

EFFECT OF BASEMENT SUMP PUMP EFFLUENT ON THE GROWTH AND PHYSIOLOGY OF URBAN BLACK ASH AND GREEN ASH ORNAMENTAL TREES

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Abstract. The effect of basement sump pump effluent discharge in proximity to boulevards and ornamental trees was studied at several sites near Edmonton, Alberta, Canada throughout the summer of 1996. The growth, leaf petiole water potentials, and gas exchange of black ash (*Fraxinus nigra*) and green ash (*F. pennsylvanica*) trees were measured at sites with and without nearby sump pump effluent discharge. Black ash trees had higher mortality, altered water relations, and significantly lower caliper increase at the site with sump pump effluent discharge compared to trees at the site without effluent discharge. Green ash trees situated away from sump pump effluent discharge had significantly greater caliper increase than trees situated near effluent discharge. Furthermore, salt injury symptoms were observed on both species of trees located at sites with nearby effluent discharge. Our results demonstrate the importance of monitoring sump pump effluent discharge and its effects on boulevard ornamental trees in areas where soils are poorly drained or contain high levels of salts. It is recommended that basement sump pump effluent discharge hoses should be positioned away from boulevards and ornamental trees.

Key Words. Effluent discharge; salt injury; soil drainage; water stress; *Fraxinus nigra*; *F. pennsylvanica*.

Poor survival and impaired post-planting growth of urban boulevard and other ornamental trees has been identified as a significant problem by a number of municipalities in the province of Alberta, Canada. The cities of St. Albert and Sherwood Park, located in central Alberta near Edmonton, are two such municipalities. The possible reasons for poor performance of ornamental boulevard trees are numerous, complex, and may result from post-transplanting water stress (Cregg 1995) and/or other site-specific environmental factors including exposure to sunlight, precipitation runoff, wind, and roadway de-icing salts (Simini and

Leone 1986; Gallant 1995). Planting site preparation such as planting hole configuration and alteration of boulevard soil structure (Arnold and Welsh 1995) was shown to influence establishment of container-grown live oak (*Quercus virginiana* Mill.). Soil compaction from sidewalk and roadway construction can influence the post-transplanting success of ornamental trees by negatively affecting root establishment and reducing the subsequent uptake of water and nutrients (Barley 1963; Eavis and Payne 1968; Taylor 1971; Heilman 1981; Grabosky and Bassuk 1995). Planting site drainage, pH-dependent nutrient availability of soils, and species selection are additional factors to consider when initiating an urban tree planting program.

Urban sprawl is forcing city planners, in prairie regions, to consider the use of land that was previously less desirable for housing developments. Engineering problems such as high water tables and poor drainage present landscape architects with an additional challenge of selecting non-native tree species able to survive in these problematic environments. Installation of basement sumps to collect seepage water and pumps to discharge this water (effluent) are common methods of dealing with high water tables and poor drainage of clay-based soils in some housing developments constructed in Alberta. Recently, poor survival of urban boulevard ornamental trees was noticed in residential areas of Sherwood Park and St. Albert that were serviced by basement sump pumps. The objective of this study was to determine the effect of basement sump pump effluent discharge, in proximity to boulevards, on the physiology, growth, and survival of ornamental black ash (*Fraxinus nigra* Marsh.) and green ash (*Fraxinus pennsylvanica* Marsh.) trees.

MATERIALS AND METHODS

Plant Material and Planting Method

Ornamental trees used in this study consisted of black ash (*Fraxinus nigra* Marsh. cv. Fallgold) and green ash (*Fraxinus pennsylvanica* Marsh. cv. Patmore). All trees were obtained from Stewart Bros. Nurseries Ltd. (Kelowna, BC, Canada). Trees were 5 to 7 years old and calipers ranged from 55 to 65 mm (2.2 to 2.6 in.) for black ash, and 50 to 70 mm (2 to 2.8 in.) for green ash. Trees were grown in containers and nursery beds using standard nursery protocols. The root ball of each tree species was wrapped in burlap, for transport, prior to installation. The same city landscape contractor, using protocols established by the city of Edmonton installed all trees.

