AMELIORATION AND REVEGETATION OF SMELTER-CONTAMINATED SOILS IN THE COEUR D'ALENE MINING DISTRICT OF NORTHERN IDAHO

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ABSTRACT

Results of two experiments, one greenhouse project and one field study, indicate that high heavy metal concentrations in smelter-contaminated soils and in tree seedlings grown thereon, increase mortality rates. Factors that increased survival and growth of trees were: (i) liming the acidic, polluted soils, and (ii) using containerized seedlings. Both methods reduced the toxic potential of heavy metals in the plant and soil systems.

Species were significantly different in their respective rates of survival and growth. These differences were due primarily to inherent growth habits and tolerances to adverse growing conditions.

Field study results indicate that differences in overall survival of tree seedlings was a function of soil type (site). Findings suggest that the major cause of plant mortality, as modified by site, was high concentrations of Zn in seedling tissue and in soils.

Additional Key Words: smelter-contaminated soils, revegetation, heavy metal toxicity.

INTRODUCTION

The Coeur d'Alene Mining District of northern Idaho has long been the site of mining and smelting activities. Zinc and lead ores, spalerite and galena, respectively, are the chief mineral products of the region. A lead smelter, owned by Bunker Hill Mining Company, has operated continuously in the Kellogg Valley since 1916, and in 1928 an electrolytic zinc plant began production (7). These facilities were run without any form of pollution control until 1954 (7).

Because the lead and zinc minerals are in sulfide form, grea quantities of sulfur dioxide and metal particulates (CdO, ZnO, and PbO) have been emitted during the process of ore roasting (15,20). These pollutants subsequently fell upon the surrounding soils and vegetation (23). Oxidation of sulfur dioxide to sulfate has served to greatly lower the soil pH, which in turn has increased the solubility of metals in the soil (25). Concomitant with the several forest fires suffered by the area in the past half century, the pollution has resulted in devegetation of the adjacent terrain. The atmospheric inversion common to the valley area has compounded the pollution effects by holding the smelter gases and particulates in the local area.

OBJECTIVES

Lime has been proven to be an effective means for revegetating acidic, heavy metal contaminated soils (6). In light of such findings, two studies were conducted to determine: (1) which of the species planted was most tolerant to the adverse soil conditions, (2) the role of various metals in seedling mortalit (3) the value of lime as a means to rehabilitate smelter-contaminated soils, (4) the value of containerized tree seedlings as a tool for revegetation of polluted soils, and (5) levels of extractable heavy metals in the soil as a function of pH.

One study, a field project, involved planting four species of tree seedlings on limed and control plots of two acidic, heavy metal contaminated soils. The species selected were black locust (Robinia pseudoacacia), Scotch pine (Pinus sylvestris), Austrian pine (Pinus nigra, Arnold), and ponderosa pine (Pinus ponderosa, Laws).

The second study, a greenhouse experiment, consisted of planting black locust and Scotch pine seedlings in a smelter-contaminated soil at five pH levels.

METHODS

Experimental Design - In the field project, a split plot, randomized, complete block design was used to determine the response of four tree species grown on two soils, under two treatments (lime and control), and two planting methods (bareroot and containerized). The two sites (lead and zinc) were chosen so that a comparison between the relative effects of pB and Zn upon seedling survival could be made. Ten plots, 9.15 square meters in size, were established at each site. Five plots at each site were limed to pH 6.0 to a depth of 6 inches. Liming rates were based on buffer curves constructed in the laboratory. The soils at both sites have tentatively been classified as Dystrochrepts.

A randomized, complete block design was employed in the greenhouse study to test the response of two tree species grown on 5 pH levels of a smelter-contaminated soil. Five seedlings of each species were planted in each of the pH levels. These seedlings were grown for four months in a controlled environment chamber with a photoperiod of 15 hours. Minimum and maximum temperature settings were $10^{o}C$ and $27^{o}C$, respectively.

Soil Sampling - For the field project, soil samples were taken at depths of 0-10, 10-20, and 20-30 cm (0-4, 4-8, and 8-12 inches). The plots were sampled just prior to planting. Field samples were sieved through a 2 mm screen and the percentages of coarse fragments were calculated. Soil samples for the greenhouse experiment were taken from the pots after harvesting the seedlings. Greenhouse soils had been sieved prior to their use as planting medium. After air-drying, the percent moisture in all soils was determined by oven-drying subsamples. The sieved, air-dry samples were saved for further analyses.

