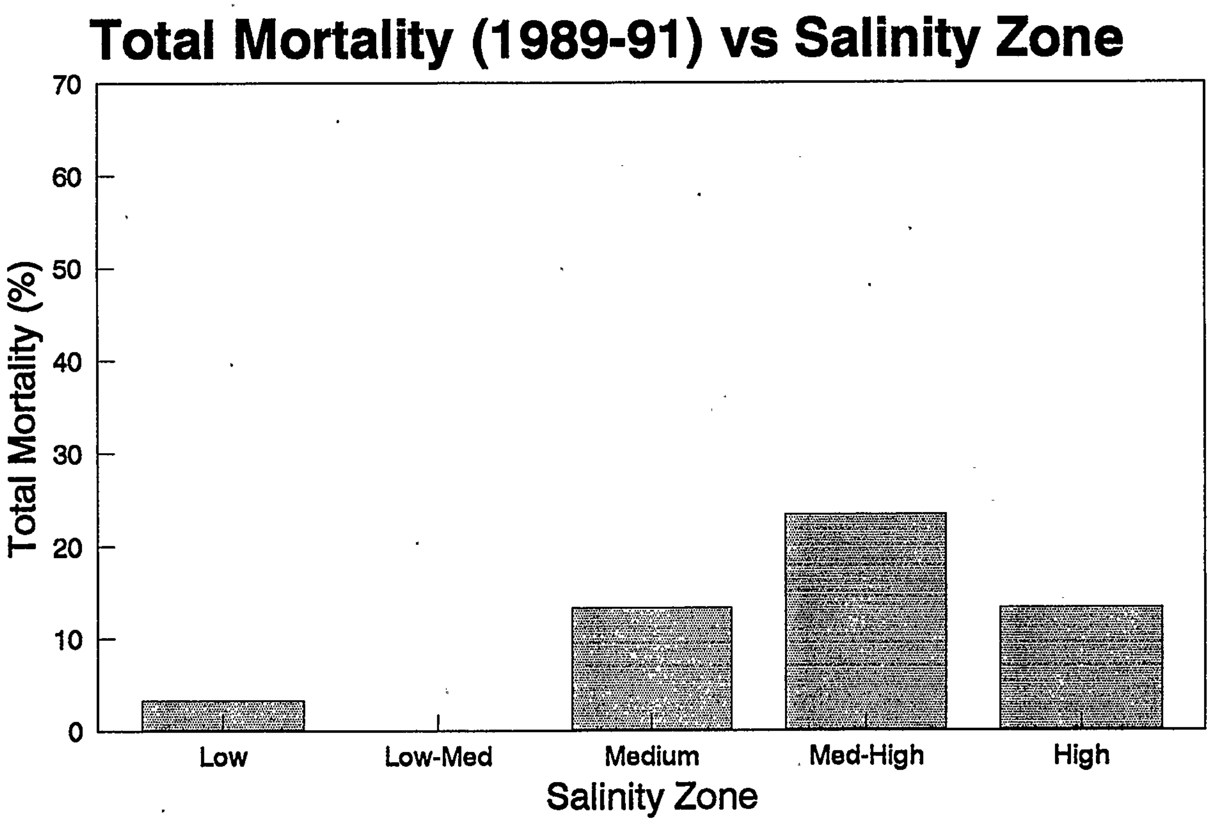
In comparison to the other varieties tested, the Siberian larch shows slow overall growth. This may be attributed to the small size (approximately 15 cm in height) of the original transplant materials. In the above graph, Siberian larch shows decreasing rates of growth with increasing salinity. Although growth rates are slow in all zones, the first three zones (1.7 to 6.9 dS/m) show nearly the same rates of growth, demonstrating that the Siberian larch is able to maintain close to optimal growth in levels of salinity of up to 6.9 dS/m. Another experiment demonstrated that the growth of Siberian larch begins to decline when soil salinity is between 3.5 and 4.0 dS/m (Carter 1980).



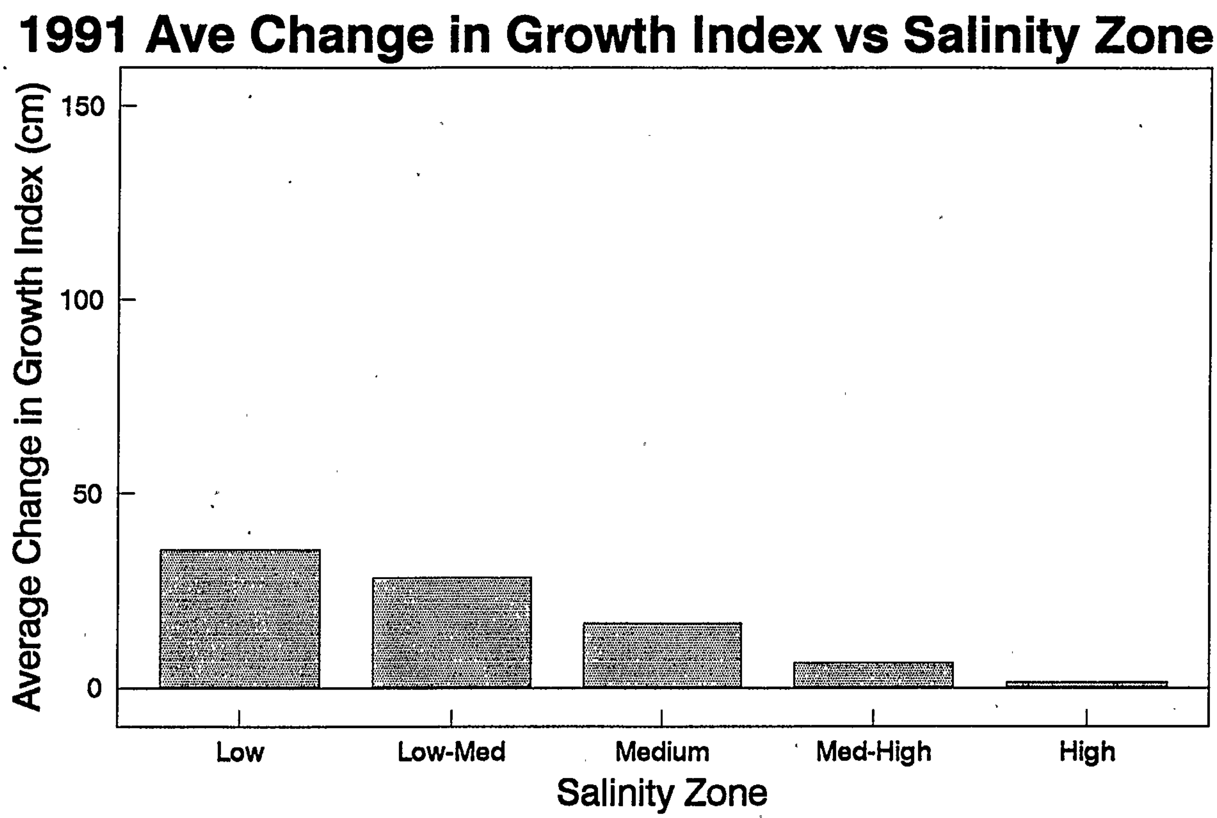
The Siberian larch had poor overall mortality rates. Again, this may be attributed to the small size of the transplant material. There is a general increase in total mortality rates with increasing soil salinity. The lowest rates of mortality occurred in the "Medium" salinity zone. This may be attributed to the higher water tables usually associated with soils having high salinity. Although the overall performance of the Siberian larch is poor, it is apparent from both of the graphs, that this variety is capable of maintaining its growth and survival in salinities up to 6.9 dS/m.



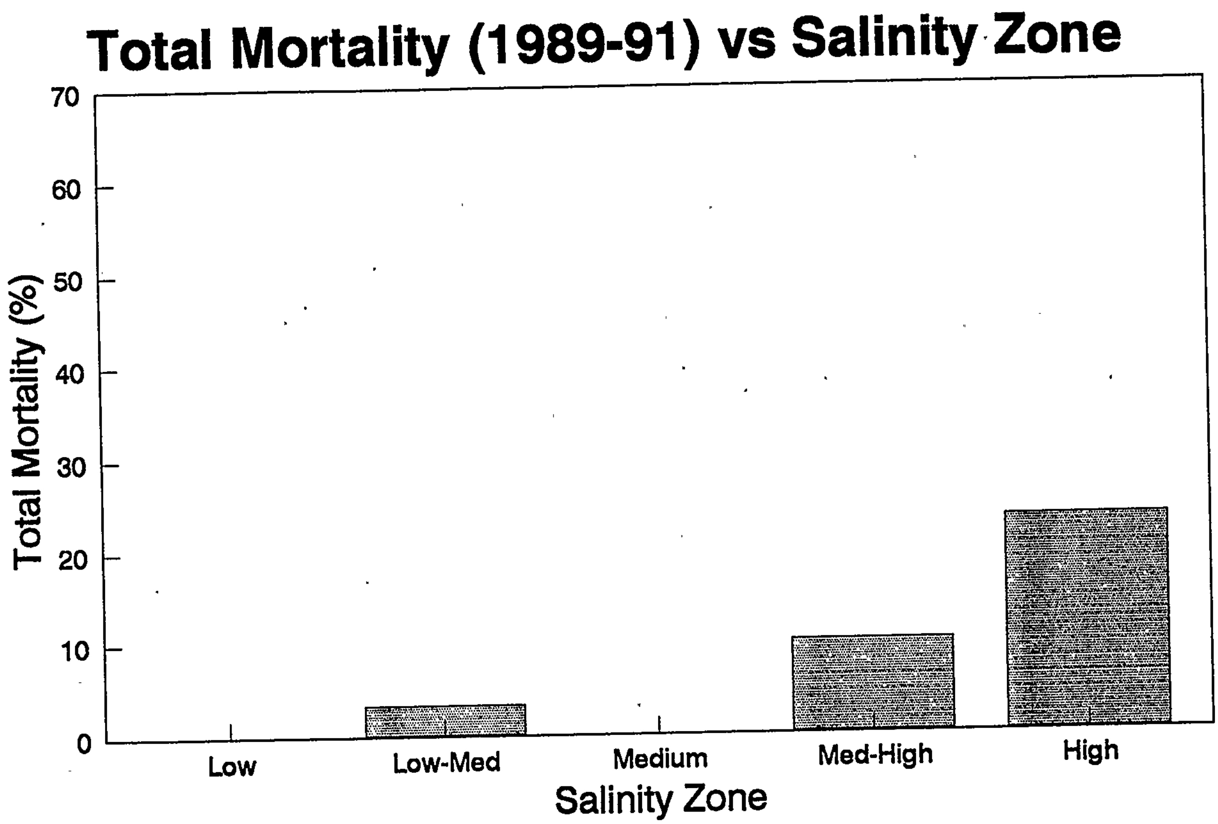
The above graph depicts the change in growth as a function of soil salinity zone for common lilac. In comparison to the other varieties tested, the common lilac shows slow overall growth. It has decreasing rates of growth with increasing salinity. There is an initial increase in growth rate and the optimal growth is in the "Low-Medium" (4.1 to 5.1 dS/m) zone. This initial increase demonstrates that small quantities of soil salts are tolerable in the presence of the increased soil moisture associated with increasing salinity. Another experiment indicated that common lilac was resistant to being severely injured by highway deicing salt (Lumis 1976).



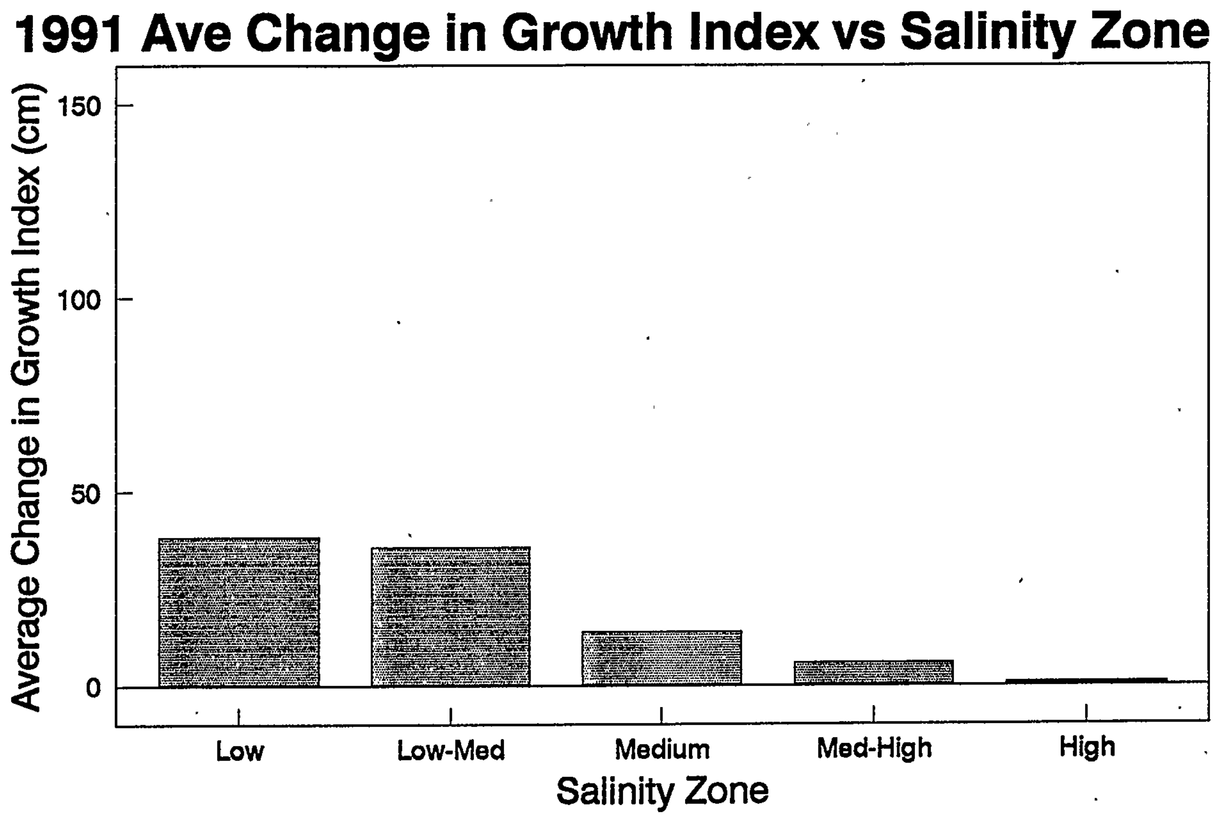
The overall survival of common lilac is good. Although the results are irregular, there is a general increase in mortality with increasing amounts of soil salinity. The optimal zone, as with growth, is the "Low-Medium" salinity zone. There is a decline in mortality for the highest salinity zone. This may be explained by examining the data for common lilac found in Appendix A. By comparing the horizontal salinity in 1991 to the average horizontal salinity from 1989 to 1991, it is evident that for the highest two salinity zones a smoothing effect has taken place. Over the last growing season the salinity has increased in the "Medium-High" zone and decreased in the "High" zone.



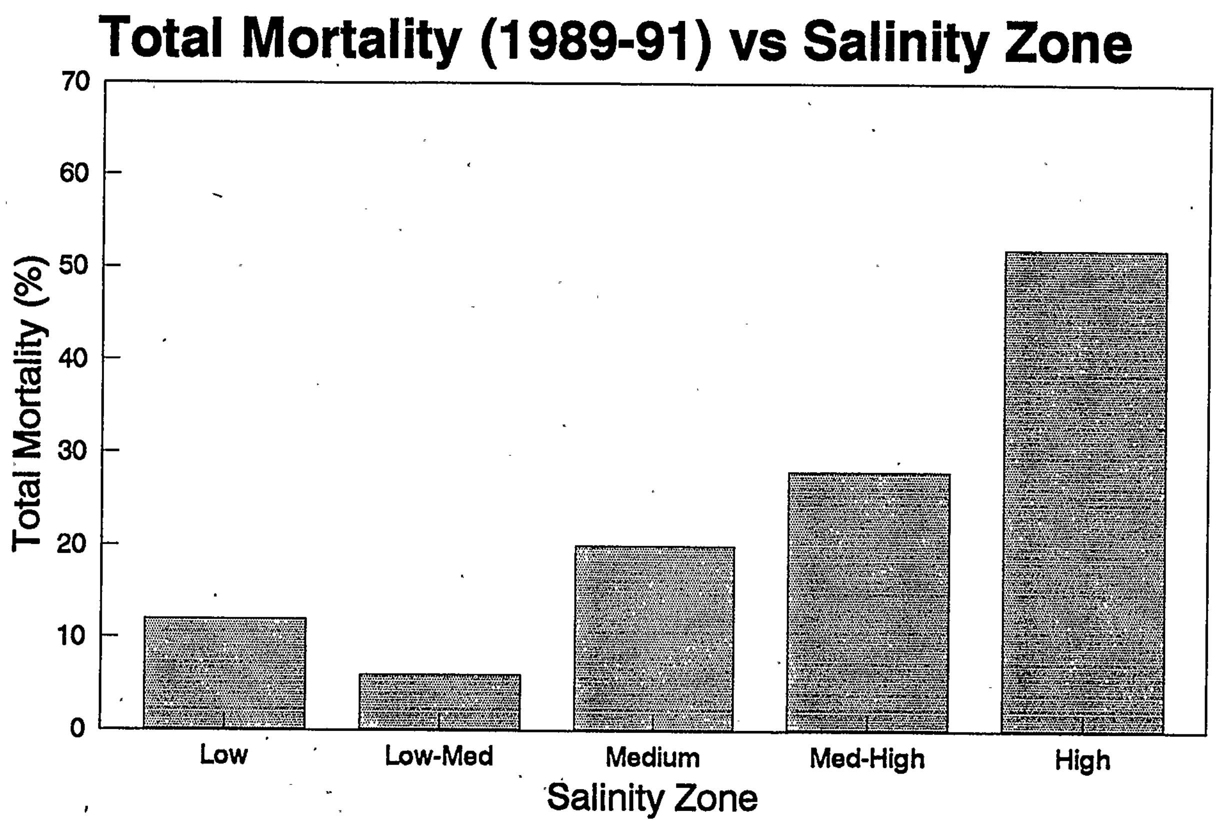
The villosa lilac had slow overall growth, as is demonstrated in the above graph. The villosa lilac has a steady decline in growth with increasing salinity. The optimal amounts of growth occur in the lowest salinity zone (1.7 to 4.0 dS/m).



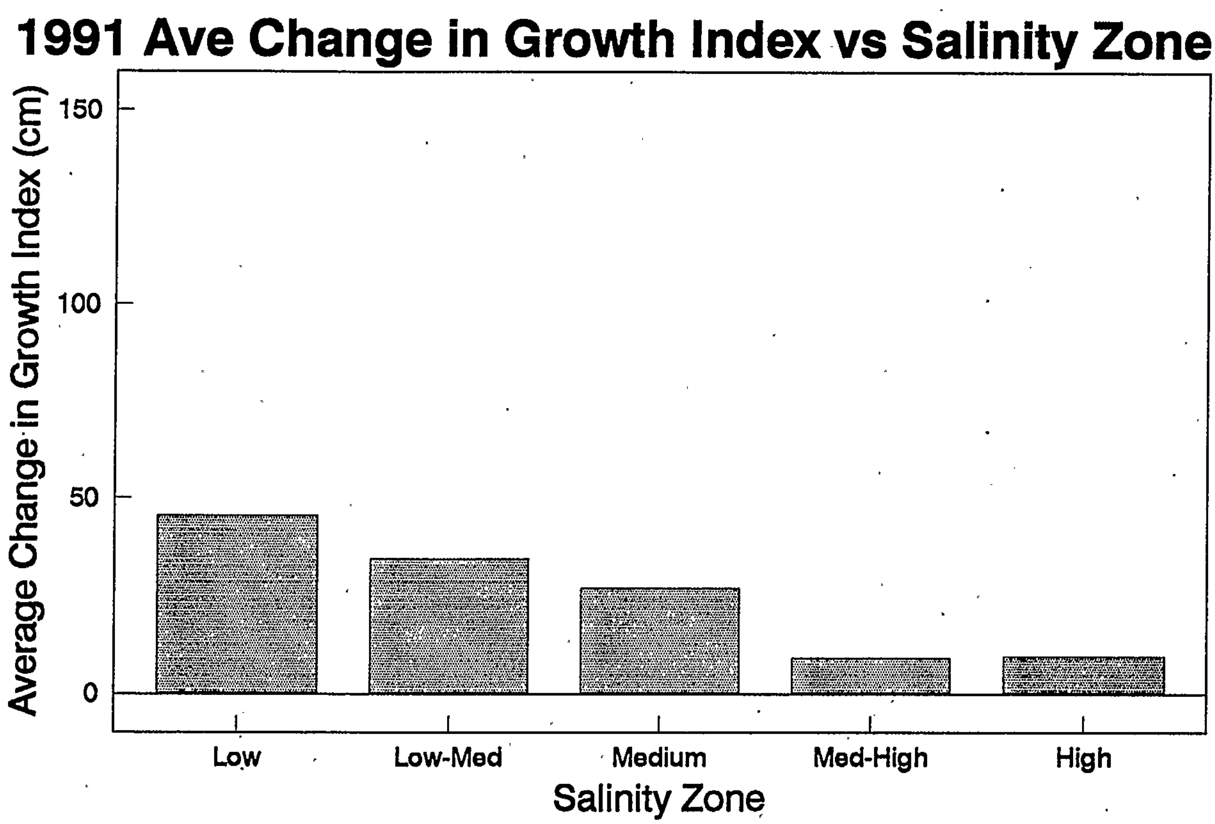
The above graph shows that an increase in the percent mortality of villosa lilac is associated with increasing soil salinity. The mortality is zero for the first and third salinity zones and is less than five percent for the second salinity zone. The mortality increases for the two highest salinity zones. These graphs show that villosa lilac is a slow grower and although it is best grown in soils with low salt contents (1.7 to 4.0 dS/m), it is capable of surviving in salinities of up to 6.9 dS/m.



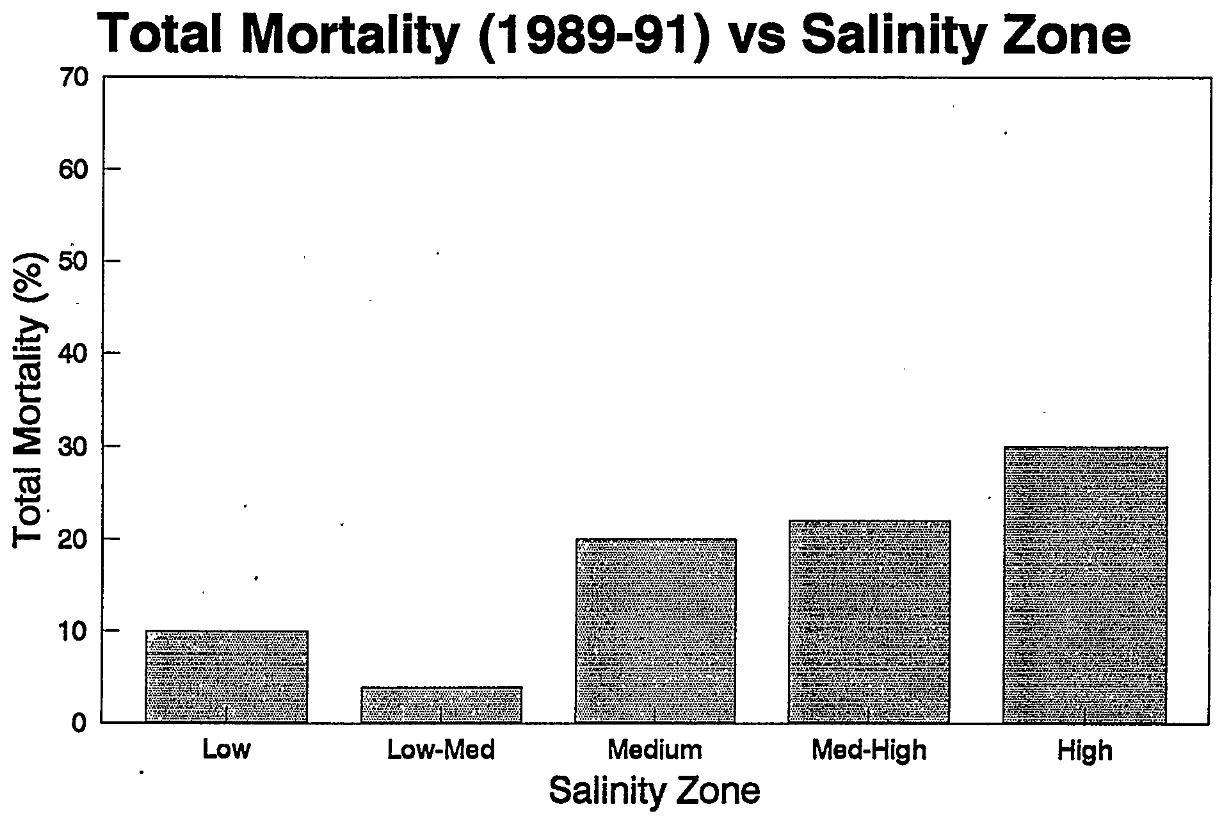
The mayday had slow overall growth, as is shown in the above graph. Growth declines steadily with increasing salinity. The optimal growth occurs in the lowest salinity zone (1.7 to 4.0 dS/m). There is a slight decline for the "Low-Medium" salinity zone and growth decreases steadily from there. This graph demonstrates that both of the lowest salinity zones are satisfactory for growing mayday.