Planting Sites

Planting sites were selected to allow physiological measurements to be collected from trees of each species that were subjected to irrigation with sump pump effluent discharge, and those that were not (Table 1).

The locations with sump pump effluent discharge (effluent+) were

- St. Albert (Deer Ridge). Northwest St. Albert, Alberta; includes Delage Crescent and Deer Ridge Drive. Black ash trees (n = 10) were planted at the Delage Crescent site, and green ash trees (n = 9) were planted at the Deer Ridge Drive site. The Deer Ridge area appears to be poorly drained, and both streets have high-volume sump pump effluent discharge in proximity to boulevard trees. Salt residues on sidewalks and roadways, in addition to flooded boulevards, were noted throughout the summers of 1995 and 1996.

- Sherwood Park (Regency). A residential site with moderate to heavy sump pump effluent discharge in proximity to boulevard trees. Green ash trees (n = 5) were studied at this site.

The following locations did not have sump pump effluent discharge (effluent-):

- St. Albert (Oakmont). A residential subdivision in northeast St. Albert. Green ash trees (n = 5) were studied at this site.
- Sherwood Park (Nottingham). A residential subdivision in southeast Sherwood Park. Black ash trees (n = 9) were studied at this site.
- Sherwood Park (Heritage Hills). A residential subdivision close to Sherwood Park, Regency, and Heritage Hills. Green ash trees (n = 8) were studied at this site.

Measurements

Annual percent caliper increase of study trees was measured for the period September 1, 1995, to September 1, 1996. Caliper measurements were made not less than 15 cm (6 in.) above ground level and a minimum of 10 cm (4 in.) above a bud union. Post-planting physiology measurements were commenced after bud flush and were recorded for the measurement dates May 28, June 7, July 9, August 9, and August 20, 1996. Transpiration rate and leaf stomatal diffusive resistance were measured on single leaves of each tree species using a steady-state porometer (Li-Cor, Lincoln, NE, U.S.) and were corrected for leaf surface area. Transpiration rates are expressed as micrograms of water per second (mg/s). Stomatal diffusive resistances are expressed as seconds per centimeter (s/cm). Leaf petiole water potentials were determined for each tree species using

Table 1. Comparison of study sites with (effluent+) or without (effluent-) sump pump effluent discharge in proximity to boulevard trees.

Site location	Site type	Soil type	Drainage	Sun exposure	Slope	Effluent discharge
St. Albert (Deer Ridge)	effluent+	clay + sand	poor	full	none	heavy
St. Albert (Oakmont)	effluent-	clay + sand	good	full	none	light
Sherwood Park (Regency)	effluent+	clay + sand	poor	full	light	moderate-heavy
Sherwood Park (Heritage Hills)	effluent-	clay + sand	good	full	moderate	none
Sherwood Park (Nottingham)	effluent-	clay + sand	good	full	light	none

excised leaves placed in a Scholander pressure chamber charged with compressed nitrogen and are expressed in mega pascals (MPa). Soil chemical composition and groundwater analyses from the Deer Ridge region of Northwest St. Albert were performed by UMA Planning & Design and were provided by the City of St. Albert Engineering Department.

Statistical Analysis

All growth data were arcsine transformed to improve homoscedasticity and normality before being tested for statistically significant differences using t-test, analysis of variance, and Tukey or Duncan's multiple comparison tests (Zar 1984). All statistical tests were performed using SPSS for MS Windows ver. 6.1.

RESULTS AND DISCUSSION

Sump Pumps and Salt

Some soils in and around the Edmonton area are classified as Solonchic (high in salt) (Toogood and Cairns 1978). Sodium, chloride, and sulfate ions are major salts commonly found in the soils of this region. The Solonchic soil zone includes the area northwest of Edmonton and includes the Deer Ridge area of St. Albert. Far inland, natural salt seepage from geological marine deposits can occur, and these deposits may be found in areas that are great distances from the ocean (Taiz and Zeiger 1991). In soils containing high levels of salts, the problem can be made worse by evaporative water loss directly from soils or evapotranspiration processes in plants, which leaves salts behind and effectively concentrates them at the soil surface. Where irrigation water quality is poor as a result of high solute concentrations, salts from irrigation water can concentrate in areas where drainage is poor or evaporation rates are high.