Seedling Tissue Collection - At the end of the studies, seedlings were severed 1 cm above soil level. Field samples were wrapped in plastic bags, sealed, and placed in an ice chest to minimize respiration and transpiration. Seedlings that died prior to the end of the growing season were collected at death and treated in the manner previously described. These seedlings were frozen until all plants were ready for analysis. In the lab, seedlings of the same species, plot, and planting method combination were treated as one sample. This left five effective replications of each treatment on each site.

All samples, from field and greenhouse studies, were washed thoroughly to remove any external contamination and then dried at 60^{o}C for 24 hours. The samples were then ground and stored for later heavy metal and nutrient content analyses.

Soil Analyses - Determinations were as follows: (a) soil acidity by pH meter, (b) percent organic matter by the Walkley-Black method (13), (c) extractable Na, K, Mg, Ca, Cd, Zn, Pb, and Mn in meg/100q of oven-dry soil by atomic absorption spectroscopy after neutral N NH_4OAc extraction (4, 12, 14, 20), (d) percent base saturation by summation of Ca, Mg, Na, and K, (e) percent heavy metals on the exchange by summation of Cd, Zn, Pb, and Mn, (f) exchangeable acidi by the triethanolamine, $BaCl_2$ method (4), (g) water soluble sulfate by the turbidimetric $BaCl_2$ method (4), using water in place of NaHC (h) total N by macro-Kjeldahl (4), (i) cation exchange capacity by neutral N NH_4OAc replacement and subsequent NH_3 distillation (4), (j) available P by dilute double acid extraction and colorimetric determination (4,9), (k) c:N ratio from percentages obtained in the Walkley-Black and Kjeldahl procedures, (l) bulk density by the clod method (3), (m) one-third and 15 atmosphere moisture holding capacities by pressure plate extraction (3), (n) soil texture by Bouyoucos hydrometer (3), and (o) available soil moisture by subtraction of 15 atmosphere water holding capacity from the one-third atmosphere values.

In the greenhouse study, only pH and extractable cations were determined in the soil analyses. Also, extractable Al was determined by atomic absorption spectroscopy after N KCl extraction (4).

Microbial Respiration Determination - Soil samples from the 0-4 cm depths of all field plots were brought to 50 percent field capacity and incubated for 75 hours in sealed jars. Each jar contained a 10 ml trap of 5 N NaOH. The mg of CO_2 evolved/day/100g of oven-dry soil was determined by back titrating the trap solution with 2 N H_2SO_4.

Seedling Analyses - The tissue determinations for field seedlings were as follows: (a) total N content by semi-micro Kjeldahl (4,8) using 0.3q of tissue, (b) S content was determined turbidimetrically with $BaCl_2$ using tissue that had been dry-ashed, taken up with 8 N HCl, and diluted accordingly (13), (c) P content was colorimetrically determined on an aliquot of the same sample (14), (d) K, Na, Ca, Mg, Zn, Pb, Cd, and Mn were determined by atomic absorption spectroscopy after diluting the dry-ashed sample, (e) seedling growth was recorded at the end of the growing season. The cumulative growth of each seedling was measured in cm from ground level to the tip of the apical bud for conifers. For the locust, growth was measured as the longest, developed lateral stem, and (f) survival percentages were recorded for each species-planting method combination on each plot.

Seedlings grown in the greenhouse were analyzed for all the elements discussed above. Also, the Al content of the tissue was determined by atomic absorption spectroscopy on an aliquot of the ashed sample. Growth of the seedlings grown in the greenhouse experiment was not determined.

Statistical Analyses of Data - Analysis of variance was used in determining differences among treatments and other experimental factors (site and planting method) in the field study, and species in the greenhouse study. Duncan's multiple range test was used to separate treatments in the greenhouse project and species and planting method combinations in the field experiment.

Step-wise multiple regression analyses (1) were run on the computer to find the best prediction model for survival and growth (dependent variables) of the eight species-planting method combinations used in the field study. The same procedure was used to determine the factors involved in mortality of the greenhouse seedlings. Before use in the statistical analyses, all soil properties were corrected for coarse fragment percentages and air-dry moisture values.

The step-wise procedure allows the programmer to select the specific pool of variables used in the prediction equation, and the maximum number of variables permissible in the prediction model. Fewer variables used in achieving an acceptable prediction equation means a more economical application of the model may be made.

All the soil, tissue, and experimental variables determined were used in the preliminary statistical analyses. In order to save space, only those that were significant are presented in Table

RESULTS AND CONCLUSIONS

Only the statistical relationships pertinent to the aim of the revegetation program will be presented here. Many meaningful relationships were established, but have no bearing upon the immediate plans for reclamation.