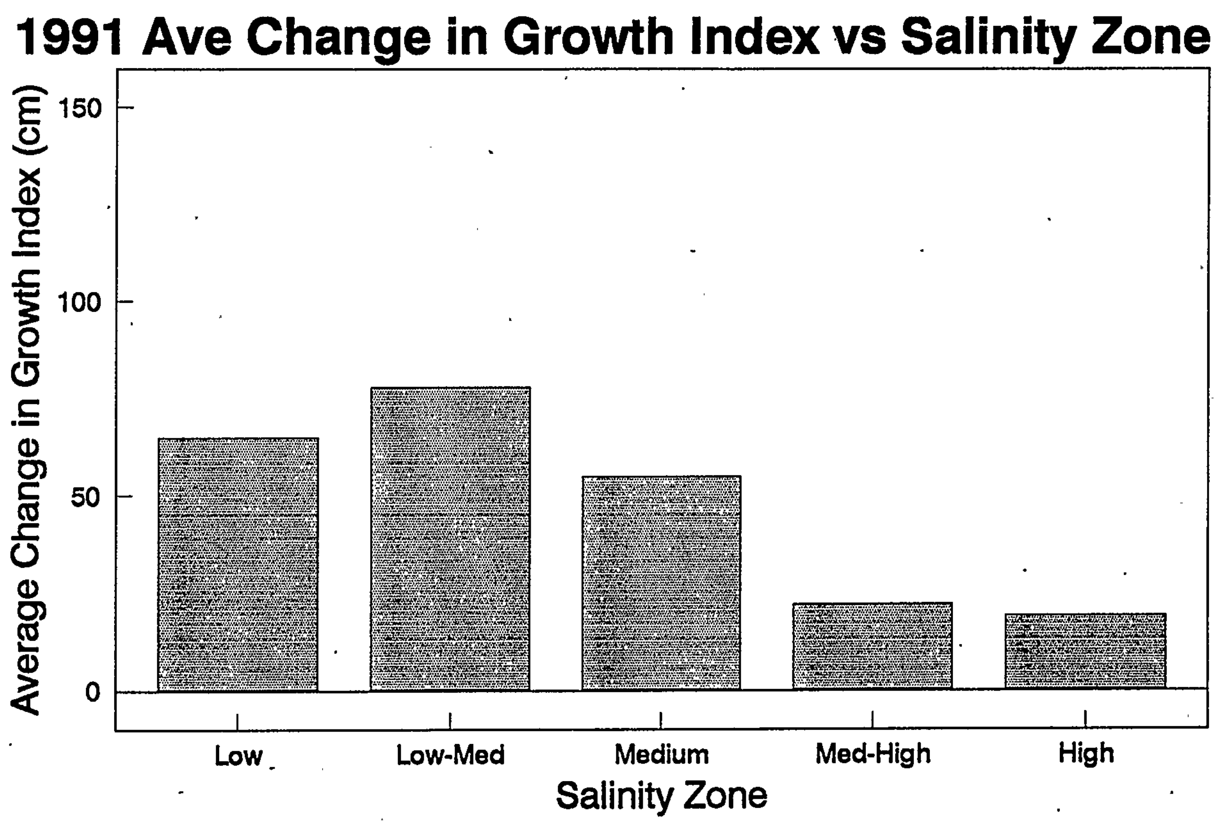
The above graph shows increasing mortality rates in mayday with increasing amounts of soil salinity. The mayday has a poor overall survival rate. There is an initial decline in mortality for the second (4.1 to 5.1 dS/m) salinity zone and then mortality increases from there. The initial decline may be due to more moisture being present in more saline soils. Together, these graphs indicate that for optimal growth and survival rates in mayday, slightly saline soils (4.1 to 5.1 dS/m) are recommended.



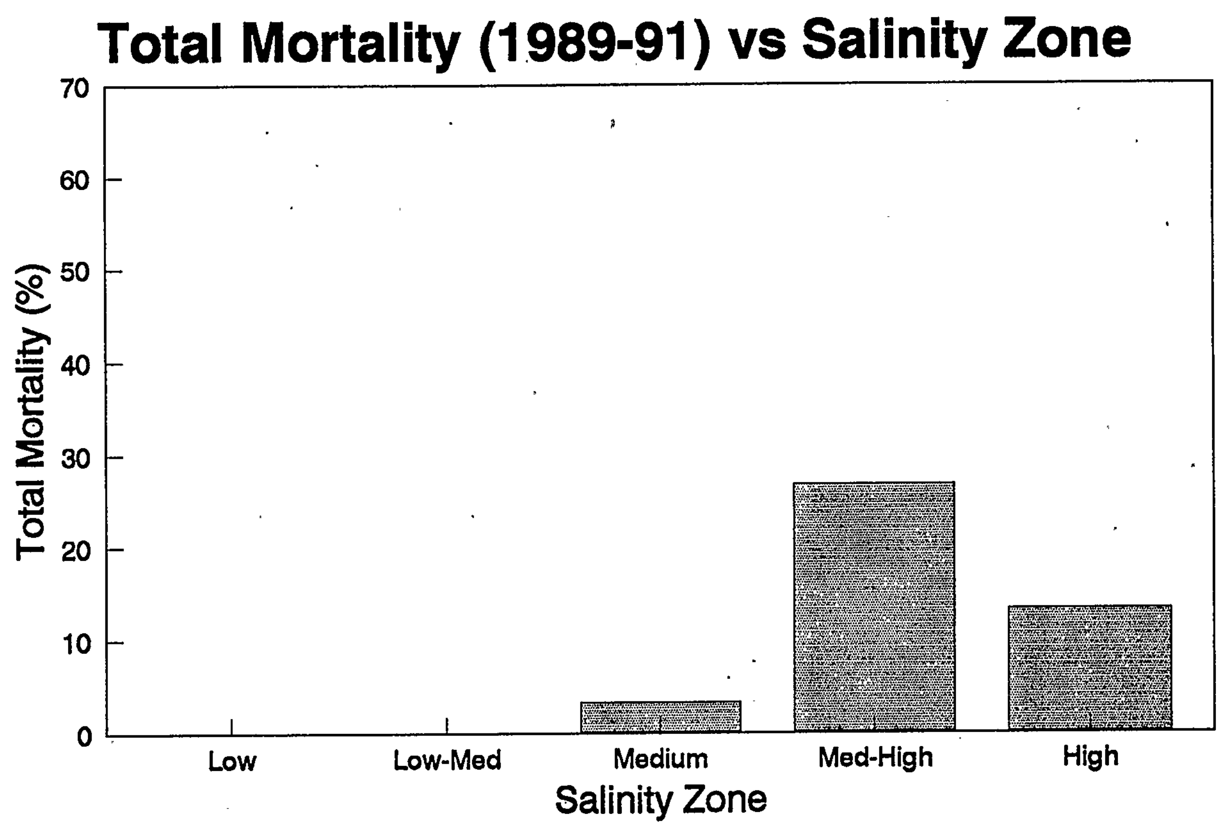
The amur maple had slow overall growth. Growth declines steadily with increasing salinity. The optimal growth occurs in the lowest salinity zone (1.7 to 4.0 dS/m) and growth decreases after that. This graph demonstrates that the lowest salinity zone is suggested for growing amur maple.



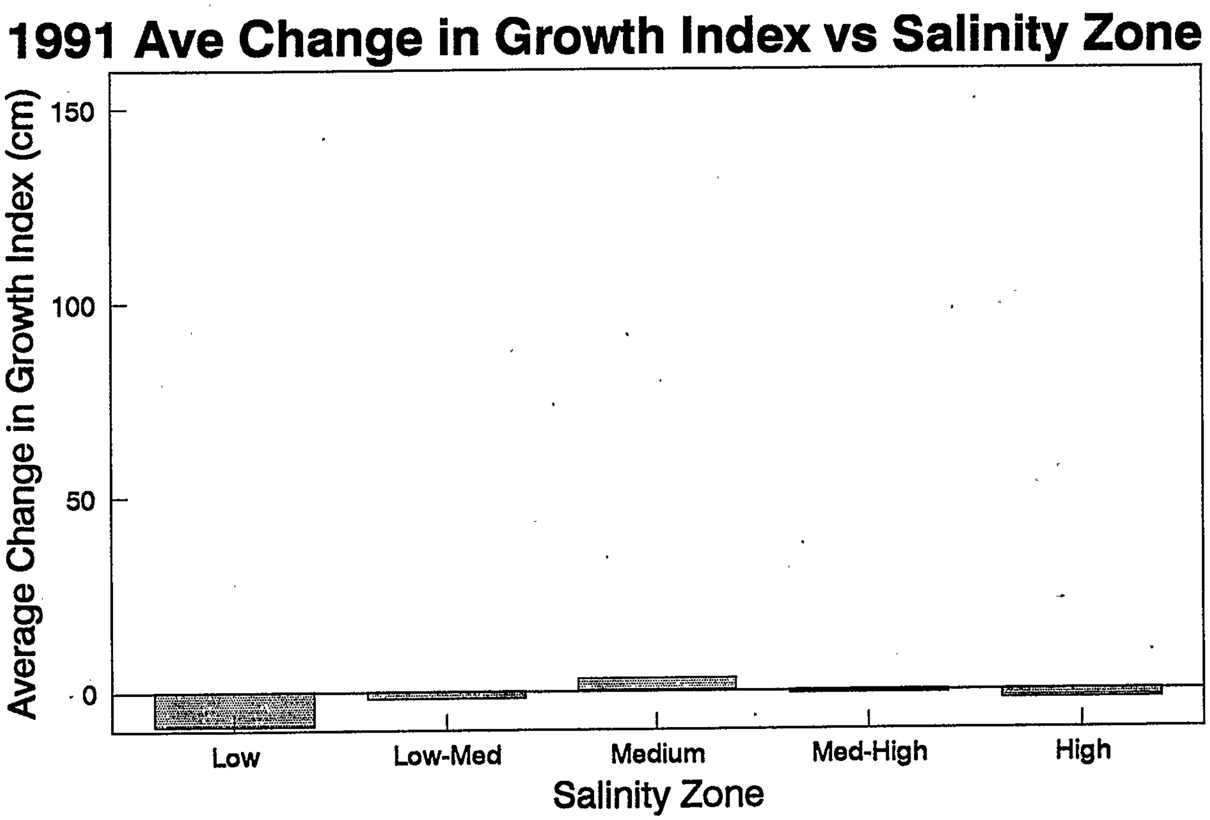
The above graph shows increasing mortality rates in amur maple with increasing amounts of soil salinity. The amur maple has a moderate overall survival rate. There is an initial decline in mortality for the second (4.1 to 5.1 dS/m) salinity zone and then mortality increases from there. The initial decline in mortality may be due to more moisture being present in the slightly more saline soil. Together, these graphs indicate that for optimal growth and survival rates in amur maple, low to slightly saline soils (1.7 to 5.1 dS/m) are recommended.



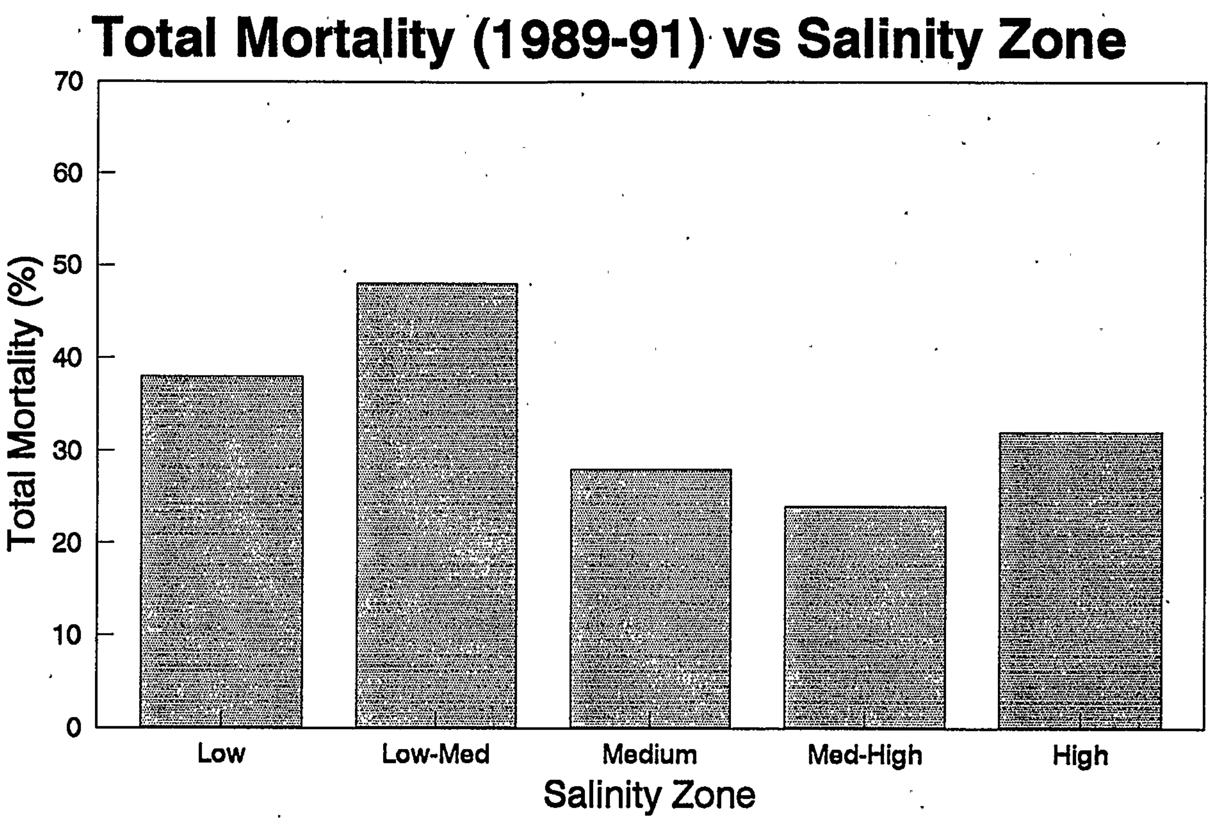
The graph shown above depicts the response of growth of Manitoba maple to increasing soil salinity. The overall rate of growth for Manitoba maple is moderate. There is an initial increase in growth followed by an overall decline in growth rates, with increased soil salinity. The initial increase may be due to the increasing soil moisture usually associated with more saline soils. Good growth is retained over the first three salinity zones (1.7 to 6.9 dS/m). Another experiment rated Manitoba maple as being severely injured by highway deicing salt (Lumis 1976).



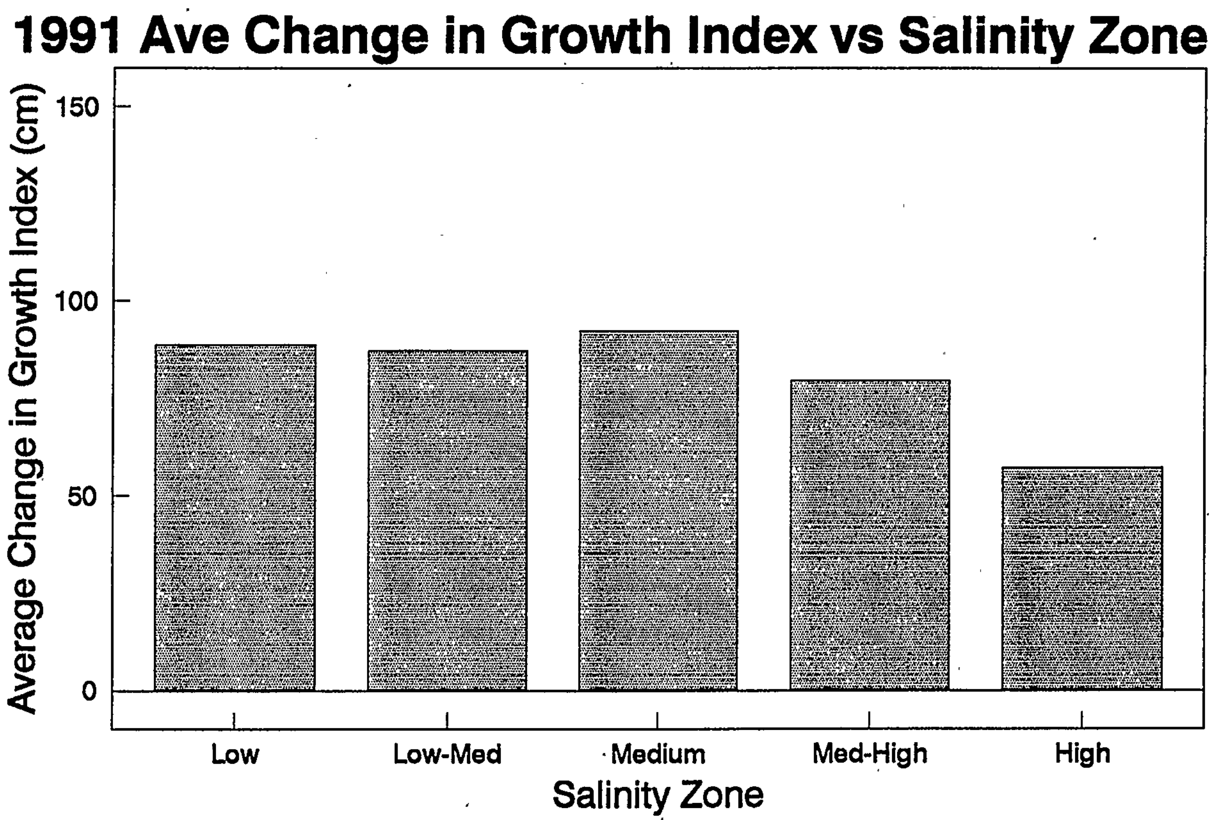
The graph of mortality as a function of soil salinity zones for Manitoba maple is pictured above. Mortality rates are generally low for Manitoba maple. There is an overall increase in mortality with increased soil salinity. The lowest three salinity zones exhibit little or no mortality over the three year period of growth. Mortality is greater for the highest two salinity zones. The information depicted on these two graphs show that optimal growth and mortality occur in the "Low-Medium" salinity range, but that good growth and low mortality are preserved in soils having as much as 6.9 dS/m of salt content.



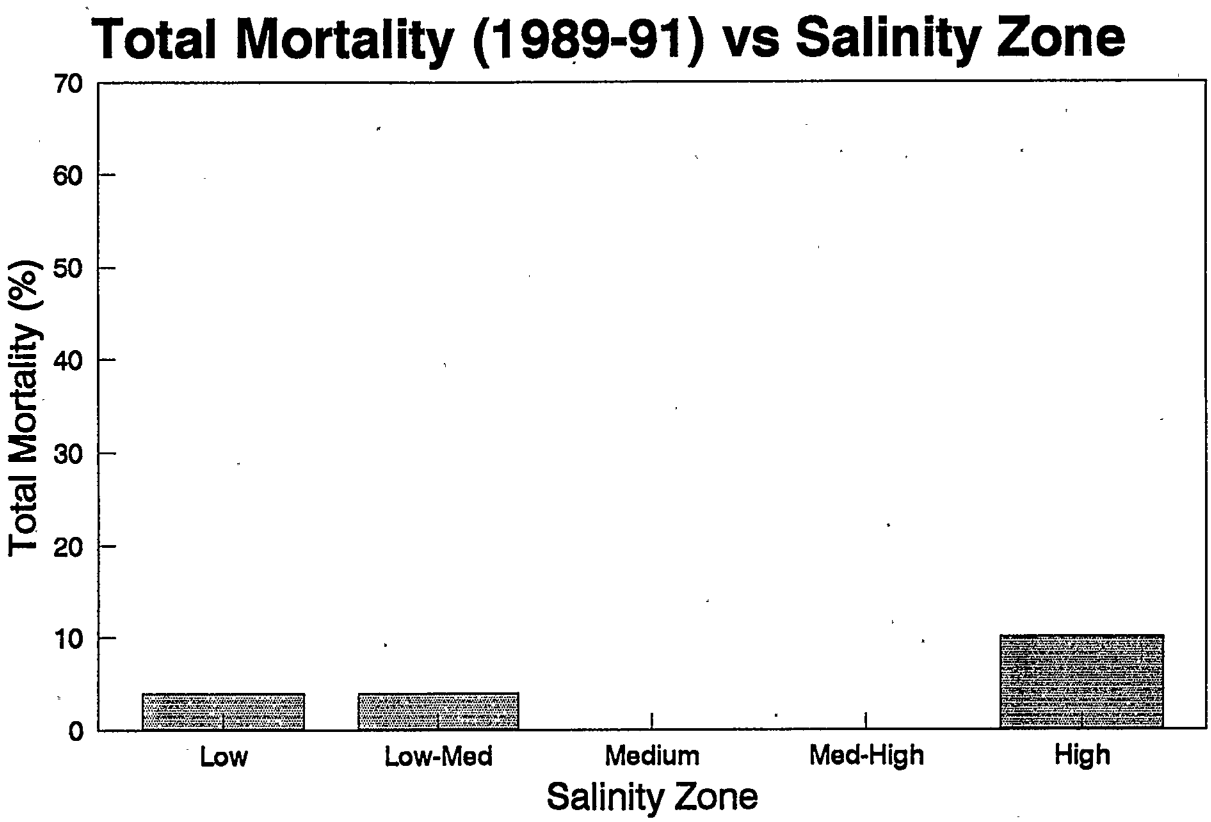
The above graph represents the average change in growth index for 1991 as a function of soil salinity zones for bur oak. Bur oak has little or no overall growth. The "Medium" (5.4 to 6.9 dS/m) zone is the only salinity zone having an average growth index greater than zero percent. The negative values represented in the other zones are a result of there being a greater amount of die back than growth in the specimens for each zone. Dead branches were pruned from the specimens. Frequently, pruning resulted in an overall decrease in size, therefore a negative change in growth index.



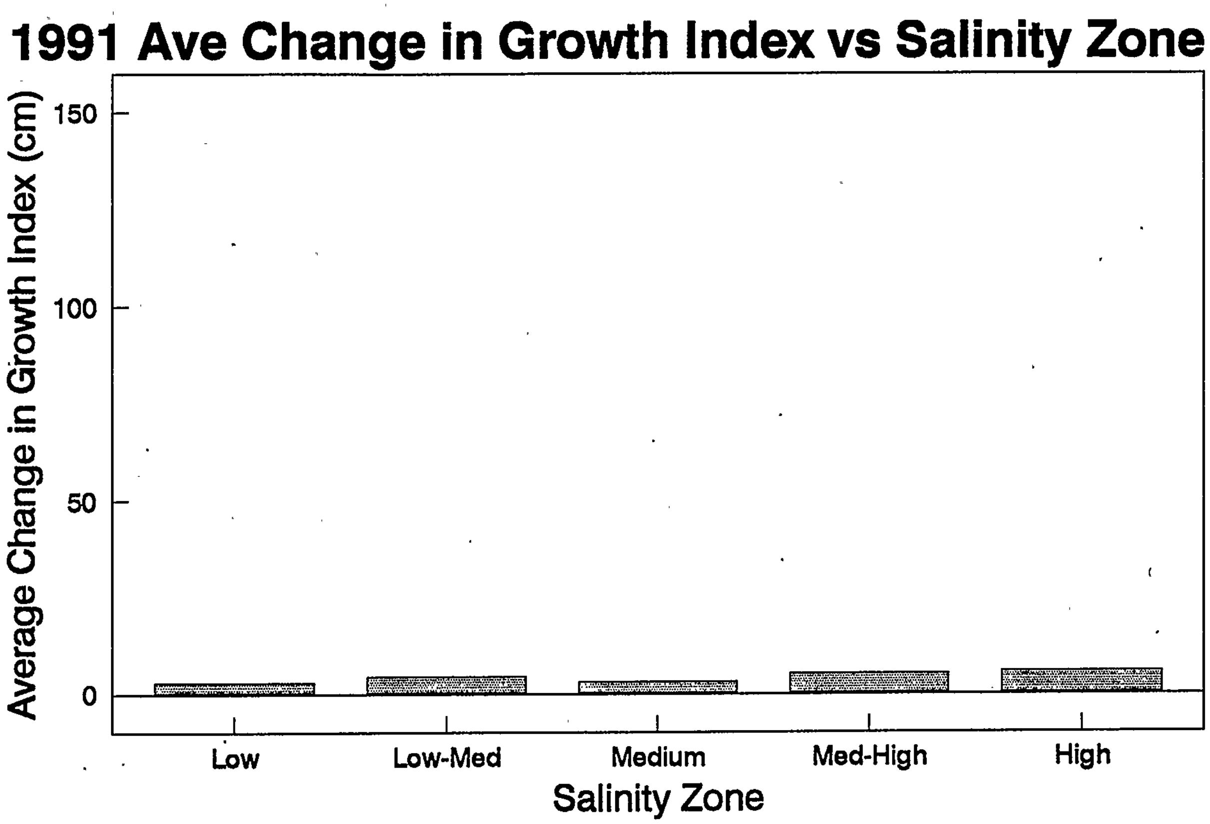
As with the growth, the mortality rates of bur oak are irregular and have no discernable trend. The overall mortality rate is very high. Bur oak is a slow grower and has high mortality. For these reasons, it is not recommended for transplanting in the plains region of southeastern Alberta.



