**FEASIBILITY OF USING PLANTS TO ASSIST IN THE REMEDIATION
OF HEAVY METAL CONTAMINATION AT J-FIELD,
ABERDEEN PROVING GROUND, MARYLAND**

FINAL REPORT

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Introduction

Most remedial technologies currently being used at hazardous waste sites (e.g., containment, excavation, soil washing, or incineration) are expensive. Further, in some locations technologies involving excavation could increase off-site releases of hazardous materials by destabilizing the site. Thus, interest in the development of *in situ* bioremediation technologies has grown substantially over the last decade. The idea of phytoremediation (i.e., using plants to clean up toxic wastes) is generating increasing attention from scientists, industry, and government agencies. The attractiveness of phytoremediation stems from its potential (1) to be less expensive than technologies involving the human engineering costs of soil manipulation, and (2) to initiate simultaneously both the clean up of hazardous materials and site restoration (Stomp et al., 1993).

The ability of plants to colonize and tolerate metalliferous soils has been known for some time (Antonovics et al., 1971). Metal tolerant plants have evolved physiological mechanisms that generally do not suppress metal uptake but rather result in internal detoxification via two basic strategies (Baker, 1981). In accumulators, metals are concentrated in aboveground parts regardless of soil concentrations. In contrast, excluders maintain aboveground concentrations that are constant and low over a wide range of soil concentrations by restricting transport from roots to shoots. Thus, the two strategies differ in their sites of detoxification (i.e., roots in excluders and shoots in accumulators) (Baker, 1981). However, heavy metal availability, uptake, and accumulation at a given site may be largely influenced by a variety of factors ranging from

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the form of metal contamination to edaphic factors affecting soil sorption capacities (Miller et al, 1975; Barry and Clark, 1978).

Most phytoremediation strategies will likely require metal tolerant plants of the accumulator type. The accumulation of metal contaminants in aboveground tissue facilitates plant harvest and, thus, cost-effective removal and disposal of the accumulated contaminants. Further, the identification or selection of "hyperaccumulator" plants (Baker et al., 1988) and the potential for similar genetically engineered capabilities (Stomp et al., 1993) offer some promise for the feasibility of such phytoremediation technologies. However, successful phytoremediation will also require species that (1) produce significant amounts of aboveground biomass, and (2) possess root systems capable of proliferating throughout and, thereby, extracting contaminants from the entire volumetric extent of the contaminated area.

The purpose of this project was to investigate the potential for using plants to remediate J-Field soils contaminated with heavy metals. *Phragmites australis*, one of the dominant species in the Toxic Burning Pits (TBP) area and other contaminated sites within J-Field, appears to be both tolerant of heavy metal contaminated soil conditions and capable of producing large amounts of biomass. Consequently, this project has concentrated on characterizing heavy metal accumulation by *Phragmites australis* growing in the TBP area relative to soil concentrations and availabilities. This type of information is necessary to determine the feasibility of using this species to assist in the remediation of metal contaminated soils at J-Field.

Materials and Methods

Thirty sampling locations (20 from upland areas and 10 from the marsh) were marked for sample collection (Fig. 1). The upland sites were selected on the basis of previous soil characterizations to provide a range of heavy metal concentrations (from high levels in the push-out area to relatively low levels in areas less directly affected by TBP activities, e.g., sites 17-20). The marsh areas were selected along a transect accessible by the boardwalks and roughly parallel to the marsh edge. In July 1994, aboveground parts of *Phragmites australis* were clipped at the soil surface and removed from each of these locations. Belowground parts were collected by digging beneath the clipped stems with an 18-cm wide spade to remove a block of soil to a depth

of 15 cm. Soil from in and around the belowground plant samples was also collected to a depth of 15 cm at each location. In December 1994, stems of *Phragmites australis* were again clipped and removed from the same 30 locations. No soil samples were taken at that time. The purpose of the second sampling was to determine whether plant uptake of heavy metals remains relatively constant throughout the growing season or lags behind the rate of plant biomass accumulation over the course of the growing season resulting in lower heavy metal concentrations in the plant tissue.

After samples were shipped to Argonne, aboveground plant tissue was washed with deionized water and separated into stems, leaves, and flowers/seeds (when present). Belowground plant tissue was thoroughly washed to remove the surrounding soil and separated into roots and rhizomes. Roots that were not attached to the *Phragmites* rhizomes were discarded. All plant tissue samples were dried at 65°C, weighed, and ground with a stainless steel Wiley mill. Soil samples were air dried and, after removing roots and other large pieces of organic debris, gently crushed to pass through a 2-mm sieve.

Plant tissue and soil samples (including duplicate samples created for QA/QC purposes by subsampling the original samples) were sent to the Research Extension Analytical Laboratory (REAL) at Ohio State University for nutrient and heavy metal (total concentration) analysis. Soil samples were also sent to the University of Wisconsin-Extension Soil and Plant Analysis Laboratory for determination of available (DTPA-extractable) heavy metals. Selected soil and plant samples were also analyzed at Wisconsin for nutrients and total heavy metals to ensure that results from the two labs were comparable. Both labs follow standard QA/QC procedures, use NIST traceable standards and other internal reference standards, and participate in external sample exchange and analysis programs with other laboratories.

Standard methods for plant and soil analysis (Page et al., 1982) or adaptations of these methods were used by the two labs. At the REAL lab, plant tissue and soil samples were digested in perchloric acid and analyzed for "total" heavy metals by inductively coupled plasma (ICP) optical emission spectroscopy. At the Wisconsin lab, soil samples were digested in 6:1 nitric/perchloric acid for "total" heavy metals and extracted by the diethylene triamine pentaacetic acid (DTPA) method for "available" heavy metals. Digests and extracts were analyzed by ICP optical emission spectroscopy. Plant tissue samples were digested with

5:3 nitric acid/hydrogen peroxide and analyzed for mineral nutrients by ICP optical emission spectroscopy and for heavy metals by ICP mass spectroscopy. At both labs, available P was determined by the Bray P₁ method. Available K was determined on the Bray P₁ extracts at Wisconsin and on ammonium acetate extracts at the REAL lab. Exchangeable Ca and Mg were determined on ammonium acetate extracts at both labs. Cation exchange capacity was determined at the REAL lab by the ammonium acetate method. Organic matter was determined by the combustion method at both labs. Total N was determined at Wisconsin by the semi-micro Kjeldahl procedure. Electrical conductivity and pH were determined by standard methods on water extracts.

Results and Discussion

All analytical results from both labs are presented in the Appendix. Visual analysis of the data indicated that the variability between duplicate samples analyzed at both labs was similar to the variability between duplicates analyzed within the same laboratory. Most duplicates were reasonably comparable. Data variability was probably due more to the inherent heterogeneity of the samples or to the variable forms of contaminants within the samples than to analytical errors within or between laboratories. Thus, valid comparisons between DTPA-extractable metals determined at Wisconsin can be made to total metals determined mostly at the REAL lab. Also, all replicate analyses were averaged to give a single value for each sampling site prior to statistical analysis of the data.

Although this report will focus on Pb because of the emphasis on it in remediation planning for the TBP site, examination of the data revealed that Cu and Zn (and possibly Cr depending on the valence state) are present in the soil at concentrations that can be toxic to many plant species (Chapman, 1966). Among the other edaphic factors that may affect plant growth at the site are P concentrations that range from very low (deficient) to extremely high (potentially toxic) and relatively low N concentrations.

Total Pb in the soil ranged from a low of 82 µg/g at site 19 located in the relatively uncontaminated area on the edge of the forest uphill from the pits to a high of >41,000 µg/g at site 2 in the push-out area (Table 1). Samples from the marsh were relatively constant at about

750 $\mu\text{g/g}$. Available (DTPA-extractable) Pb in the soil ranged from 20 $\mu\text{g/g}$ at site 15 to about 1400 $\mu\text{g/g}$ at site 4. Available Pb in the marsh samples were again relatively constant with a mean of 233 $\mu\text{g/g}$.

The sites with the lowest and highest values for available Pb did not correspond to the sites with the lowest and highest total Pb concentrations, however available and total Pb were highly correlated ($r = 0.75$; $P < 0.001$) in the upland area because of its wide range in soil Pb contents. In the marsh, available and total Pb were not significantly correlated. The proportion of total Pb extracted by the DTPA procedure ranged from 0.01 at site 2 to 0.45 at site 26 and was generally higher in the marsh than in the upland area (Table 1). The proportion of available Pb was negatively associated with total Pb as well as available Pb ($r = -0.64$ and -0.58 , respectively; $P < 0.01$) in the upland area, but it was positively correlated with available Pb ($r = 0.66$; $P < 0.05$) in the marsh.

The highest concentration of Pb found in aboveground plant tissue during July was 23 $\mu\text{g/g}$ in the leaves of the plant located at site 3, which had the second highest concentration of available soil Pb. In December, leaves from plants at this location contained 110 $\mu\text{g/g}$ Pb. However, most plants from both sampling times had considerably lower concentrations of Pb in their aboveground tissue (Tables 2 and 3). Mean Pb concentrations in the entire shoot were greater at the end of the growing season than in July. Shoot Pb concentrations were also higher in the upland area than in the marsh, partly because mean concentrations of Pb in the soil were greater in the upland area and partly because of the diluting effects of greater phytomass production in the marsh.

The concentration of Pb in belowground tissue was considerably greater than in aboveground tissue (Tables 2 and 3), suggesting that *Phragmites* tolerates high soil Pb concentrations by using an excluder (Baker, 1981) or an avoidance (Shann, 1995) strategy. Most Pb taken up by the plant is apparently sequestered in belowground tissue, possibly in the cell walls of conductive tissue and in root intercellular spaces. Gries and Garbe (1989) suggested that Pb and other heavy metals may be bound as co-precipitates in iron hydroxide plaques on root surfaces, pointing out that the binding of heavy metals as oxides can be an uptake avoidance mechanism in flooded (reduced) root environments. Concentrations were highest in the rhizomes from site 4 (801 $\mu\text{g/g}$), which also had the highest available soil Pb and in the roots

from site 2 (3400 $\mu\text{g/g}$), which had the highest total soil Pb. Again, most plants had considerably lower Pb concentrations in their belowground tissue (Tables 2 and 3).

Plant:soil concentration ratios were calculated for the marsh and upland areas (Table 4). Lead concentration ratios for shoots were very small and were at least an order of magnitude lower than for roots. Rhizome concentration ratios were intermediate. These ratios, to a certain extent, assist in comparisons of relative uptake by plants growing on soils with different Pb contents and also emphasize how little Pb is translocated to shoot tissue.

Shoot and belowground tissue concentrations of Pb were highly correlated with both total and available soil Pb concentrations in the upland area (correlation coefficients were generally greater than 0.80; $P < 0.001$). In the marsh, however, there were no significant relationships between soil Pb concentrations and plant tissue concentrations above or below ground in July. In December, shoot concentrations were negatively correlated with total soil Pb ($r = -0.68$; $P < 0.05$) and available Pb ($r = -0.56$; $P < 0.10$). This finding suggests that other edaphic factors (Table 5) in the marsh (e.g., the higher organic matter content and/or cation exchange capacity) are influencing Pb availability and that this effect is not being measured under these conditions by the DTPA extraction method for estimating Pb availability. In fact, available (DTPA extractable) Pb in the marsh was negatively correlated with organic matter ($r = -0.81$; $P < 0.01$), available P ($r = -0.68$; $P < 0.10$), cation exchange capacity ($r = -0.57$; $P < 0.10$), and electrical conductivity ($r = -0.81$; $P < 0.01$).