Figure 1 shows the positioning of sump pump effluent-discharge hoses in proximity to boulevards, salt residues that were left behind after evaporation of effluent, and some of the damage to vegetation and a steel utility box caused by the effluent.

Late spring foliage of black ash trees located in proximity to sump pump effluent discharge was

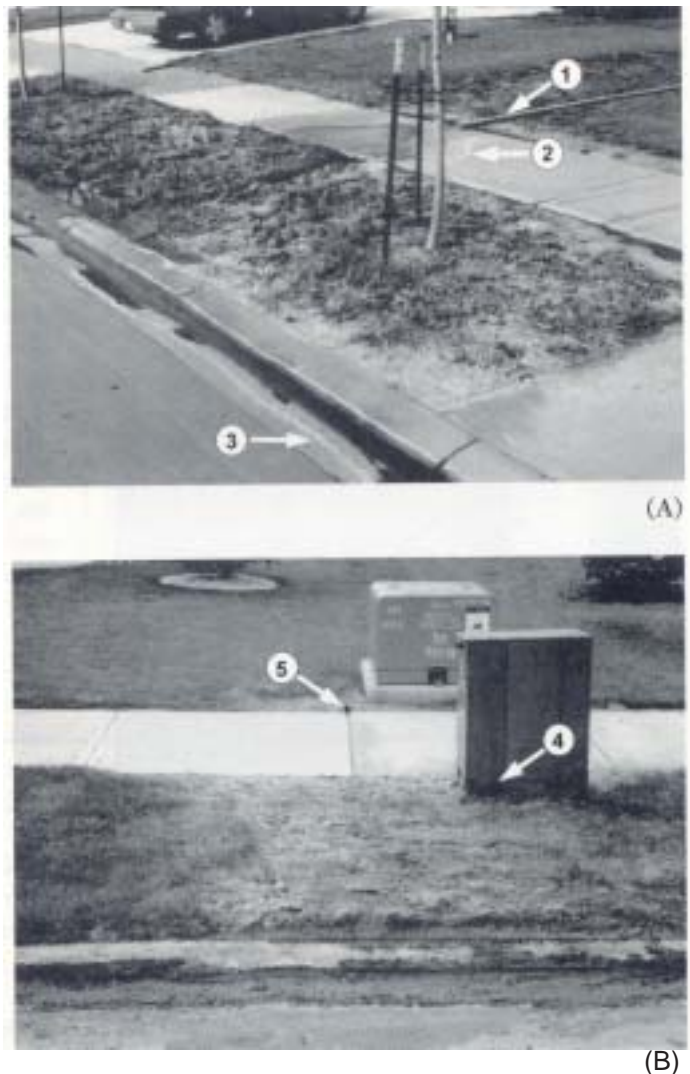


Figure 1. Positioning of sump pump effluent discharge hose at edge of sidewalk in proximity to boulevard. (A) New discharge hose (arrow 1) is visible prior to sod grass installation; salt residues (arrows 2 and 3) are evident on sidewalk and roadway after evaporation of effluent. (B) Damage caused by sump pump effluent seen as browning of boulevard grass and corrosion of a metal utility box (arrow 4) resulting from a hidden discharge hose (arrow 5).

stunted and showed signs of necrosis when compared to black ash trees located away from sump pump effluent discharge (Figure 2). New shoot die-back, leaf tip or leaf marginal browning, and many other injury symptoms exhibited by black ash trees located in proximity to sump pump effluent dis-

charge hoses were identical to symptoms described for trees and shrubs damaged by excessive roadway deicing salts (Hanes et al. 1971; Gallant 1995). Sodium, chloride, and sulfate ions, which are common components of the soils around Edmonton, have different effects on plants. Excess sodium displaces calcium associated with plant membranes and may negatively affect enzymes vital for plant metabolism (Cramer et al. 1985). Both sodium and chloride may accumulate in chloroplasts, inhibiting photosynthe-