The graph of the response of growth to soil salinity for Russian olive is pictured above. Russian olive has rapid overall growth. The rate of growth is maintained over the first two salinity zones and increases slightly in the third. The slight increase may be due to increasing amounts of soil moisture associated with increasing soil salinity. The growth rate decreases slightly over the highest two salinity zones. Optimal growth rates are maintained over the first four salinity zones (1.7 to 8.8 dS/m). Russian olive has been rated as salt tolerant (Monk 1961).

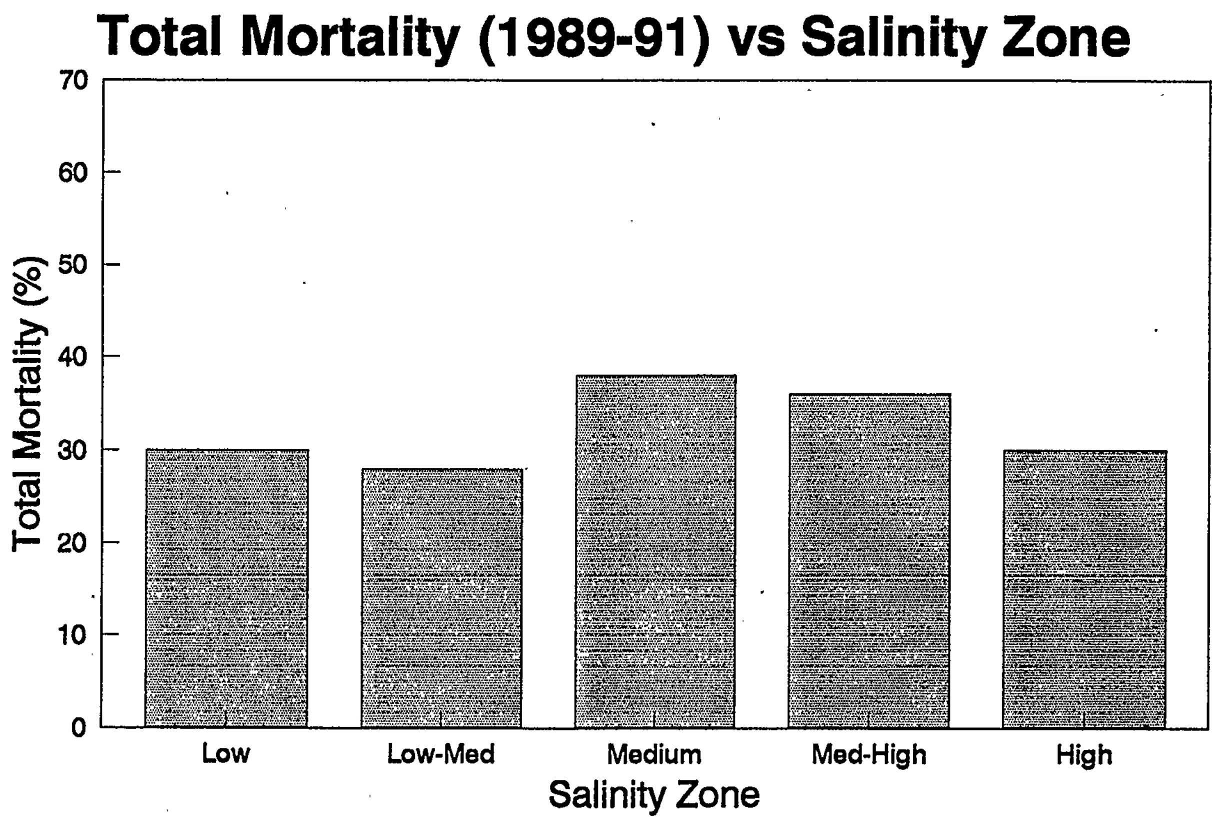


The above graph shows the mortality rate of Russian olive as a function of increasing soil salinity. Overall mortality is very low (less than 5 %) over the four lowest salinity zones and increases only slightly to 5 % for the highest salinity zone. Russian olive is not only a fast grower but has an excellent survival rate throughout the spectrum of soil salinities tested. This conclusion corresponds with the results of another experiment (Monk 1962). Russian olive is strongly recommended for the soils of southeastern Alberta, especially extremely saline soils.



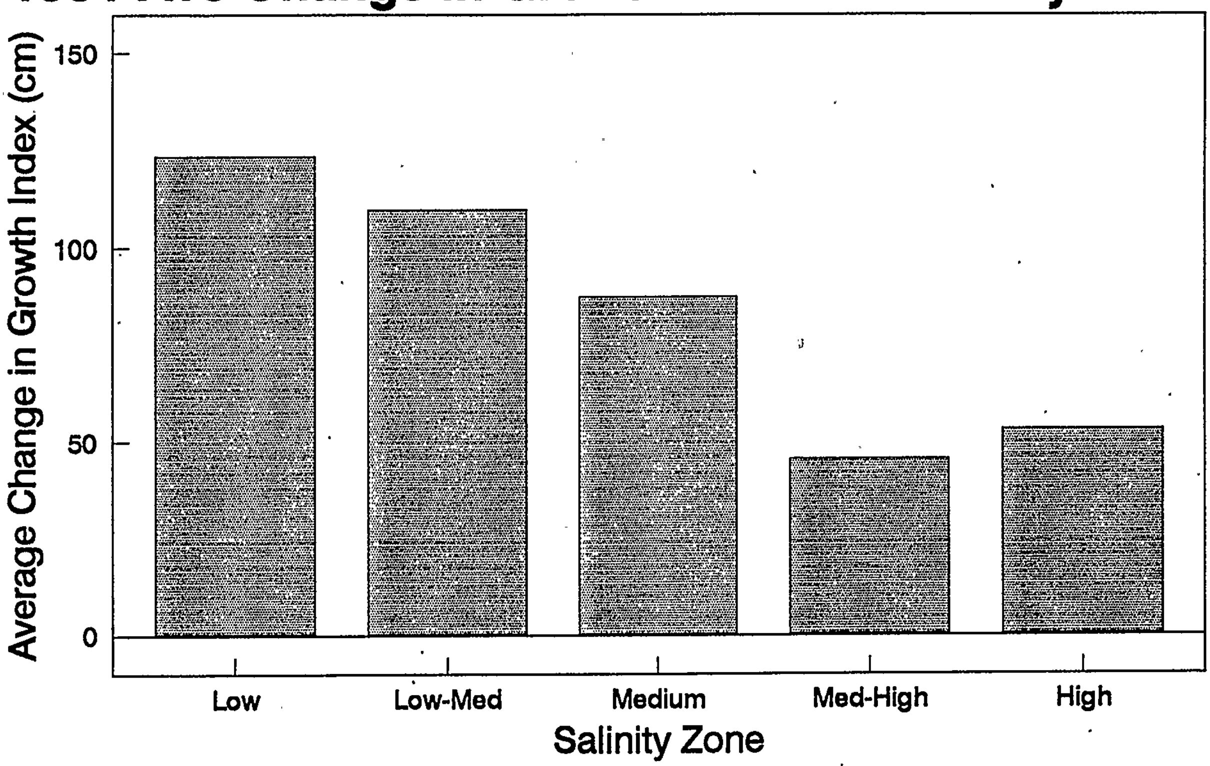
The graph pictured above shows the very slow overall rate of growth for scots pine.

The growth rate appears to remain nearly constant with increasing soil salinity.

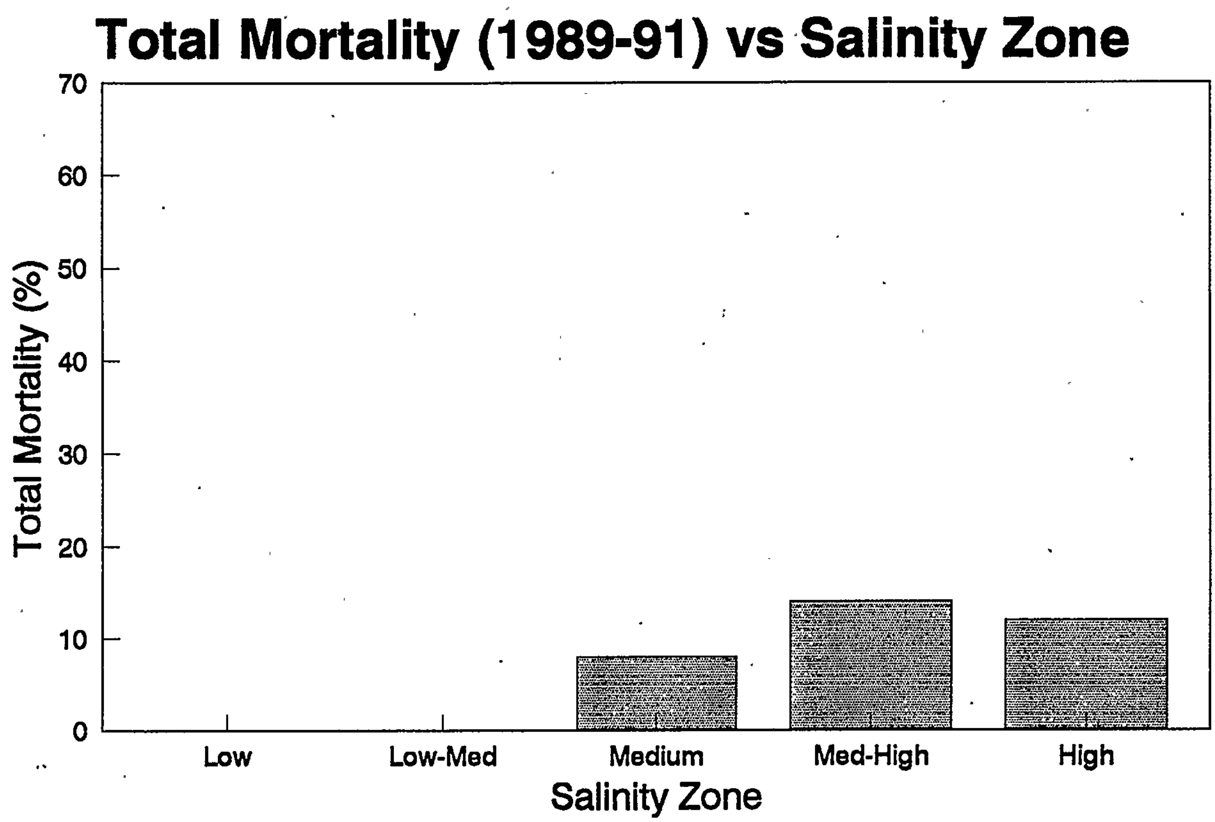


The graph of mortality as a function of soil salinity zone for scots pine is pictured above. Scots pine has a high overall mortality rate. In terms of survival, the critical soil salinity for scots pine is near 6 dS/m (Werkhoven 1966). There is no regular pattern to the information. It may be concluded, however, that scots pine is not suitable for southern Alberta's dry and saline soils.

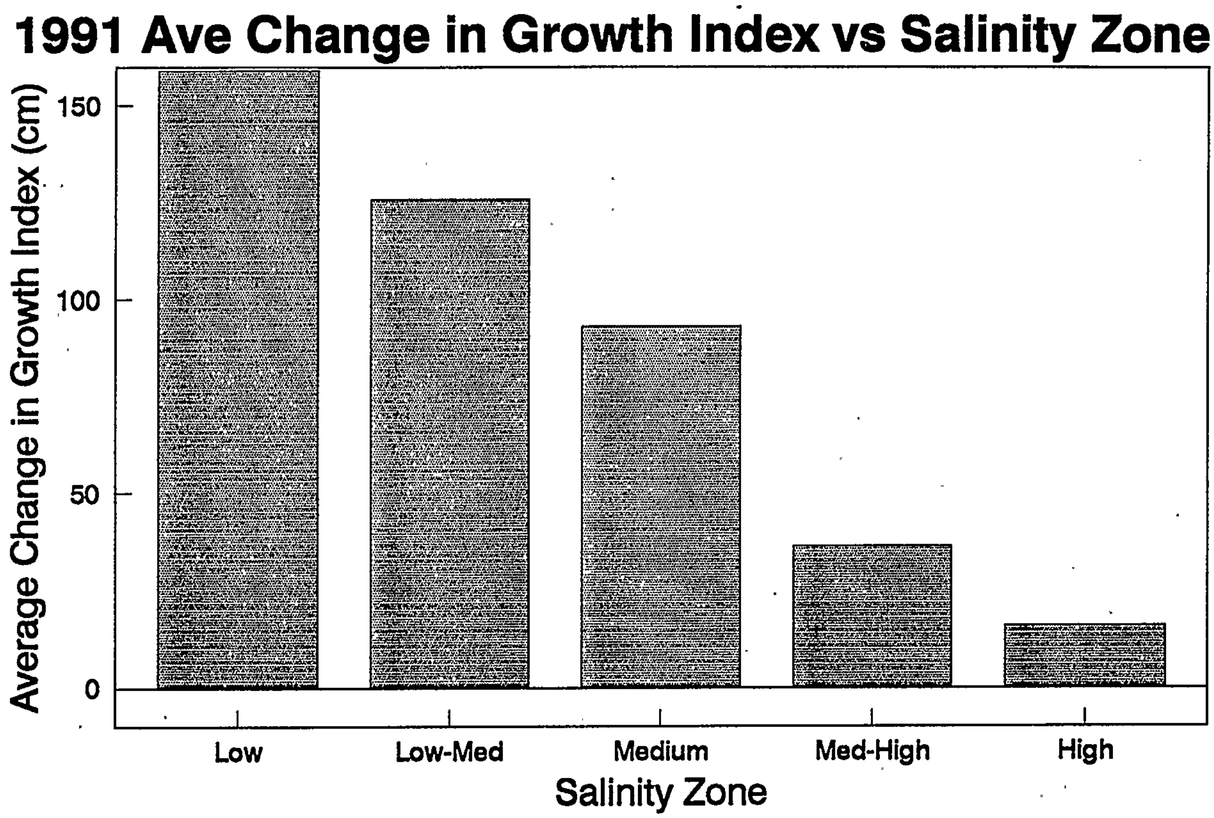
1991 Ave Change in Growth Index vs Salinity Zone



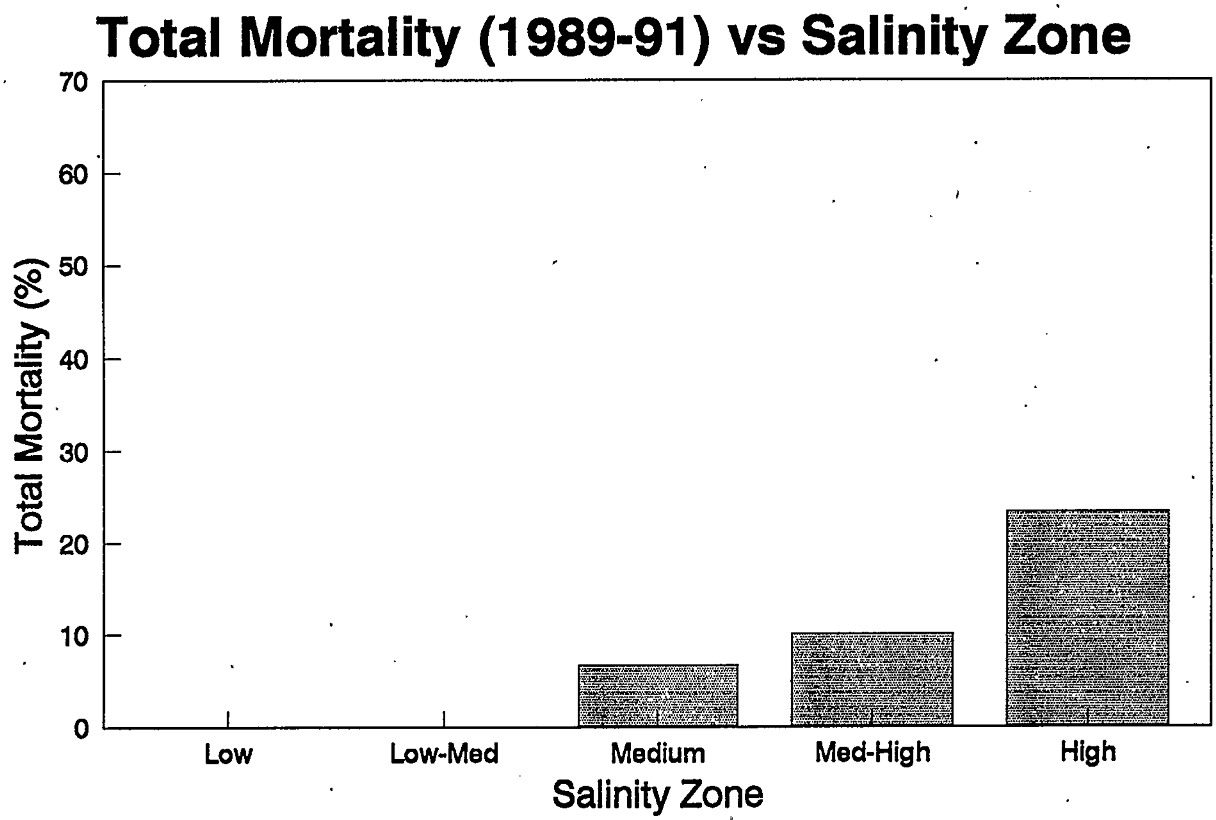
The Brooks poplar is a selection made in the 1970's from natural hybrids that occurred at Brooks. It has a rapid overall growth rate. There is a decline in growth with increasing salinity. The "Low" (1.7 to 4.0 dS/m) salinity zone has the fastest rate of growth. Compared to the other species tested, the Brooks poplar has a rapid rate of growth, even in soils with high salinity.



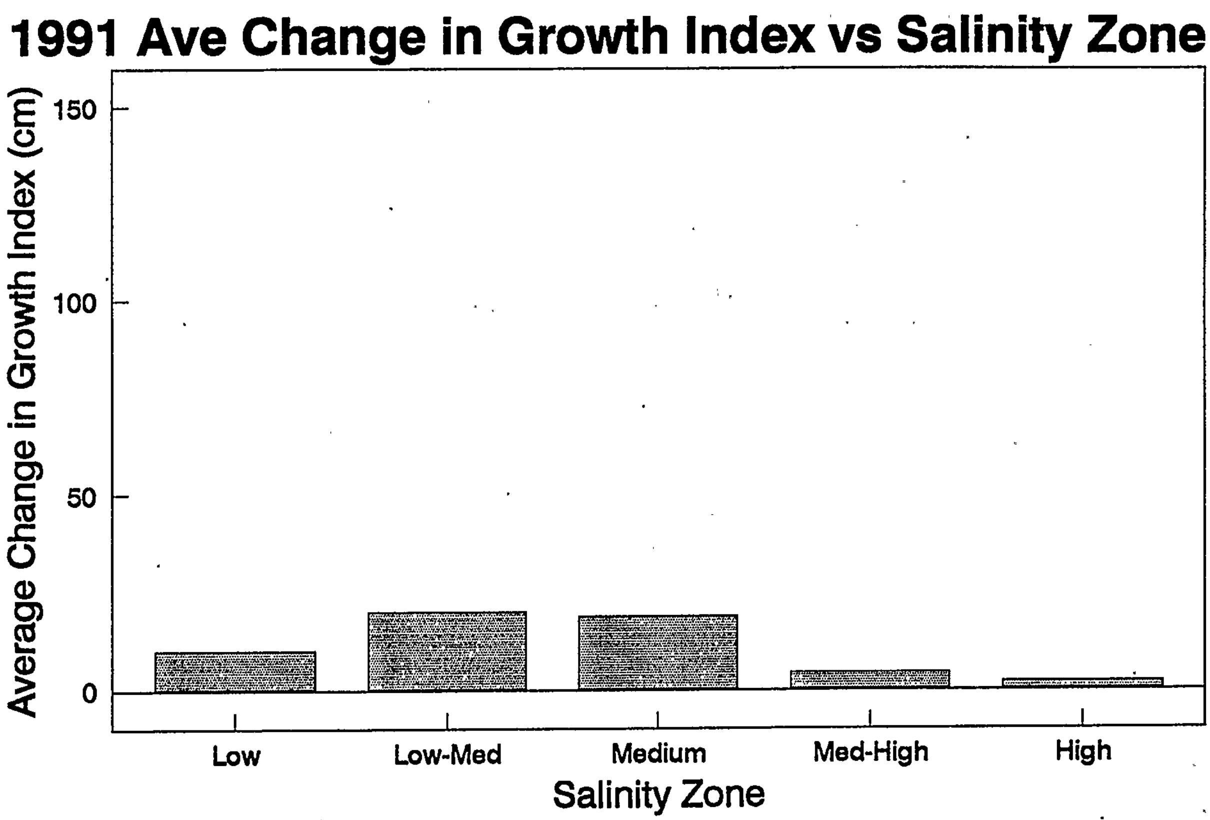
The Brooks poplar had a very low overall rate of mortality. The above graph depicts the total percent mortality of Brooks poplar as a function of increasing soil salinity zones. The first two zones had zero mortalities over the three year growing period. Although the rate of mortality shows a general increase with increasing soil salinity, the highest three salinity zones also have a low rate of mortality. The Brooks poplar is recommended for projects requiring fast growing and hardy trees.



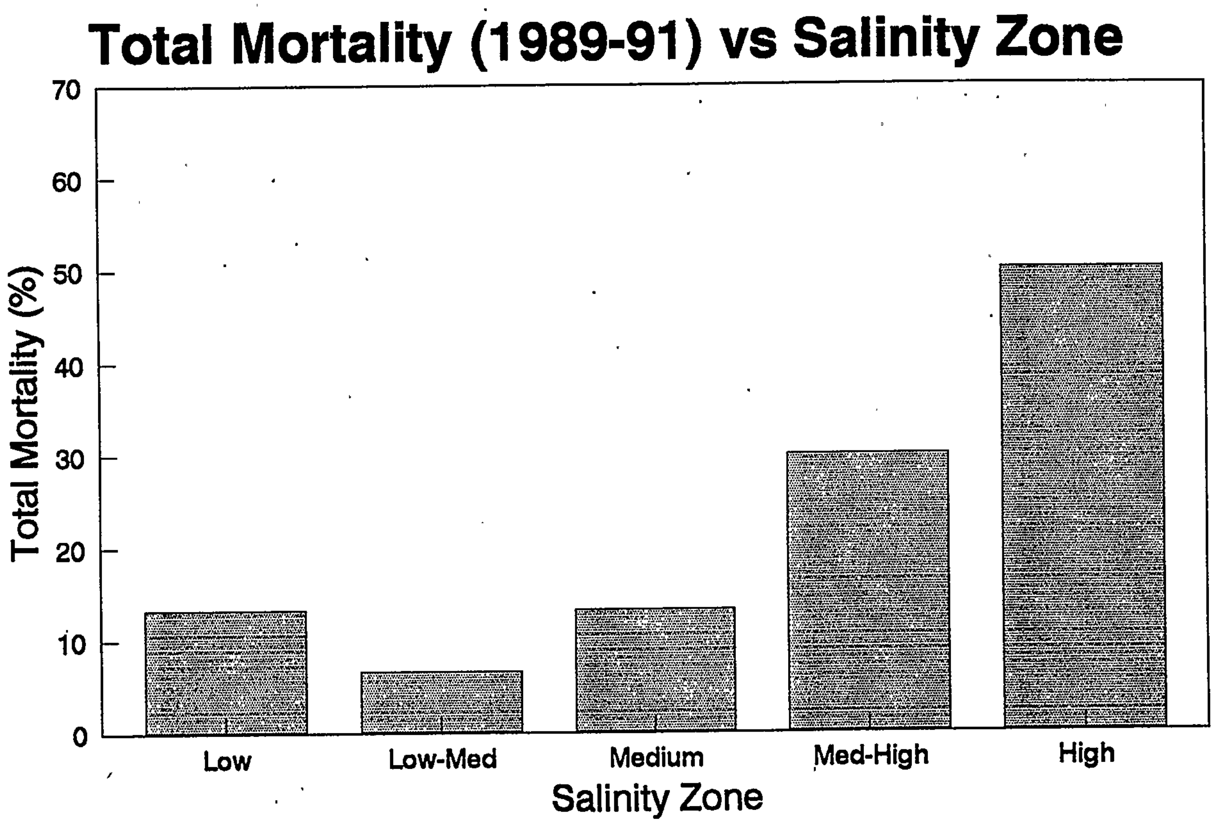
The results for northwest poplar are similar to those found for the Brooks poplar. The above graph depicts the 1991 average change in growth index as a function of soil salinity zone for the northwest poplar. There is a rapid overall growth rate, which declines with increasing soil salinity. The optimum growth occurred in the lowest (1.7 to 4.0 dS/m) salinity zone, however rapid rates of growth continued in soils having salinities as high as 6.9 dS/m.