Closer examination of the relationships between plant tissue Pb and soil Pb in the upland areas, however, revealed that the strong correlations were due primarily to the influence of sites with very high soil Pb concentrations as illustrated, for example, in Fig. 2. Yet, phytoremediation would not likely be used as a remediation strategy at the J-Field Site until total Pb concentrations in the soil were reduced by other technologies to 500 $\mu\text{g/g}$ or less. Because only six of the sampled sites had total soil Pb concentrations that were $< 500 \mu\text{g/g}$, all further evaluations of the feasibility of using *Phragmites* for phytoremediation at the site were based on the 17 sites with total soil Pb concentrations $< 1000 \mu\text{g/g}$, which gives more realistic assessments than can be made by using all 30 sites. This subset of sites provides a mean total soil Pb concentration of 534 $\mu\text{g/g}$ (Table 6) and includes nine sites from the marsh and eight from the upland areas. Plant tissue concentrations and plant:soil concentration ratios for this subset of

sites are characterized in Table 7 and 8. After deleting those sites with higher soil Pb from the dataset, plant tissue concentrations were, indeed, no longer significantly correlated with total or available soil Pb concentrations (e.g., Fig. 3).

Total aboveground uptake of Pb by the sampled plants was calculated by multiplying shoot Pb concentrations by sample dry weights (Table 9). Lead uptake was about 3 to 4 times greater for marsh plants than for plants growing in upland areas, in part because Pb concentrations were slightly higher in marsh plants but mostly because plants were larger in the marsh. Uptake was not significantly correlated with total soil Pb but was positively correlated with available Pb in both July and December (Table 10). Aboveground Pb uptake was also negatively correlated with soil pH but was positively correlated with soil organic matter, cation exchange capacity, and electrical conductivity. However, it is unclear whether these relationships are truly indicative of the effects of the edaphic factors on Pb availability because the relationships are being driven, to a large extent, by the fact that Pb uptake is highest in the marsh, which also has higher organic matter, cation exchange capacity, and electrical conductivity as well as lower pH than the upland areas.

Although Pb uptake was much greater at the end of the growing season, the values presented in Table 9 for December are underestimates of potential Pb uptake because most samples had few if any leaves remaining on the stems at the time of sampling. By making several assumptions, a better estimate of potential Pb uptake by *Phragmites* shoots was calculated (Table 11). Although the assumption that the biomass of the sampled area can be used to project average *Phragmites* production over a large area may result in an overestimate, the values presented in Table 11 represent a realistic estimate of the best potential aboveground Pb uptake that can be expected for *Phragmites* without any soil manipulations to enhance Pb availability.

Conclusions

The estimates of potential Pb uptake on an areal basis do not appear to be high enough to make harvesting of aboveground *Phragmites* tissue a viable phytoremediation strategy unless (1) uptake can be enhanced by soil amendments or (2) it is not necessary to remove all of the Pb

Thus, it appears that tissue concentrations must be increased by at least an order of magnitude while at the same time maintaining the same high level of biomass production in

order to effectively phytoremediate the site within a reasonable time frame, unless removal of even less than 200 µg/g of soil Pb is acceptable. It is impossible to say, based on this study, whether other measures such as belowground phytomass harvesting, soil manipulations, or the use of another plant species would help to achieve such a goal.

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Table 1. Total and available (DTPA-extractable) Pb concentrations in soil and the proportion of available Pb (available Pb divided by total Pb)

Sample location	Variable	Mean ($\mu\text{g/g}$)	SE ($\mu\text{g/g}$)	Minimum ($\mu\text{g/g}$)	Maximum ($\mu\text{g/g}$)
All sites n=30	Total Pb	5751	1983	82	41414
	Available Pb	343	69	20	1408
	Proportion avail.	0.19	0.02	0.01	0.45
Upland sites n=20	Total Pb	8249	2831	82	41414
	Available Pb	399	101	20	1408
	Proportion avail.	0.13	0.02	0.01	0.37
Marsh sites n=10	Total Pb	755	65	445	1258
	Available Pb	233	19	140	319
	Proportion avail.	0.32	0.03	0.20	0.45

Table 2. Pb concentrations in plant tissue sampled in July and December for upland sites (n = 20)

Sample date	Plant part	Mean ($\mu\text{g/g}$)	SE ($\mu\text{g/g}$)	Minimum ($\mu\text{g/g}$)	Maximum ($\mu\text{g/g}$)
July	Stems	8.4	1.2	3.0	21.8
	Leaves	8.4	1.3	1.0	23.4
	Shoots ^a	8.5	1.1	3.5	22.5
	Rhizomes	140.4	46.4	5.8	801.1
	Roots ^b	571.7	284.4	41.4	3400.3
December	Stems	11.1	2.9	1.0	51.6
	Leaves ^c	20.3	7.5	3.9	109.7
	Flowers/seeds ^d	7.9	1.5	4.7	20.2
	Shoots ^a	11.3	2.7	0.9	48.4

^a Value for each sampling site was a weighted average (based on tissue mass) of concentration data for stems and leaves (July) and stems, leaves, and seeds (December).

^b n = 12

^c n = 16

^d n = 10

Table 3. Pb concentrations in plant tissue sampled in July and December for marsh sites (n = 10)

Sample date	Plant part	Mean ($\mu\text{g/g}$)	SE ($\mu\text{g/g}$)	Minimum ($\mu\text{g/g}$)	Maximum ($\mu\text{g/g}$)
July	Stems	4.7	0.5	2.8	7.8
	Leaves	4.9	0.7	2.8	8.4
	Shoots ^a	4.7	0.4	2.8	6.4
	Rhizomes	45.1	21.5	5.4	232.2
	Roots	128.8	38.3	21.5	338.8
December	Stems	8.3	1.0	3.2	14.3
	Leaves ^b	6.7	2.4	4.3	9.1
	Flowers/seeds ^b	3.4	0.0	3.4	3.4
	Shoots ^a	7.7	0.9	3.0	13.3

^a Value for each sampling site was a weighted average (based on tissue mass) of concentration data for stems and leaves (July) and stems, leaves, and seeds (December).

^b n = 2

Table 4. Plant:soil Pb concentration ratios for plants sampled in July and December on upland (n = 20) and marsh (n=10) sites

Sample date	Plant part	Mean	SE	Minimum	Maximum
Upland sites					
July	Shoots	0.011	0.003	0.0003	0.056
	Rhizomes	0.047	0.012	0.008	0.157
	Roots ^a	0.281	0.077	0.023	0.899
December	Shoots	0.012	0.004	0.0003	0.065
Marsh sites					
July	Shoots	0.007	0.001	0.003	0.013
	Rhizomes	0.062	0.030	0.007	0.330
	Roots	0.183	0.065	0.029	0.710
December	Shoots	0.011	0.002	0.002	0.024

^a n = 12

Table 5. Characterization of edaphic factors that may affect Pb availability

Sample Location	Variable	Mean	SE	Minimum	Maximum
Upland sites n=20	pH	7.26	0.20	5.95	8.65
	Organic matter (%)	2.43	0.24	0.75	4.90
	Available P ($\mu\text{g/g}$)	101	44	2	884
	Cation exchange capacity (meq)	6.5	0.7	2	13
	Electrical conductivity (dS/m)	0.26	0.06	0.05	1.08
Marsh sites n=10	pH	5.73	0.14	5.30	6.80
	Organic matter (%)	13.14	1.72	7.40	22.50
	Available P ($\mu\text{g/g}$)	105	16	49	204
	Cation exchange capacity (meq)	18.9	1.4	15	29
	Electrical conductivity (dS/m)	3.45	0.67	1.50	8.45

Table 6. Total and available (DTPA-extractable) Pb concentrations in soil and the proportion of available Pb (available Pb divided by total Pb) for sites where total Pb in soil is < 1000 $\mu\text{g/g}$ (n = 17)

Variable	Mean ($\mu\text{g/g}$)	SE ($\mu\text{g/g}$)	Minimum ($\mu\text{g/g}$)	Maximum ($\mu\text{g/g}$)
Total Pb	534	63	82	848
Available Pb	147	25	20	319
Proportion avail.	0.27	0.03	0.06	0.45

Table 7. Pb concentrations in plant tissue sampled in July and December for sites where total Pb in soil is < 1000 $\mu\text{g/g}$ (n = 17)

Sample date	Plant part	Mean ($\mu\text{g/g}$)	SE ($\mu\text{g/g}$)	Minimum ($\mu\text{g/g}$)	Maximum ($\mu\text{g/g}$)
July	Stems	4.8	0.4	2.8	7.8
	Leaves	4.4	0.5	1.0	8.4
	Shoots ^a	4.7	0.2	2.8	6.4
	Rhizomes	29.4	12.8	5.4	232.2
	Roots ^b	101.4	23.6	21.5	316.0
December	Stems	7.4	0.8	1.0	14.3
	Leaves ^c	9.0	3.6	3.9	33.6
	Flowers/seeds ^d	5.1	0.7	3.4	7.9
	Shoots ^a	7.3	0.8	0.9	13.3

^a Value for each sampling site was a weighted average (based on tissue mass) of concentration data for stems and leaves (July) and stems, leaves, and seeds (December).

^b n = 14

^c n = 8

^d n = 6

Table 8. Pb concentration ratios for plants sampled in July and December on sites where total Pb in soil is < 1000 $\mu\text{g/g}$ (n = 17)

Sample date	Plant part	Mean	SE	Minimum	Maximum
July	Shoots	0.015	0.004	0.004	0.056
	Rhizomes	0.072	0.021	0.007	0.330
	Roots	0.232	0.061	0.029	0.726
December	Shoots	0.020	0.004	0.002	0.065

Table 9. Pb uptake by sampled plant shoots in July and December for sites where total Pb in soil is $< 1000 \mu\text{g/g}$

Sample location	Sample date	Mean (μg)	SE (μg)	Minimum (μg)	Maximum (μg)
Upland sites n = 8	July	78	9	36	112
	December	291	81	57	704
Marsh sites n = 9	July	313	36	150	492
	December	828	118	491	1677
All sites n = 17	July	202	35	36	492
	December	575	97	57	1677

Table 10. Correlation between edaphic factors and Pb uptake by sampled plant shoots in July and December for sites where total Pb in soil is $< 1000 \mu\text{g/g}$

Edaphic factor	July	December
Total Pb ($\mu\text{g/g}$)	0.46	0.37
Available Pb ($\mu\text{g/g}$)	0.70**	0.58*
pH	-0.76***	-0.63**
Organic matter (%)	0.77***	0.51*
Available P ($\mu\text{g/g}$)	-0.07	-0.16
Cation exchange capacity (meq)	0.79***	0.50*
Electrical conductivity (dS/m)	0.74***	0.47
* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$		

Table 11. Estimated biomass and Pb uptake for *Phragmites* shoots in December for sites where total Pb in soil is < 1000 $\mu\text{g/g}$

Sample location	Variable	Mean	SE	Minimum	Maximum
Upland sites n = 8	Sampled area biomass (g dry wt) ^a	94	18	23	148
	Sampled area Pb uptake (μg) ^b	470	110	116	999
	Pb uptake (mg/m^2) ^c	15	3	4	31
Marsh sites n = 9	Sampled area biomass (g dry wt) ^a	152	14	82	215
	Sampled area Pb uptake (μg) ^b	1379	203	858	2879
	Pb uptake (mg/m^2) ^c	43	6	26	89

^a The sum of the measured stem and flower/seed masses plus an estimated leaf mass based on the average relationship between leaf mass and stem mass for the marsh and upland areas in July.

^b Calculated using estimated leaf and flower/seed Pb concentrations for sites where leaf samples were not available or flower/seed samples were not analyzed. Estimated leaf and flower/seed Pb concentrations were calculated by using the average relationships between stem Pb concentrations and leaf or flower/seed Pb concentrations for the marsh and upland areas.