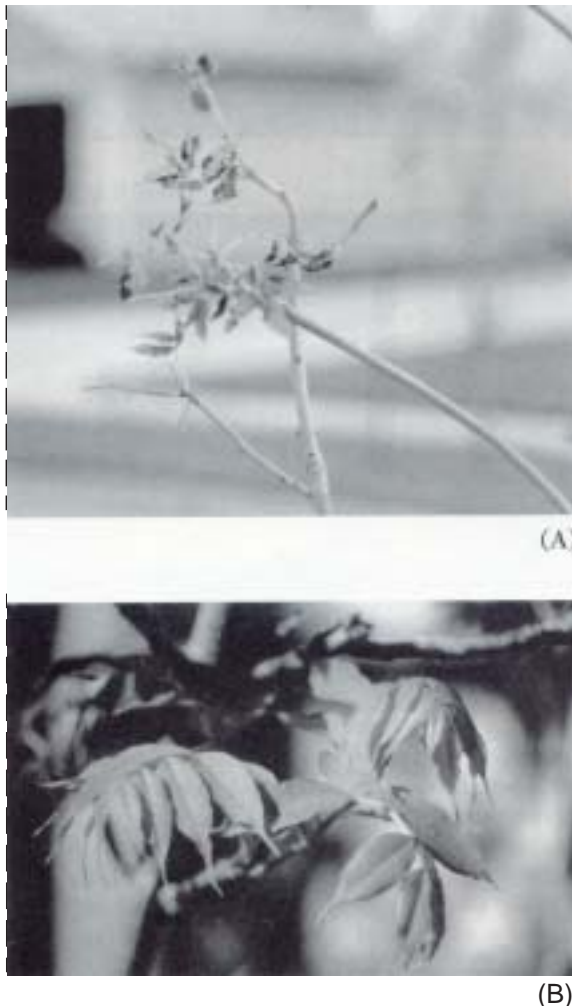


Figure 2. Appearance of late spring foliage on transplanted black ash trees at two different sites. (A) St. Albert-Deer Ridge, where sump pump effluent was discharged into boulevards. (B) Sherwood Park-Nottingham, where there was no sump pump effluent discharge.

sis (Robinson and Downton 1984). Sulfate and chloride ions contribute to high salinity and can cause osmotic damage or physical damage to plant cell membranes as well as cellular toxicity.

UMA Planning & Design group measured representative soil electrolytic conductivity and major ion levels at several locations, near our study trees, in the Deer Ridge area (Table 2). Soil electrolytic conductivities and levels of sodium and sulfate varied widely but were among the highest at the St. Albert, Deer Ridge streets Donald Place and Delage Crescent. Both sites contained boulevard ornamental trees used in this study, and had abnormally high tree mortality rates where sump pump effluent was discharged directly into boulevards. At the Deer Ridge (Delage Crescent) site, 70% of the black ash study trees died before the end of the experiment, while the remaining 30% exhibited severely stunted growth and delayed spring bud flush. In black ash trees, altered water relations and significantly lower mean percent caliper increase (two-sample t-test significance level 0.01, $P < 0.005$) were recorded at the St. Albert Deer Ridge site (effluent+) compared to trees at the Sherwood Park Nottingham site (effluent-) (Figure 3).

Sump pump activity at the Deer Ridge site was very high, and sump pump effluent collected from a local basement pump had an electrolytic conductivity of 10.2 dS m^{-1} . The high electrolytic conductivity of sump pump effluent suggests very high ion content, which likely contributed to the high levels of ions measured in soil from the Deer Ridge boulevards (Table 2). This might account for injury symptoms observed on boulevard ornamental trees (Figure 2A) and grass (Figure 1B) in the area.

Sump Pumps and Flooding

Flooding of boulevards is another consequence of sump pump activity. Flooding of soils causes a reduction in the availability of oxygen to plant roots. Roots require oxygen to survive, and when a sump pump hose is placed in proximity to a boulevard containing ornamental trees, the potential exists for flooding with large volumes of effluent. The soil types found at our study sites were of high clay content. These soils often have poor drainage characteristics and poor oxygenation, possibly made worse by compacting from local roadway and sidewalk construction (Grabosky and Bassuk 1995). In poorly