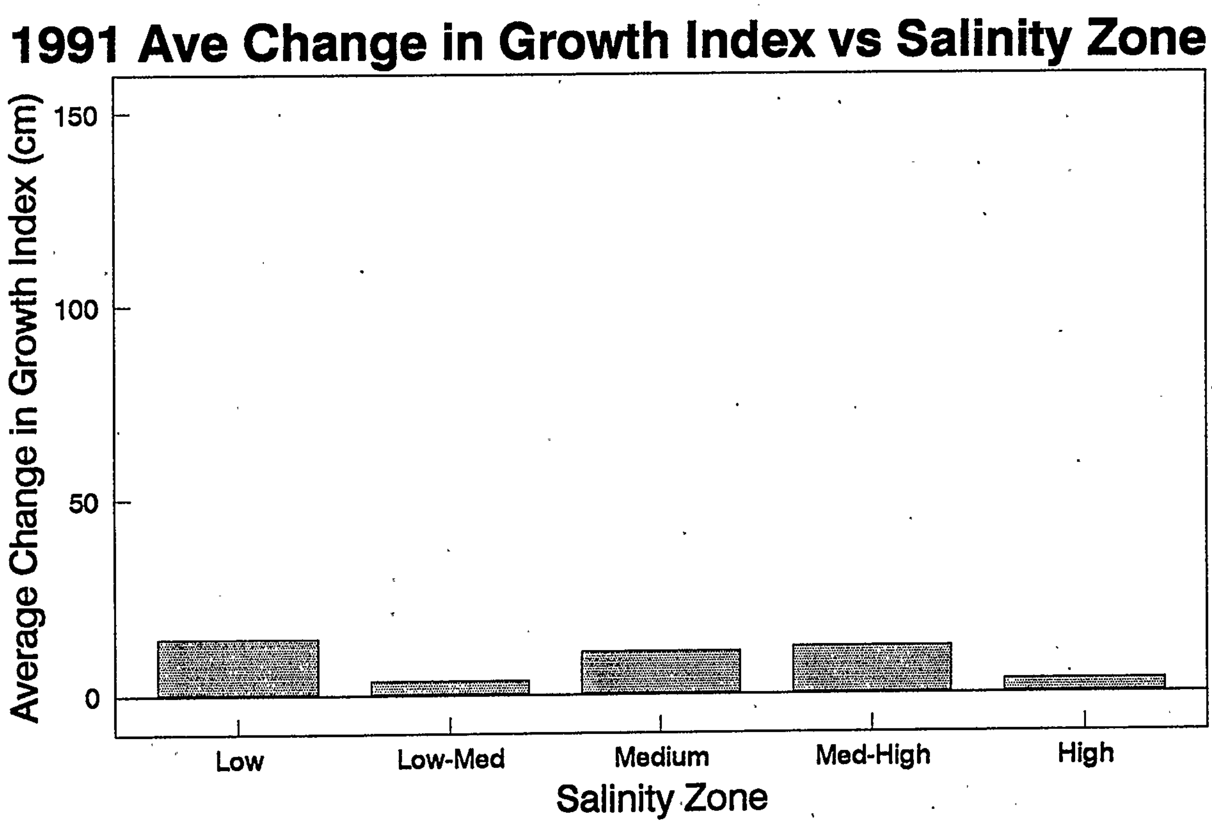
Total mortality versus salinity zone for northwest poplar is pictured above. Northwest poplar, in general, has a low rate of mortality. The lowest two salinity zones (1.7 to 5.1 dS/m) had zero mortalities throughout the three years. A low mortality rate occurs in soils having salinities as high as 8.8 dS/m. The northwest poplar is also a favourable choice for projects requiring fast growing and hardy trees.



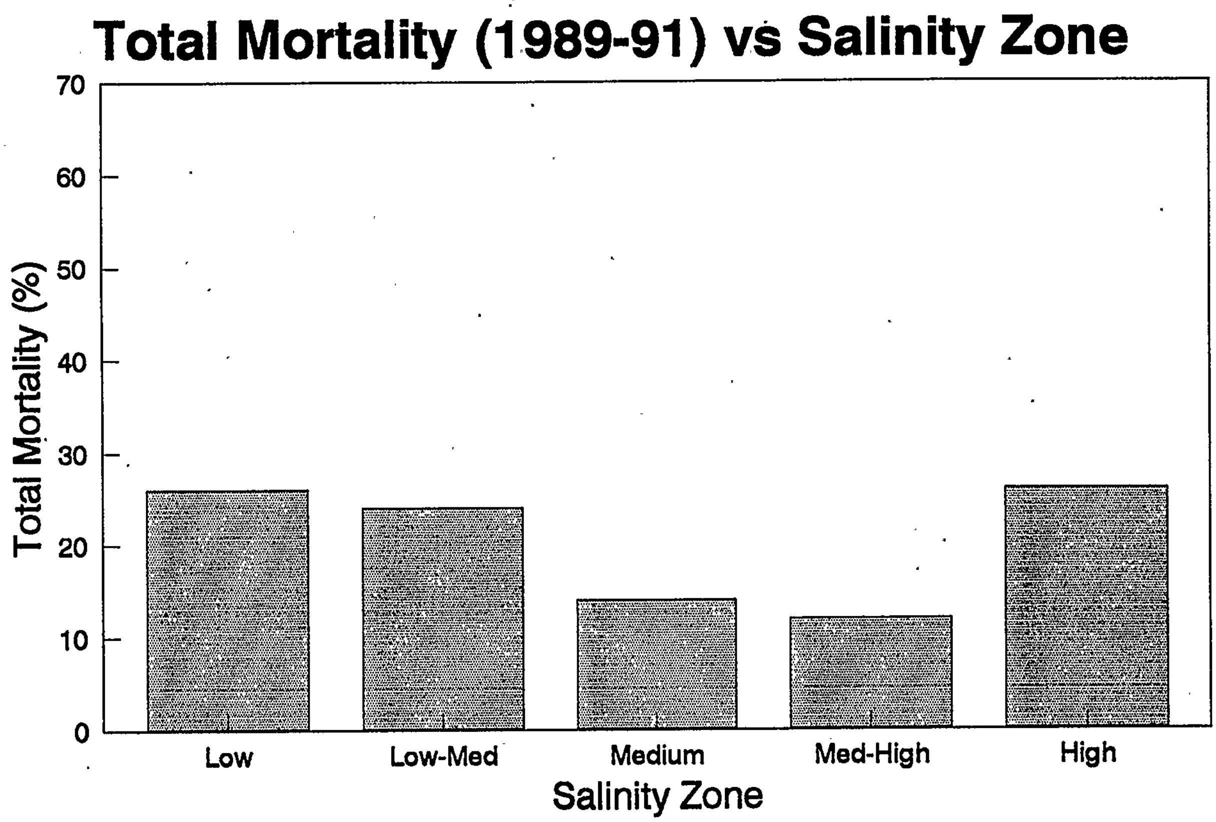
The above graph depicts the data for the change in growth rate of potentilla with increasing soil salinity. In general, potentilla has a slow rate of growth, with an overall decline in growth with increasing salinity. Optimal growth occurs in the second (4.1 to 5.1 dS/m) salinity zone and near to optimal growth occurs in the next (5.4 to 6.9 dS/m) salinity zones. The initial increase in growth may be due to the greater amounts of soil moisture usually associated with saline soils.



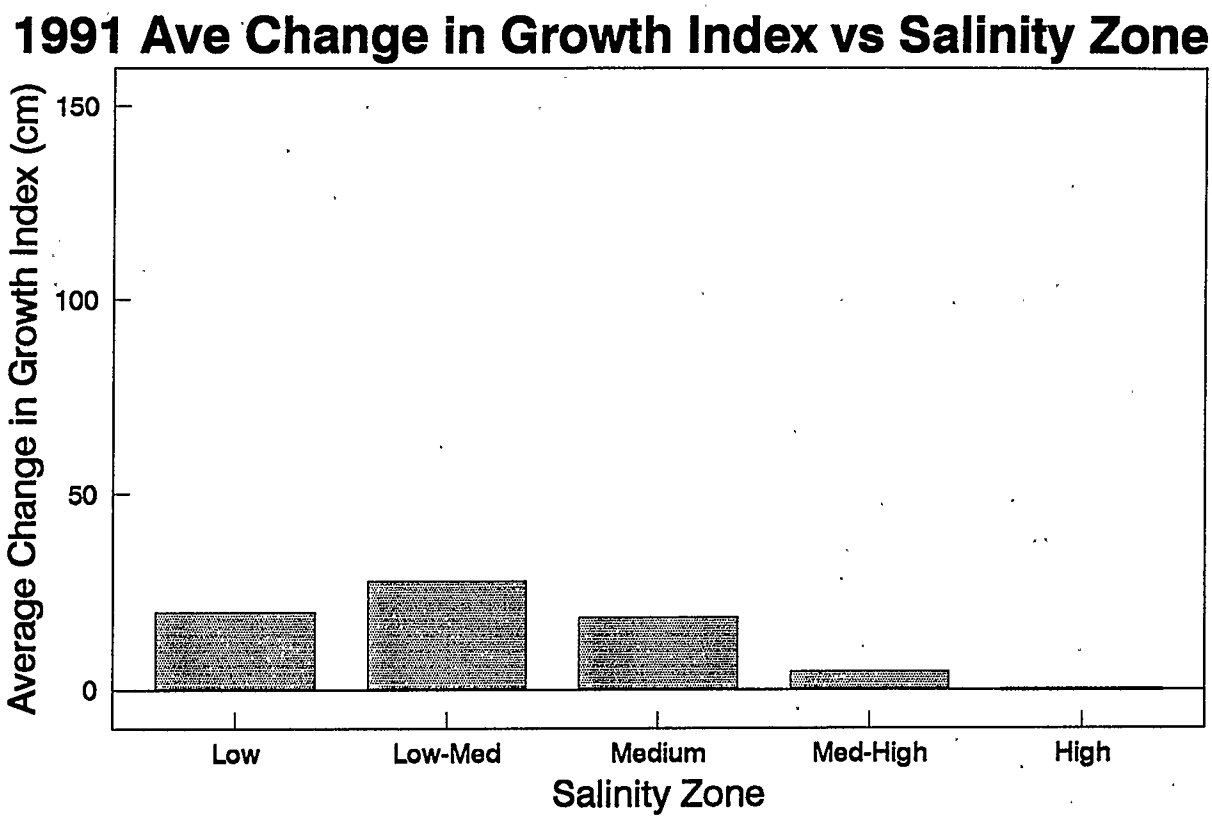
The mortality rate of potentilla increases with increased soil salinity. There is an initial decrease in mortality, which may be attributed to the greater soil moisture often associated with increasingly saline soils. The first three salinity zones (1.7 to 6.9 dS/m) show the optimal rates of mortality.



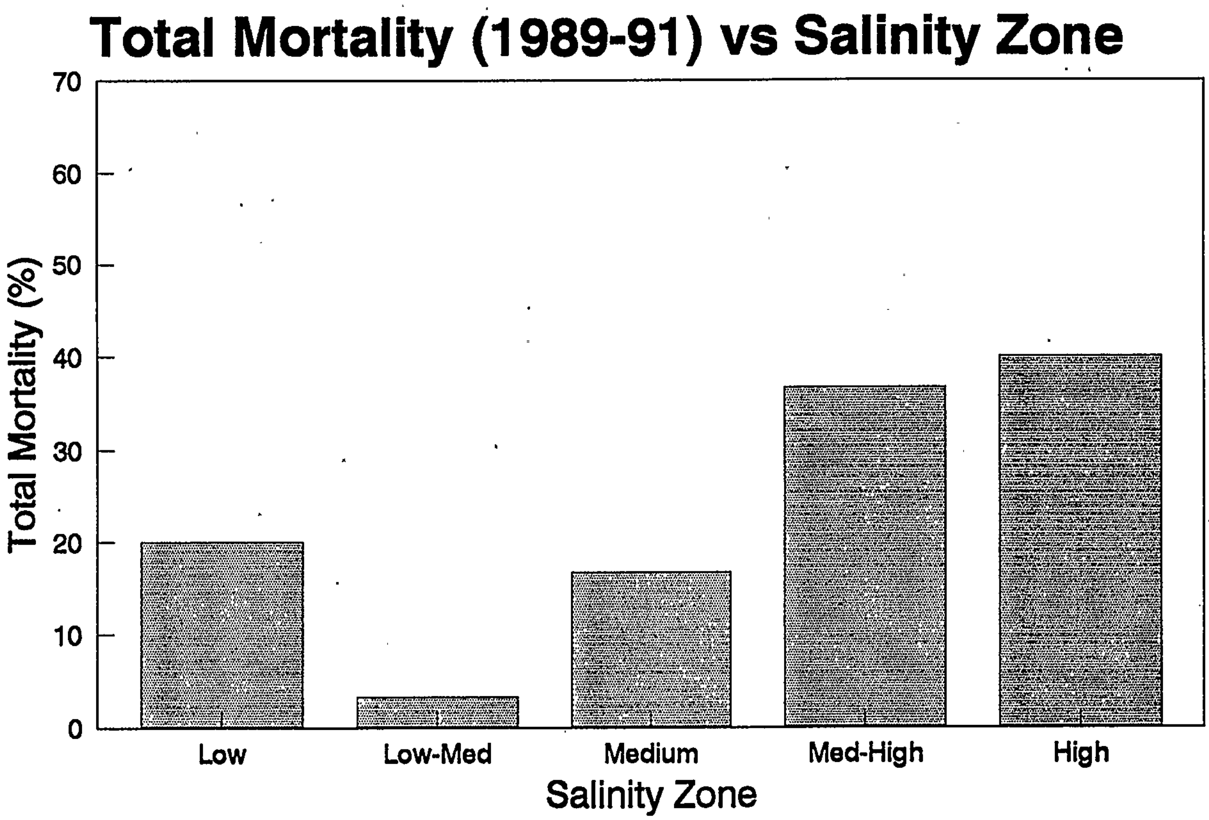
The Siberian salt tree has a slow overall rate of growth. The results depicted on the above graph are irregular. The poor results for Siberian salt tree are due to the small size of transplant material. The trees were seeded into pots in the summer of 1989 and grown in a greenhouse until planted, early in the summer of 1990. The seedlings were transplanted to the field in 1990. Their average size was less than 10 cm in height. In order for a fair evaluation, larger seedlings must be used as transplant material.



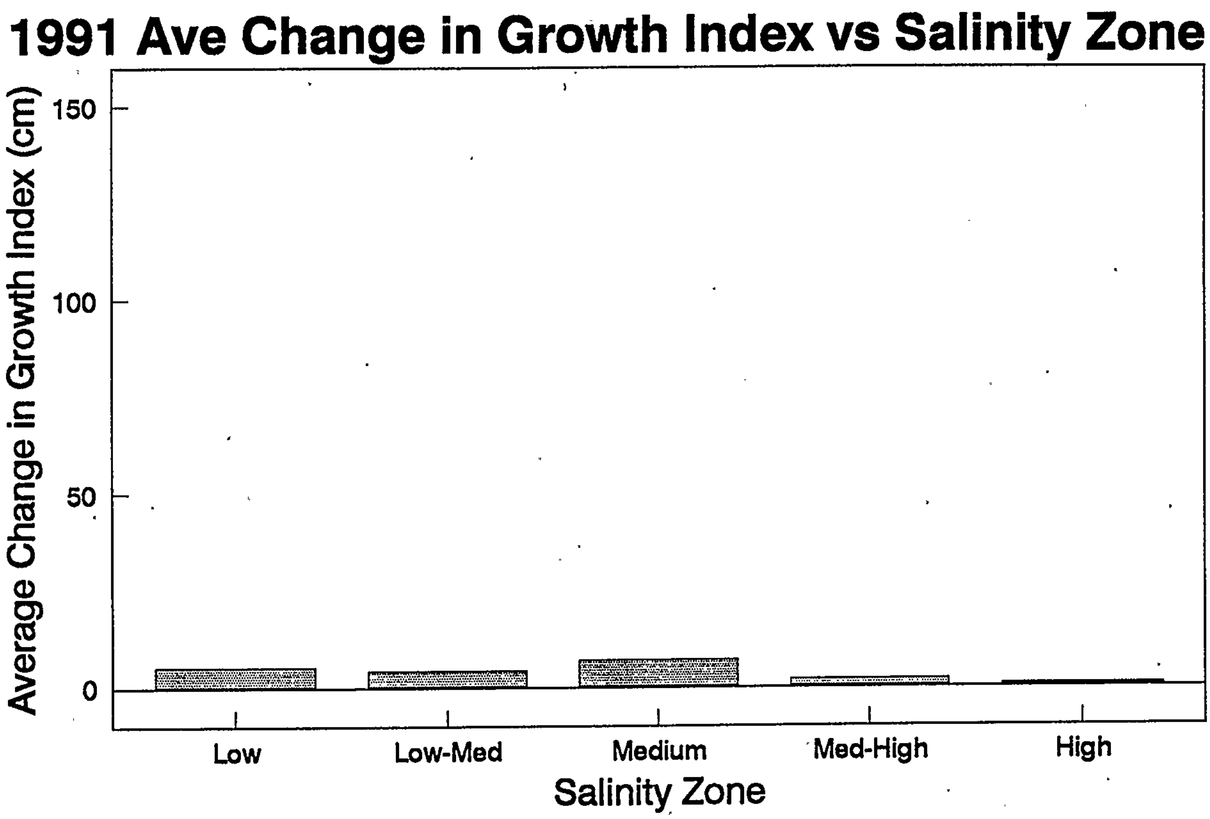
The mortality rates of the Siberian salt tree show unusual results. There is a decline in mortality with increasing salinity over the first four salinity zones and a sudden increase in the highest salinity zone. These unusual results may be a result of the small size of the seedlings or they may indicate a preference for more saline soils. With regard to mortality rates, the optimal range of soil salinity is between 5.4 and 8.8 dS/m. The Siberian salt tree, as its name suggests, is purported to be saline tolerant, however the results shown here are inconclusive.



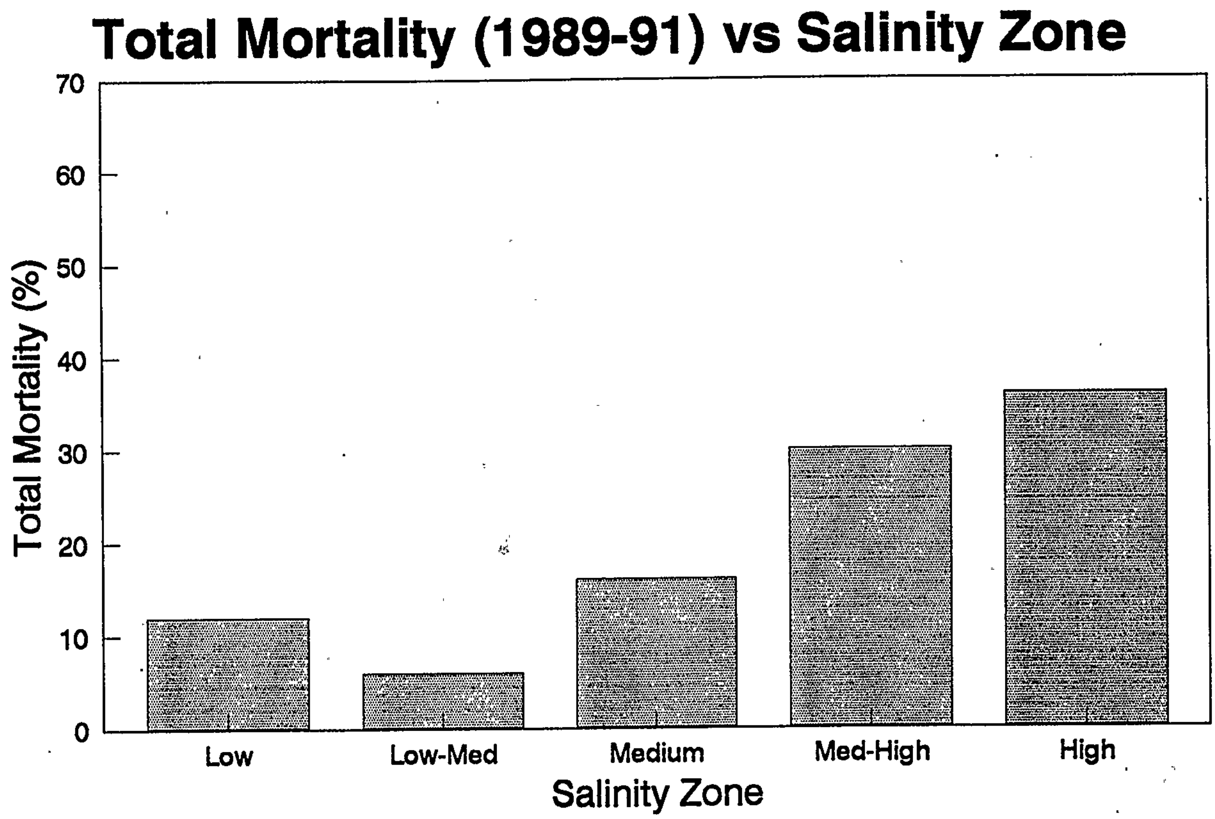
In general, the Saskatoon had slow growth. Suckering took place and was accounted for by the measurement of minimum width (Figure 3.7). There is however an overall decrease in growth rate as soil salinity increases. There is an initial increase in growth rate in the second salinity zone. This may be due to the higher water table that accompanies more saline soils. The optimal salinity zone for the growth rate of the Saskatoon is "Low-Medium" (4.1 to 5.1 dS/m).



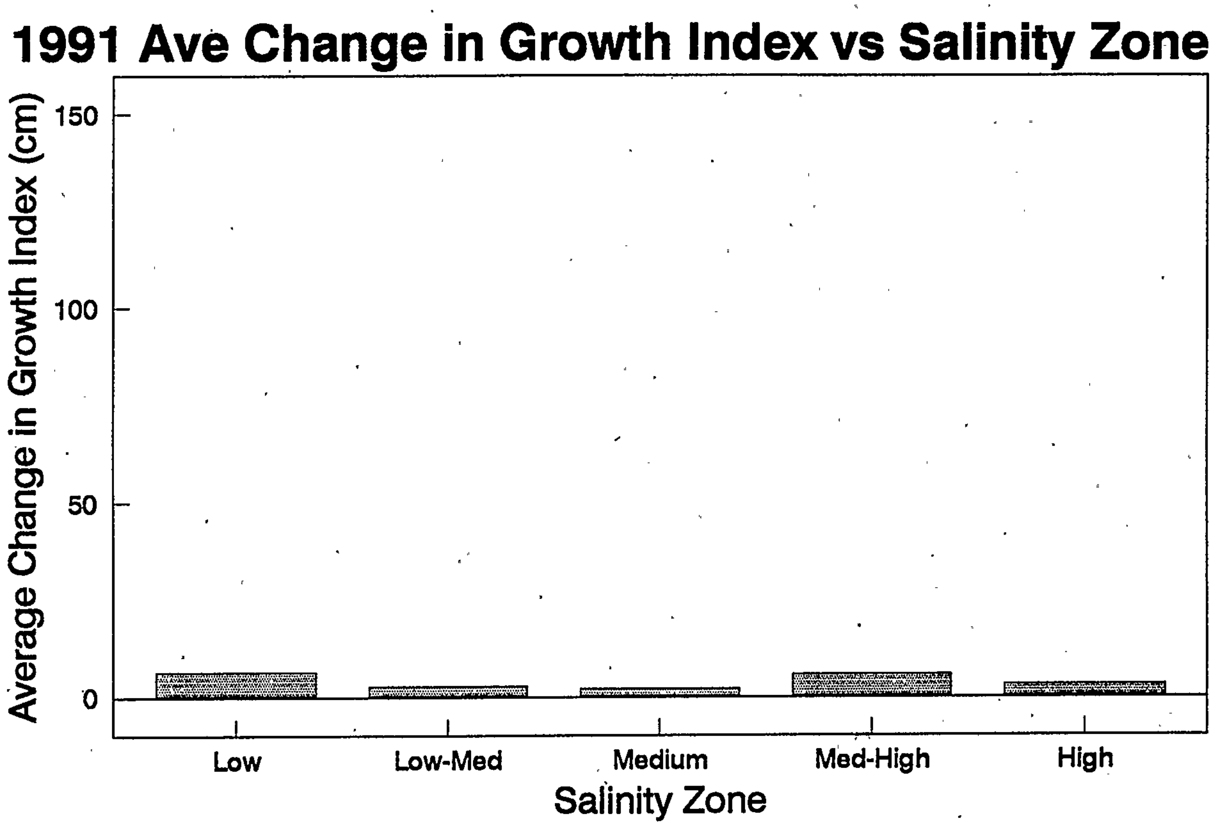
The Saskatoon has a moderate mortality rate, which increases with increasing soil salinity. As with the growth rate, the optimal salinity zone for the mortality rate of the Saskatoon is "Low-Medium" (4.1 to 5.1 dS/m). In the case of the Saskatoon, water may be a limiting factor. The higher water table in the more saline second salinity zone may counteract the possible adverse effects of increased salinity in this zone.