^c Assumes that the plant mass in the sampled area (18 x 18 cm) is representative of an average potential plant production per m^2 .

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Fig. 1 Locations of sampling sites. TBPR-1 through TBPR-20 indicate spatial locations of sites in upland areas. Marsh sites (TBPR-21 through TBPR-30) are not located spatially.

Fig. 2 Relationships between ^{Pb} tissue ~~concent~~ concentrations in Phragmites shoots and available (DTPA-extractable) and total Pb in soil in December for all 20 upland sampling sites.

TIME=2

Plot of SHPB*AVPB. Symbol is value of LOC.

Available Pb in soil (ug/g)

Plot of SHPB*PB. Symbol is value of LOC.

Total soil Pb (ug/g)

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Fig. 3 Relationships between Pb tissue concentrations in Phragmites shoots and available (DTPA-extractable) and total Pb in soil in December for sites with <1000 ug/g total Pb in the soil. U = upland sites; M = marsh sites.

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APPENDIX

Table A.1 Results of soil analyses.

				AVAIL	AVAIL	EXCH	EXCH									
SITE/				pH	P	K	Ca	Mg	N	CEC	BSCA	BSMG	BSK	O.M.	EC	
STUDY	ID	LAB	TYPE		(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(%)	(meq)	(%)	(%)	(%)	(%)	(dS/cm)	
TBPR	1	OSU		6.3	106	108	855	333		7	49	32	3.2	4.9	0.20	
TBPR	2	OSU		6.5	2	51	302	76		2	67	28	5.7	3.7	0.12	
TBPR	3	OSU		6.4	7	67	243	78		2	60	32	8.4	3.5	0.12	
TBPR	3	WIS	DUP													
TBPR	4	OSU		6.1	1	38	196	68		3	36	21	3.5	3.3	0.12	
TBPR	4	WIS		5.8	4	50	250	60	0.08					3.4	0.06	
TBPR	4	WIS	DUP													
TBPR	5	OSU		6.6	9	54	539	96		4	74	22	3.8	3.7	<0.10	
TBPR	5	WIS		6.1	13	50	500	90	0.07					3.1	0.05	
TBPR	6	OSU		7.2	49	80	970	385		8	59	39	2.5	3.0	0.20	
TBPR	6	OSU	DUP	7.3	49	71	927	364		8	59	38	2.7	3.2	0.17	
TBPR	7	OSU		7.1	234	96	866	309		6	61	36	3.4	3.8	0.11	
TBPR	7	WIS		5.7	200	75	700	290	0.12					3.3	0.07	
TBPR	8	OSU		8.4	128	75	1047	971		12	39	60	1.4	2.2	1.08	
TBPR	8	WIS	DUP													
TBPR	9	OSU		7.4	55	49	948	118		6	81	17	2.1	2.0	0.43	
TBPR	10	OSU		7.6	45	92	1125	259		7	70	27	2.9	2.5	0.22	
TBPR	10	WIS	DUP													
TBPR	11	OSU		7.4	35	23	1278	86		7	89	10	0.8	1.0	1.08	
TBPR	11	WIS		6.7	33	40	1250	100	0.03					0.9	0.69	
TBPR	11	WIS	DUP													
TBPR	12	OSU		8.6	188	52	663	854		11	31	67	1.3	1.8	0.19	
TBPR	12	OSU	DUP	8.7	192	54	651	789		10	33	66	1.4	1.6	0.19	
TBPR	13	OSU		8.4	884	99	491	1268		13	18	80	1.9	2.3	0.26	
TBPR	13	WIS	DUP													
TBPR	14	OSU		8.6	61	53	742	565		9	43	55	1.6	1.6	0.28	
TBPR	14	WIS		6.9	56	50	750	440	0.04					1.5	0.23	
TBPR	15	OSU		8.0	15	17	415	174		4	58	41	1.2	0.8	0.11	
TBPR	15	OSU	DUP	8.0	11	19	420	169		4	59	40	1.4	0.7	<0.10	
TBPR	16	OSU		8.0	130	77	907	781		9	40	58	1.7	2.5	0.36	
TBPR	17	OSU		8.6	57	53	619	929		10	28	71	1.2	2.2	0.38	
TBPR	17	WIS	DUP													
TBPR	18	OSU		7.3	17	26	563	120		4	72	26	1.7	1.1	<0.10	
TBPR	19	OSU		6.2	9	46	592	92		3	77	20	3.1	2.0	<0.10	
TBPR	19	WIS		6.6	8	50	500	100	0.06					1.5	0.04	
TBPR	20	OSU		6.5	10	39	585	92		4	77	20	2.6	1.6	<0.10	
TBPR	21	OSU		5.7	60	206	1100	1043		15	23	36	2.2	7.4	1.90	
TBPR	21	WIS	DUP													
TBPR	22	OSU		6.0	55	201	1371	1265		15	29	45	2.2	7.9	1.50	
TBPR	23	OSU		5.7	87	323	1316	1241		16	26	41	3.3	9.0	2.60	
TBPR	24	OSU		5.7	113	289	1732	1525		20	25	36	2.1	14.1	3.45	
TBPR	25	OSU		5.6	100	275	1618	1528		18	25	40	2.2	10.6	2.70	
TBPR	26	OSU		5.6	104	348	1667	1470		21	23	34	2.5	12.8	1.88	
TBPR	27	OSU		5.3	185	571	2463	1885		20	25	31	2.9	20.7	4.00	
TBPR	28	OSU		5.6	92	387	1965	1467		20	27	34	2.7	17.5	5.50	
TBPR	29	OSU		5.3	204	412	4187	2336		29	36	33	1.8	22.5	8.45	
TBPR	30	OSU		6.8	49	96	2310	1147		15	54	45	1.2	8.9	2.54	

Table A.1 cont.

SITE/				Pb	Cd	Ni	Cr	Cu	Zn	Hg	As	Mo	Se	Fe	Co
STUDY	ID	LAB	TYPE	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
TBPR	1	OSU		11737	1.09	42.8	175.3	780	2900	<1.0	22.2	<0.2	0.06		
TBPR	2	OSU		41414	5.96	46.0	242.5	2692	9079	<1.0	27.6	<0.2	0.05		
TBPR	3	OSU		35704	1.75	50.0	166.7	821	4966	<1.0	34.9	<0.2	0.06		
TBPR	3	WIS	DUP												
TBPR	4	OSU		25053	0.87	32.8	159.3	918	2686	<1.0	23.7	<0.2	0.05		
TBPR	4	WIS		23316	7.14	27.9	141.5	807	2330		<27.9			78353	5.31
TBPR	4	WIS	DUP	21661	13.25	28.2	397.1	888	2367		<27.9			72483	4.53
TBPR	5	OSU		23108	2.52	58.4	316.5	1699	7963	<1.0	34.5	<0.2	0.04		
TBPR	5	WIS		23464	10.71	40.8	313.4	1328	6186		<27.9			66671	10.52
TBPR	6	OSU		9553	3.92	39.0	168.0	1316	4689	<1.0	24.7	<0.2	0.05		
TBPR	6	OSU	DUP	6696	3.62	37.7	151.9	1054	4919	<1.0	26.3	<0.2	0.08		
TBPR	7	OSU		10607	5.85	39.9	254.5	1001	5569	<1.0	26.5	<0.2	0.07		
TBPR	7	WIS		10368	6.42	22.9	150.9	593	4259		<27.9			46115	5.39
TBPR	8	OSU		1950	5.15	22.4	127.6	524	1284	<1.0	22.0	<0.2	0.14		
TBPR	8	WIS	DUP												
TBPR	9	OSU		1447	0.81	19.9	152.3	691	894	<1.0	17.3	<0.2	0.11		
TBPR	10	OSU		1746	1.63	25.7	105.3	388	1645	<1.0	47.8	<0.2	0.10		
TBPR	10	WIS	DUP												
TBPR	11	OSU		3211	1.07	16.7	53.0	204	1001	<1.0	17.9	<0.2	0.09		
TBPR	11	WIS		423	3.99	15.5	229.8	377	783		<27.9			18144	3.13
TBPR	11	WIS	DUP	1596	4.02	15.5	106.7	433	879		<27.9			23457	3.16
TBPR	12	OSU		393	3.80	25.3	89.5	506	1906	<1.0	12.6	<0.2	0.08		
TBPR	12	OSU	DUP	351	5.08	22.4	48.7	360	1785	<1.0	12.0	<0.2	0.11		
TBPR	13	OSU		610	3.65	45.9	148.8	496	1552	<1.0	18.6	0.6	0.10		
TBPR	13	WIS	DUP												
TBPR	14	OSU		496	2.18	22.1	82.2	361	936	<1.0	12.2	<0.2	0.08		
TBPR	14	WIS		995	1.79	9.1	109.9	189	872		<27.9			12827	3.36
TBPR	15	OSU		60	0.62	9.2	28.4	84	132	<1.0	3.9	<0.2	0.07		
TBPR	15	OSU	DUP	189	0.45	8.4	29.8	65	123	<1.0	4.1	<0.2	0.10		
TBPR	16	OSU		1205	1.78	27.8	96.0	348	988	<1.0	16.8	<0.2	0.19		
TBPR	17	OSU		564	1.32	25.6	48.6	330	914	<1.0	11.9	<0.2	0.15		
TBPR	17	WIS	DUP												
TBPR	18	OSU		121	0.95	11.5	30.3	101	201	<1.0	5.9	<0.2	0.07		
TBPR	19	OSU		79	<0.20	11.6	52.0	255	209	<1.0	4.7	<0.2	0.08		
TBPR	19	WIS		84	<1.00	6.9	70.4	203	170		<27.9			11039	3.17
TBPR	20	OSU		173	1.36	11.7	48.1	232	272	<1.0	5.3	<0.2	0.08		
TBPR	21	OSU		746	<0.20	43.0	95.6	401	1076	<1.0	41.9	0.8	0.15		
TBPR	21	WIS	DUP												
TBPR	22	OSU		784	<0.20	51.4	117.8	507	1413	<1.0	43.6	<0.2	0.15		
TBPR	23	OSU		704	0.44	46.5	94.7	452	1302	<1.0	42.5	<0.2	0.17		
TBPR	24	OSU		685	0.80	37.3	91.4	426	983	<1.0	39.3	1.0	0.12		
TBPR	25	OSU		711	<0.20	48.3	104.0	445	1194	<1.0	40.3	<0.2	0.22		
TBPR	26	OSU		703	<0.20	39.9	89.3	312	947	<1.0	25.7	<0.2	0.28		
TBPR	27	OSU		665	0.45	29.7	79.0	322	747	<1.0	25.6	1.1	0.29		
TBPR	28	OSU		848	1.21	30.3	63.6	393	1005	<1.0	27.5	<0.2	0.28		
TBPR	29	OSU		445	2.01	21.1	69.4	346	952	<1.0	18.6	<0.2	0.25		
TBPR	30	OSU		1258	0.87	24.1	78.6	387	1417	<1.0	17.9	<0.2	0.09		

Table A.1 Cont.