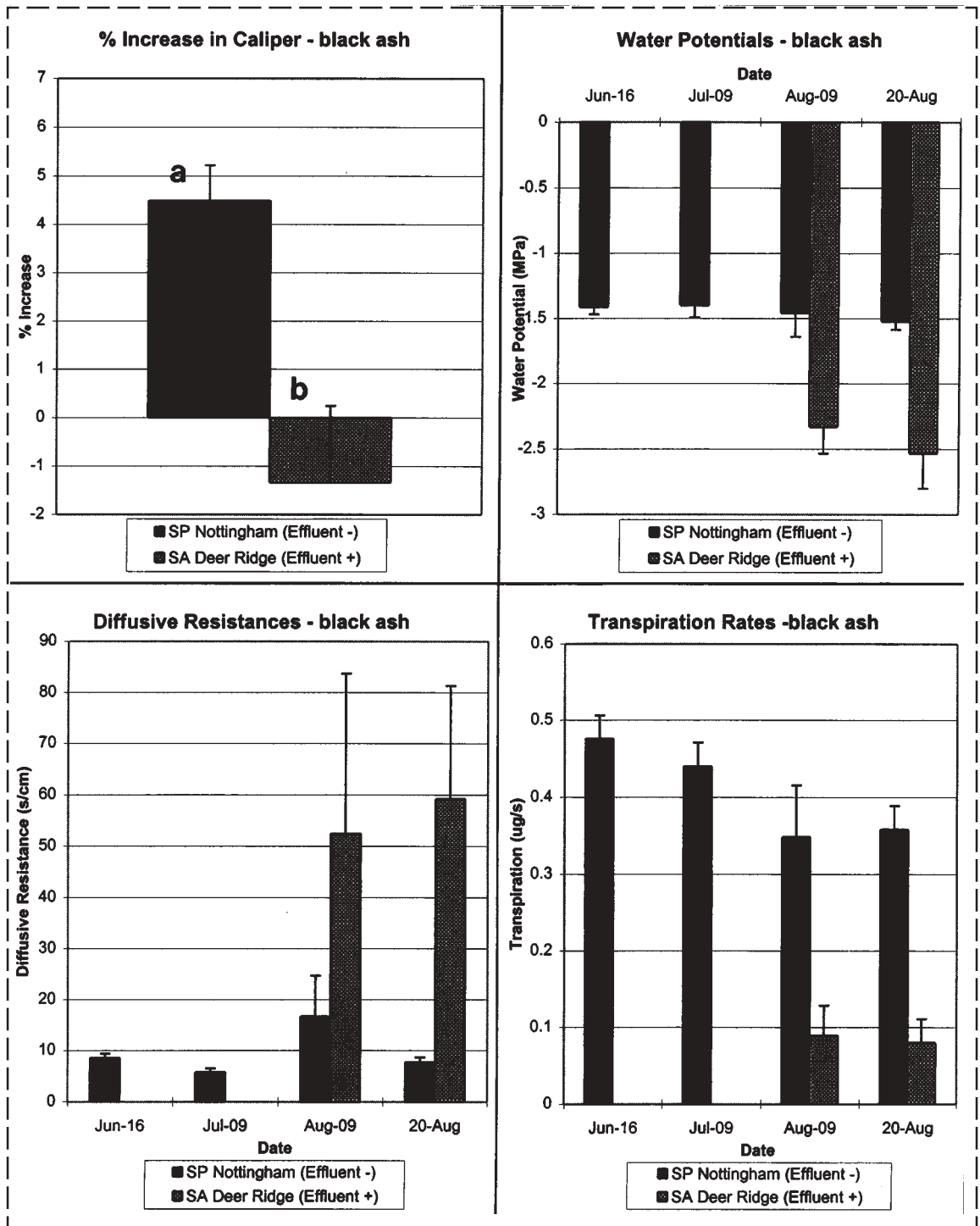


Figure 3. Caliper growth, leaf petiole water potentials, and gas exchange of black ash trees irrigated with sump pump effluent discharged into boulevards (effluent+), and black ash trees not irrigated with sump pump effluent (effluent-). Bars are means \pm standard error. Bars with the same letter are not significantly different.

Table 2. Representative pH, electrolytic conductivity (EC), and major ion composition of soil sampled from the St. Albert, Deer Ridge study site. Selected salt ions shown include calcium, magnesium, potassium, sulfate, and chloride.