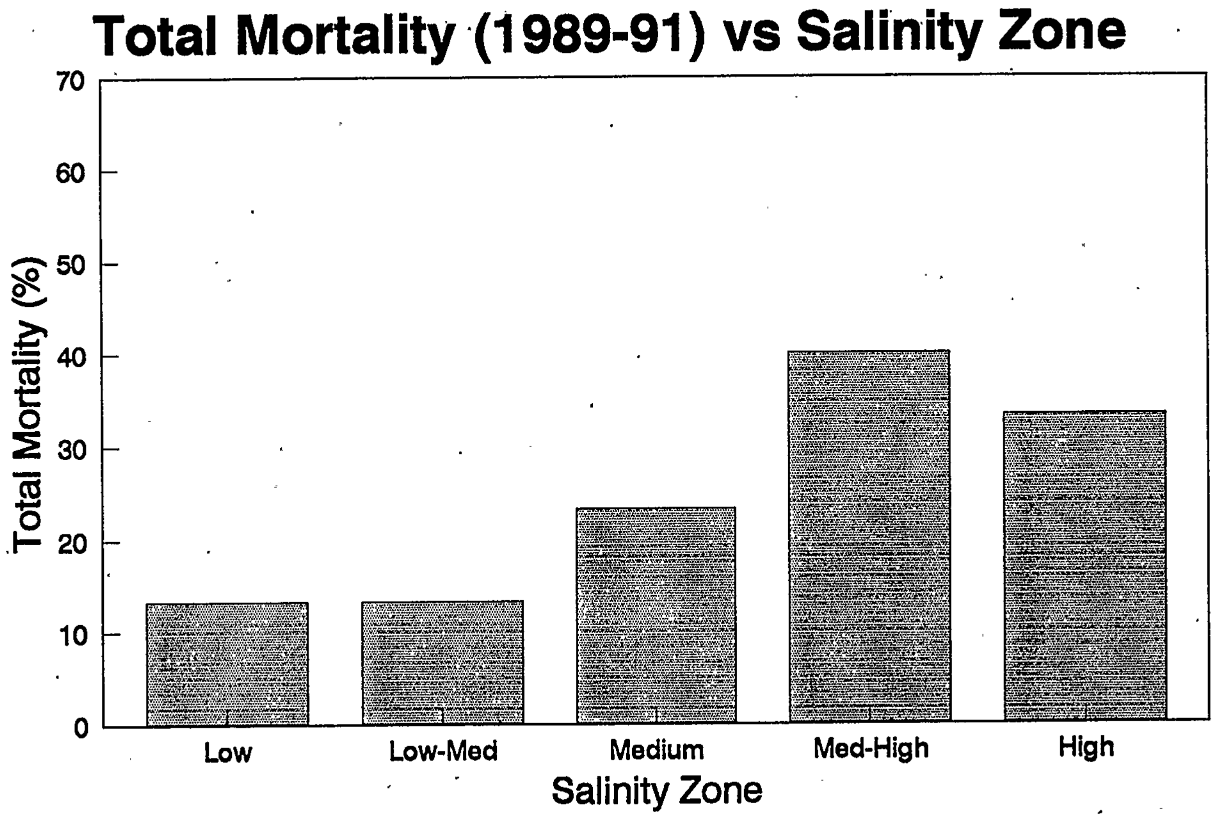
Colorado spruce has very slow overall growth, as shown above. In general, the Colorado spruce did not respond favourably to transplanting. It is difficult to draw conclusions from the above data but there is a discernable decrease in growth with increasing soil salinity. The optimal growth occurred in the "Medium" salinity zone (5.4 to 6.9 dS/m). Other experiments have concluded that this variety is not tolerant to highway deicing salts (Monk 1961 and Monk 1962).



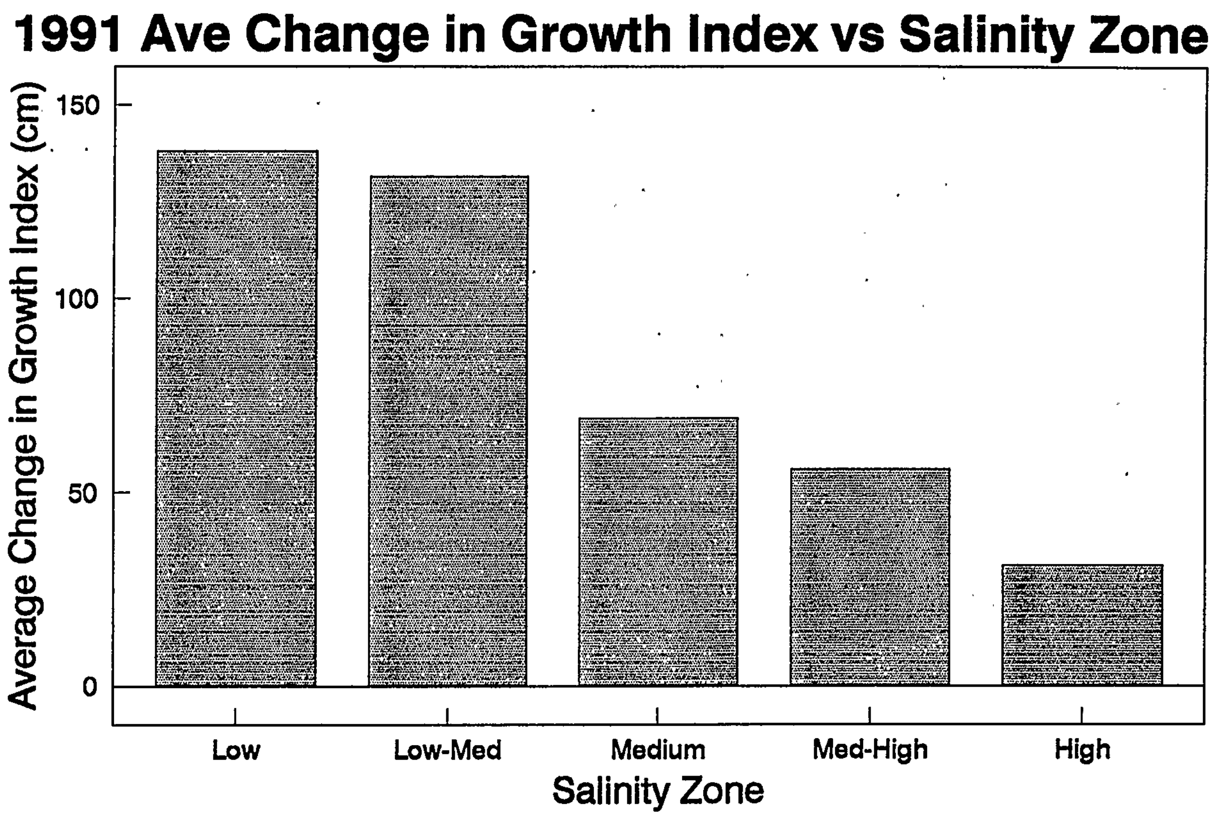
Colorado spruce had a moderate overall mortality rate. There is an initial decrease in mortality, which may be a result of the increased amount of water normally available in more saline soils. The lowest mortality rate, for Colorado spruce, is found in the second salinity zone (4.1 to 5.1 dS/m). One study showed that salinities greater than 4 dS/m were detrimental to Colorado spruce (Werkhoven 1966). As shown above, the rate of mortality increases as soil salinity increases.



White spruce has very slow overall growth, as shown above. As with the Colorado spruce, the white spruce did not respond favourably to transplanting. The information on the above graph is irregular. No conclusions can be made with regard to the response of growth to increasing salinity.

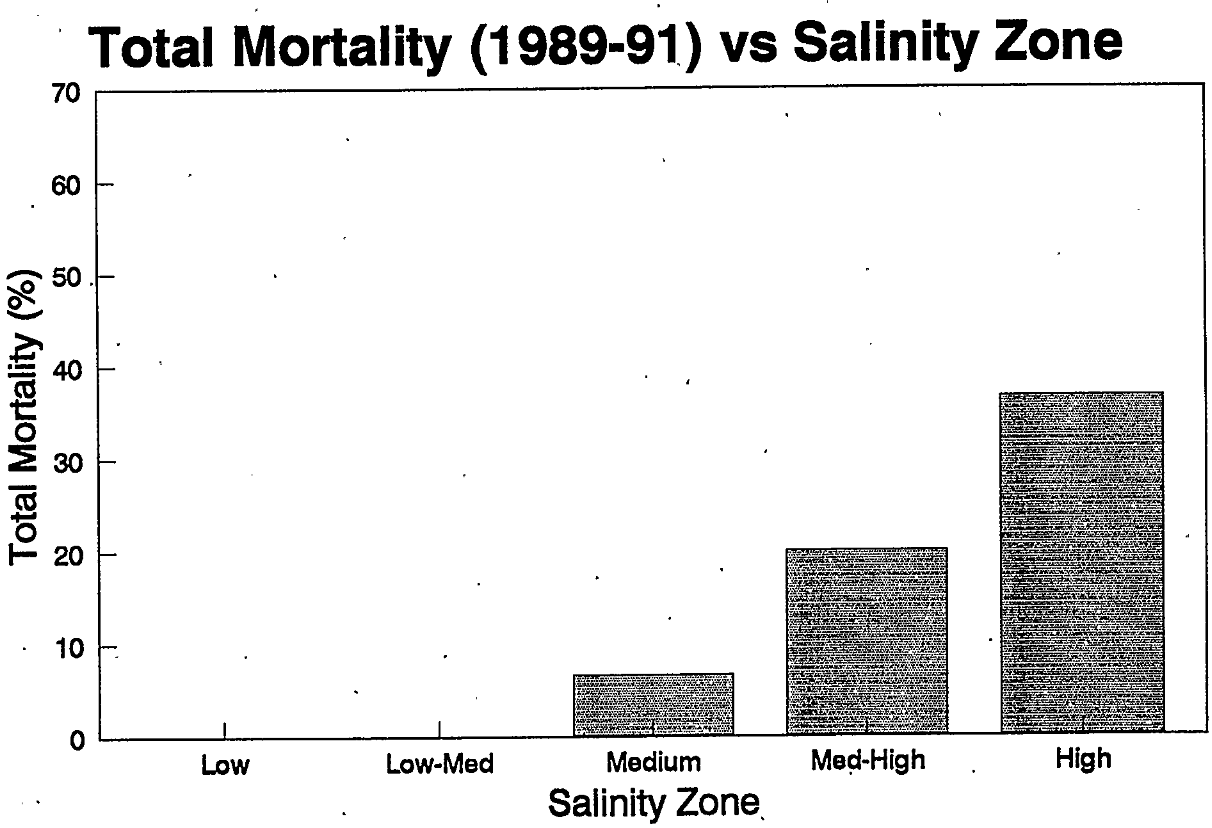


White spruce had a moderate overall mortality rate. As shown above, the rate of mortality increases as soil salinity increases. The lowest mortality rate, for white spruce, is found in the lowest two salinity zones (1.7 to 5.1 dS/m). The needles and stems of white spruce have been shown to hold large amounts of sodium, when subjected to highway deicing salts (Langille 1978).

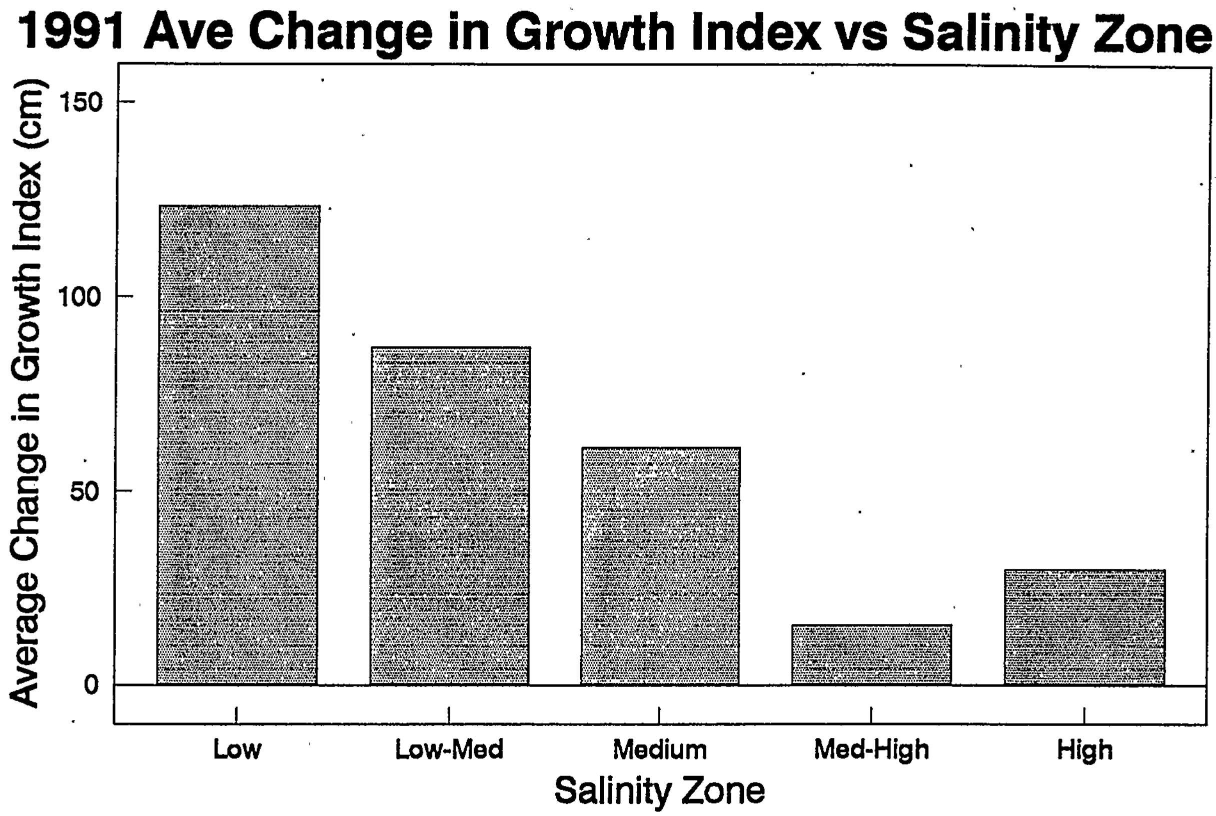


The general rate of growth of the acute leaf willow is very rapid. The above graph demonstrates a decreasing growth rate with increasing soils salinity. The lowest salinity zone (1.7 to 4.0 dS/m) has the fastest rate of growth but the growth rate is also substantial for the second salinity zone.

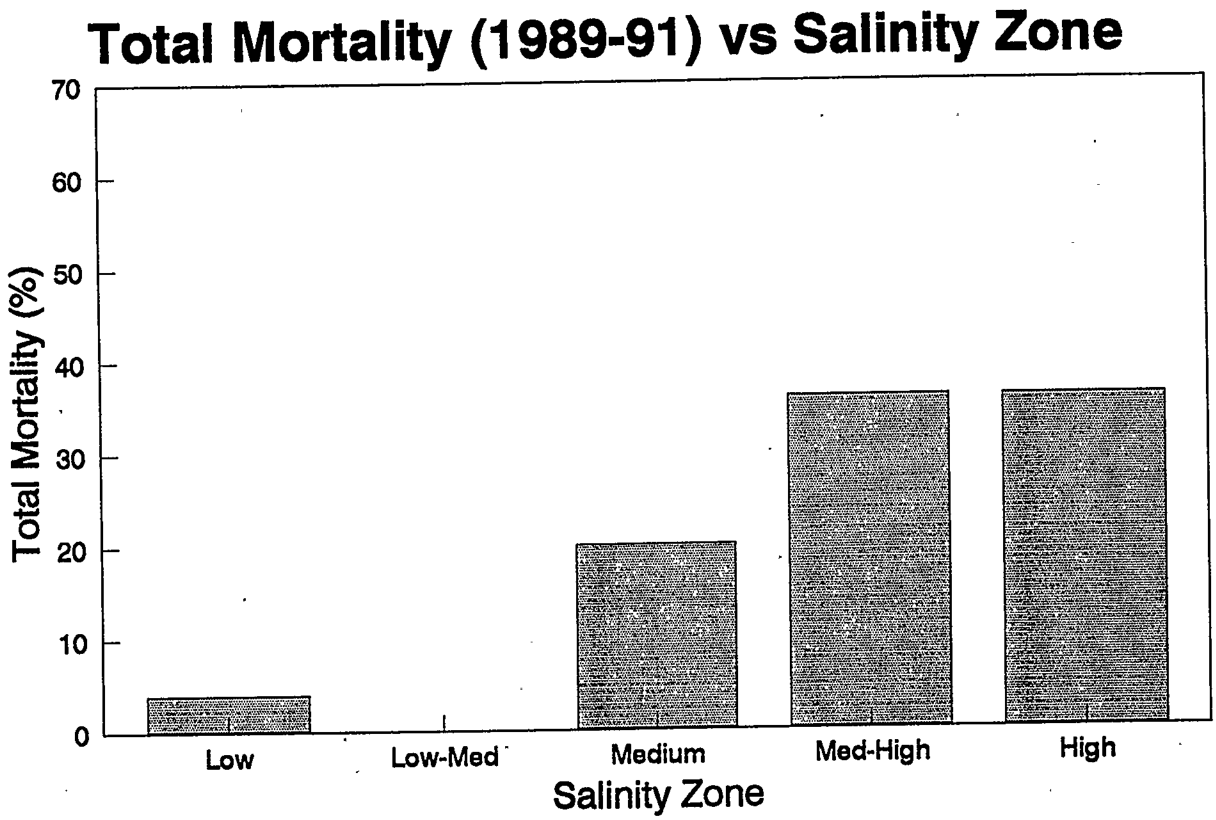
ACUTE LEAF WILLOW



As shown above, the total percent mortality of acute leaf willow increases with increased soil salinity. The lowest two salinity zones (1.7 to 5.1 dS/m) had zero percent mortality for the three year growing period. The acute leaf willow is recommended for sites requiring fast growers and is suggested for soils having electrical conductivities of less than 5.1 dS/m.



The general rate of growth of the laurel leaf willow is rapid. The above graph demonstrates a decreasing growth rate with increasing soil salinity. The lowest salinity zone (1.7 to 4.0 dS/m) has the fastest rate of growth. There is a slight increase in growth rate for the highest salinity zone.



As shown above, the total percent mortality of laurel leaf willow increases with increased soil salinity. The second salinity zone (4.1 to 5.1 dS/m) had zero percent mortality for the three year growing period. The laurel leaf willow is recommended for sites requiring fast growers and is suggested for soils having salinities smaller than 5.1 dS/m.

4.2.2 Discussion

The bar graphs show specific information for each variety, but a general pattern can be identified.

For growth index as a function of salinity zone, there is a general decline in growth as soil salinity increases. For some varieties, an initial increase is followed by a decline on growth. For these, the "Low-Medium" salinity zone shows more growth than the "Low" zone. This indicates that the presence of some soil salts (between 4.1 and 5.1 dS/m) are tolerable, and that soils with small amounts of salts (1.7 to 4.0 dS/m) can be limiting for some species of trees. This may be because a higher water table, and therefore greater soil moisture, is often associated with saline soils. Growth tends to decline for soils having salinities greater than 5.4 dS/m (7.3 for Russian olive).

Some types do not exhibit a pattern to growth as a function of salinity zone. These are dogwood, hawthorn, Siberian salt tree, scots pine and bur oak. For the latter three of these, the small size of the transplant material could be the reason for erratic growth. For the former two, poor condition of transplant material is indicated.

4.3 REGRESSION ANALYSIS

4.3.1 Results

The data were assessed, using the SAS statistical package, to provide a quantitative method of distinguishing between varieties. A regression analysis was run on the 1991 growth index data as a function of horizontal salinity, to determine if there was a relationship between the two variables, and to determine if the relationship was first, second or third degree. The results were used to determine the technique best suited to compare between varieties.

4.3.2 Discussion

The results of this analysis are summarized in Table 4.1. The first degree equation was the predominant relationship found and, therefore, the model used for all subsequent statistical analyses.

Table 4.1 Summary of Regression Analysis

Type of Relationship	Number
first degree	17
second degree	6
third degree	1
none	4

4.4 LINEAR ANALYSIS OF GROWTH

4.4.1 Results

The 1991 change in growth index was tested as a linear function of 1991 horizontal salinity, using a general linear model procedure in the SAS statistical package. In addition to calculating a number of statistical values describing the data, this program also provides an analysis of means for each variety and a numerically ascending list, categorized using significant difference (Waller 1969). The following table summarizes the results of this statistical analysis. This analysis sorts the 28 tree varieties in order from fastest to slowest growing specimens. Those marked with an asterisk are prone to suckering.

Table 4.2 1991 Average Changes in Growth Index (cm) of 28 Types of Trees and Shrubs Across All Salinity Zones.

Rapid growth	Moderate growth	Fair growth	Slow growth	Very slow growth
Northwest Poplar* (86.0)	Manitoba maple (47.7)	Amur maple (25.1)	Paper birch* (15.0)	Hawthorn (6.1)
Acute leaf willow* (85.1)	Sea buckthorn (42.9)	Mountain ash (24.8)	Saskatoon* (14.0)	Scots pine (4.3)
Brooks poplar* (83.8)	Green ash (40.3)	Columbia crab (22.2)	Potentilla (11.0)	White spruce (4.1)
Russian olive* (80.9)	Dogwood* (37.1)	Nanking cherry* (20.3)	Siberian larch (9.9)	Colorado spruce (3.7)
Laurel leaf willow* (63.3)	Caragana* (35.0)	Mayday* (18.8)	Siberian salt tree (8.9)	Bur oak (-2.2)
		Common lilac* (17.9)	Prince of Wales Juniper (7.3)	
		Villosa lilac* (17.6)		

4.4.2 Discussion

The analysis of means shows that one group ("Rapid growth") had growth significantly greater than all of the others. This holds true for soils having from 43 to 91 ppm of nitrogen and from 37 to 55 ppm of phosphorous. The laurel leaf willow had the slowest rate of growth for this group, but it still had significantly faster growth than the "Moderate growth" group. The slowest growing were white and Colorado spruce and bur oak. The negative value for the rate of growth for bur oak is due to there being more die back than growth, for a majority of the specimens.

4.5 LINEAR ANALYSIS OF NORMALIZED GROWTH

4.5.1 Results

The same procedure was used to analyze the 1991 normalized growth index as a function of 1991 horizontal (0-60cm) salinity, again including an analysis of means.

The following table summarizes the results of the statistical analysis of the 1991 normalized changes in growth index. This analysis was an attempt to rate the trees by their ability to grow as well in saline soils as in non-saline soils.

Table 4.3 Salinity tolerance as measured by 1991 average normalized growth index.

Good salt tolerance	Moderate salt tolerance	Fair salt tolerance	Poor salt tolerance	Very poor salt tolerance
Russian olive (0.67)	Northwest poplar (0.44)	Villosa lilac (0.32)	White spruce (0.21)	Saskatoon (0.16)
Brooks poplar (0.54)	Green ash (0.43)	Amur maple (0.30)	Mayday (0.20)	Scots pine (0.16)
Caragana (0.53)	Laurel leaf willow (0.39)	Nanking cherry (0.29)	Siberian salt tree (0.20)	Hawthorn (0.11)
Acute leaf willow (0.50)	Common lilac (0.38)	Prince of Wales Juniper (0.28)	Siberian larch (0.19)	Bur oak (-0.12)
Manitoba maple (0.49)	Mountain ash (0.37)	Columbia crab (0.27)	Colorado spruce (0.18)	
	Dogwood (0.36)	Paper birch (0.24)		
	Sea buckthorn (0.36)			
	Potentilla (0.35)			

4.5.2 Discussion

As indicated in Chapter 3 (methods), the calculation of normalized growth index was an attempt to eliminate unfair comparisons between fast and slow growing trees. The results from the analysis of normalized change in growth index show Russian olive to be superior to all other varieties tested. This means that the Russian olive was best able to maintain its growth, even in highly saline soils. Brooks poplar, caragana, acute leaf willow, Manitoba maple, northwest poplar and green ash also scored well. The poorest results for normalized change in growth index were for bur oak.

4.6 LINEAR ANALYSIS OF SURVIVAL

4.6.1 Results

Statistical analysis was also done on the mortality data for each variety, which also appear in the right hand side bar graphs in section 4.2.1. Again, a linear model was used.

In order to have the results list the species in order from highest to lowest rates of survival, the variable percent survival was used.

Replants may have been required more than once at any given site, so it was theoretically possible to have a total percent survival of less than zero. This, however, did not occur. The calculation of percent survival takes into account the total number of specimens per variety (30 or 50), therefore it is a useful value for comparing between varieties.

The following table shows the results of the statistical analysis for the measure of percent survival, which was calculated from the total percent mortality. These results demonstrate the hardiness of each type of tree or shrub.

Table 4.4 Survival rates of 28 trees and shrubs (Columns listed in decreasing hardiness).

Excellent survival rate	Good survival rate	Moderate survival rate	Fair survival rate	Poor survival rate
Caragana (97.4)	Green ash (94.8)	Common lilac (89.3)	Colorado spruce (80.0)	White spruce (74.5)
Russian olive (96.4)	Columbia crab (94.0)	Acute leaf willow (87.3)	Sea buckthorn (80.0)	Mountain ash (72.0)
	Brooks poplar (93.2)	Hawthorn (84.0)	Siberian salt tree (79.6)	Siberian larch (70.8)
	Villosa lilac (92.7)	Nanking cherry (83.2)	Potentilla (77.3)	Scots pine (67.6)
	Northwest poplar (92.0)	Amur maple (82.8)	Saskatoon (76.7)	Bur oak (66.0)
	Manitoba maple (91.3)	Laurel leaf willow (80.8)	Mayday (76.4)	Paper birch (57.6)
	Prince of Wales Juniper (91.3)			
	Dogwood (91.2)			

4.6.2 Discussion

Caragana, Russian olive and green ash had the highest rates of survival. Scots pine, bur oak and paper birch had the lowest rates of survival, requiring the most replants per site. Examination of the statistical results shows that the range of survival rates is between 57.6 % (paper birch) and 97.4 % (caragana). The high overall survival rates may be due to the high degree of care taken during the planting process and due to the fact that the specimens were irrigated and weeded regularly.