SITE/				DTPA	DTPA	DTPA	DTPA	DTPA	DTPA	DTPA	DTPA
STUDY	ID	LAB	TYPE	Cd	Cr	Cu	Zn	Ni	Pb	Fe	Mn
				(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
TBPR	1	WIS		1.42	0.41	212.8	762.7	2.22	998.1	86.18	6.13
TBPR	2	WIS		1.48	<0.08	224.9	1083.0	1.28	424.8	1.69	0.51
TBPR	3	WIS		1.50	0.14	136.7	663.9	1.72	1324.0	9.34	1.53
TBPR	3	WIS	DUP	1.38	0.09	125.4	594.4	1.46	1385.0	9.76	1.53
TBPR	4	WIS		0.49	<0.08	158.3	391.3	0.75	1408.0	49.91	1.40
TBPR	4	WIS									
TBPR	4	WIS	DUP								
TBPR	5	WIS		1.39	1.14	230.8	745.7	0.93	1028.0	15.42	1.35
TBPR	5	WIS									
TBPR	6	WIS		1.87	0.30	203.3	608.4	0.64	617.9	49.06	8.13
TBPR	6	WIS	DUP								
TBPR	7	WIS		1.85	0.09	145.1	956.8	1.44	531.4	85.25	4.98
TBPR	7	WIS									
TBPR	8	WIS		2.18	0.48	114.8	145.3	0.31	279.8	57.99	6.61
TBPR	8	WIS	DUP	1.80	0.40	99.5	130.9	0.26	279.4	53.53	5.71
TBPR	9	WIS		0.73	0.16	116.2	97.7	<0.18	129.2	19.08	8.42
TBPR	10	WIS		1.18	0.17	76.8	200.2	0.27	340.0	49.05	7.94
TBPR	10	WIS	DUP	1.13	<0.08	77.1	186.7	0.21	332.5	47.98	7.88
TBPR	11	WIS		0.69	0.15	45.7	171.4	<0.18	312.6	19.00	7.67
TBPR	11	WIS									
TBPR	11	WIS	DUP								
TBPR	12	WIS		1.27	0.22	54.2	273.9	0.35	91.2	32.98	3.51
TBPR	12	WIS	DUP								
TBPR	13	WIS		0.91	0.18	44.6	207.3	0.62	35.9	82.93	5.60
TBPR	13	WIS	DUP	0.85	<0.08	42.7	184.7	0.53	35.7	79.75	5.29
TBPR	14	WIS		0.87	0.12	64.8	115.4	0.24	90.4	49.91	5.08
TBPR	14	WIS									
TBPR	15	WIS		0.54	0.14	17.1	9.6	<0.18	19.7	13.18	4.61
TBPR	15	WIS	DUP								
TBPR	16	WIS		1.27	0.15	73.1	107.9	0.33	111.8	71.86	7.54
TBPR	17	WIS		1.11	0.19	58.4	96.3	0.36	102.3	49.50	7.33
TBPR	17	WIS	DUP	1.11	0.16	56.0	99.8	0.38	113.1	50.59	7.38
TBPR	18	WIS		0.92	<0.08	26.1	17.4	<0.18	24.8	27.51	6.03
TBPR	19	WIS		0.59	0.21	91.0	37.8	0.31	29.8	45.48	9.39
TBPR	19	WIS									
TBPR	20	WIS		2.19	0.18	105.0	48.9	0.28	40.9	29.27	11.75
TBPR	21	WIS		1.36	0.18	114.7	121.6	1.06	239.5	607.80	6.73
TBPR	21	WIS	DUP	1.45	0.22	116.2	122.2	1.08	241.5	624.30	6.94
TBPR	22	WIS		1.80	0.16	134.2	154.7	1.27	254.5	442.20	8.43
TBPR	23	WIS		2.84	0.17	145.2	206.7	1.30	269.3	551.90	7.82
TBPR	24	WIS		2.63	0.21	157.3	198.4	1.87	230.0	774.40	9.34
TBPR	25	WIS		1.65	0.21	144.2	172.8	1.50	286.7	569.80	7.83
TBPR	26	WIS		1.62	0.19	112.2	156.0	1.71	318.8	694.80	5.17
TBPR	27	WIS		1.09	0.28	56.9	107.9	1.95	153.3	891.90	9.90
TBPR	28	WIS		1.55	0.22	75.4	206.5	2.16	168.9	845.50	7.97
TBPR	29	WIS		2.40	0.24	138.6	325.2	2.35	140.4	666.70	9.07
TBPR	30	WIS		1.42	0.14	150.6	312.1	1.60	267.8	221.40	13.50

Table A.2 Results of plant tissue analyses for July samples

SITE/ STUDY	ID	LAB	TYPE	STEM P (%)	STEM K (%)	STEM Ca (%)	STEM Mg (%)	STEM N (%)	STEM Na (ug/g)	STEM Fe (ug/g)	STEM Mn (ug/g)	STEM B (ug/g)	STEM Pb (ug/g)	STEM Cd (ug/g)	STEM Ni (ug/g)	STEM Cr (ug/g)	STEM Cu (ug/g)	STEM Zn (ug/g)	STEM Hg (ug/g)	STEM As (ug/g)	STEM Mo (ug/g)	STEM Se (ug/g)
TBPR	1	OSU		0.08	0.75	0.05	0.06	0.60	429.0	38.8	21.9	2.8	7.1	<0.2	3.8	1.5	6.5	83.4	<1.0	<2.0	0.43	<0.02
TBPR	1	WIS		0.07	0.77	0.05	0.06	0.45	420.0	15.6	19.7	3.6	7.5	<0.2	2.3	0.8	5.9	75.3		<2.0		
TBPR	2	OSU		0.03	0.45	0.03	0.05	0.42	133.1	34.4	2.5	2.4	14.8	<0.2	2.4	1.8	6.1	117.2	<1.0	<2.0	0.38	<0.02
TBPR	3	OSU		0.06	1.03	0.07	0.12	0.97	1432.4	44.7	5.8	2.9	22.9	<0.2	2.7	2.0	8.3	441.6	<1.0	<2.0	0.40	0.02
TBPR	3	OSU	DUP																			
TBPR	3	WIS		0.07	1.12	0.07	0.12	0.85	1337.0	38.6	5.3	2.2	20.6	<0.2	2.0	1.1	8.7	481.4		<2.0		
TBPR	4	OSU		0.08	1.13	0.06	0.10	0.68	720.1	26.7	9.0	2.5	9.1	<0.2	2.0	1.5	4.7	166.4	<1.0	<2.0	0.20	<0.02
TBPR	4	OSU	DUP																			
TBPR	4	WIS																				
TBPR	4	WIS	DUP																			
TBPR	5	OSU		0.03	0.81	0.11	0.10	0.57	245.5	59.1	3.7	3.7	19.5	<0.2	3.4	2.7	10.0	287.2	<1.0	<2.0	0.56	0.03
TBPR	6	OSU		0.08	1.17	0.08	0.15	0.72	397.8	76.9	12.9	4.1	15.9	<0.2	4.2	2.9	9.5	113.2	<1.0	<2.0	0.50	<0.02
TBPR	6	OSU	DUP	0.08	1.16	0.07	0.14	0.72	369.5	46.4	10.5	2.9	12.2	<0.2	3.6	1.6	8.3	100.9	<1.0	<2.0	0.56	0.11
TBPR	7	OSU		0.07	0.51	0.04	0.07	0.60	310.3	46.9	12.1	3.3	7.3	<0.2	4.2	1.8	6.1	94.3	<1.0	<2.0	0.43	0.02
TBPR	8	OSU		0.08	1.10	0.12	0.38	0.76	691.7	40.0	20.1	5.1	7.7	<0.2	2.9	2.3	15.7	147.0	<1.0	<2.0	3.80	0.05
TBPR	9	OSU		0.12	1.38	0.22	0.09	0.95	270.4	64.9	70.1	4.5	8.3	<0.2	4.9	3.5	18.2	173.8	<1.0	<2.0	0.33	<0.02
TBPR	9	OSU	DUP																			
TBPR	9	WIS		0.09	1.56	0.20	0.10	0.81	285.0	52.5	65.0	2.5	6.0	<0.2	2.2	1.6	16.9	139.1		<2.0		
TBPR	9	WIS	DUP						49.5	63.8	6.2	<0.2	2.1	1.6	17.0	138.5		<2.0				
TBPR	10	OSU		0.10	0.92	0.12	0.09	0.53	198.1	43.8	23.6	3.7	8.4	<0.2	6.1	2.2	14.8	159.4	<1.0	<2.0	0.54	<0.02
TBPR	10	OSU	DUP	0.10	0.88	0.10	0.08	0.57	173.8	50.9	20.4	1.8	6.9	<0.2	4.3	1.2	13.7	141.0	<1.0	<2.0	0.71	0.07
TBPR	11	OSU		0.08	0.72	0.38	0.05	0.54	156.9	33.4	49.1	2.2	6.0	<0.2	4.8	1.9	14.7	112.5	<1.0	<2.0	0.26	0.03
TBPR	11	OSU	DUP	0.08	0.69	0.33	0.05	0.48	132.2	34.9	45.5	1.3	6.2	<0.2	4.6	0.9	13.7	102.5	<1.0	<2.0	0.43	0.06
TBPR	12	OSU		0.09	1.05	0.06	0.18	0.56	246.4	33.6	9.0	4.2	3.3	<0.2	2.8	2.5	9.9	84.0	<1.0	<2.0	0.43	0.07
TBPR	13	OSU		0.14	0.88	0.04	0.12	0.41	188.8	31.3	5.5	2.6	3.0	<0.2	3.1	1.8	7.2	49.6	<1.0	<2.0	0.58	0.07
TBPR	14	OSU		0.12	1.09	0.03	0.10	0.54	322.5	41.3	6.6	3.2	5.3	<0.2	2.7	2.2	8.6	34.0	<1.0	<2.0	0.59	0.03
TBPR	14	WIS																				
TBPR	15	OSU		0.11	1.10	0.10	0.08	0.60	221.6	36.9	14.2	2.3	4.8	<0.2	5.5	1.7	9.5	74.2	<1.0	<2.0	0.39	0.17
TBPR	15	OSU	DUP	0.09	0.91	0.08	0.07	0.53	206.1	88.4	11.5	1.4	2.1	<0.2	3.1	5.3	8.4	69.7	<1.0	<2.0	0.63	0.05
TBPR	16	OSU		0.12	1.19	0.06	0.17	0.74	363.2	51.4	21.6	3.9	9.2	<0.2	6.5	3.6	10.6	59.9	<1.0	<2.0	1.00	0.07
TBPR	16	WIS																				
TBPR	17	OSU		0.08	0.68	0.03	0.16	0.51	224.2	32.5	12.7	3.7	6.5	<0.2	5.1	2.7	10.1	31.5	<1.0	<2.0	0.54	0.13
TBPR	18	OSU		0.07	0.50	0.10	0.07	0.70	1797.3	26.9	22.8	2.2	6.6	<0.2	3.3	1.6	11.1	84.5	<1.0	<2.0	0.23	0.13
TBPR	18	OSU	DUP																			
TBPR	19	OSU		0.10	1.06	0.10	0.03	0.65	107.6	27.2	8.1	2.9	3.9	<0.2	4.0	1.9	10.3	127.8	<1.0	<2.0	0.65	0.12
TBPR	19	WIS																				
TBPR	20	OSU		0.10	1.07	0.11	0.03	0.67	192.4	37.4	15.4	2.7	5.2	<0.2	5.2	2.0	15.8	147.4	<1.0	<2.0	<0.2	0.07
TBPR	21	OSU		0.09	1.02	0.06	0.08	0.63	1641.0	48.8	58.6	3.0	3.9	<0.2	4.6	2.3	13.4	89.0	<1.0	<2.0	0.39	0.04
TBPR	22	OSU		0.15	1.53	0.07	0.08	0.81	2184.4	77.4	51.7	4.8	7.8	<0.2	7.1	3.6	18.2	93.0	<1.0	<2.0	0.53	<0.02
TBPR	23	OSU		0.12	1.29	0.05	0.04	0.54	1635.1	34.0	32.5	3.7	3.1	<0.2	4.6	3.2	8.9	82.7	<1.0	<2.0	0.72	0.02
TBPR	23	WIS																				
TBPR	24	OSU		0.13	1.13	0.08	0.07	0.64	1246.8	46.8	55.1	3.4	2.8	<0.2	4.5	2.8	14.0	103.8	<1.0	<2.0	0.66	0.03
TBPR	24	WIS																				
TBPR	25	OSU		0.11	0.85	0.08	0.09	0.84	1456.7	44.5	66.7	3.0	5.1	<0.2	5.5	2.2	11.1	139.5	<1.0	<2.0	0.43	0.07
TBPR	26	OSU		0.20	1.28	0.07	0.07	1.00	1654.6	43.7	74.9	4.7	6.9	0.2	5.8	2.7	12.5	102.4	<1.0	<2.0	0.66	0.04
TBPR	26	OSU	DUP																			
TBPR	27	OSU		0.17	1.44	0.09	0.08	0.86	2309.5	44.6	84.1	4.7	4.5	<0.2	5.7	3.1	10.3	96.1	<1.0	<2.0	0.49	0.03
TBPR	28	OSU		0.11	0.84	0.04	0.05	0.51	3413.9	136.1	37.4	3.3	5.5	<0.2	3.9	2.4	11.3	76.0	<1.0	<2.0	0.32	0.04
TBPR	29	OSU		0.09	0.88	0.10	0.10	0.91	2479.0	34.8	87.9	4.3	3.8	<0.2	3.4	1.6	11.0	157.6	<1.0	<2.0	0.31	0.02
TBPR	29	OSU	DUP																			
TBPR	29	WIS		0.08	0.84	0.09	0.09	0.69	2605.0	25.9	81.4	4.4	4.7	<0.2	2.2	0.9	10.3	133.9		<2.0		
TBPR	30	OSU		0.11	1.02	0.06	0.08	0.77	1656.9	28.3	63.6	3.0	2.9	<0.2	3.3	1.7	12.0	101.4	<1.0	<2.0	0.42	<0.02