Sample location	pH	EC (ds/m)	CA (mg/kg)	MG (mg/kg)	NA (mg/kg)	K (mg/kg)	SO ₄ (mg/kg)	CL (mg/kg)
Dufferin St.	5.7	3.2	244	39.5	68.1	6	276	23.5
Delaney Pl.	6.6	2.3	115	39.9	163	7.1	236	14.9
Douglas Cr.	6.7	3.6	199	84.7	287	21.4	443	21.5
Dorchester	6.7	1.9	159	38.1	102	5.5	219	11.6
Donald Pl.	6.8	5.4	368	143	505	15.2	758	96.7
Delage Cr.	6.5	1.2	127	24.3	37.6	5.8	140	5.7
#95 Delage Cr.	6.4	3.4	102	46.3	132	12.2	235	3.6
Deer Ridge	7.4	0.9	81.6	26.9	25.4	11.5	72.4	10.1
Derome Cr.	6.7	1.2	135	32	43.3	8.6	125	22.2
Deslaurier Cr.	6.5	0.8	101	16.9	26.1	9.4	83	7.2

drained soils, salts do not leach efficiently and can quickly reach levels injurious to plants (Taiz and Zeiger 1991). Flooding of boulevards with sump pump effluent was observed at the Deer Ridge study site where black ash trees were located and could be partially the result of compacted soils under nearby roadways and sidewalks. Poor tree growth and physiology was observed at the Sherwood Park Regency development, where green ash appeared to be negatively influenced by flooding with sump pump effluent. A comparison between the physiology and growth of green ash trees irrigated with sump pump effluent and those that were not was made using data obtained from green ash trees at St. Albert and Sherwood Park. The St. Albert sites were Deer Ridge (effluent+) and Oakmont (effluent-). The Sherwood Park sites were Regency (effluent+) and Heritage Hills (effluent-). Figure 4 shows the differences in growth, photosynthesis, and water relations of the green ash trees from each site. Inhibited photosynthesis and water relations have been shown for flooded poplar trees (Liu and Dickmann 1993); therefore, if the volume of sump pump effluent discharge into boulevards becomes sufficient to cause flooding, similar effects might be observed for black ash and green ash ornamental trees. There was a significantly higher mean percent caliper increase for green ash trees located at Sherwood Park Heritage Hills (effluent-)(one-way ANOVA Duncan test significance level 0.05). This site was not affected by sump pump effluent, and it had a moderate slope with adequate drainage. The Heritage Hills (effluent-) green ash trees increased caliper significantly

more than green ash trees at the Regency (effluent+) site. Green ash mean caliper percent increases at the two St. Albert sites (effluent+/-) were not significantly different. Green ash trees appeared to be more resistant to the negative effects of sump pump effluent discharge than black ash trees, as suggested by similar physiological responses between green ash trees subjected to irrigation with sump pump effluent and those that were not (Figure 4). However,

before statistically rigorous conclusions can be made, further study must be done to compare the direct effects of sump pump effluent on the water relations and physiology of various ornamental tree species typically used for urban reforestation. Such studies have been done using experimental irrigation of boreal forest reclamation species with tailings effluent originating from oil sand processing in northern Canada (Renault et al. 1998).

Successful establishment of urban ornamental trees and species selection for contrasting urban sites are of major concern for cities across Canada. There are many distinct geographical/geological regions across the country and a broad range of climatic conditions for each. Native vegetation types within these regions can sometimes vary widely and are usually limited by a combination of soil, climatic properties, and the ecology of vegetation already present. The contrast between native and introduced vegetation in the urban forest of the Great Plains region of the United States was best described as an "oasis of trees surrounded by open prairie" (Grey and Deneke 1978). The prairie regions of western Canada could be described in a similar way. New urban and residential beautification programs involving the introduction of non-native ornamental trees to prairie cities have been affected by some of the same environmental limitations imposed on native vegetation. In addition, modern roadway, sidewalk, and building construction practices have negatively impacted urban ornamental tree establishment. This study demonstrated the combined negative effects of salts and flooding on the physiology, growth, and survival