4.7 SUMMARY

The statistical interpretation from the previous sections provided three lists which rank the varieties of trees and shrubs according to three different characteristics.

1. Total growth
2. Normalized growth
3. Survival

Each of these lists may provide useful information applicable to specific needs. In order to provide more general information in a summary form, an overall rank was assigned to each tree (Table 4.5).

The ranking values were calculated by converting the mean values of the dependent variables to a scale ranging from 1 to 100. A value of 1 corresponds to the best (most desirable) mean score and 100 the poorest.

This was done for each of the three sets of statistical results. The slope (m) and intercept (b) of the conversion line is given at the bottom for each of the three lists. For these conversion equations, the x axis is the mean value and the y is the ranking value.

The resulting three ranking values for each variety were then added together, giving a possible range of "ranking value totals" from 3 to 300. A lower value indicates a "better" overall performance. For this calculation, it was assumed that each of the three rankings was of equal importance. If this is not the case with a specific project, a formula could easily be developed to apply this same technique.

$$Total_v = (I_g \times R_g) + (I_n \times R_n) + (I_s \times R_s)$$

For this formula, the I represents the relative importance of that characteristic to the specific project and the R represents the rank of the specific variety (v) for each characteristic: growth(g), normalized growth (n) or survival (s).

For example, if a reclamation project requires fast growing trees, then the first list (R_g) will be most important and the third (R_s) of some importance. Therefore, I_g will be assigned a larger number than I_s and I_s a larger value than I_n. For the calculations in Table 4.5, I_g, I_n and I_s were all assigned the value of one.
It must be noted that these values should in no way be interpreted as a quantitative description of the trees or their corresponding data. These values are merely a numerical method to qualitatively rank the trees. This technique, however, should not be dismissed as it is both useful and flexible.

Table 4.5: Summary of Results

VARIETY NAME	RANKING VALUES			OVERALL RANKING
	GROWTH (R_g)	N-GROWTH (R_n)	SURVIVAL (R_s)	
Russian Olive	7	1	4	12
Brooks Poplar	3	17	11	31
Acute Leaf Willow	2	23	26	51
Northwest Poplar	11	30	14	55
Caragana	58	18	1	77
Manitoba Maple	44	24	16	84
Green Ash	52	32	8	92
Laurel Leaf Willow	26	36	42	104
Dogwood	56	39	16	111
Sea Buckthorn	49	40	44	133
Columbia Crab	73	51	10	134
Villosa Lilac	78	44	13	135
Common Lilac	77	37	21	135
Amur Maple	69	47	37	153
Prince of Wales Juniper	89	50	16	155
Nanking Cherry	75	49	36	160
Mountain Ash	70	38	64	172
Potentilla	85	41	51	177
Mayday	76	60	53	189
Siberian Salt Tree	88	60	45	193
Hawthorn	91	71	34	196
Saskatoon	82	65	53	200
Colorado Spruce	93	63	44	200
White Spruce	93	59	58	210
Siberian Larch	86	61	67	214
Scots Pine	93	65	75	233
Paper Birch	81	55	100	236
Bur Oak	100	100	79	279
SLOPE (m)	-1.12	-125.29	-2.49	
INTERCEPT (b)	97.51	84.89	243.20	

4.8 CONCLUSIONS

Upon examination of the totals in Table 4.2, it is apparent that a number of varieties have proven to be outstanding and three inferior. This empirical data concurs with the intuitive information gained from the experience of working in the field for three seasons with these varieties.

Russian olive, Brooks poplar, caragana, northwest poplar, acute leaf willow, green ash and Manitoba maple proved to be the hardiest and easiest to establish, even in increasingly saline soils. The scots pine and bur oak were poor overall and are not recommended for use on the saline soils of southern Alberta. For these two varieties, as well as the Siberian salt tree, the small size of the transplant materials may have been a contributing factor to their substandard results.

CHAPTER 5 APPLICATIONS

5.1 INTRODUCTION

Information on the salinity tolerance of ornamentals has relevance to both the urban and the rural landscape. The information can be applied to immediate short term problems and can also be applied to long term benefits.

Some urban uses may be the planting on boulevards of salted roadways, the creation of barriers for sound or for visually offensive spaces and the landscaping of areas with saline soils.

Examples of rural applications may be soil erosion prevention through farmland shelterbelts and land reclamation projects, especially those with salinity problems.

5.2 URBAN APPLICATIONS

5.2.1 Salted Roadway Boulevards

Twig dieback is most severe in locations receiving the most deicing salts (Sucoff 1976). Dudley (1991) identified a problem in Calgary, Alberta, where the salting of roadways has had a fatal effect on surrounding trees. She described alternatives to salting roads in winter, but recommended use of salt tolerant species as the most feasible solution. In this case, the results of the statistical analysis of normalized growth index (section 4.5) should be referred to. For boulevards and sidewalks which are next to salted roads, Russian olives would be the most desirable. If these are not preferred because of their sharp thorns or because of their shape, size, colour or texture, Brooks poplar and caragana are other alternatives. An example for the use for the formula presented in section 4.7 may be a project to replace the trees along a roadway where deicing salts are applied. For this project priorities may be high survival, which translates into cost savings, and salt tolerance, which provides as even a stand as possible throughout a range of soil salinities. Speed of growth may not be important. The project manager may decide to assign values to the relative importance factors of; $I_g=0$, $I_n=2$ and $I_s=3$. When these are placed in the formula, the resulting formula,specific for this project becomes:

$Total_v = 2xR_n + 3xR_s$. When calculations are made for each variety, by this formula, Russian olive and caragana compute to be the most desirable. These two varieties are also prone to suckering (Table 4.2), which may be a desired characteristic.

5.2.2 Visual Barriers

When industrial areas infringe upon residential developments, aside from the possible health factors that must be considered, the issue of the quality of the vista arises and may affect property values, as well as quality of life. Where the possibility of danger to human health and safety has been eliminated, the creation of visual barriers may be advantageous to the developer or home owner. When this is the major objective for a project, fast growing species are the most desirable. For projects such as this, the results from the analysis of growth index (Table 4.2) are of interest. Northwest poplars, acute leaf willows, Brooks poplars and Russian olives would all be candidates for planting. If a shrub was more beneficial here, then the fastest growing shrub may be selected from the list; dogwood and caragana both rank well.

5.2.3 Sound Barriers

Related to visual barriers, is the use of trees and shrubs as sound barriers. When a busy roadway is built adjacent to a residential area or *vice versa*, the noise can be extremely disruptive and also have a negative effect on property values.

An economic and possibly more attractive alternative to two meter high cement walls is a sound barrier made of trees and shrubs. Another advantage is that trees and shrubs have a variety of surfaces to deflect noise in many directions, rather than straight back to where it came from, replacing noise with the soothing sound of rustling leaves. Vegetative sound barriers can be taller than cement ones without taking on the appearance of a bunker. Vegetative sound barriers can also be used in combination with cement fences to increase the effectiveness of the sound barrier and to mask the appearance of the cement fence. A home owner can use a variety of species for a combination of thickness and height. An added benefit is that salt tolerant species can be chosen, if it is near a salted road (Table 4.3). For example, a combination of Russian olive and caragana may be effective.

5.2.4 Home Landscaping

In the case of home landscaping, cost is often the most important variable to the home owner. In order to keep landscaping costs down, it is necessary to choose hardy trees which will not be difficult to establish and will not require replacement. In this case, a high rate of survival (Table 4.4) is necessary. The potential landscaper can see that a good number of trees show excellent survival rates. This provides a wide range of choices and, subsequently, a wide variety of shapes, textures and colours to choose from.

5.2.5 Wildlife Habitat

The presence of trees and shrubs will attract wildlife, particularly birds. This can create a more pleasant environment and is desirable for both urban parks and boulevards, as well as private dwellings. If deicing salts are used nearby, soil salinity can hinder the establishment of many types of trees and shrubs. If this is the case, there are several varieties that have shown good salt tolerance (Table 4.3), especially Russian olive.

5.3 RURAL APPLICATIONS

5.3.1 Farm Land Shelterbelts

Shelterbelts are commonly used to lessen soil erosion. Revel (1985) describes four characteristics of a shelterbelt which affect its efficiency. These are:

1. length
2. height
3. density
4. orientation

The length of à shelterbelt affects the horizontal distance protected, on both the windward and leeward sides. Its height is proportional to distance before the wind returns to the ground. The increasing density of a shelterbelt leads to decreasing wind velocity; however it also leads to the quick return to ground of high velocity winds. For this reason, the optimum wind penetration has been suggested to be 35 to 50 percent. The optimum orientation of a shelterbelt is at a right angle to the prevailing wind.

In addition to decreasing wind erosion of soil, shelterbelts have other benefits. They increase snow accumulation and therefore soil moisture and they have been shown to increase productivity. There are some problems associated with shelterbelts. They result in a lack of uniformity in crop height and ripening and cultivation dates. This causes difficulties with modern agricultural machinery (Revel 1985).

If however, the decision has been made to plant a shelterbelt, there are a number of factors to consider when choosing the types of trees to use. Because height and density are so important, fast growers will be the most desirable, both those that grow tall and those that are bushy. Examples are poplars and caragana. The presence of the shelterbelt will cause an increase in snow accumulation and soil moisture, which may lead to an elevation of the water table and soil salinity. For this reason, a degree of salinity tolerance may also be a desirable trait. Two more factors which should also be considered and are possibly the most important to the farmer are the cost and availability of specific varieties. Because prices and availability can fluctuate, this information should be sought just prior to planting.

5.3.2 Land Reclamation Projects

After decommissioning, many former industrial sites are left with marred soil that may not sustain the types of vegetation that are required, particularly when native vegetation is the ultimate goal. In the cases where soil salinity is the limiting factor, saline tolerant species can be planted to prevent soil erosion and to assist in breaking up the soil horizon. More saline tolerant species can be grown until the soil is appropriate for introduction of the desired species. In this case both salinity tolerance and speed of growth would be of interest, therefore change in growth index (Table 4.2) and normalized change in growth index results (Table 4.3) should be referred to. Other factors of importance are also cost and availability.

5.4 BUSINESS APPLICATIONS

The EM38 salinity meter can be used to diagnose the presence of a soil salinity problem and to estimate its severity. This information would be useful to landscapers, nursery growers and persons involved in landscaping and maintaining parks, golf courses and cemeteries. Providing this service to interested parties presents an opportunity for establishing a business.

The Brooks Campus of Medicine Hat College, which is located West of Brooks on the Trans Canada Highway, required a soil salinity map of its property for its long range landscape plan. Because the soil surrounding the new building is on poorly drained soil, salinization was of particular concern to the landscape planner. The first step of this survey was an examination of the area to be mapped. The area was then staked, at intervals of 5 meters to give a visual indication of columns to be followed. On March 31, 1992, the vertical (0-1.20 m) EM38 salinity measurements were then taken at 2 meter intervals and recorded using a Tandy portable computer. The EM38 measurements were then transferred to a PC computer, where they were converted to paste extract equivalent values (EC_e). At this point, suspiciously high salinity values were eliminated and the remainder were mapped using the Geosoft software and a Hewlett-Packard plotter. The maps and information regarding the salinity tolerance of ornamental trees and shrubs were then presented to the landscape planner. The entire process required 22.5 hours, and approximately 6.7 hectares of land were surveyed.

Several problems were encountered during the course of the project. The first was that thick and tall ground cover prevented access to two locations on the site. The vegetation became entangled with the wires connecting the portable computer and the salinity meter, causing the disconnection of the two. This problem was dealt with by manually recording a few sample measures, in the affected area, and inputting these values directly into the PC. Another solution to this problem could have been better preparation of the site, by elimination of unruly vegetation, prior to taking the salinity readings.

Another problem which was encountered was the presence of metal near or under the soil surface. Because the salinity meter operates on the principles of electrical conductivity, proximity to metal (a good conductor) produces an artificially high conductivity reading. In the case of this project, the area surveyed was bordered on two sides by a barbed wire fence, and conduit in the cement near the building also produced interference. Once the EM38 salinity readings were converted to EC_s, the suspicious measures could be identified by their location and unusually high values (greater than 12 dS/m). The problem was resolved by identifying and eliminating these numbers. This did not interfere with the overall effectiveness of the salinity map because of the large total number of values recorded (nearly three thousand).

The final problem which was encountered during the course of this project was a limitation in the software used for mapping the values. The Geosoft program will not produce maps for small data sets (3 columns by 60 rows). For the purposes of this project, visual examination of the numbers and estimates of the average salinity were adequate. For another project, this form may not be appropriate and another software package should be sought.

This project demonstrated that the EM38 salinity meter is a quick and inexpensive method of measuring soil salinity and therefore can be applied to both small and large scale projects. The high degree of customer satisfaction showed that this is a valuable service and the resulting information will be used in the development of the landscape plans. This project demonstrated that the service of providing salinity maps and salinity tolerance information is both feasible and desirable.

The predominant range of soil salinities recorded on the site was between 6 and 9 dS/m, which corresponds to the "Medium-High" salinity zone (Table 3.2). The varieties best suited to this site are those with good salt tolerance (Table 4.3). Russian olive is most highly recommended.

CHAPTER 6 CONCLUSIONS

Soil salinity can result in greatly reduced yields and is a growing problem. There are a number of techniques which are effective in managing soil salinity. One is the use of salt tolerant species. Twenty eight types of trees and shrubs were tested for their tolerance to soil salinity and were ranked according to growth (Table 4.2), salinity tolerance (Table 4.3) and percent survival (Table 4.4).

It was found that, for the majority of the varieties tested, growth rate and survival rate decrease with increasing soil salinity. Five varieties showed no discernable pattern relating growth and survival rates to soil salinity. These were dogwood, hawthorn, Siberian salt tree, scots pine and bur oak. For these five the small size or poor condition of the transplant material may have resulted in the irregular results.

A formula was developed (section 4.7), which allowed the 28 types of trees and shrubs to be ranked based on their growth, salinity tolerance and survival rate (Table 4.5). Russian olive ranked highest overall, followed by Brooks poplar, northwest poplar and acute leaf willow. In terms of growth and survival, all of these are suitable for planting on southern Alberta's saline soils.

The results of this test can be applied in urban and rural environments. In the urban landscape, this information may be used when landscaping homes and boulevards on salted roadways, and when creating visual and sound barriers and urban wildlife habitats. In a rural setting, this information may be applied to farm land shelterbelts and land reclamation projects. Use of the EM38 salinity meter allows for quick and inexpensive collection of soil salinity information and demonstrates the practicality of a business to provide this service.

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APPENDIX A: Growth, Salintiy and Mortality Data

GREEN ASH					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI 1991	REPLANTS 1989-91
		1991	1989-91		
424	2.7	1.12	1.67	74.5	0
226	2.8	0.43	1.32	79.0	0
348	3.1	1.08	1.54	48.0	0
498	3.1	2.65	2.79	48.5	0
52	3.2	1.97	2.16	20.8	0
92	3.3	1.77	2.02	73.6	0
178	3.3	1.25	1.84	94.8	0
149	3.5	2.35	2.49	57.5	0
145	3.6	1.74	2.21	-1.6	0
88	3.7	2.40	2.70	53.0	0
184	4.2	2.13	2.41	64.9	0
165	4.3	1.73	2.38	66.4	0
185	4.4	2.05	2.54	39.8	0
120	4.6	3.88	3.22	89.8	0
722	4.7	3.07	3.60	51.0	0
13	4.7	2.92	3.49	37.8	0
353	4.8	2.01	2.48	66.5	0
285	4.9	2.51	3.25	79.5	0
626	5.0	3.81	4.10	71.8	0
870	5.1	4.32	4.52	94.0	0
405	5.5	3.87	4.27	39.1	0
851	5.6	4.97	4.93	39.1	0
624	5.7	4.83	4.98	53.3	0
863	6.0	4.90	5.52	32.8	0
783	6.1	5.93	5.85	34.3	0
776	6.1	5.71	5.61	16.3	0
637	6.2	4.34	4.76	67.8	0
938	6.2	5.20	5.23	51.3	0
782	6.2	5.44	5.49	49.3	0
925	6.5	5.63	5.68	45.5	0
696	7.4	6.53	6.69	22.0	0
592	7.5	6.87	7.34	9.0	1
1157	7.5	7.49	7.26	1.6	0
763	7.8	7.56	7.20	49.9	0
1234	8.1	6.87	7.05	48.0	0
674	8.4	8.17	8.60	7.0	1
964	8.5	6.96	7.35	49.5	0
837	8.6	9.50	8.86	26.8	0
836	8.6	9.66	9.06	-0.5	1
889	8.7	7.87	7.98	61.1	0
745	8.9	7.66	7.88	47.3	0
912	8.9	9.02	8.75	1.5	1
1048	9.0	8.45	8.25	37.8	0
740	9.2	9.30	9.17	0.5	2
1271	9.2	7.83	8.42	7.3	1
808	9.2	8.56	7.71	5.5	1
817	9.3	9.61	9.67	-1.0	1
504	9.7	10.15	10.05	-2.8	2
891	9.8	8.90	9.52	3.3	1
981	10.0	10.37	10.38	2.3	1

MOUNTAIN ASH					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI 1991	REPLANTS 1989-91
		1991	1989-91		
427	2.3	0.56	1.17	5.8	2
378	2.5	0.91	1.18	59.3	0
395	3.0	2.57	2.59	58.3	0
494	3.0	2.14	2.12	49.5	0
130	3.1	1.10	1.58	58.5	0
144	3.4	1.69	2.14	66.5	0
166	4.5	2.97	3.07	34.0	0
186	4.6	2.21	2.87	52.0	0
66	4.8	3.07	3.26	51.0	0
76	5.0	2.97	3.21	38.0	0
119	5.1	3.32	3.46	53.8	0
518	5.1	4.89	5.13	0.8	2
319	5.5	2.78	3.38	44.3	0
940	5.6	4.76	5.01	18.5	2
709	5.9	4.43	4.83	-18.3	3
700	6.3	5.14	5.63	41.5	0
527	6.3	5.61	6.10	-20.8	2
545	6.5	5.91	6.01	14.5	3
1078	7.4	6.39	6.58	16.8	2
1106	7.7	8.41	7.38	14.5	2
1235	7.9	6.36	6.78	24.8	2
829	8.2	8.48	8.79	-38.0	2
1198	8.3	7.94	8.04	-19.3	2
1072	8.8	6.67	7.20	0.3	1
751	8.9	9.23	9.14	21.0	4
1218	9.8	8.46	8.83	2.0	2
606	9.9	8.23	8.88	62.8	2
812	9.9	7.93	8.38	23.0	2
1287	10.0	9.10	9.69	12.0	3
1251	10.1	7.78	8.93	18.0	4

PAPER BIRCH					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI	REPLANTS
		1991	1989-91	1991	1989-91
446	2.7	1.54	1.79	50.1	1
232	3.0	1.39	1.87	-1.8	2
345	3.1	1.63	2.01	33.4	0
396	3.1	1.94	2.27	-17.5	2
450	3.2	1.66	2.12	27.8	0
233	3.2	1.48	2.03	47.0	0
343	3.4	1.29	1.90	42.4	0
87	3.6	2.49	2.55	30.1	2
273	3.7	1.50	2.16	52.1	1
112	3.7	2.27	2.35	-8.3	2
873	4.3	3.02	3.46	36.0	0
218	4.4	1.97	2.70	15.1	0
524	4.4	3.41	3.97	14.5	1
383	4.4	2.48	2.83	62.1	0
523	4.5	3.82	4.10	14.4	2
488	4.6	4.31	3.76	24.3	2
417	4.7	2.56	3.10	24.1	2
189	4.8	3.00	3.40	43.5	0
942	4.9	4.59	4.82	-5.5	3
409	5.1	3.05	3.47	42.0	2
402	5.4	2.92	3.37	47.0	0
566	5.5	4.42	4.45	46.0	0
634	5.5	4.32	4.45	20.0	1
785	6.1	5.79	5.62	-11.9	3
1173	6.2	6.34	6.32	15.5	2
884	6.2	7.13	6.26	2.0	4
542	6.6	6.54	6.39	13.1	4
1007	6.6	5.46	5.60	-6.8	3
955	6.7	6.83	5.72	34.0	0
1101	6.8	7.80	6.63	4.5	2
961	7.3	6.09	6.07	-10.8	3
534	7.3	8.58	8.03	27.1	3
904	7.5	8.34	7.99	5.0	5
689	7.5	5.65	6.35	10.3	1
886	7.8	7.47	7.45	-14.5	1
905	8.0	7.05	7.42	5.0	3
1233	8.1	7.06	7.26	25.0	2
742	8.1	6.63	6.84	0.3	5
909	8.4	8.88	8.69	6.5	5
1197	8.6	6.31	7.05	-6.5	3
755	9.0	8.05	8.37	6.3	3
668	9.1	8.29	8.98	-2.3	5
1115	9.4	8.54	8.37	-6.0	3
1222	9.4	8.24	7.87	15.5	2
677	9.5	8.89	9.44	6.5	2
1288	9.7	9.58	10.17	-14.3	4
506	9.8	10.58	11.02	1.5	3
1267	9.8	9.33	9.74	-1.0	5
602	10.0	10.45	10.86	5.5	4
1065	10.1	8.15	8.30	-0.3	3

SEA BUCKTHORN					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC 1991	HORIZONTAL EC 1989-91	^ GI 1991	REPLANTS 1989-91
329	2.8	0.96	1.40	87.8	1
324	3.1	1.10	1.64	23.5	1
103	3.1	1.21	1.65	51.5	0
10	3.3	1.24	1.89	73.5	0
312	3.4	1.64	1.98	72.8	0
172	3.5	1.61	2.03	55.4	0
32	3.5	1.58	2.45	49.3	1
340	3.6	1.22	1.86	72.8	1
381	3.6	2.14	2.25	72.3	1
94	3.7	2.28	2.59	67.1	0
459	4.4	2.48	2.70	48.0	0
266	4.4	2.33	2.81	120.0	0
251	4.4	1.85	2.77	59.5	1
1016	4.5	3.71	3.73	62.9	0
1019	4.6	3.98	4.21	56.4	0
462	4.7	2.65	3.11	59.0	0
944	4.7	3.88	4.00	55.8	0
204	4.8	2.47	3.27	59.5	2
455	4.9	2.71	2.93	-4.0	2
205	5.1	2.98	3.62	64.5	1
1094	5.6	4.83	5.03	41.5	0
547	5.7	4.65	4.80	75.3	1
711	5.8	4.39	5.34	62.8	1
866	5.9	4.93	5.03	25.0	1
636	6.1	5.07	5.07	76.5	0
713	6.2	4.62	5.32	49.0	1
537	6.2	7.68	6.75	35.8	1
861	6.4	6.26	5.97	77.3	0
595	6.6	6.28	6.33	57.8	0
698	6.8	6.64	6.49	55.8	0
952	7.3	7.53	7.78	-8.8	1
530	7.4	7.24	6.56	40.5	0
1002	7.5	6.07	5.87	69.3	0
610	8.0	7.94	8.08	38.0	1
807	8.3	8.81	8.34	29.5	1
532	8.3	9.37	8.92	8.5	1
809	8.5	8.74	8.30	4.5	2
1258	8.6	8.31	8.05	-4.8	3
1109	8.7	8.78	8.11	41.0	1
1144	8.8	7.98	8.10	37.8	1
833	9.1	10.24	10.22	4.5	4
753	9.3	9.09	9.60	0.0	3
1069	9.6	7.71	7.94	44.5	0
1066	9.8	9.33	8.29	0.8	1
1146	9.8	8.33	8.73	53.3	2
1117	10.1	9.61	9.65	-1.0	3
818	10.2	9.94	9.83	-3.5	2
1128	10.4	9.08	9.79	30.3	1
1279	10.9	10.19	11.42	-0.8	3
1294	11.8	12.07	11.95	-1.8	4

CARAGANA					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI 1991	REPLANTS 1989-91
		1991	1989-91		
425	2.5	0.68	1.24	43.0	0
175	3.2	1.11	1.76	45.0	0
802	3.2	2.90	2.61	50.3	0
449	3.3	1.66	2.00	58.5	0
85	3.7	1.90	2.18	59.1	0
194	3.7	1.75	2.00	46.8	0
62	4.1	2.37	2.64	46.5	0
236	4.3	2.16	2.80	47.8	0
461	4.3	3.42	3.01	51.3	0
420	4.4	2.47	2.73	65.5	0
629	5.0	3.55	3.72	43.0	0
550	5.1	4.41	4.16	49.3	0
411	5.5	3.21	3.81	42.5	0
716	5.8	4.66	4.77	26.0	0
707	5.8	4.13	4.84	51.3	0
638	6.1	4.94	4.84	7.5	0
934	6.2	5.55	5.64	32.8	0
937	6.4	5.90	5.76	32.8	0
1083	6.9	6.35	6.18	30.4	0
999	7.4	5.12	5.56	33.5	0
688	7.6	7.19	7.39	23.6	0
920	8.0	6.84	7.28	47.3	0
1111	8.2	9.62	9.12	20.3	0
772	8.3	8.61	8.36	49.4	0
1256	8.5	7.76	7.84	-1.8	2
734	9.2	8.56	8.55	48.3	0
1131	9.4	11.44	11.39	2.3	1
1191	9.6	10.99	10.31	-3.3	0
1272	9.7	8.36	8.97	-0.5	0
1283	10.1	10.15	10.11	15.5	0
1054	10.8	10.10	10.66	21.8	1