Table A.2 cont

SITE/ STUDY	ID	LAB	TYPE	LEAF P (%)	LEAF K (%)	LEAF Ca (%)	LEAF Mg (%)	LEAF N (%)	LEAF Na (ug/g)	LEAF Fe (ug/g)	LEAF Mn (ug/g)	LEAF B (ug/g)	LEAF Pb (ug/g)	LEAF Cd (ug/g)	LEAF Ni (ug/g)	LEAF Cr (ug/g)	LEAF Cu (ug/g)	LEAF Zn (ug/g)	LEAF Hg (ug/g)	LEAF As (ug/g)	LEAF Mo (ug/g)	LEAF Se (ug/g)
TBPR	1	OSU		0.17	1.42	0.23	0.14	1.75	110.1	50.0	41.7	13.2	5.6	<0.2	5.1	3.0	6.7	101.1	<1.0	<2.0	1.00	0.04
TBPR	1	WIS		0.14	1.64	0.19	0.14	1.56	118.0	44.1	34.1	9.6	4.4	<0.2	1.8	0.6	5.6	60.0		<2.0		
TBPR	2	OSU		0.12	1.46	0.22	0.27	1.80	37.0	70.9	11.0	13.5	8.8	<0.2	4.5	3.6	6.9	57.1	<1.0	<2.0	1.60	0.06
TBPR	3	OSU		0.13	1.27	0.27	0.26	2.63	222.9	113.9	15.2	13.2	25.0	<0.2	4.6	3.5	8.6	338.4	<1.0	<2.0	1.30	0.08
TBPR	3	OSU	DUP	0.12	1.28	0.21	0.24	2.53	226	72.4	11.8	9.2	21.7	<0.2	2.7	1.8	7	278.9	<1.0	<2.0	0.91	0.02
TBPR	3	WIS																				
TBPR	4	OSU		0.17	1.32	0.16	0.16	2.32	89.2	63.4	13.7	10.2	16.1	<0.2	3.9	3.3	6.9	71.6	<1.0	<2.0	0.63	0.06
TBPR	4	OSU	DUP																			
TBPR	4	WIS		0.14	1.64	0.15	0.17	2.18	121.0	62.6	12.0	6.0	16.2	<0.2	1.7	0.7	5.7	60.9		<2.0		
TBPR	4	WIS	DUP							62.6	12.0		16.1	<0.2	1.7	0.7	5.7	60.7		<2.0		
TBPR	5	OSU		0.11	1.13	0.39	0.22	2.08	43.5	63.9	9.4	9.0	18.7	<0.2	3.7	2.8	7.9	187.4	<1.0	<2.0	1.20	0.07
TBPR	6	OSU		0.16	1.30	0.32	0.34	2.18	119.0	76.3	22.9	14.2	13.3	<0.2	5.2	5.0	9.1	59.7	<1.0	<2.0	1.00	0.24
TBPR	6	OSU	DUP	0.15	1.38	0.26	0.32	2.37	119.4	60.6	19.1	11.5	11.0	<0.2	3.0	2.0	7.8	50.0	<1.0	<2.0	0.78	0.10
TBPR	7	OSU		0.19	1.40	0.20	0.17	1.74	55.2	70.5	27.8	13.9	9.3	<0.2	6.6	5.2	7.0	37.5	<1.0	<2.0	1.20	0.20
TBPR	8	OSU		0.16	1.14	0.30	0.51	2.22	83.7	68.6	29.6	15.7	7.2	<0.2	5.7	4.0	10.6	51.5	<1.0	<2.0	4.80	0.31
TBPR	9	OSU		0.16	1.25	0.91	0.19	2.42	72.6	93.9	139.2	10.7	9.6	<0.2	6.6	4.5	11.9	108.8	<1.0	<2.0	0.63	0.22
TBPR	9	OSU	DUP																			
TBPR	9	WIS																				
TBPR	9	WIS	DUP																			
TBPR	10	OSU		0.18	1.52	0.53	0.20	1.83	47.0	85.3	47.7	11.2	10.3	<0.2	7.5	5.5	10.9	47.0	<1.0	<2.0	1.60	0.17
TBPR	10	OSU	DUP																			
TBPR	11	OSU		0.15	1.10	1.06	0.09	1.86	52.1	60.4	75.7	8.0	11.0	<0.2	5.2	3.0	10.0	39.3	<1.0	<2.0	0.62	0.08
TBPR	11	OSU	DUP																			
TBPR	12	OSU		0.13	1.08	0.23	0.38	1.82	85.3	73.1	16.5	10.0	6.5	<0.2	4.7	4.1	6.7	24.3	<1.0	<2.0	0.92	0.32
TBPR	13	OSU		0.15	1.23	0.23	0.37	1.42	62.4	76.6	29.3	11.4	6.0	<0.2	7.2	5.1	7.2	28.3	<1.0	<2.0	2.40	0.40
TBPR	14	OSU		0.15	1.46	0.20	0.31	1.62	85.8	86.2	21.8	8.3	3.9	<0.2	5.6	4.7	6.9	30.3	<1.0	<2.0	1.20	0.08
TBPR	14	WIS																				
TBPR	15	OSU		0.19	1.15	0.43	0.22	1.81	47.6	58.7	30.5	9.2	3.5	<0.2	6.8	3.9	8.9	30.9	<1.0	<2.0	1.40	0.64
TBPR	15	OSU	DUP																			
TBPR	16	OSU		0.16	1.36	0.32	0.41	2.11	49.5	76.6	36.4	15.5	3.0	<0.2	5.4	4.9	7.8	37.1	<1.0	<2.0	2.60	0.43
TBPR	16	WIS		0.15	1.71	0.28	0.44	2.02	71.0	64.8	34.2	9.7	2.5	<0.2	2.6	1.4	6.6	21.5		<2.0		
TBPR	17	OSU		0.13	0.90	0.18	0.56	1.73	53.6	53.0	36.0	9.3	<2.0	<0.2	3.6	3.2	6.4	28.3	<1.0	<2.0	1.20	0.29
TBPR	18	OSU		0.17	1.34	0.42	0.18	2.02	565.2	65.0	51.4	13.0	3.2	<0.2	5.2	3.4	8.5	32.2	<1.0	<2.0	0.89	
TBPR	18	OSU	DUP	0.16	1.46	0.41	0.19	1.96	631.7	59.4	49.3	11.4	2.7	<0.2	3.6	1.9	7.4	22.6	<1.0	<2.0	0.64	0.13
TBPR	19	OSU		0.16	1.32	0.43	0.10	2.09	48.6	65.3	17.4	8.4	5.2	<0.2	7.3	4.2	9.5	48.1	<1.0	<2.0	1.50	0.19
TBPR	19	WIS																				
TBPR	20	OSU		0.14	1.42	0.59	0.12	1.52	52.2	71.3	24.4	6.6	4.8	<0.2	7.2	4.7	7.6	87.7	<1.0	<2.0	0.60	0.17
TBPR	21	OSU		0.20	1.29	0.33	0.22	2.75	199.6	99.4	149.7	11.0	3.2	<0.2	8.1	3.6	10.9	27.8	<1.0	<2.0	1.40	0.07
TBPR	22	OSU		0.23	1.34	0.30	0.21	2.96	194.4	108.5	108.7	14.7	3.0	0.2	5.8	4.3	13.3	30.7	<1.0	<2.0	1.50	0.08
TBPR	23	OSU		0.23	1.36	0.37	0.17	2.48	224.1	123.5	125.9	11.4	4.5	<0.2	6.2	3.2	8.9	46.5	<1.0	<2.0	1.10	0.09
TBPR	23	WIS																				
TBPR	24	OSU		0.22	1.34	0.31	0.19	2.73	96.2	96.9	97.0	12.2	4.2	0.3	4.4	3.7	9.9	49.0	<1.0	<2.0	1.50	0.06
TBPR	24	WIS		0.19	1.79	0.26	0.20	2.45	142.0	75.5	87.7	6.8	1.4	<0.2	2.3	0.6	77.5	18.8		<2.0		
TBPR	25	OSU		0.18	1.26	0.40	0.17	2.70	79.6	157.1	161.4	14.3	2.9	<0.2	4.6	3.7	9.3	29.4	<1.0	<2.0	1.80	0.11
TBPR	26	OSU		0.27	1.60	0.27	0.16	2.97	163.9	134.4	142.2	11.8	4.7	<0.2	5.4	3.6	13.5	32.1	<1.0	<2.0	1.40	0.08
TBPR	26	OSU	DUP	0.25	1.65	0.25	0.17	2.92	174.9	107.2	121.6	9.6	3.9	<0.2	4.4	1.9	12.1	28.1	<1.0	<2.0	1.00	0.04
TBPR	27	OSU		0.21	1.46	0.37	0.18	2.81	460.3	140.5	144.8	15.0	3.9	<0.2	4.4	2.7	10.5	28.1	<1.0	<2.0	1.00	0.10
TBPR	28	OSU		0.24	1.53	0.30	0.21	2.57	577.8	123.5	118.3	15.6	8.4	<0.2	14.4	3.1	12.7	26.0	<1.0	<2.0	1.20	0.14
TBPR	29	OSU		0.17	1.16	0.63	0.29	2.89	389.4	127.7	216.3	21.7	8.4	<0.2	3.1	2.8	9.2	41.3	<1.0	<2.0	0.64	0.07
TBPR	29	OSU	DUP																			
TBPR	29	WIS																				
TBPR	30	OSU		0.18	1.26	0.43	0.21	2.29	291.1	68.2	165.4	14.4	7.2	<0.2	4.7	2.9	8.7	23.5	<1.0	<2.0	1.10	0.08