PART I: FIELD STUDY

SEPARATION OF SPECIES MEANS

Determining tree species that can tolerate harsh soil conditions has been a primary goal of rehabilitation research (10,19). The data presented in Table 2 indicates the relative success of the four tree species, grown in the field, in surviving and growing under the severe conditions. Because site stabilization is foremost in initial revegetation efforts (6,29), survival was judged more important than growth. Therefore, Austrian pine, Scotch pine, and ponderosa pine were selected as the best species to utilize in future reclamation plans.

The effect of another experimental factor, planting method, is presented in Table 3, in the form of a mean separation. It is evident that containerized seedlings were highly superior to their bareroot counterparts in terms of survival rates.

The effect of the containers upon seedling survival was two-fold. The primary effect was to buffer the root system of the seedling against the toxic constituents of the soil system. More specifically, the presence of phosphate in the rhizosphere has been shown to precipitate, and make unavailable, various heavy metal ions (5, 15).

SEPARATION OF TREATMENT, PLANTING METHOD AND SITE MEANS

The effects of treatment, planting method, and site upon several variables, dependent and independent, are shown in Table 4. Of primary interest are the effects of site upon many of the variables.

Zn concentration in the soil was found to be six times as great at the zinc site as at the lead site. In like manner, Zn concentration was three times as great in the seedlings grown at the zinc site. Cd concentration in the soil at the zinc site was also three times as great as at the lead site. When comparing the survival rates at the two sites, in light of the other data presented,

TABLE 1 - List of Variables Found to be Significant in the Statistical Analyses and their Respective Abbreviations.

Variable	Abbreviation
PART I: Field Study	
Soil Chemical Properties	
Extractable Na (meq/100g)	Na
Extractable Mg (meq/100g)	Mg
Extractable Zn (meq/100g)	Zn
Extractable Pb (meq/100g)	Pb
Extractable Cd (meq/100g)	Cd
Extractable Mn (meq/100g)	Mn
Percent Heavy Metals on the Exchange	%HM
Exchangeable Acidity	EXAC
CO_2 Evolved/Day/100g	CO2
C:N Ratio	CN
Soil Physical Properties	
Wilting Point (15 atmospheres)	WP
Site	
Zinc	ZINC
Tissue Elemental Content	
Percent Ca	%Ca
Percent Zn	%Zn
Percent Mn	%Mn
Percent P	%P
Dependent Variables	
Survival Percentage	%SUR
Growth in cm	GRO_CM
PART II: Greenhouse Study	
Soil Chemical Properties	
Extractable Zn (meq/100g)	SZn
Extractable Pb (meq/100g)	SPb
Extractable Mn (meq/100g)	SMn
Percent Al in the Tissue	TAl
Treatment (lime level)	LIMLEV
Percent Survival	PSUR

Table 2 - Mean Separation of the Percent Survival and Growth of Four Tree Species Grown on Smelter-Contaminated Soils.

Species	%Survival (mean)	Growth in cm (mean)
Austrian Pine	65.5 (A)	.42 (B)
Ponderosa Pine	61.0 (A)	.89 (B)
Scotch Pine	60.5 (A)	.57 (B)
Black Locust	36.0 (B)	2.45 (A)

Table 3 - Percent Survival of Four Tree Species as Affected by Species and Planting Method Interaction.

Species	Planting Method	%Survival (mean)
Ponderosa Pine	Container	99.0 (A)
Austrian Pine	Container	95.0 (A)
Scotch Pine	Container	94.0 (A)
Black Locust	Container	62.0 (B)
Austrian Pine	Bareroot	36.0 (C)
Scotch Pine	Bareroot	27.0 (CD)
Ponderosa Pine	Bareroot	23.0 (D)
Black Locust	Bareroot	10.0 (E)

Means with the same letter are not significantly different at the 5% level.

it is evident that the Zn concentrations (in soils and tissue), and the overall heavy metal content played a large role in seedling mortality. These metals compete with, and displace Fe and other ions in enzyme systems, altering the stereostructure and the operation of the enzyme in the plant's metabolism (15). Although the Cd concentrations found at both sites were high, no Cd was found in the seedlings. This is attributable to the Zn-Cd antagonism phenomona presented by Haghiri (12).

The effect of treatment upon extractable heavy metal concentration in the soil was much less pronounced, and often nonsignificant. This is probably due to the tremendous quantities of heavy metals present in the soil and the form they are in. Page (18) and Lagerwerff (15) found good correlation between the organic matter content in soils and heavy metal availability. Organic materials in the soil will chelate, and thus solubilize larg quantities of heavy metals. These chelates may be more stable than an inorganic form of the metal would be, and therefore liming will not reduce the availability of the ions significantly. The effect of lime in raising soil pH was slight below the 10 cm depth. This was due to the buffering capacity and gravelly nature of the soil, which would not permit thorough mixing of the lime at lower depths. Because the roots of both containerized and bareroot seedlings extended below 10 cm, the uptake of soluble heavy metals at those depths was not reduced by the lime treatment.