NANKING CHERRY					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI 1991	REPLANTS 1989-91
		1991	1989-91		
476	2.4	1.70	1.44	70.5	0
56	2.6	1.64	1.59	44.3	0
379	2.8	1.04	1.45	62.0	0
231	2.9	1.05	1.59	36.3	0
398	3.0	1.59	2.04	62.8	0
1	3.2	1.45	2.12	-8.4	2
344	3.3	1.58	1.95	27.8	0
500	3.3	5.21	3.31	2.0	0
38	3.4	1.30	1.97	27.0	0
310	3.6	2.19	2.19	45.8	0
334	4.1	1.84	2.17	48.5	0
211	4.2	2.44	2.83	56.8	0
96	4.3	2.87	2.93	41.0	0
723	4.3	2.72	3.58	27.8	0
15	4.4	2.50	3.03	42.0	0
876	4.5	4.40	4.07	45.0	0
796	4.5	3.66	4.01	58.0	0
322	4.5	2.38	2.76	62.5	0
74	4.9	3.16	3.52	45.5	0
464	5.0	4.40	3.89	41.3	0
565	5.5	4.74	4.51	29.0	0
857	5.6	5.42	5.56	-8.3	1
337	5.6	3.00	3.49	63.5	0
779	5.8	5.37	5.19	3.3	1
787	6.1	5.47	5.15	39.3	0
862	6.1	5.93	6.13	3.0	2
69	6.2	3.89	4.16	36.3	0
536	6.4	6.85	6.59	-4.8	2
1010	6.4	5.49	5.53	3.5	0
578	6.9	5.99	6.09	-9.3	1
1238	7.3	5.65	6.03	3.3	2
690	7.4	6.55	6.85	9.3	1
613	7.5	6.96	6.85	-0.5	2
683	7.7	7.44	7.50	-1.5	1
1076	8.2	7.14	7.11	9.8	1
815	8.4	7.49	7.70	2.5	2
1195	8.5	8.61	8.42	-6.3	1
1075	8.5	6.94	7.28	8.8	1
970	8.7	8.57	8.35	-2.8	1
814	8.8	7.60	7.81	-1.5	1
1260	8.9	9.06	8.97	-23.5	2
1201	8.9	8.87	8.82	-4.0	2
898	9.0	8.57	8.78	0.0	2
899	9.3	8.99	8.80	0.5	2
1266	9.3	9.47	10.03	-2.3	4
887	9.5	8.14	8.09	4.0	0
1114	9.6	9.32	8.80	21.3	0
893	10.0	11.53	10.91	-2.3	2
1263	10.8	10.92	11.42	5.4	4
1039	11.3	9.56	9.85	0.8	2

COLUMBIA CRAB					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI 1991	REPLANTS 1989-91
		1991	1989-91		
277	2.7	0.29	1.13	74.0	0
105	2.8	1.38	1.51	60.5	0
278	3.0	0.73	1.40	83.0	0
59	3.2	1.83	1.93	48.0	0
155	3.7	2.46	2.56	49.3	0
140	3.7	2.15	2.54	14.8	0
169	4.2	1.98	2.33	29.8	0
362	4.3	2.30	2.59	15.3	0
12	4.5	2.20	2.96	34.8	0
520	4.7	4.32	4.61	30.5	0
21	5.0	2.49	3.03	52.3	0
188	5.1	2.93	3.46	21.5	0
704	5.9	5.01	5.48	34.5	0
786	6.1	5.87	5.64	-3.3	0
1174	6.2	6.34	6.37	9.1	1
594	6.2	6.14	6.11	8.3	1
1011	6.6	5.24	5.30	-36.8	0
953	6.9	6.76	5.93	16.3	0
581	7.3	6.99	6.62	16.1	0
684	7.6	8.24	8.31	17.0	0
1237	8.0	6.52	6.89	21.3	0
1200	8.2	7.75	7.70	12.0	2
693	8.2	8.40	9.11	-25.8	1
901	8.6	8.36	8.37	4.3	0
1027	8.9	8.92	8.12	33.1	0
1253	9.0	7.25	7.32	28.3	1
990	9.8	9.51	9.37	14.3	0
1140	9.9	9.13	9.15	6.8	0
980	10.3	9.31	9.69	-1.9	1
1280	10.5	11.42	12.43	0.0	2

DOGWOOD					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI	REPLANTS
		1991	1989-91	1991	1989-91
101	1.7	2.47	2.75	38.5	0
301	2.6	2.39	3.03	54.8	0
444	2.8	1.39	1.76	54.8	0
228	2.9	1.34	1.68	55.8	0
495	3.0	2.23	2.09	67.8	0
223	3.1	0.66	1.53	57.3	0
391	3.5	1.49	2.11	58.5	0
33	3.6	1.67	2.40	69.3	0
803	3.6	3.86	2.96	44.0	0
148	3.7	2.28	2.46	102.3	0
152	4.1	2.52	2.92	10.9	1
239	4.2	2.20	2.72	67.8	0
237	4.5	2.60	3.24	-2.5	0
360	4.5	3.19	3.04	67.3	0
358	4.7	2.89	2.98	58.3	0
272	4.7	2.33	3.03	42.3	0
646	4.7	3.18	3.53	50.8	0
949	4.8	4.55	4.52	24.8	2
434	4.9	3.50	3.88	34.5	0
201	5.0	2.74	3.16	42.8	0
401	5.5	3.53	3.61	73.0	0
256	5.5	3.09	3.98	5.0	1
320	5.5	3.65	3.92	66.3	0
856	5.9	4.97	5.25	54.5	0
705	6.0	4.47	5.30	46.0	0
730	6.2	5.81	5.34	31.0	0
1248	6.3	4.24	4.74	47.3	0
850	6.4	5.84	5.41	46.5	0
1162	6.8	6.68	6.42	28.3	0
956	6.9	7.15	5.78	8.0	2
1189	7.5	6.67	6.25	33.0	0
1123	7.6	7.29	7.32	72.3	0
911	7.9	8.06	7.83	21.5	0
1154	8.0	7.54	7.59	14.5	1
1232	8.1	7.11	7.29	-0.3	1
1236	8.1	6.79	7.13	38.0	0
826	8.4	9.36	9.12	1.3	2
831	8.4	9.23	8.78	1.5	2
825	8.5	9.04	8.73	-1.0	2
1110	8.7	9.71	8.88	-1.0	2
1118	8.9	9.00	8.70	7.9	2
1071	8.9	7.14	7.46	64.8	0
895	9.1	9.04	9.08	0.3	1
1136	9.2	6.87	6.98	19.5	0
1060	9.2	6.07	6.45	30.0	0
1037	9.3	8.19	8.25	47.5	0
510	9.8	9.69	10.04	35.8	0
1252	9.8	7.12	8.01	4.5	2
1208	10.1	7.54	7.86	5.8	1
1057	11.1	9.33	9.48	53.8	0

HAWTHORN					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI 1991	REPLANTS 1989-91
		1991	1989-91		
428	2.5	0.78	1.25	4.3	0
374	2.7	1.06	1.34	8.5	0
496	3.0	2.27	2.18	-3.5	0
2	3.1	2.17	2.49	1.4	2
293	3.3	1.62	2.03	19.5	0
40	3.4	2.16	2.36	0.8	1
244	4.2	2.13	2.86	36.8	0
115	4.2	1.80	2.25	52.8	0
260	4.5	2.71	2.98	0.5	2
720	4.6	2.65	3.33	-3.0	0
556	4.6	4.30	3.87	29.0	0
284	4.8	2.35	2.94	11.0	0
1100	5.6	5.67	5.48	3.8	2
486	6.0	5.50	4.74	-1.6	0
712	6.0	4.97	5.65	0.0	0
1169	6.1	6.43	6.52	-1.0	2
849	6.5	9.42	7.24	-3.8	2
922	6.6	6.18	6.03	-16.0	2
910	7.3	8.08	7.71	3.8	2
616	7.6	7.91	7.99	3.4	1
1107	7.8	8.80	7.63	-3.6	0
694	8.2	6.95	7.75	9.0	1
1047	8.5	7.39	7.32	14.8	0
1125	8.8	8.17	8.34	4.4	0
678	9.3	8.76	9.21	-3.4	1
672	9.4	8.59	9.08	13.0	2
1113	9.4	9.14	8.68	6.3	0
1225	9.8	8.37	8.47	-2.0	2
1297	10.1	9.78	10.14	2.3	1
972	10.1	9.27	9.60	-6.0	1

PRINCE OF WALES JUNIPER					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI 1991	REPLANTS 1989-91
		1991	1989-91		
328	2.7	0.45	1.14	18.3	0
106	2.8	1.60	1.83	26.5	0
291	3.3	1.72	2.13	-18.8	0
108	3.5	1.13	1.76	1.5	0
297	3.6	1.80	2.32	17.8	0
490	3.7	3.28	2.80	-3.3	0
262	4.3	2.55	2.80	12.0	0
265	4.3	2.71	2.94	13.5	0
357	4.5	2.46	2.84	13.3	0
24	4.6	2.57	3.02	24.5	0
438	4.7	2.91	3.40	9.3	0
558	4.8	4.14	4.07	15.8	0
487	5.5	5.34	4.63	5.5	0
644	5.7	3.93	4.26	4.0	0
1171	5.7	6.37	6.13	0.8	1
784	6.0	6.48	5.91	14.5	0
540	6.7	7.05	7.27	1.8	1
541	6.9	7.79	7.34	4.0	0
1005	7.3	5.35	5.57	3.8	1
686	7.5	7.63	7.88	3.8	0
680	7.6	6.86	7.25	2.8	0
731	7.7	7.27	6.67	0.8	0
692	8.1	8.05	8.75	2.0	1
1216	8.8	8.62	8.46	7.0	0
841	8.9	7.83	7.86	3.0	0
1143	9.5	8.23	8.29	-2.0	2
1265	9.8	8.34	9.63	11.0	2
1290	10.2	9.95	10.61	-1.8	1
1276	10.8	10.96	11.94	0.0	2
1275	11.6	11.19	12.31	8.5	2

SIBERIAN LARCH					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI 1991	REPLANTS 1989-91
		1991	1989-91		
447	2.6	1.22	1.70	-4.3	3
54	2.9	2.12	2.16	16.1	0
330	3.0	1.10	1.59	15.8	2
497	3.2	2.63	2.67	1.8	1
102	3.3	1.48	1.84	27.3	1
197	3.4	1.19	1.74	52.9	0
393	3.4	2.11	2.55	9.3	2
473	3.4	2.77	2.44	17.3	0
467	3.7	2.81	2.61	16.3	1
50	3.8	2.81	3.04	1.8	0
315	4.1	1.76	2.23	52.3	0
572	4.1	3.31	3.52	-0.8	1
191	4.2	2.00	2.35	25.1	0
384	4.2	2.04	2.53	16.0	0
521	4.6	4.55	4.57	-1.8	2
364	4.6	3.10	3.29	0.0	0
23	4.7	2.08	2.87	15.8	2
519	4.8	5.12	5.09	28.3	3
25	4.9	2.56	3.12	20.0	0
416	5.0	3.07	3.77	4.8	2
206	5.5	3.03	4.11	27.0	0
270	5.5	3.59	4.10	38.3	0
852	5.7	4.28	4.53	42.5	0
414	5.7	3.43	3.97	22.5	0
710	6.0	4.21	4.83	-3.5	0
855	6.0	5.54	5.37	14.3	2
853	6.1	5.41	5.39	4.5	3
576	6.2	5.25	4.76	8.1	0
881	6.6	8.16	6.62	-20.8	2
515	6.9	6.13	6.75	0.4	1
1121	7.3	6.59	6.65	1.5	2
921	7.4	6.49	6.37	-0.3	2
756	8.1	8.38	8.29	4.0	3
962	8.3	15.68	9.76	19.0	1
1153	8.4	7.61	7.94	-1.1	1
1026	8.4	8.96	7.94	5.8	2
902	8.4	8.50	8.22	9.5	2
533	8.5	8.51	8.61	2.3	2
769	8.6	8.21	8.08	6.5	2
907	8.6	8.09	8.32	-2.3	4
822	8.9	8.04	8.36	-1.0	3
1273	9.0	8.56	8.88	-5.8	4
890	9.1	7.60	8.01	12.5	2
739	9.2	10.40	9.98	0.0	3
1206	9.3	8.54	8.34	-0.5	1
1034	9.5	9.42	8.74	10.3	2
976	9.6	9.53	8.91	-3.1	1
1268	9.7	10.72	10.60	-14.5	4
892	10.1	10.38	10.45	3.0	3
1141	10.2	9.18	9.25	3.3	1

COMMON LILAC					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI 1991	REPLANTS 1989-91
		1991	1989-91		
55	2.7	1.92	1.93	32.8	0
474	2.9	2.21	1.84	30.3	0
423	3.0	1.70	1.86	22.8	0
129	3.2	1.55	1.90	2.5	1
181	3.3	1.37	1.92	27.5	0
308	3.6	2.10	2.18	42.6	0
95	4.1	2.23	2.71	35.0	0
306	4.1	1.65	2.11	33.5	0
245	4.2	2.25	2.87	33.5	0
219	4.4	2.00	2.65	32.8	0
158	4.5	3.55	3.68	30.5	0
209	5.1	2.53	3.26	2.3	0
564	5.4	4.45	4.41	-0.5	0
19	5.5	2.94	3.39	33.0	2
563	5.6	5.39	4.88	2.3	0
483	5.8	5.11	4.27	30.5	0
714	6.2	4.47	4.79	17.5	0
1088	6.6	6.53	6.67	15.8	2
1239	7.3	5.56	5.66	22.0	0
764	7.7	7.86	7.65	0.3	2
995	7.9	6.95	7.11	29.0	0
903	8.1	8.45	8.31	-0.8	3
1124	8.3	7.86	7.60	15.5	0
810	8.5	8.47	8.46	-2.0	2
1220	9.0	7.64	7.82	21.5	0
1148	9.1	7.39	7.44	2.0	0
1059	9.2	7.34	7.67	19.5	0
1270	9.3	8.39	8.59	5.0	1
1149	9.4	8.08	8.16	0.8	1
1058	10.5	9.18	9.82	0.3	2

VILLOSA LILAC					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI 1991	REPLANTS 1989-91
		1991	1989-91		
227	2.8	1.24	1.58	34.8	0
429	3.0	1.60	1.88	20.8	0
177	3.3	1.19	1.89	38.0	0
43	3.5	1.69	2.25	57.8	0
141	3.5	1.59	2.12	46.3	0
143	3.5	1.85	2.11	15.0	0
875	4.2	3.83	3.86	35.0	0
264	4.2	2.51	2.78	36.5	0
647	4.4	2.32	3.14	19.5	0
302	4.5	1.81	2.62	34.5	0
116	4.6	2.93	3.12	9.5	1
482	5.1	4.56	3.92	34.5	0
790	5.6	4.88	5.19	13.0	0
643	5.7	4.53	4.99	34.3	0
484	5.9	5.62	4.88	5.3	0
641	6.1	4.48	4.95	29.5	0
775	6.3	6.58	6.24	7.0	0
1043	6.8	5.51	5.63	11.0	0
681	7.4	7.40	7.63	16.0	0
657	7.7	7.07	7.03	-4.5	0
501	7.8	8.12	7.77	4.0	0
1108	7.9	8.96	7.95	6.0	0
811	8.4	8.28	8.17	9.5	1
1212	8.6	7.92	7.63	7.0	2
1203	9.1	10.67	10.37	3.0	1
1289	9.7	9.54	9.86	-6.3	3
1192	10.0	11.88	11.32	3.3	0
1264	10.1	9.18	10.01	-0.5	3
1133	10.4	11.08	10.80	3.5	0
509	10.9	11.03	11.94	5.5	0

MAYDAY					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI	REPLANTS
		1991	1989-91	1991	1989-91
426	2.3	0.26	1.02	-1.0	2
82	3.0	2.06	1.96	44.3	0
346	3.1	1.38	1.92	20.6	1
443	3.1	1.55	1.52	95.5	0
380	3.2	1.55	1.80	55.3	0
801	3.2	2.94	2.96	18.4	0
36	3.3	1.38	1.95	70.5	0
392	3.5	1.71	2.38	36.0	0
89	3.5	2.32	2.53	41.5	1
200	3.7	2.16	2.38	1.5	2
489	4.1	3.53	3.02	29.5	0
289	4.2	1.81	2.46	63.3	0
573	4.2	3.00	3.25	22.0	0
948	4.5	4.05	4.18	9.8	1
137	4.5	2.91	3.19	58.6	0
354	4.6	3.10	2.81	33.8	0
335	4.6	2.11	2.50	16.1	0
336	5.0	2.52	3.10	27.6	1
630	5.0	3.47	3.81	78.0	0
941	5.1	4.76	4.92	17.5	1
868	5.6	4.93	5.09	51.5	1
562	5.7	5.24	4.92	-2.6	0
561	5.8	5.13	5.24	11.5	0
781	5.9	5.38	5.31	-3.0	3
651	6.0	5.67	5.74	1.8	1
864	6.0	4.38	5.00	22.3	1
1244	6.1	4.65	4.95	12.8	1
1009	6.5	5.00	5.15	29.3	1
1097	6.7	6.09	6.43	5.5	1
960	6.7	6.51	5.88	8.5	1
761	7.6	7.98	7.92	4.8	2
513	7.7	7.08	7.40	21.5	1
1046	7.8	6.60	6.79	6.0	0
1261	8.0	8.78	8.75	-14.5	2
915	8.2	8.93	8.94	8.6	3
1231	8.3	7.62	7.36	3.0	2
760	8.4	8.62	8.38	6.8	1
996	8.6	6.85	7.14	-1.8	1
1228	8.6	7.80	7.82	3.8	2
1199	8.8	8.31	7.91	19.5	0
583	8.9	9.17	9.50	0.6	3
1259	9.0	7.11	8.10	1.0	2
670	9.1	8.05	8.21	-5.0	2
732	9.1	9.92	9.47	-1.0	3
1202	9.3	10.10	9.56	4.3	2
978	9.6	9.68	9.63	7.1	2
983	10.0	11.13	10.25	0.3	3
979	10.2	9.65	9.40	-1.5	3
989	10.3	9.96	9.42	1.5	2
1051	10.7	9.90	10.24	-0.3	4

AMUR MAPLE					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI 1991	REPLANTS 1989-91
		1991	1989-91		
477	2.5	1.61	1.61	82.8	0
475	2.6	1.70	1.56	67.0	0
274	3.1	0.30	1.45	69.8	0
51	3.2	2.42	2.35	-2.1	3
294	3.2	1.36	1.94	34.8	0
292	3.2	1.41	1.92	65.0	0
397	3.3	1.53	2.00	66.3	0
110	3.4	1.91	2.20	38.9	1
53	3.4	2.19	2.29	-3.5	1
430	3.6	1.42	2.24	34.3	0
122	4.1	2.30	2.38	63.8	0
138	4.2	4.85	3.75	15.3	1
339	4.3	1.87	2.35	67.5	0
160	4.4	2.30	2.82	57.8	0
557	4.6	4.08	4.02	-16.5	0
628	4.7	3.67	3.92	-7.5	1
355	4.7	3.00	2.90	37.3	0
795	4.7	3.75	4.30	39.5	0
77	4.9	3.17	3.39	12.5	0
304	5.0	2.66	3.27	74.5	0
715	5.9	4.26	4.74	15.5	0
706	6.0	4.53	4.99	57.3	0
701	6.2	4.98	5.34	8.0	1
924	6.3	5.34	5.57	34.5	1
854	6.3	7.16	6.17	36.8	1
927	6.4	5.49	5.67	44.3	2
1086	6.5	5.84	5.98	31.8	2
930	6.5	5.31	5.70	8.0	1
954	6.7	6.95	5.81	30.0	0
880	6.8	8.97	7.81	2.5	2
588	7.5	7.66	7.93	3.1	1
685	7.5	8.56	8.43	17.9	1
968	8.0	7.40	7.21	24.1	1
1274	8.0	7.40	7.63	-0.3	2
757	8.3	8.39	7.97	-0.5	1
502	8.4	8.31	8.13	10.4	2
842	8.5	7.76	8.10	7.3	0
1230	8.7	7.36	7.82	-0.1	0
1255	8.7	7.40	7.63	2.4	3
1112	8.7	9.17	8.83	28.0	0
1205	9.1	8.81	8.45	26.5	1
503	9.2	8.46	8.61	20.9	2
1254	9.3	5.56	7.26	14.0	2
1147	9.5	8.27	8.43	1.0	0
1064	9.5	8.54	8.55	-1.0	0
819	9.7	9.90	10.22	7.8	2
1050	9.8	10.09	9.73	23.5	2
603	9.8	9.68	10.29	-2.8	2
1116	9.9	9.57	9.49	1.4	2
1295	10.8	11.52	11.31	5.0	2

MANITOBA MAPLE					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI 1991	REPLANTS 1989-91
		1991	1989-91		
377	2.4	0.65	0.94	79.5	0
81	3.0	1.92	1.88	90.4	0
493	3.1	2.41	2.23	24.6	0
93	3.3	1.92	2.21	62.8	0
183	3.7	2.02	2.43	53.9	0
163	3.8	2.59	2.61	77.4	0
121	4.3	2.46	2.55	88.5	0
78	4.4	2.54	2.91	57.1	0
945	4.6	3.75	3.90	79.8	0
872	4.7	3.50	3.96	89.0	0
554	4.7	4.39	4.07	90.8	0
359	5.0	2.72	2.91	61.3	0
71	5.5	3.77	3.97	66.0	0
516	5.7	5.45	5.72	0.0	1
642	5.9	4.78	5.08	44.3	0
639	6.0	4.13	4.57	97.8	0
577	6.4	6.11	5.54	49.0	0
1087	6.6	6.30	6.36	72.0	0
1001	7.6	5.73	6.12	16.0	1
618	7.7	8.60	8.13	10.3	1
759	8.3	8.83	8.68	-0.3	4
844	8.4	8.03	7.83	70.5	0
967	8.6	8.18	7.72	32.9	0
823	8.7	7.48	8.12	1.8	2
813	9.1	8.36	9.04	33.8	2
1209	9.2	8.29	8.31	26.9	1
1227	9.4	7.95	8.07	-0.8	0
1049	9.6	8.84	8.89	23.5	0
1135	9.9	9.34	9.11	30.0	0
1130	10.2	9.71	10.25	0.8	1

BUR OAK					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI 1991	REPLANTS 1989-91
		1991	1989-91		
57	2.7	1.27	1.47	-1.0	1
394	3.1	2.11	2.39	-7.5	2
3	3.2	1.74	2.27	-2.0	2
280	3.3	0.91	1.75	-24.0	2
91	3.3	1.75	2.10	-30.8	3
182	3.4	1.73	2.23	-11.4	2
142	3.5	1.51	2.01	0.0	2
150	3.6	2.64	2.75	0.0	2
468	3.6	2.80	2.50	-9.8	2
114	3.7	1.81	2.10	-3.8	1
574	4.2	3.73	3.85	-4.5	2
458	4.6	1.82	2.56	-0.5	3
151	4.6	2.80	3.25	-1.5	2
366	4.7	3.04	3.31	-1.0	2
555	4.8	4.21	4.04	0.5	3
728	4.9	4.57	4.34	-2.0	3
22	4.9	2.64	2.96	-6.5	3
365	5.0	3.03	3.26	-2.8	2
410	5.0	3.38	3.87	0.0	1
388	5.0	2.99	3.48	-0.3	3
412	5.4	3.47	3.84	18.3	1
207	5.5	3.46	4.12	7.8	1
789	5.8	5.26	5.06	0.5	0
859	6.0	4.77	4.82	4.3	0
878	6.0	7.10	6.97	-8.3	2
936	6.2	5.41	5.54	1.8	1
1246	6.3	4.64	4.94	7.8	3
1163	6.5	5.98	5.90	2.8	2
1085	6.6	5.80	5.93	-2.3	3
958	6.9	6.26	5.67	-0.3	1
1241	7.3	6.09	6.27	-3.8	1
600	7.4	6.43	6.65	0.0	1
848	7.4	6.26	6.23	-4.5	2
1041	7.7	7.05	6.89	2.5	1
1077	7.8	6.90	6.90	-0.5	2
846	7.9	6.85	6.73	0.8	1
1155	7.9	7.70	7.40	-1.0	1
919	8.3	7.24	7.43	0.0	1
609	8.5	8.77	8.82	-9.8	2
993	8.7	6.36	6.74	6.8	0
754	9.0	8.38	8.77	0.0	2
752	9.0	9.70	9.46	2.3	2
660	9.2	7.91	8.39	-2.0	2
835	9.3	10.00	10.68	-0.8	2
1033	9.4	9.44	9.23	-11.8	3
1217	9.4	8.99	8.87	4.8	0
820	9.5	9.72	10.03	-16.8	2
1223	9.6	8.88	8.85	-1.5	1
1224	9.7	8.56	8.54	0.3	1
839	9.9	9.08	9.05	0.5	1