Table A.2 cont

SITE/				RHIZ	RHIZ	RHIZ	RHIZ	RHIZ	RHIZ	RHIZ	RHIZ	RHIZ	RHIZ	RHIZ	RHIZ	RHIZ	RHIZ	RHIZ	RHIZ	RHIZ	RHIZ	RHIZ
STUDY	ID	LAB	TYPE	P	K	Ca	Mg	N	Na	Fe	Mn	B	Pb	Cd	Ni	Cr	Cu	Zn	Hg	As	Mo	Se
				(%)	(%)	(%)	(%)	(%)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)
TBPR	1	OSU		0.04	0.75	0.04	0.08	0.34	982.1	306.9	39.6	4.8	102.0	<0.2	8.3	8.0	20.4	218.7	<1.0	<2.0	1.80	<0.02
TBPR	1	WIS		0.04	0.80	0.04	0.08	0.22	972.0	311.1	57.4	1.8	95.6	0.4	8.1	7.1	23.0	289.9		<2.0		
TBPR	2	OSU		0.03	0.79	0.05	0.07	0.67	779.5	1001.1	13.6	5.0	434.2	0.7	6.2	8.9	102.9	576.6	<1.0	<2.0	1.10	<0.02
TBPR	3	OSU		0.05	0.88	0.05	0.09	0.62	1139.2	303.0	19.4	4.5	458.9	0.7	6.7	3.9	47.4	697.8	<1.0	<2.0	0.84	0.02
TBPR	3	OSU	DUP																			
TBPR	3	WIS																				
TBPR	4	OSU		0.04	0.40	0.03	0.07	0.76	898.7	1136.3	19.3	3.7	726.4	<0.2	4.6	6.2	53.8	375.3	<1.0	<2.0	0.44	0.03
TBPR	4	OSU	DUP	0.02	0.40	0.03	0.07	0.73	879.4	260.7	17.8	3.3	875.7	<0.2	4.7	4.9	55.3	384.6	<1.0	<2.0	<0.2	0.04
TBPR	4	WIS																				
TBPR	4	WIS	DUP																			
TBPR	5	OSU		0.03	0.75	0.05	0.07	0.59	805.4	200.5	8.9	2.8	286.3	0.5	8.6	5.8	54.5	462.2	<1.0	<2.0	0.91	0.04
TBPR	6	OSU		0.05	0.69	0.06	0.15	0.46	973.7	649.8	23.2	5.4	196.2	0.5	6.6	19.8	143.8	270.2	<1.0	<2.0	0.93	0.12
TBPR	6	OSU	DUP																			
TBPR	7	OSU		0.05	0.87	0.05	0.11	0.41	1453.7	365.9	28.6	4.2	145.9	<0.2	10.0	6.7	50.5	336.2	<1.0	<2.0	0.96	0.07
TBPR	8	OSU		0.06	0.92	0.06	0.20	0.34	1956.1	399.4	26.0	6.7	51.7	0.5	7.3	12.6	49.8	92.2	<1.0	<2.0	1.60	0.03
TBPR	9	OSU		0.05	1.04	0.09	0.11	0.34	1012.2	213.6	58.7	4.8	32.0	1.3	11.4	9.6	41.6	152.0	<1.0	<2.0	0.60	<0.02
TBPR	9	OSU	DUP	0.05	0.95	0.08	0.10	0.40	830.1	130.1	48.0	4.6	36.2	1.1	12.1	9.2	39.4	142.7	<1.0	<2.0	0.54	<0.02
TBPR	9	WIS																				
TBPR	9	WIS	DUP																			
TBPR	10	OSU		0.05	0.79	0.07	0.12	0.42	1172.3	768.3	47.8	4.4	93.0	0.9	6.5	5.4	34.4	205.4	<1.0	3.7	0.86	0.03
TBPR	10	OSU	DUP																			
TBPR	11	OSU		0.04	0.45	0.31	0.14	0.44	897.6	483.3	28.9	5.1	69.7	3.8	5.2	8.0	31.7	226.7	<1.0	<2.0	0.54	0.02
TBPR	11	OSU	DUP																			
TBPR	12	OSU		0.06	0.61	0.04	0.17	0.32	502.2	329.5	9.4	4.6	9.3	0.6	3.6	7.7	26.4	100.9	<1.0	<2.0	1.00	0.03
TBPR	13	OSU		0.11	0.93	0.04	0.19	0.29	261.2	267.7	10.0	5.3	5.8	0.5	4.7	5.5	22.0	90.2	<1.0	<2.0	1.20	<0.02
TBPR	14	OSU		0.04	0.67	0.06	0.16	0.59	1152.1	512.6	14.4	4.4	15.9	0.2	3.9	7.9	41.1	76.2	<1.0	<2.0	0.79	<0.02
TBPR	14	WIS		0.04	0.68	0.06	0.16	0.52	1096.0	765.6	15.6	2.5	25.6	0.4	3.0	5.9	45.7	73.1		<2.0		
TBPR	15	OSU		0.05	0.45	0.04	0.09	0.27	439.7	222.7	20.7	2.9	18.5	<0.2	10.0	4.9	11.7	78.6	<1.0	<2.0	0.84	0.03
TBPR	15	OSU	DUP	0.05	0.42	0.04	0.09	0.23	420.4	290.4	20.7	2.5	20.4	<0.2	10.7	5.1	11.8	75.6	<1.0	<2.0	0.87	0.26
TBPR	16	OSU		0.09	0.82	0.05	0.19	0.37	2963.0	313.9	19.8	3.0	21.8	0.4	6.3	9.7	32.7	53.8	<1.0	<2.0	1.40	<0.02
TBPR	16	WIS																				
TBPR	17	OSU		0.11	1.14	0.03	0.12	0.31	884.1	304.5	15.6	4.8	11.3	<0.2	4.9	6.3	14.2	49.6	<1.0	<2.0	1.00	<0.02
TBPR	18	OSU		0.07	0.56	0.05	0.10	0.41	2306.5	808.0	27.7	2.6	18.8	0.9	7.6	6.1	15.8	65.2	<1.0	<2.0	0.67	0.02
TBPR	18	OSU	DUP																			
TBPR	19	OSU		0.06	0.63	0.05	0.07	0.36	358.6	387.3	17.1	3.6	13.9	0.4	4.7	12.1	43.6	125.9	<1.0	<2.0	0.90	0.02
TBPR	19	WIS		0.06	0.65	0.05	0.07	0.31	363.0	284.4	15.8	5.0	11.7	0.5	2.7	9.0	46.9	122.1		<2.0		
TBPR	20	OSU		0.03	0.36	0.05	0.04	0.31	438.8	293.3	14.9	1.9	18.7	0.2	6.7	6.6	20.9	106.9	<1.0	<2.0	0.55	<0.02
TBPR	21	OSU		0.04	0.40	0.03	0.05	0.30	2512.4	140.0	89.1	5.0	5.4	1.6	3.1	2.6	9.1	62.9	<1.0	<2.0	0.31	<0.02
TBPR	22	OSU		0.03	0.36	0.04	0.07	0.36	3118.8	163.2	107.2	4.3	21.9	1.8	3.1	1.6	12.1	76.9	<1.0	<2.0	0.59	<0.02
TBPR	23	OSU		0.03	0.56	0.04	0.06	0.39	3067.2	161.0	89.0	4.9	10.3	0.8	4.4	2.0	9.7	85.9	<1.0	<2.0	0.27	<0.02
TBPR	23	WIS		0.03	0.47	0.03	0.05	0.02	2506.0	158.7	155.2	1.4	12.8	2.0	4.1	1.1	12.9	144.0		<2.0		
TBPR	24	OSU		0.05	0.71	0.03	0.05	0.31	2962.1	316.4	64.6	4.1	7.4	0.7	3.6	2.1	10.4	47.7	<1.0	<2.0	0.41	<0.02
TBPR	24	WIS																				
TBPR	25	OSU		0.05	0.54	0.03	0.07	0.31	3530.5	1009.2	177.7	5.4	23.8	2.0	8.1	10.9	15.2	88.4	<1.0	<2.0	0.68	<0.02
TBPR	26	OSU		0.07	0.45	0.04	0.06	0.40	2773.7	204.6	98.2	4.3	232.2	1.8	14.9	2.7	13.7	94.7	<1.0	<2.0	0.48	<0.02
TBPR	26	OSU	DUP																			
TBPR	27	OSU		0.04	0.39	0.06	0.10	0.38	4999.4	780.7	118.3	5.6	22.9	0.7	7.4	7.2	14.5	86.4	<1.0	<2.0	0.59	<0.02
TBPR	28	OSU		0.03	0.30	0.06	0.12	0.31	4747.9	1941.2	62.4	5.9	28.0	0.8	4.9	5.8	17.4	104.9	<1.0	5.1	0.47	<0.02
TBPR	29	OSU		0.04	0.64	0.08	0.14	0.42	5016.9	1053.9	91.4	9.0	30.6	2.7	5.3	4.0	19.9	168.5	<1.0	2.4	0.42	<0.02
TBPR	29	OSU	DUP	0.04	0.67	0.08	0.13	0.45	4868.7	76.2	60.8	7.6	30.0	2.6	5.0	3.1	18.7	154.3	<1.0	2.3	0.3	0.04
TBPR	29	WIS																				
TBPR	30	OSU		0.05	0.33	0.08	0.11	0.34	4304.3	3548.3	121.7	6.1	67.3	0.6	11.0	9.2	37.8	158.0	<1.0	10.5	0.58	<0.02

Table A.2 cont.