Although it did not reduce the levels of labile heavy metals in the soil, liming was significant in improving seedling survival, and highly significant in increasing growth. The Ca supplied in the lime reduced the proportion of the soil system occupied by heavy metals. The improvement shown in seedling growth is attributable to the role Ca plays in apical bud development and cell wall construction. The degree of correlation varied with species, but tissue analysis showed that percent Ca was negatively correlated with percent Zn in the seedlings.

Table 4 - A Comparison of the Effects of Experimental Factors on the Values of Dependent and Independent Variables.

Factor of Comparison	Mean of Affected Variables								
	%Survival	Growth in cm	%Zn in Tissue	%Mn in Tissue	Zn in Soil meq/100g	Cd in Soil meq/100g	Mn in Soil meq/100g	% of Exchange in Heavy Metals	Pb in Soil meq/100g
Site									
Lead	72.00***	1.88***	.15	.065***	.044	.003	.019	1.54	.046*
Zinc	39.50	.28	.45***	.031	.276***	.009**	.031*	5.46***	.026
Treatment									
Limed	58.25**	1.39***	.31	.044	.153	.006	.027	3.30	.025
Control	53.25	.77	.29	.052**	.167	.005	.022	3.71	.047*
Planting Method									
Bareroot	24.00	.80	.24	.029					
Container	87.50***	1.36***	.36***	.067***					

*** Significant at the 1% level.
** Significant at the 5% level.
* Significant at the 20% level.

Planting method had highly significant effects upon all the variables concerned. Tissue levels of Zn and Mn were higher in containerized than in bareroot seedlings. This seems contradictory, but because the metabolic rate of plants varies with age, the length of seedling survival may have greatly influenced heavy metal uptake. The containerized seedlings survived until the harvest date and were able to accumulate higher concentrations of the metals. At the same time, the toxic effects of these metals in the plant were reduced by the availability of nutrient elements present in the container. The root systems of bareroot seedings were directly and totally exposed to the soil toxins at the time of planting. In conjunction with the lack of nutrients, the heavy metal concentrations in the soils increased the mortality rate of the bareroot seedlings. Containerized seedlings were able to survive the growing season, and in time could probably develop root systems that would reach below the toxic, surface layers of the soils. Once the root systems were fully developed, tree seedlings would be able to grow normally with the decrease in interference from the soil toxins.

REGRESSIONS FOR PREDICTING SURVIVAL AND GROWTH OF TREE SEEDLINGS

Because of the difficulty in establishing predictive models for the containerized seedlings, due to the buffering effect of the containers, only equations involving bareroot seedlings will be presented here. More specifically, regressions concerning bareroot seedlings of Austrian pine will be evaluated. This particular species did well in the field trials and the predictive variables are representative of the other species.

Rregression equations for prediction of survival and growth are shown in Table 5. Growth was more difficult to predict than percent survival, as evidenced by the respective R^2 values. This phenomona is in part due to the sensitivity of height growth to site conditions, and the complexity of factors affecting growth (2). Also, the internal variability of the seedlings, in terms of nutrient content, would affect their initial growth rates.

In terms of predicting survival, two factors were of great value. The microbial respiration rate (mg CO_2 evolved/day/100 g of soil) was highly positively correlated with survival (r=.841). The percent Zn in the tissue was negatively correlated with survival (r=.806). Also, percent Zn and percent survival were found to be highly correlated with site (r=.915 and .889, respectively). As was the case with survival, growth was correlated with percent Zn in the tissue (r=-.568), the microbial respiration rate (r=.633), and with site (r=-.592).

PREDICTION OF SEEDLING SURVIVAL RATE USING MICROBIAL RESPIRATION AS AN INDICATOR

If conditions in a soil system are adverse for plant growth and development, it follows that those conditions will affect the metabolism of soil microorganisms. Heavy metal particulate buildup and acidification of smelter-contaminated soils greatly decreases the microbial populations therein. In this study, microbial respiration rate (mg CO_2 evolved/day/100 g) was found to be highly correlated with the heavy metal content of the soil (r=-.803). Because this relationship, and that between seedling survival and microbial respiration rate, are so good, it may be possible, with further investigation, to use respiration rates as indicators of the success of future revegetation efforts.