RUSSIAN OLIVE					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI 1991	REPLANTS 1989-91
		1991	1989-91		
107	3.1	1.37	1.86	-12.0	0
179	3.2	1.70	1.89	97.8	0
34	3.3	1.35	2.15	109.8	1
180	3.3	1.33	1.76	107.3	0
173	3.3	1.03	1.72	89.8	1
650	3.3	2.58	2.94	85.5	0
234	3.4	1.47	2.11	118.3	0
469	3.6	2.72	2.38	84.0	0
113	3.7	1.86	2.31	108.8	0
170	3.8	1.86	2.17	97.3	0
727	4.4	4.05	3.64	71.0	0
798	4.4	4.00	3.94	120.8	0
190	4.4	2.28	2.82	89.8	0
16	4.6	1.77	2.45	54.0	2
456	4.7	2.56	3.04	105.3	0
134	4.8	3.07	3.33	99.0	0
871	4.8	3.53	4.18	91.0	0
522	4.9	4.13	4.47	88.8	0
435	5.0	3.42	3.99	74.3	0
568	5.1	3.74	4.17	78.5	0
632	5.5	4.60	4.68	107.8	0
1249	5.8	3.67	4.31	105.0	0
780	5.8	5.70	5.51	93.0	0
1172	5.9	5.51	5.75	109.8	0
858	6.0	5.65	5.35	96.8	0
703	6.1	4.18	4.97	85.0	0
883	6.1	7.61	5.88	68.8	0
932	6.2	5.62	4.91	80.0	0
593	6.2	6.69	6.54	68.8	0
1006	6.7	5.89	5.67	106.3	0
1000	7.5	6.17	6.01	83.5	0
695	8.0	7.07	6.89	95.3	0
897	8.2	8.03	8.51	80.0	0
1213	8.3	7.76	7.81	71.8	0
1074	8.6	6.81	7.09	101.5	0
994	8.6	8.02	7.31	92.3	0
1138	8.7	7.68	7.26	86.5	0
838	8.7	9.62	9.45	61.8	0
965	8.8	7.90	8.21	77.0	0
659	8.8	8.65	9.60	44.8	0
1226	9.4	8.39	8.67	54.1	0
1207	9.4	8.08	8.20	65.8	0
605	9.7	10.23	10.52	55.8	1
1284	9.8	9.82	10.14	36.8	0
1129	9.9	10.49	10.66	78.8	0
507	10.0	11.29	11.68	34.4	2
1038	10.2	8.69	8.96	71.8	0
1127	10.4	8.75	9.45	92.5	0
1292	11.3	11.72	12.12	-16.3	2
1053	11.8	9.17	10.52	97.5	0

SCOTS PINE					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI 1991	REPLANTS 1989-91
		1991	1989-91		
326	2.4	0.65	1.08	14.3	1
445	2.7	1.35	1.64	-2.3	1
279	3.0	0.89	1.57	3.6	1
230	3.0	0.92	1.59	1.0	1
331	3.1	1.14	1.62	6.1	3
499	3.2	2.80	2.48	-5.8	2
399	3.3	1.30	1.74	13.4	1
311	3.4	1.66	1.90	6.6	3
442	3.6	1.95	1.90	-12.5	1
154	3.7	1.99	2.53	4.0	1
804	4.2	4.18	3.50	5.8	1
316	4.2	1.81	2.50	-11.8	3
800	4.2	3.40	4.15	4.0	1
943	4.6	3.71	4.01	4.6	1
356	4.6	2.79	3.02	6.5	1
317	4.7	2.12	2.71	6.5	0
159	4.8	2.86	3.37	-3.8	1
300	5.0	2.55	3.51	6.0	3
1021	5.0	3.62	4.05	-1.3	3
719	5.0	2.83	3.64	27.3	0
517	5.6	5.24	5.24	4.0	3
939	5.6	4.63	5.13	7.8	2
805	5.9	5.78	5.58	3.3	1
882	6.0	8.00	6.21	2.3	0
485	6.1	5.81	4.87	-1.1	2
1168	6.2	6.49	6.55	-3.5	3
654	6.4	5.63	5.41	2.8	2
1012	6.5	5.43	5.47	2.8	2
1084	6.7	6.43	6.45	9.3	2
662	6.8	6.62	6.69	4.0	2
1079	7.4	6.25	6.37	7.5	2
1105	7.7	8.26	7.20	3.5	2
843	8.1	7.80	8.24	0.6	0
758	8.1	8.50	8.28	13.3	2
511	8.3	7.59	7.89	7.9	3
773	8.3	7.44	7.38	1.5	1
918	8.4	7.14	7.19	1.3	2
963	8.4	6.85	6.92	5.0	2
736	8.5	7.35	7.45	6.5	1
832	8.6	9.74	9.17	6.0	3
591	8.9	8.47	8.94	4.6	3
1210	9.1	8.16	7.75	2.8	0
667	9.2	9.20	9.88	5.5	2
584	9.4	9.03	9.45	5.8	3
607	9.5	9.29	9.20	12.3	2
1145	9.6	7.75	7.95	5.3	1
1126	9.7	8.40	8.70	8.8	2
1028	9.8	9.89	8.98	9.1	0
977	9.8	9.42	9.47	2.9	2
1062	10.1	8.35	8.85	1.5	0

BROOKS #6 POPLAR					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI 1991	REPLANTS 1989-91
		1991	1989-91		
229	3.1	1.46	1.63	121.8	0
448	3.2	1.41	1.86	125.0	0
198	3.3	1.56	2.03	121.8	0
42	3.3	1.45	1.96	154.6	0
342	3.4	1.40	1.81	130.5	0
132	3.5	1.95	2.17	127.3	0
422	3.5	1.71	1.91	88.3	0
171	3.7	2.11	2.18	137.3	0
164	3.7	2.47	2.51	132.5	0
214	3.8	1.82	2.25	94.0	0
98	4.2	1.99	2.55	138.5	0
363	4.4	3.05	2.90	97.5	0
457	4.5	2.65	3.17	78.8	0
253	4.7	1.78	2.62	105.3	0
419	4.7	2.62	2.77	81.3	0
367	4.8	3.04	3.26	115.5	0
569	4.9	3.44	3.91	99.8	0
187	4.9	2.90	3.50	122.8	0
288	4.9	2.68	3.02	133.8	0
254	5.0	2.63	3.52	123.0	0
1014	5.5	4.46	4.60	99.8	0
70	5.7	3.66	3.88	119.5	0
1095	5.7	5.24	5.42	91.5	0
404	5.9	3.83	4.16	109.8	0
935	6.3	5.56	5.75	86.5	0
597	6.3	6.59	6.10	91.4	1
1099	6.4	6.15	6.23	33.5	2
538	6.5	7.30	6.95	28.8	1
926	6.5	5.56	5.63	117.0	0
1008	6.6	5.84	5.65	96.8	0
1120	7.5	7.31	7.05	42.5	1
1286	7.5	6.21	6.69	25.8	2
1156	7.6	7.39	7.12	39.5	2
675	7.9	8.17	8.41	13.3	0
827	8.1	8.95	8.78	17.5	2
661	8.2	6.93	7.19	55.8	0
1298	8.2	8.24	8.01	55.8	0
997	8.4	6.96	7.01	70.5	0
966	8.5	8.30	8.10	122.8	0
830	8.7	9.43	9.15	10.0	0
590	9.2	8.77	9.51	17.8	0
1067	9.3	7.98	7.63	87.0	0
1040	9.5	8.21	8.20	125.0	0
1061	9.6	7.16	7.88	111.5	0
505	9.6	9.55	9.85	9.0	2
747	9.7	9.43	9.58	24.0	1
1150	9.8	8.62	9.31	94.5	0
1269	10.3	9.81	10.15	-5.3	3
1055	11.2	9.60	10.63	60.3	0
1296	11.4	11.40	11.71	7.4	0

NORTHWEST POPLAR					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI 1991	REPLANTS 1989-91
		1991	1989-91		
349	3.3	1.76	1.95	145.0	0
290	3.4	1.84	2.12	160.3	0
86	3.4	2.04	2.08	183.9	0
332	3.6	1.58	2.08	141.8	0
128	3.6	4.55	3.25	195.8	0
193	3.7	1.95	2.16	127.0	0
299	4.1	2.55	3.08	113.3	0
432	4.4	2.96	3.45	122.8	0
1017	4.5	3.58	3.65	131.0	0
465	4.5	3.89	3.40	126.3	0
267	4.7	2.55	3.00	128.8	0
305	4.8	1.41	2.44	132.0	0
1170	5.7	6.74	6.39	26.8	1
1090	5.8	5.53	5.45	138.8	0
560	5.8	5.05	5.10	95.0	0
931	6.3	5.30	5.27	135.8	1
622	6.5	6.28	6.20	81.8	0
529	6.8	6.06	5.91	79.8	0
531	7.7	8.26	8.16	0.0	1
917	7.8	7.59	7.41	89.0	0
665	7.9	8.24	8.47	-2.4	2
582	8.0	6.91	7.24	22.0	0
1119	8.1	8.12	7.82	66.5	0
1211	8.6	7.09	7.15	42.8	0
673	9.0	8.56	9.27	1.8	0
746	9.5	8.90	8.82	60.5	0
821	9.6	9.95	9.84	4.3	1
913	9.9	10.19	10.13	12.9	1
982	10.2	10.63	10.28	18.0	3
1293	10.8	11.64	11.91	-2.5	2

POTENTILLA					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI 1991	REPLANTS 1989-91
		1991	1989-91		
104	2.7	0.97	1.41	24.5	0
492	3.2	2.49	2.33	29.0	0
479	3.3	2.47	2.38	0.3	4
41	3.4	1.21	1.96	-8.3	0
84	3.6	2.17	2.19	2.3	0
124	3.7	1.93	2.06	12.5	0
361	4.4	2.70	2.73	19.8	0
433	4.6	2.50	3.27	31.3	0
1018	4.6	3.74	3.70	18.3	2
63	4.6	2.38	2.75	16.0	0
252	4.7	1.99	2.88	25.5	0
451	5.1	3.25	3.35	8.3	0
792	5.7	4.85	5.05	25.0	0
526	5.8	4.93	5.19	19.3	2
640	5.8	4.45	4.87	9.5	0
1165	5.9	5.63	5.63	24.3	0
860	6.1	5.66	5.50	22.3	2
598	6.3	6.21	6.19	11.5	0
762	7.3	7.60	7.32	0.8	2
619	7.4	7.56	7.54	3.8	3
951	7.5	7.56	8.04	-1.0	1
765	7.6	8.04	7.93	8.3	1
771	8.7	8.87	8.67	9.3	0
908	8.8	8.28	8.61	5.0	2
750	8.9	8.75	8.63	3.8	3
1204	9.0	10.39	10.26	-10.8	1
1139	9.1	8.07	8.11	-1.5	2
749	9.1	9.72	9.33	-7.0	4
1194	9.9	8.25	7.93	23.8	0
1291	11.0	10.13	11.16	4.5	5

SIBERIAN SALT TREE					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI 1991	REPLANTS 1989-91
		1991	1989-91		
325	2.5	0.48	1.06	45.3	0
58	2.9	1.34	1.66	-2.8	1
295	3.0	1.23	1.75	-4.5	3
176	3.1	1.35	1.86	4.5	1
35	3.2	1.47	2.03	29.3	0
491	3.4	3.13	2.59	11.8	2
49	3.5	2.14	2.78	19.3	1
109	3.5	1.92	2.22	14.3	1
199	3.5	2.00	2.21	29.0	1
400	3.7	2.10	2.41	-1.8	3
439	4.2	2.55	2.97	-5.5	1
575	4.3	2.86	3.12	-1.0	2
799	4.4	3.77	4.00	3.3	0
552	4.5	3.95	3.93	-2.0	3
385	4.5	2.30	2.66	-3.8	2
570	4.5	3.41	3.88	12.5	0
14	4.7	2.94	3.50	-2.5	2
17	4.7	2.37	2.86	-4.6	2
1020	5.0	4.31	4.52	17.8	0
286	5.1	3.21	3.69	22.0	0
257	5.6	3.22	4.12	5.8	2
867	5.8	6.52	5.63	19.5	0
865	5.8	5.38	5.43	11.0	0
1175	5.9	5.75	5.84	1.5	0
777	6.0	5.49	5.50	24.8	0
1096	6.2	5.25	5.62	-1.5	1
546	6.4	5.79	5.54	12.8	1
778	6.4	5.33	5.29	13.3	1
655	6.5	6.09	5.80	13.5	1
928	6.6	5.56	6.07	8.5	1
847	7.4	6.85	6.64	-6.0	2
514	7.6	7.60	8.03	-1.5	1
743	7.8	6.35	6.79	19.0	0
969	8.0	7.54	7.52	12.0	0
768	8.2	7.63	7.85	15.5	1
992	8.4	6.75	6.76	38.8	0
845	8.5	7.56	7.89	-3.5	1
991	8.6	7.86	8.02	15.0	1
1215	8.7	7.85	8.27	17.0	0
985	8.8	9.75	9.37	14.8	0
666	8.9	8.83	9.24	-5.3	1
816	9.0	8.44	7.28	0.0	1
1285	9.0	7.29	7.92	-3.0	3
1219	9.1	8.28	8.24	14.3	1
1151	9.2	7.92	8.28	-3.0	2
971	9.7	8.36	8.66	-1.0	1
1030	9.7	10.35	9.58	8.8	1
733	10.1	9.78	9.59	21.8	0
508	10.6	12.45	12.23	-7.5	1
1277	11.3	11.02	12.13	9.3	2

SASKATOON					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI 1991	REPLANTS 1989-91
		1991	1989-91		
327	2.5	0.49	1.12	31.0	0
478	2.8	2.01	1.91	11.3	0
347	3.1	0.94	1.51	32.3	0
80	3.2	1.68	1.89	-4.3	3
4	3.2	1.41	2.05	-2.4	3
60	3.8	2.03	2.40	51.0	0
97	4.1	2.45	2.75	38.3	0
721	4.3	2.82	3.45	87.5	0
797	4.4	3.81	4.06	-9.5	1
238	4.6	2.61	3.31	17.0	0
167	4.6	3.10	3.15	24.5	0
551	4.8	4.48	3.93	8.3	0
370	5.7	4.08	4.02	37.5	0
788	5.8	5.20	5.02	50.3	0
791	6.0	4.49	5.02	0.8	3
933	6.2	4.79	5.01	1.3	0
1243	6.4	4.68	4.91	20.3	0
923	6.6	5.42	5.42	1.3	2
1159	7.4	6.87	6.86	0.8	2
528	7.6	6.76	6.57	5.9	2
767	8.1	7.78	7.82	-1.3	2
735	8.4	7.97	7.85	-5.3	4
1137	8.6	6.31	6.47	28.3	0
1035	8.7	8.55	8.01	-0.5	1
888	8.9	7.63	7.68	6.8	1
1193	9.0	11.17	10.15	0.5	0
984	9.8	9.57	9.43	-3.3	3
1029	10.0	10.15	9.37	-7.0	2
1278	10.2	10.40	11.73	-1.5	3
1056	11.1	10.27	10.53	1.5	3

COLORADO SPRUCE					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI 1991	REPLANTS 1989-91
		1991	1989-91		
131	3.0	1.46	1.73	5.0	1
8	3.1	1.31	1.90	3.1	0
373	3.4	1.86	2.05	10.0	0
83	3.4	2.03	2.15	6.3	0
313	3.5	1.46	1.87	9.3	0
281	3.6	1.34	2.00	-1.5	1
48	3.6	2.06	2.71	2.0	2
247	3.7	1.94	2.45	6.6	0
79	3.7	2.02	2.39	11.6	0
323	3.8	1.42	2.04	-0.8	2
372	4.3	2.44	2.64	3.5	0
571	4.4	3.25	3.54	0.8	1
418	4.4	2.50	2.83	0.8	0
553	4.5	3.75	3.76	0.8	1
481	4.7	4.30	3.72	1.6	0
136	4.7	2.84	3.28	5.0	0
64	4.8	2.97	3.15	8.9	0
259	4.9	2.66	3.06	2.5	0
454	5.0	2.42	3.10	14.0	0
202	5.1	3.25	3.63	4.6	1
633	5.6	4.50	4.52	6.8	0
635	5.6	4.09	4.53	11.5	0
68	5.6	3.79	4.12	6.0	1
717	5.8	3.72	4.48	15.3	0
708	5.8	4.28	4.89	20.8	0
387	5.9	3.56	4.22	9.3	0
1245	6.0	4.39	4.72	0.3	2
959	6.5	6.50	5.71	-0.8	2
957	6.7	6.58	5.41	1.0	2
699	6.9	5.26	5.72	-1.8	1
697	7.3	6.57	6.31	9.3	1
682	7.6	7.12	7.24	0.5	2
1104	7.7	7.79	6.65	1.3	1
766	7.8	8.01	7.49	1.8	2
998	7.9	5.53	5.92	-1.0	1
741	8.2	7.64	7.87	-1.3	2
679	8.3	7.05	7.87	-2.3	1
824	8.4	7.81	7.96	5.3	1
1152	8.5	8.18	7.85	5.3	2
585	8.5	8.67	8.65	0.4	2
1073	8.9	6.38	7.03	2.3	1
986	8.9	9.29	8.75	-2.3	1
601	9.0	8.56	8.86	-3.3	3
1229	9.1	7.88	7.89	2.8	1
914	9.1	10.02	10.13	0.3	4
748	9.6	9.50	9.78	-2.8	2
1032	9.7	9.04	9.09	-2.1	1
834	9.7	10.83	10.55	-3.3	2
1142	10.3	8.76	8.65	3.3	1
1282	10.7	9.27	9.97	10.0	2

WHITE SPRUCE					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI 1991	REPLANTS 1989-91
		1991	1989-91		
375	2.3	1.07	1.18	19.8	0
224	3.0	0.53	1.38	-4.0	1
6	3.2	1.22	2.00	3.8	2
196	3.3	1.76	2.09	4.3	0
90	3.4	2.33	2.46	7.5	0
147	3.6	2.10	2.46	7.1	1
460	4.3	2.31	2.54	-2.3	0
168	4.4	2.54	2.84	4.3	0
261	4.4	2.80	3.14	2.5	0
210	4.6	2.68	3.07	8.0	0
26	4.8	2.53	3.28	3.3	3
1015	5.1	4.62	4.34	0.8	1
702	5.9	4.27	5.01	1.5	0
1166	5.9	5.72	5.78	2.8	1
1089	6.4	6.47	6.27	0.0	2
535	6.5	6.90	6.75	2.8	2
663	6.8	6.60	6.52	3.3	2
687	7.4	6.98	7.04	0.0	2
691	7.6	7.42	7.62	5.9	2
806	7.7	7.68	7.01	6.5	2
1196	8.0	7.59	7.92	5.8	2
1257	8.4	8.32	8.13	3.3	2
676	8.7	8.51	8.37	13.0	2
894	9.2	10.47	9.61	8.5	2
975	9.5	8.60	8.98	7.3	1
604	9.8	9.57	9.73	0.5	2
973	10.3	9.63	9.57	2.8	2
1134	10.9	11.52	11.23	4.3	2
1052	11.4	10.41	10.53	-4.9	1

ACUTE LEAF WILLOW					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI 1991	REPLANTS 1989-91
		1991	1989-91		
376	2.3	0.76	1.00	115.8	0
225	2.8	1.07	1.51	127.5	0
5	3.3	1.45	2.07	145.8	0
296	3.4	1.54	1.84	171.5	0
390	3.5	1.70	2.06	141.8	0
111	3.5	2.29	2.53	126.5	0
157	4.3	2.98	3.06	120.0	0
283	4.4	1.89	2.67	161.5	0
303	4.5	2.72	3.27	122.0	0
27	4.7	2.21	3.27	166.8	0
627	4.8	4.10	4.11	93.3	0
371	5.1	2.97	3.48	125.0	0
729	5.6	5.59	5.02	68.5	0
369	5.6	3.92	4.21	93.3	0
1013	6.2	5.82	5.48	72.0	0
652	6.3	7.72	7.04	42.6	1
623	6.5	5.59	5.63	99.3	0
1098	6.8	6.80	6.82	37.5	1
744	8.1	7.22	7.38	58.5	1
1214	8.3	7.92	7.93	58.8	2
770	8.3	8.36	8.50	70.5	0
658	8.4	7.68	8.20	61.8	1
737	8.6	8.50	8.20	19.9	1
669	8.6	8.57	8.56	65.3	1
1221	9.4	8.32	8.14	26.0	3
988	9.5	9.90	9.44	32.0	2
840	9.6	8.86	8.86	68.8	0
974	9.9	10.10	9.95	54.8	2
1031	10.1	9.83	9.13	3.8	1
1281	10.5	10.11	10.74	1.3	3

LAUREL LEAF WILLOW					
SITE NUMBER	ORIGINAL VERT EC	HORIZONTAL EC		^ GI 1991	REPLANTS 1989-91
		1991	1989-91		
276	2.6	0.62	1.15	160.8	0
275	2.8	0.82	1.42	135.8	0
9	3.1	1.41	1.85	57.0	0
7	3.3	1.27	2.03	145.8	0
222	3.3	1.32	1.89	113.8	0
174	3.3	1.18	1.72	123.0	2
39	3.3	1.47	2.11	118.8	0
37	3.4	1.66	2.33	139.8	0
341	3.4	1.28	1.74	116.3	0
241	3.7	1.98	2.34	121.0	0
100	4.2	2.55	2.93	72.5	0
480	4.2	2.88	2.84	96.3	0
28	4.3	2.38	3.30	131.3	0
947	4.5	4.19	3.97	83.8	0
946	4.6	3.60	4.04	89.5	0
65	4.7	2.67	3.15	47.8	0
73	4.9	3.13	3.25	100.5	0
203	5.0	3.14	3.50	96.8	0
645	5.0	4.01	4.04	93.3	0
75	5.0	3.26	3.36	58.5	0
793	5.6	5.64	5.30	124.3	0
403	5.7	3.38	3.87	84.8	0
1164	5.9	5.59	5.68	99.8	2
1167	6.1	5.51	5.73	62.5	2
1247	6.2	4.37	4.94	87.8	0
653	6.5	6.57	6.23	24.3	3
599	6.5	6.37	6.17	10.5	1
596	6.6	6.06	5.98	31.0	0
1242	6.8	5.90	5.98	79.0	1
539	6.9	6.65	6.60	9.0	1
611	7.4	7.16	7.14	46.5	2
617	7.5	7.91	7.96	0.3	1
512	7.6	6.96	7.12	-20.0	0
586	7.6	7.85	7.68	38.5	1
615	7.8	7.98	8.00	17.5	2
828	7.9	8.69	8.31	16.0	3
906	8.0	7.59	7.67	17.5	1
589	8.5	9.59	9.37	26.6	2
1036	8.7	8.33	7.89	11.3	1
738	8.8	10.16	9.68	-0.5	5
900	8.9	8.12	8.35	44.3	2
1190	9.1	9.26	8.61	53.3	2
1070	9.1	6.84	7.60	48.0	2
896	9.1	7.24	8.38	0.3	3
1068	9.2	8.20	8.36	32.0	0
608	9.2	8.60	9.01	11.8	3
671	9.3	8.58	9.11	55.0	2
987	9.4	9.56	9.16	-2.5	2
1132	10.0	9.01	9.23	19.5	2
1063	10.5	8.98	8.65	34.5	0

GLOSSARY

Exchangeable Sodium Percentage (ESP) - defines the extent to which the adsorption complex of a soil is occupied by sodium.

$$ESP = \frac{[exchangeable\ sodium]}{[cation\ exchange\ capacity]} \times 100$$

Halomorphic Soil - a suborder of soil which is formed under imperfect drainage in arid regions and is subdivided into soil groups such as saline and sodic (Brady, 1974).

Halophyte - a category of plants that are able to survive in habitats of excess alkali salt concentrations (Boyko, 1966). These can be placed in two categories, miohalophytes (border halophytes) and euhalophytes, which will grow in the following ranges of sodium salt concentrations (Boyko, 1966).

Halophytes

Type	concentration ranges
Miohalophytes	0.01% to 1.0%
Euhalophytes	
mesohalophytes	0.5% to 1.0% .
meso-euhalophytes	0.5% to > 1.0%.
euhalophytes	only > 1.0%.

Saline Soil (solonchak or white alkali) - one in which soluble salts have accumulated in sufficient quantity to adversely affect growth (Harpstead, 1988). Saline soils are predominant in southern Alberta and have an excess of soluble salts such as chlorides and sulphates of sodium, calcium and magnesium (Brady, 1974).

Sodic Soil (black alkali) - one that contains enough sodium to become highly dispersed so that yields are adversely affected (Harpstead, 1988).

Sodium Adsorption Ratio (SAR) - provides a value for the predicted rate of sodium adsorption to the soil. It is calculated by:

$$SAR = \frac{1}{2} \times \frac{[Na^{+}]}{\sqrt{[Ca^{2+}] + [Mg^{2+}]}}$$

Soluble Sodium Percentage (SSP) - describes the proportion of sodium in a solution and is produced by the formula:

$$SSP = \frac{[soluble\ sodium]}{[total\ cation]} \times 100$$

Solute Potential (γ_s) - a term used to describe the amount of soluble materials (such as salts) found in the soil solution. It can be calculated by the formula

$$\gamma_s = -RTC_s$$

where R is the universal gas constant, T the absolute temperature and Cs the solute concentration. The resulting value is a measure of energy per unit volume, usually expressed as J/m3 (Hanks, 1980).

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