SITE/ STUDY	ID	LAB	TYPE	ROOT P (%)	ROOT K (%)	ROOT Ca (%)	ROOT Mg (%)	ROOT N (%)	ROOT Na (ug/g)	ROOT Fe (ug/g)	ROOT Mn (ug/g)	ROOT B (ug/g)	ROOT Pb (ug/g)	ROOT Cd (ug/g)	ROOT Ni (ug/g)	ROOT Cr (ug/g)	ROOT Cu (ug/g)	ROOT Zn (ug/g)	ROOT Hg (ug/g)	ROOT As (ug/g)	ROOT Mo (ug/g)	ROOT Se (ug/g)
TBPR	1	OSU		0.03	0.34	0.10	0.07		1305.1	406.8	60.0	6.3	268.7	<0.9	5.3	6.3	112.9	497.8	<4.5	<9.1	<0.91	
TBPR	1	WIS																				
TBPR	2	OSU		0.06	0.47	0.20	0.11		1678.3	7641.3	76.8	11.5	3400.3	3.8	48.2	90.0	782.9	2498.1	<4.5	<9.1	<0.91	
TBPR	3	OSU						1.72														
TBPR	3	OSU	DUP																			
TBPR	3	WIS																				
TBPR	4	OSU																				
TBPR	4	OSU	DUP																			
TBPR	4	WIS																				
TBPR	4	WIS	DUP																			
TBPR	5	OSU						1.42														
TBPR	6	OSU																				
TBPR	6	OSU	DUP																			
TBPR	7	OSU						1.36														
TBPR	8	OSU		0.07	0.46	0.22	0.25		2014.6	2719.0	184.9	14.9	365.8	2.9	7.7	62.0	432.1	260.0	<5.0	<10.0	<1.0	
TBPR	9	OSU		0.04	0.58	0.21	0.13		1529.3	2257.0	76.9	13.7	177.3	9.0	12.2	42.4	288.7	364.3	<3.3	<6.7	<0.67	
TBPR	9	OSU	DUP																			
TBPR	9	WIS																				
TBPR	9	WIS	DUP																			
TBPR	10	OSU		0.04	0.57	0.22	0.15		1480.3	3634.0	91.6	12.0	524.2	2.2	19.8	23.7	217.9	488.1	<3.8	10.7	0.92	
TBPR	10	OSU	DUP																			
TBPR	11	OSU		0.07	0.24	0.63	0.17		1327.0	4868.0	201.5	18.6	1567.0	11.1	18.7	32.5	334.7	574.9	<5.0	11.2	<1.0	
TBPR	11	OSU	DUP																			
TBPR	12	OSU		0.05	0.43	0.15	0.26		829.4	1809.6	36.6	12.2	71.8	5.5	9.4	20.8	147.7	267.5	<3.6	<7.1	<0.71	
TBPR	13	OSU																				
TBPR	14	OSU		0.07	0.45	0.21	0.29		1991.7	3449.5	87.5	14.3	210.6	2.5	11.9	51.6	457.1	342.8	<4.5	<9.1	<0.91	
TBPR	14	WIS																				
TBPR	15	OSU		0.06	0.46	0.20	0.13		1674.4	2852.2	77.0	15.2	41.4	4.2	9.6	14.5	103.8	144.6	<3.1	<6.2	0.76	
TBPR	15	OSU	DUP																			
TBPR	16	OSU		0.07	0.54	0.14	0.23		1743.3	3943.2	84.9	14.3	86.9	1.8	15.6	38.5	158.9	191.3	<4.5	<9.1	2.00	
TBPR	16	WIS																				
TBPR	17	OSU		0.06	0.58	0.12	0.26		1493.7	1355.9	48.9	11.6	87.7	1.3	12.0	21.2	127.8	144.3	<3.1	<6.2	<0.62	
TBPR	18	OSU																				
TBPR	18	OSU	DUP																			
TBPR	19	OSU		0.05	0.41	0.29	0.10		1306.6	1832.5	70.9	13.9	59.2	5.6	7.0	71.9	341.4	303.4	<3.6	<7.1	<0.71	
TBPR	19	WIS																				
TBPR	20	OSU						0.92														
TBPR	21	OSU		0.04	0.11	0.19	0.12	1.07	1794.4	1024.4	53.1	21.1	21.5	11.5	4.8	4.4	79.9	227.0	<1.0	2.6	0.42	
TBPR	22	OSU		0.04	0.19	0.18	0.15	1.06	3884.1	1459.7	40.3	17.3	32.7	15.4	4.3	5.5	100.1	251.3	<1.0	3.6	0.85	0.03
TBPR	23	OSU		0.05	0.18	0.16	0.15	1.13	3456.9	2154.4	42.8	16.9	26.0	7.4	5.0	5.7	93.4	410.6	<1.0	4.1	0.63	<0.02
TBPR	23	WIS																				
TBPR	24	OSU		0.07	0.38	0.18	0.19	0.99	4267.2	3411.1	67.5	20.1	39.2	10.8	7.3	5.7	62.9	328.8	<1.0	7.7	0.69	<0.02
TBPR	24	WIS																				
TBPR	25	OSU		0.07	0.16	0.18	0.20	1.09	2552.9	6809.0	55.8	12.9	94.1	29.6	7.0	12.4	142.0	412.3	<1.0	12.2	1.00	<0.02
TBPR	26	OSU		0.06	0.18	0.19	0.13	1.23	2010.3	2398.6	50.9	26.4	68.8	51.9	7.4	9.2	108.8	352.2	<1.0	5.9	0.98	<0.02
TBPR	26	OSU	DUP																			
TBPR	27	OSU		0.05	0.28	0.17	0.14	1.09	4056.7	3999.2	43.6	24.9	129.7	2.5	10.3	14.6	133.3	208.0	<1.0	11.0	1.70	
TBPR	28	OSU		0.06	0.20	0.17	0.16	0.84	4577.0	9471.6	39.1	20.5	221.1	7.0	10.5	12.5	238.9	499.2	<1.0	34.8	1.40	<0.02
TBPR	29	OSU		0.06	0.18	0.24	0.17	1.27	2309.1	6379.0	103.7	30.3	316.0	11.7	11.2	18.1	240.3	450.8	<1.0	17.1	0.22	
TBPR	29	OSU	DUP																			
TBPR	29	WIS																				
TBPR	30	OSU		0.09	0.15	0.22	0.13	0.94	2638.6	9385.2	115.4	25.4	338.8	0.2	6.2	7.9	155.7	479.1	<1.0	33.9	0.20	

Table A.3 Results of plant tissue analyses for December samples

SITE/ STUDY	ID	LAB	TYPE	STEM P (%)	STEM K (%)	STEM Ca (%)	STEM Mg (%)	STEM N (%)	STEM Na (ug/g)	STEM Fe (ug/g)	STEM Mn (ug/g)	STEM B (ug/g)	STEM Pb (ug/g)	STEM Cd (ug/g)	STEM Ni (ug/g)	STEM Cr (ug/g)	STEM Cu (ug/g)	STEM Zn (ug/g)	STEM Hg (ug/g)	STEM As (ug/g)	STEM Mo (ug/g)	STEM Se (ug/g)
TBPR	1	OSU		0.01	0.15	0.05	0.03	0.40	726.8	51.2	18.9	1.7	12.4	0.2	4.0	1.2	3.2	98.9	<1.0	<2.0	0.20	<0.02
TBPR	2	OSU		0.01	0.16	0.03	0.04	0.24	524.1	40.8	2.1	2.9	15.1	0.2	3.6	1.5	2.4	222.9	<1.0	<2.0	0.20	
TBPR	2	OSU	DUP	0.01	0.16	0.03	0.04	0.25	523.1	38.7	1.7	1.1	14.5	<0.2	3.8	0.9	2.2	204.6	<1.0	<2.0	<0.2	<0.02
TBPR	2	WIS																				
TBPR	3	OSU		0.01	0.13	0.04	0.03	0.39	351.6	40.3	3.7	2.3	26.9	0.2	1.8	1.2	2.9	184.3	<1.0	<2.0	0.23	<0.02
TBPR	4	OSU		0.01	0.07	0.05	0.05	0.37	348.2	80.4	5.3	1.5	51.6	<0.2	3.0	1.5	4.8	298.6	<1.0	<2.0	0.26	<0.02
TBPR	5	OSU		0.01	0.21	0.07	0.06	0.46	214.2	87.2	2.7	1.9	35.2	<0.2	2.4	2.2	6.6	220.9	<1.0	<2.0	0.37	0.03
TBPR	5	WIS																				
TBPR	6	OSU		0.03	0.23	0.04	0.06	0.54	704.6	25.9	3.1	1.6	7.3	<0.2	2.9	1.2	5.0	72.1	<1.0	<2.0	0.31	0.05
TBPR	7	OSU		0.01	0.07	0.05	0.05	0.33	640.0	36.8	6.1	1.7	3.0	<0.2	2.7	1.8	3.1	147.2	<1.0	<2.0	0.33	0.03
TBPR	7	WIS		0.01	0.09	0.06	0.06	0.33	603.0	20.9	5.4	2.0	3.3	<0.2	2.4	1.1	3.2	165.1		<2.0		
TBPR	8	OSU		0.01	0.14	0.04	0.09	0.27	345.1	44.4	7.8	1.7	8.2	<0.2	7.4	1.4	5.8	28.5	<1.0	<2.0	0.46	0.03
TBPR	9	OSU		0.02	0.20	0.09	0.03	0.37	299.4	41.2	30.6	1.4	<2.0	<0.2	2.4	1.9	4.6	43.5	<1.0	<2.0	<0.2	0.03
TBPR	9	OSU	DUP	0.02	0.21	0.09	0.03	0.36	327.2	40.0	30.7	1.1	2.4	<0.2	1.6	<0.6	4.6	42.1	<1.0	<2.0	0.27	0.03
TBPR	10	OSU		0.01	0.13	0.07	0.05	0.30	257.2	35.0	18.2	1.1	4.0	<0.2	2.4	1.5	4.5	62.3	<1.0	<2.0	0.43	0.04
TBPR	11	OSU		0.01	0.13	0.19	0.03	0.20	278.1	33.8	16.2	2.4	2.9	<0.2	2.0	2.0	4.3	80.9	<1.0	<2.0	<0.2	<0.02
TBPR	11	WIS		0.01	0.15	0.19	0.03	0.15	334.0	19.0	16.6	3.0	2.8	0.3	1.4	1.2	4.0	77.9		<2.0		
TBPR	12	OSU		0.02	0.13	0.05	0.08	0.34	77.3	45.9	4.4	3.5	6.9	<0.2	4.7	2.3	6.3	64.6	<1.0	<2.0	0.54	<0.02
TBPR	13	OSU		0.03	0.22	0.05	0.12	0.29	126.6	36.5	3.6	1.7	8.4	<0.2	5.4	2.2	6.5	51.0	<1.0	<2.0	0.83	<0.02
TBPR	13	OSU	DUP	0.03	0.22	0.05	0.12	0.33	145.3	49.0	3.2	1.3	9.4	<0.2	5.5	<0.6	6.0	47.4	<1.0	<2.0	0.74	0.08
TBPR	14	OSU		0.02	0.22	0.03	0.08	0.77	219.6	24.1	4.9	3.0	8.4	<0.2	3.2	1.5	6.2	12.9	<1.0	<2.0	0.50	<0.02
TBPR	15	OSU		0.02	0.27	0.02	0.10	0.39	273.0	36.5	5.2	3.5	8.4	<0.2	3.5	1.6	6.4	11.6	<1.0	<2.0	0.40	0.03
TBPR	16	OSU		0.02	0.11	0.05	0.08	0.48	362.2	24.9	8.8	3.9	7.7	<0.2	3.3	1.2	5.1	21.3	<1.0	<2.0	0.46	0.02
TBPR	17	OSU		0.01	0.07	0.07	0.03	0.31	355.2	35.4	7.6	2.8	<2.0	<0.2	2.1	1.5	6.8	50.6	<1.0	<2.0	0.39	0.03
TBPR	18	OSU		0.01	0.22	0.07	0.05	0.15	145.0	26.4	5.4	2.4	<2.0	<0.2	2.2	1.8	3.7	43.4	<1.0	<2.0	0.38	0.04
TBPR	19	OSU		0.01	0.02	0.05	0.02	0.30	122.5	37.6	2.2	2.4	2.7	<0.2	2.3	1.7	6.6	70.3	<1.0	<2.0	0.24	0.05
TBPR	20	OSU		0.01	0.08	0.08	0.02	0.24	212.7	25.8	3.7	0.8	6.7	<0.2	4.6	0.8	4.9	45.1	<1.0	<2.0	<0.2	
TBPR	20	OSU	DUP	0.01	0.07	0.07	0.02	0.26	202.1	25.5	3.4	0.8	6.7	<0.2	2.9	<0.6	4.4	42.5	<1.0	<2.0	<0.2	0.05
TBPR	20	WIS		0.01	0.08	0.08	0.02	0.21	212.0	31.3	6.5	0.8	15.1	<0.2	6.4	1.5	6.9	82.6		<2.0		
TBPR	21	OSU		0.03	0.18	0.07	0.05	0.59	1431.2	24.2	23.1	1.3	7.3	<0.2	4.9	0.8	8.8	78.2	<1.0	<2.0	0.33	0.02
TBPR	22	OSU		0.02	0.16	0.04	0.03	0.47	1497.3	30.5	25.7	0.9	6.1	<0.2	2.1	1.1	5.4	44.0	<1.0	<2.0	0.30	<0.02
TBPR	23	OSU		0.02	0.17	0.06	0.03	0.47	1138.1	34.0	29.5	1.1	8.5	<0.2	2.9	<0.6	6.0	60.3	<1.0	<2.0	0.46	
TBPR	23	OSU	DUP	0.02	0.15	0.06	0.03	0.45	1103.9	21.0	26.7	1.1	8.2	<0.2	4.3	<0.6	5.5	58.9	<1.0	<2.0	0.26	0.04
TBPR	24	OSU		0.01	0.06	0.07	0.03	0.26	1025.0	27.1	23.1	1.0	14.3	<0.2	4.9	0.7	4.1	72.9	<1.0	<2.0	0.30	<0.02
TBPR	25	OSU		0.01	0.06	0.05	0.04	0.32	1737.0	24.6	22.7	0.9	6.7	<0.2	2.4	<0.6	4.4	73.5	<1.0	<2.0	<0.2	<0.02
TBPR	26	OSU		0.01	0.18	0.08	0.05	0.44	1701.1	20.9	20.0	1.1	6.3	<0.2	2.9	<0.6	6.3	76.2	<1.0	<2.0	0.25	<0.02
TBPR	27	OSU		0.01	0.10	0.04	0.04	0.34	2635.7	27.3	22.2	0.7	8.3	<0.2	2.9	<0.6	4.4	65.6	<1.0	<2.0	<0.2	
TBPR	27	OSU	DUP	0.01	0.09	0.05	0.04	0.38	2495.8	28.8	22.7	1.1	11.3	<0.2	3.9	<0.6	4.8	68.6	<1.0	<2.0	0.21	<0.02
TBPR	28	OSU		0.01	0.19	0.03	0.06	0.19	1685.4	26.2	31.5	1.3	9.1	<0.2	4.2	0.7	3.2	56.8	<1.0	<2.0	0.25	0.02
TBPR	29	OSU		0.02	0.22	0.06	0.05	0.59	1398.9	38.3	36.9	1.1	11.5	<0.2	3.3	<0.6	5.9	177.0	<1.0	<2.0	0.21	<0.02
TBPR	30	OSU		0.02	0.15	0.05	0.03	0.34	2186.9	25.2	22.0	0.9	3.2	<0.2	1.6	0.6	3.4	30.9	<1.0	<2.0	<0.2	<0.02