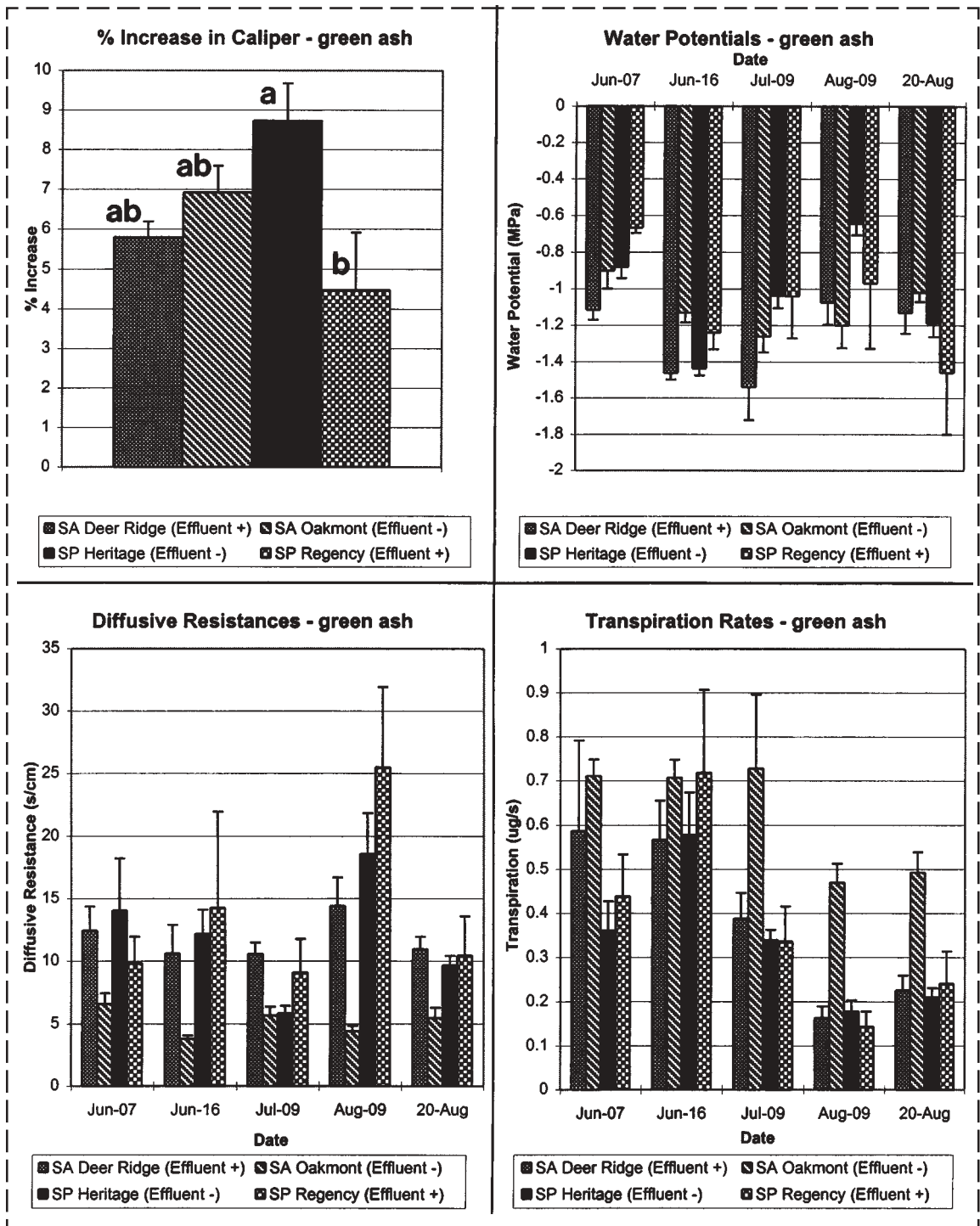


Figure 4. Caliper growth, leaf petiole water potentials, and gas exchange of green ash trees irrigated with sump pump effluent discharged into boulevards (effluent+), and green ash trees not irrigated with sump pump effluent (effluent-). Bars are means \pm standard error. Bars with the same letter are not significantly different.

of ornamental black ash and green ash boulevard trees caused by basement sump pump effluent discharge. We suggest that the effects of sump pump effluent discharge on ornamental trees be monitored closely, particularly in areas with elevated soil salt levels. In addition, it is recommended that basement sump pump effluent discharge hoses be positioned to prevent drainage into boulevards or in proximity to ornamental trees.