SUMMARY

Thorough chemical and physical characterization of smelter-contaminated soils, and chemical analyses of tree seedlings grown on those soils, permitted significant regression predictions to be made concerning seedling growth and survival. Predictions based on all the measured independent variables were very effective. All variable sets used to predict growth and survival provided significant R^2 values. However, in prediction of growth, using heavy metal content of tissue, the percent variation explained was low.

Table 5 - Results of Step-wise Multiple Regression Analyses Relating Growth and Survival of Bareroot Austrian Pine to Soil and Tissue Characteristics.

Types of Data Included in the Independent Variables	Regression Equation	R^2 Values
	I - Equation for the dependent variable %survival (%SUR)	
All independent variables (tissue and soil values)	%SUR = 99.36 + 153.50(Na2) + 2.21(CO21) + .87(CN1) -13.00(WP1) + 179.58(%Ca)	.915**
Soil and tissue heavy metal content, exchangeable acidity, soil S content, site and treatment	%SUR = 149.24 - 442.42(Pb2) - 70.53(ZINC)	.827**
Soil heavy metal content and exchangeable acidity	%SUR = 104.36 - 706.04(Pb2) + 863.43(Mn1) - .547.62(Mn2) - 10.43(HM1) - 11.25(HM2)	.835**
Tissue heavy metal content	%SUR = 87.46 - 189.74(%Zn)	.649**
	II - Equation for the dependent variable growth in cm (GRO-CM)	
All independent variables (tissue and soil values)	GRO-CM = .51 + 4.45(Mg3) + 3.68(Pb2) - .02(EXAC1) +.01(CO21) - 5.23(%P)	.865**
Soil and tissue heavy metal content, exchangeable acidity, soil S content, site and treatment	GRO-CM = .66 + 9.83(Pb2) + 16.51(Cd3) - .04(EXAC3) - .29(ZINC) - 4.43(%Mn)	.788**

Table 5 - Results of Step-wise Multiple Regression Analyses Relating Growth and Survival of Bareroot Austrian Pine to Soil and Tissue Characteristics (continued).

Types of Data Included in the Independent Variables	Regression Equation	R^2 Values
	II - Equation for the dependent variable growth in cm (GRO-CM)	
Soil heavy metal content and exchangeable acidity	$GRO\text{-}CM = .36 + .38(Zn3) + 6.97(Pb2) - 32.22(Cd1) - .05(HM1) - .03(EXAC3)$	.605**
Tissue heavy metal content	$GRO\text{-}CM = .32 - .63(\%Zn)$	.323*

Numerals following variable abbreviations designate the depth in the soil from which the value was obtained.
*Significant at the 5% level.
**Significant at the 1% level.

Perhaps the best predictive factor for growth and survival o the seedlings, was the respiration rate of the microbial populations. It seems feasible, at this point, that microbial respiration measurements could be used as an index to gauge the survival of tree seedlings planted on contaminated soils. This would be a rapid and inexpensive means to measure site quality of mining-disturbed soils.

Two experimental factors were especially useful in increasin the percent survival of tree seedlings. The most successful means of maximizing survival was the utilization of containerized seedlings in planting the contaminated sites. Secondly, liming the soil improved survival. Because the concentrations of the metal toxins were so great, survival could probably have been increased, to an even greater extent, by raising the pH of the soil to 7.0-7.5, instead of 6.0. Both methods of rehabilitating smelter-contaminated soils, planting containerized seedlings and liming, hold potential for future reclamation efforts.

PART II: GREENHOUSE STUDY

Percent survival of seedlings was a function of the heavy metal content of the soil, as modified by pH. Increased pH reduced heavy metal solubility and thus enhanced tree survival, as shown in Table 6. The effect of lime levels upon labile heavy metal content of the soil is presented in Table 7 in the form of a mean separation. In all instances, increased pH was associated with a decrease in the soil level of extractable metals. The specific factors involved in the multiple regression analyses for prediction of seedling survival are shwon in Table 8. Tree survival was positively correlated with soil pH (lime level) and negatively correlated with soil content of Zn and Mn. This data supports the conclusions of Haghiri (12) and Morris (17) that high concentrations of Zn and Mn can cause mortality of plants due to their interference in Fe metabolism and uptake.

The results of simple linear regression equations are contained in Table 9. Increased pH was negatively correlated with the extractability of the metals (16), which explains the value of lime as a tool for revegetating acidic, polluted soils.

The soil levels of Zn, Pb, and Mn were important in explaining the survival rates of both tree species. Highly significant negative correlations between extractable Zn, Pb, and Mn and seedling survival were measured. Mn was found to give the highest correlation for both tree species studied, followed closely by zinc. All three metals had a slightly greater impact upon black locust than on Scotch pine.