Table A.3 cont.

SITE/ STUDY	ID	LAB	TYPE	LEAF P	LEAF K	LEAF Ca	LEAF Mg	LEAF N	LEAF Na	LEAF Fe	LEAF Mn	LEAF B	LEAF Pb	LEAF Cd	LEAF Ni	LEAF Cr	LEAF Cu	LEAF Zn	LEAF Hg	LEAF As	LEAF Mo	LEAF Se
				(%)	(%)	(%)	(%)	(%)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)
TBPR	1	OSU		0.03	0.04	0.13	0.05	1.24	103.5	107.8	16.1	7.7	7.1	<0.2	1.8	1.3	2.2	56.8	<1.0	<2.0	0.74	
TBPR	2	OSU		0.03	0.04	0.18	0.06	0.92	52.6	151.4	6.1	3.7	107.0	<0.2	3.3	2.3	9.1	450.1	<1.0	<2.0	0.82	0.04
TBPR	2	OSU	DUP																			
TBPR	2	WIS		0.03	0.07	0.32	0.13	0.79	73.0	104.6	7.8	6.9	44.6	<0.2	3.6	1.7	5.3	406.1		<2.0		
TBPR	3	OSU		0.04	0.06	0.22	0.10	1.16	83.6	254.2	10.6	6.5	109.7	<0.2	3.2	1.4	5.7	509.1	<1.0	<2.0	0.91	0.04
TBPR	4	OSU		0.04	0.05	0.17	0.07		110.9	118.3	9.6	8.2	15.3	<0.2	3.5	1.1	3.2	329.2	<1.0	<2.0	0.33	
TBPR	5	OSU		0.02	0.03	0.32	0.09	0.75	80.2	66.4	6.3	6.4	22.4	<0.2	2.1	1.1	3.1	297.2	<1.0	<2.0	0.64	0.08
TBPR	5	WIS		0.02	0.05	0.38	0.09	0.56	106.0	95.6	7.5	5.7	22.9	<0.2	2.1	1.4	3.2	377.9		<2.0		
TBPR	6	OSU																				
TBPR	7	OSU		0.04	0.05	0.17	0.07		97.1	79.1	5.7	2.9	4.5	<0.2	2.8	1.2	2.4	148.3	<1.2	<2.5	0.96	
TBPR	7	WIS																				
TBPR	8	OSU		0.03	0.03	0.21	0.13	0.71	118.6	102.5	32.2	6.5	5.3	<0.2	3.4	1.4	2.7	41.2	<1.0	<2.0	2.80	0.15
TBPR	9	OSU		0.03	0.04	0.38	0.04	0.83	151.9	116.1	62.7	7.8	8.0	<0.2	3.4	1.9	4.3	81.4	<1.0	<2.0	0.41	0.11
TBPR	9	OSU	DUP																			
TBPR	10	OSU																				
TBPR	11	OSU		0.05	0.04	0.38	0.04		162.1	99.0	40.4	11.7	9.8	<0.2	9.4	1.4	3.4	86.9	<1.0	<2.0	0.61	
TBPR	11	WIS																				
TBPR	12	OSU		0.05	0.07	0.30	0.16	0.78	135.1	894.6	24.7	11.1	33.6	0.2	11.8	12.7	29.7	136.5	<1.0	<2.0	1.20	
TBPR	13	OSU		0.05	0.05	0.29	0.15	0.71	117.3	99.3	11.4	6.2	4.0	<0.2	3.7	1.5	2.7	87.7	<1.0	<2.0	3.40	
TBPR	13	OSU	DUP																			
TBPR	14	OSU		0.04	0.07	0.21	0.14	0.82	92.1	65.1	12.1	6.8	5.9	<0.2	3.6	1.5	2.6	30.7	<1.0	<2.0	1.50	0.13
TBPR	15	OSU		0.04	0.04	0.18	0.16		132.8	115.4	66.3	10.1	4.6	<0.2	4.1	1.6	3.0	30.3	<1.2	<2.4	1.40	
TBPR	16	OSU		0.03	0.04	0.38	0.14		128.5	89.4	42.4	10.7	8.3	<0.3	7.2	1.2	4.2	47.3	<1.4	<2.8	2.30	
TBPR	17	OSU																				
TBPR	18	OSU		0.05	0.05	0.36	0.06		133.5	96.6	20.4	9.7	3.9	<0.2	2.2	1.6	3.5	80.0	<1.1	<2.3	1.10	
TBPR	19	OSU																				
TBPR	20	OSU		0.02	0.03	0.27	0.04	0.78	167.1	114.6	8.3	5.6	6.9	<0.2	4.1	1.6	4.0	82.6	<1.0	<2.0	0.39	
TBPR	20	OSU	DUP																			
TBPR	20	WIS																				
TBPR	21	OSU		0.04	0.04	0.23	0.15	0.81	163.7	102.5	35.4	7.1	9.1	<0.2	4.4	1.3	3.9	207.8	<1.0	<2.0	0.88	0.13
TBPR	22	OSU																				
TBPR	23	OSU																				
TBPR	23	OSU	DUP																			
TBPR	24	OSU																				
TBPR	25	OSU																				
TBPR	26	OSU		0.05	0.04	0.15	0.15		77.9	125.9	18.9	6.8	4.3	<0.2	6.1	2.8	3.7	40.3	<1.2	<2.3	1.30	
TBPR	27	OSU																				
TBPR	27	OSU	DUP																			
TBPR	28	OSU																				
TBPR	29	OSU																				
TBPR	30	OSU																				

Table A.3 cont.

SITE/				SEED	SEED	SEED	SEED	SEED	SEED	SEED	SEED	SEED	SEED	SEED	SEED	SEED	SEED	SEED	SEED	SEED	SEED	SEED
STUDY	ID	LAB	TYPE	P	K	Ca	Mg	N	Na	Fe	Mn	B	Pb	Cd	Ni	Cr	Cu	Zn	Hg	As	Mo	Se
				(%)	(%)	(%)	(%)	(%)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)	(ug/g)
TBPR	1	OSU																				
TBPR	2	OSU		0.14	0.12	0.09	0.09	2.14	141.6	148.2	6.9	6.1	10.2	<0.2	2.9	1.6	10.5	278.0	<1.0	<2.0	1.00	0.16
TBPR	2	OSU	DUP																			
TBPR	2	WIS																				
TBPR	3	OSU																				
TBPR	4	OSU		0.09	0.06	0.09	0.06	1.54	192.9	125.3	9.8	6.0	20.2	<0.2	3.0	0.8	7.5	363.2	<1.0	<2.0	0.55	0.24
TBPR	5	OSU																				
TBPR	5	WIS																				
TBPR	6	OSU		0.17	0.10	0.10	0.08	1.83	146.3	110.9	28.4	5.9	5.0	<0.2	2.0	1.1	10.0	114.6	<1.0	<2.0	0.79	0.13
TBPR	7	OSU		0.14	0.08	0.09	0.10	1.36	154.1	115.7	9.3	4.7	10.8	<0.2	2.6	1.0	8.0	203.8	<1.0	<2.0	0.93	
TBPR	7	WIS		0.12	0.10	0.10	0.09	1.23	179.0	92.4	8.7	4.6	4.0	<0.2	2.1	0.9	10.1	245.8		<2.0		
TBPR	8	OSU																				
TBPR	9	OSU		0.11	0.05	0.11	0.04		391.8	277.3	18.1	7.1	6.5	<0.5	2.9	<1.4	9.7	96.7	<2.3	<4.5	0.73	
TBPR	9	OSU	DUP																			
TBPR	10	OSU																				
TBPR	11	OSU		0.07	0.04	0.13	0.03		183.1	92.7	11.5	4.6	6.4	<0.4	2.0	<1.2	11.9	102.0	<2.1	<4.2	0.92	
TBPR	11	WIS																				
TBPR	12	OSU																				
TBPR	13	OSU		0.12	0.06	0.09	0.11	1.35	340.8	195.2	10.1	8.2	4.7	<0.2	3.5	1.2	12.0	124.7	<1.0	<2.0	2.60	
TBPR	13	OSU	DUP																			
TBPR	14	OSU		0.14	0.10	0.09	0.15		119.3	142.1	11.8	18.4	6.2	<0.3	7.0	1.4	10.6	66.6	<1.5	<2.9	1.50	
TBPR	15	OSU																				
TBPR	16	OSU																				
TBPR	17	OSU																				
TBPR	18	OSU		0.12	0.06	0.11	0.07	1.40	200.9	214.3	11.6	4.5	4.7	<0.2	2.8	<0.6	11.8	146.2	<1.0	<2.0	1.40	0.59
TBPR	19	OSU		0.11	0.10	0.09	0.06	1.87	590.6	179.5	8.9	8.3	7.9	<0.2	4.2	1.6	19.6	149.2	<1.0	<2.0	0.54	0.33
TBPR	20	OSU																				
TBPR	20	OSU	DUP																			
TBPR	20	WIS																				
TBPR	21	OSU		0.08	0.04	0.07	0.03	1.24	161.9	95.5	21.5	2.6	3.4	<0.2	2.1	<0.6	8.0	94.6	<1.0	<2.0	0.97	0.15
TBPR	22	OSU																				
TBPR	23	OSU																				
TBPR	23	OSU	DUP																			
TBPR	24	OSU																				
TBPR	25	OSU																				
TBPR	26	OSU		0.24	0.14	0.12	0.10	1.95	103.4	83.3	35.7	6.4	3.4	<0.2	2.1	<0.6	9.8	97.8	<1.0	<2.0	0.67	0.12
TBPR	27	OSU																				
TBPR	27	OSU	DUP																			
TBPR	28	OSU																				
TBPR	29	OSU																				
TBPR	30	OSU																				