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Résumé. Les effets de la décharge d'effluents de pompes à puisard sur des arbres ornementaux situés à proximité de boulevards a été étudié sur différents sites près d'Edmonton en Alberta au Canada durant l'été 1996. La croissance, le potentiel en eau des pétioles foliaires et les échanges gazeux du frêne noir et du frêne de Pennsylvanie ont été mesurés sur différents sites avec et sans décharge à proximité d'effluents de pompes à puisard. Les frênes noirs avaient un taux de mortalité plus élevé, des processus impliquant l'eau altérés ainsi qu'un accroissement en calibre significativement plus faible dans les zones de décharge des pompes à puisard par rapport à ceux situés dans les zones où il y avait absence d'effluents provenant de ces pompes. Les frênes de Pennsylvanie situés loin des zones de décharge d'effluents de pompes à puisard avaient un accroissement en diamètre significativement plus important que celui des arbres situés près de ces zones. De plus, des symptômes de dommages par le sel ont été observés sur les deux espèces d'arbres localisés près des zones de décharges de ces effluents. Nos résultats démontrent l'importance de gérer la décharge des effluents des pompes à puisard ainsi que de contrôler leurs effets sur les arbres ornementaux des boulevards, et ce là où les sols sont mal drainés ou renferment des quantités élevées de sels. Il est recommandé que les boyaux de décharge de ces pompes devraient être positionnés vers une autre direction que les boulevards et les arbres ornementaux.

Zusammenfassung. Während des Sommers 1996 wurde an verschiedenen Standorten bei Edmonton, Alberta, Canada, die Einflüsse von der Entleerung von Abflusssammelbehältern in unmittelbarer Nähe von Gehwegen und Zierbäumen untersucht. Das Wachstum, Blattwasserpotential und der Gasaustausch von Schwarzen und Grünen Eschen wurde an Standorten mit und ohne Nähe zu nahen Abflusssentleerungen gemessen. Die Schwarz-en Eschen hatten eine höhere Sterberate, veränderte Wasser-

beziehungen und deutlich niedrigeren Durchmesser auf den Standorten mit Entleerung im Vergleich zu den Bäumen an den anderen Standorten. Grüne Esche, die mit Abstand von zu solchen Standorten wuchsen, hatte deutlich größeren Durchmesserzuwachs als die Bäume in der Nähe solcher Anlagen. Darüber hinaus wurden bei beiden Spezies in der Nähe dieser Anlagen Symptome von Salzschädigungen beobachtet. Unsere Ergebnisse zeigen deutlich, dass Abflusssammelbehälterentleerungen und ihre Einflüsse auf Zierbäume in Bereichen von schwach drainierten oder hochsalzhaltigen Böden zu überwachen sind. Es ist empfehlenswert, die Entleerung dieser Anlagen nicht im Bereich von Gehwegen und Zierbäumen zu positionieren.

Resumen. Durante el verano de 1996 se estudió el efecto de las descargas residuales de agua de lluvia en los bulevares con árboles ornamentales de varios sitios cercanos a Edmonton Alberta, Canadá. Se midió el crecimiento, los potenciales hídricos de los peciolo foliares y el intercambio gaseoso de árboles de fresno negro y verde, en sitios con y sin descarga residual cercana. Los fresnos negros tuvieron mayor mortalidad, relaciones hídricas alteradas, y significativamente menor incremento en calibre, en los sitios con descarga comparados con los árboles sin estos afluentes. Los árboles de fresno verde situados lejos de los afluentes tuvieron significativamente mayor incremento en diámetro que los árboles situados cerca de los mismos. Además, los síntomas de daño por sales fueron observados en las dos especies localizadas en los sitios cercanos a la descarga. Nuestros resultados demuestran la importancia del monitoreo de los sitios con descarga de aguas residuales, en áreas donde los suelos son pobremente drenados o contienen altos niveles de sales. Se recomienda que las mangueras de descargas residuales sean ubicadas lejos de los bulevares y de los árboles ornamentales.