Relating tissue content of the metals to survival rates was more difficult. The survival of Scotch pine was negatively correlated to seedling content of Al. Although the relationship with Scotch pine was good, the effect of Al on black locust was positive and of low magnitude. Al toxicity is usually due to its accumulation and precipitation in the plant rhizosphere, which interferes with the plants uptake of Ca and Fe (2). In light of the data presented in Table 5, and the mode of Al toxicity, it appears that black locust may have the ability to actively exclude Al from root uptake, and prevent its translocation to aerial portions of the plant. Due to the nature of this study, it was not desirable or possible to ascertain the mechanisms of Al toxicity and/or its prevention within the tree seedlings. Scotch pine, although detrimentally affected by high concentrations of Al, was able to accumulate more Al before mortality resulted.

SUMMARY

Lime has great potential as a tool for increasing the survival of seedlings grown on smelter-contaminated soils. By increasing the soil pH and reducing solubility of heavy metal ions, lime reduces the toxic effects of those metals (6, 16). Increased levels of lime, up to pH 6.5, improved tree seedling survival.

Table 6 - The Effects of Soil pH (lime level) Upon the Survival of Tree Seedlings Grown on Smelter-Contaminated Soil.

	% Survival by Species	
Soil pH	Black Locust	Scotch Pine
4.4	0 (A)	0(A)
5.0	20 (B)	80(C)
5.5	60 (C)	40(B)
6.0	100 (E)	100(D)
6.5	80 (D)	100(D)

Means with letter are not significantly different at the 1% level.

Table 7 - Results of Mean Separation Procedures Relating the Effects of Increased Soil pH (lime level) Upon Extractability of Heavy Metals in a Smelter-Contaminated Soil.

	Extractable Metals: Means (meq/100g)		
Soil pH	Zn	Mn	Pb
4.4	.457(A)	.102(A)	.043(A)
5.0	.403(B)	.081(B)	.036(B)
5.5	.319(C)	.080(B)	.030(C)
6.0	.200(D)	.057(C)	.028(CD)
6.5	.138(E)	.050(C)	.023(D)

Means with the same letter, by metal species, are not significantly different at the 5% level.

Table 8 - Results of Step-wise Multiple Regression Analyses Relating Percent Survival of Black Locust and Scotch Pine Seedlings to Soil and Tissue Characteristics.

Types of Data Included in the Independent Variables	Regression Equation	R^2 Value
	I - Scotch Pine	
All independent variables (tissue and soil values and lime level)	PSUR = 89.27 + 14.63(LIMLEV) - 800.59(SMn)	.782**
Soil heavy metal content	PSUR = 186.79 - 130.75(SZn) -984.74(SMn)	.739**
	II - Black Locust	
All independent variables (tissue and soil values and lime level)	PSUR = 142.04 - 134.30(SZn) - 767.52(SMn)	.893**
Soil heavy metal content	PSUR = 142.04 - 134.30(SZn) -767.52(SMn)	.893**

**Significant at the 1% level.

Table 9 - Results of simple regression analyses showing the various relationships of percent survival of seedlings, soil heavy metal content, and lime level (soil pH).

Dependent Variable	Independent Variable	R Values by Species Black Locust	 Scotch Pine
PSUR	SZn	-.851**	-.702**
PSUR	SPb	-.737**	-.598**
PSUR	SMn	-.882**	-.771**
PSUR	TAl	.111	-.784**
PSUR	LIMLEV	.915**	.802**
SZn	LIMLEV	-.923**	-.931**
SPb	LIMLEV	-.754**	-.777**
SMn	LIMLEV	-.852**	-.585**

**Significant at the 1% level.
Correlation coefficients are based on 25 observations.

Findings of this study indicate that Al is very toxic to Scotch pine seedlings grown on low pH, contaminated soils. Black locust seedlings were not as sensitive to Al, but were more susceptible to the toxic effects of Zn, Mn, and Pb.

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PROCEEDINGS

OF

THE SECOND ANNUAL GENERAL MEETING

OF THE

CANADIAN LAND RECLAMATION ASSOCIATION

August 17, 18, 19 & 20 — 1977 Edmonton, Alberta

(Sponsored by the Faculty of Extension, University of Alberta)

P R O G R A M

Canadian Land Reclamation Association

Second Annual General Meeting

August 17, 18, 19, 20, 1977

Edmonton, Alberta

Wednesday, August 17 (Optional Field Trips)

Field Trip No. 1 (Athabasca Tar Sands)

Leader: Philip Lulman (Syncrude Canada Ltd.)

Fee: $100.00 (covers bus and air transportation, lunch, and field trip information pamphlets)

Schedule: 7:30 am.- delegates board bus at Parking Lot T, located immediately south of the Lister Hall Student Residence complex. Air transportation from Edmonton Industrial Airport to Fort McMurray and return. Guided bus tour of surface mining and reclamation operations on Syncrude Canada Ltd. and Great Canadian Oil Sands Ltd. leases. 6:30 p.m.- delegates arrive back at Parking Lot T, University of Alberta campus.

Field Trip No. 2 (Aspen Parkland; Forestburg Coal Mine Reclamation)

Leader: George Robbins (Luscar Ltd.)

Fee: $25.00 (covers bus transportation, lunch, and field trip information pamphlets)

Schedule: 8:00 a.m. - delegates board bus at Parking Lot T, located immediately south of the Lister Hall student residence complex. Guided bus tour southeast of Edmonton, stopping at various points of interest (oil spill reclamation field plots; Black Nugget Park [abandoned minesite]; trench plots on Dodds-Roundhill Coal Field; solonetzic soil deep ploughing site) on the way to the Luscar Ltd. Coal Mine at Forestburg. 6:30 p.m. - delegates arrive back at Parking Lot T, University of Alberta campus.

Thursday, August 18

Events: Opening of Formal Meeting; Presentation of Papers

Location: Multi-Media Room, located on second floor of Education Building, University of Alberta.

8:00 a.m. Authors of papers being presented on August 18 meet with paper presentation chairmen and audio-visual co-ordinator (Douglas Patching)

9:00 a.m. Meeting Opened by Dr. Jack Winch (President of the C.L.R.A.; Head of the Department of Crop Science, University of Guelph). Comments by Dr. Winch.

9:15 a.m. Welcome to delegates on behalf of the Government of Alberta by the Hon. Mr. Dallas Schmidt, (Associate Minister Responsible for Lands, Alberta Department of Energy and Natural Resources)

9:25 a.m. Commencement of Paper Presentations. Morning session chaired by Mr. Henry Thiessen (Chairman of the Land Surface Conservation and Reclamation Council and Assistant Deputy Minister, Alberta Department of Environment).

9:30 a.m. Paper 1. Combined Overburden Revegetation and Wastewater Disposal in the Southern Alberta Foothills by H.F. Thimm, G.J. Clark and G. Baker (presented by Harald Thimm of Chemex Reclamation and Sump Disposal Services Ltd., Calgary, Alberta).

10:00 a.m. Paper 2. Brine Spillage in the Oil Industry; The Natural Recovery of an Area Affected by a Salt Water Spill near Swan Hills, Alberta by M.J. Rowell and J.M. Crepin (presented by Michael Rowell of Norwest Soils Research Ltd., Edmonton, Alberta)

10:30 a.m. Coffee Recess

11:00 a.m. Paper 3. The Interaction of Groundwater and Surface Materials in Mine Reclamation by Philip L. Hall of Groundwater Consultants Group Ltd., Edmonton, Alberta.

11:30 a.m. Paper 4. Subsurface Water Chemistry in Mined Land Reclamation; Key to Development of a Productive Post-Mining Landscape by S.R. Moran and J.A. Cherry (presented by Stephen Moran of the Research Council of Alberta, Edmonton, Alberta).

12:00 noon Lunch Recess

1:25 p.m. Continuation of Paper Presentations. Afternoon session chaired by Mr. Philip Lulman (member of C.L.R.A. executive; reclamation research ecologist with Syncrude Canada Ltd.).

1:30 p.m. Paper 5. Coal Mine Spoils and Their Revegetation Patterns in Central Alberta by A.E.A. Schumacher, R. Hermesh and A.L. Bedwany (presented by Alex Schumacher of Montreal Engineering Company Ltd., Calgary, Alberta).

2:00 p.m. Paper 6. Surface Reclamation Situations and Practices on Coal Exploration and Surface Mine Sites at Sparwood, B.C. by R.J. Berdusco and A.W. Milligan (presented by Roger Berdusco of Kaiser Resources Ltd., Sparwood, B.C.).

2:30 p.m. Paper 7. Agronomic Properties and Reclamation Possibilities for Surface Materials on Syncrude Lease #17 by H.M. Etter and G.L. Lesko (presented by Harold Etter of Thurber Consultants Ltd., Victoria, B.C.).

3:00 p.m. Paper 8. The Use of Peat, Fertilizers and Mine Overburden to Stabilize Steep Tailings Sand Slopes by Michael J. Rowell of Norwest Soils Research Ltd., Edmonton, Alberta.

3:30 p.m. Coffee Recess

4:00 p.m. Paper 9. Oil Sands Tailings; Integrated Planning to Provide Long-Term Stabilization by David W. Devenny of E.B.A. Engineering Consultants Ltd., Edmonton, Alberta.

4:30 p.m. Paper 10. Bioengineering. The Use of Plant Biomass to Stabilize and Reclaim Highly Disturbed Sites by H. Schiechtel and K. (Nick) Horstmann (presented by Margit Kuttler).

5:00 p.m. End of August 18 Sessions.

Friday, August 19

Events: Presentation of Papers; C.L.R.A. Annual General Business Meeting; C.L.R.A. Annual Dinner.

Locations: Paper presentations and C.L.R.A. Annual General Business Meeting in Multi-Media Room, located on second floor of Education Building, University of Alberta.
- Annual Dinner held in Banquet Room located on second floor of Lister Hall.

8:00 a.m. Authors of Papers being presented on August 19 meet with paper presentation chairmen and audio-visual co-ordinator (Douglas Patching).

8:30 a.m. Showing of Film Rye on the Rocks. This film depicts reclamation situations at Copper Cliff, Ontario and is being shown for the purpose of introducing delegates to the site of the 1978 C.L.R.A. meeting (Sudbury, Ontario).

8:55 a.m. Continuation of Paper Presentations. Morning session chaired by Dr. J.V. Thirgood (Vice-President of C.L.R.A.; member of Forestry Faculty, University of British Columbia).

9:00 a.m. Paper 11. Reclamation of Coal Refuse Material on an Abandoned Mine Site at Staunton, Illinois by M.L. Wilkey and S.D. Zellmer (presented by Michael Wilkey of the Argonne National Laboratory, Argonne, Illinois).

9:30 a.m. Paper 12. A Case Study of Materials and Techniques Used in the Rehabilitation of a Pit and a Quarry in Southern Ontario by Sherry E. Yundt of the Ontario Ministry of Natural Resources, Toronto, Ontario).

10:00 a.m. Coffee Recess.

10:30 a.m. Paper 13. Amelioration and Revegetation of Smelter-Contaminated Soils in the Coeur D'Alene Mining District of Northern Idaho by D.B. Carter, H. Loewenstein and F.H. Pitkin (presented by Daniel Carter of Technicolor Graphic Services Inc., Sioux Falls, South Dakota).

11:00 a.m. Paper 14. The Influence of Uranium Mine Tailings on Tree Growth at Elliot Lake, Ontario by David R. Murray of the Elliot Lake Laboratory, Elliot Lake, Ontario.

11:30 a.m. Paper 15. Weathering Coal Mine Waste. Assessing Potential Side Effects at Luscar, Alberta by D.W. Devenny and D.E. Ryder (presented by David Devenny of E.B.A. Engineering Consultants Ltd., Edmonton, Alberta).

12:00 noon Lunch Recess.

1:25 p.m. Continuation of Paper Presentations. Afternoon session chaired by Dr. John Railton, (Manager, Environmental Planning, Calgary Power Ltd., Calgary, Alberta).

1:30 p.m. Paper 16. The Distribution of Nutrients and Organic Matter in Native Mountain Grasslands and Reclaimed Coalmined Areas in Southeastern B.C. by Paul F. Ziemkiewicz of the Faculty of Forestry, University of B.C., Vancouver, British Columbia.

2:00 p.m. Paper 17. Systems Inventory of Surficial Disturbance, Peace River Coal Block, B.C. by D.M. (Murray) Galbraith of the British Columbia Ministry of Mines and Petroleum Resources, Victoria, British Columbia.

2:30 p.m. Paper 18. The Selection and Utilization of Native Grasses for Reclamation in the Rocky Mountains of Alberta by D. Walker, R.S. Sadasivaiah and J. Weijer (presented by David Walker of the Department of Genetics, University of Alberta, Edmonton, Alberta).

3:00 p.m. Coffee Recess; Distribution of Proceedings.

3:30 p.m. Commencement of 1977 General Business Meeting of the Canadian Land Reclamation Association. Meeting chaired by Dr. J.V. Winch, C.L.R.A. President.

7:30 p.m. Commencement of C.L.R.A. Annual Dinner in Banquet Room, second floor of Lister Hall.

Guest Speaker: William T. Plass, Principal Plant Ecologist, U.S.D.A. Forest Service, Northeastern Forest Experiment Station, Princeton, West Virginia.

Topic of Speech: Challenges in Co-operative Reclamation Research.

Note: Following the Annual Dinner and Mr. Plass's speech, delegates may retire to the adjacent Gold Room. A bartender will be on service until midnight.