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United States Nuclear Regulatory Commission

Protecting People and the Environment

Transfer Factors for Contaminant Uptake by Fruit and Nut Trees

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Transfer Factors for Contaminant Uptake by Fruit and Nut Trees

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ABSTRACT

Transfer of radionuclides from soils into plants is one of the key mechanisms for long-term contamination of the human food chain. Plants absorb nutrients through their roots and transport them via the phloem to active portions of the plant. Nearly all computer models that address soil-to-plant uptake of radionuclides use empirically-derived transfer factors to address this process. Essentially all available soil-to-plant transfer factors are based on measurements in annual crops. Very few measurements are available for tree fruits.

In order to address this limitation, a sampling of various “standard” crops and fruit and nut trees from a single farm was made. This particular farm uses irrigation water from the local aquifer using surface irrigation (not overhead sprinklers) and is registered as an organic farm (no pesticides or refined fertilizers are used). Samples of alfalfa and oats (to compare with available transfer factors) and stems, leaves, and fruits and nuts of almond, apple, apricot, carob, fig, grape, nectarine, pecan, pistachio (natural and grafted), and pomegranate were collected, along with local surface soil. The samples were dried, ground, weighed, and analyzed for trace constituents through a combination of induction-coupled plasma mass spectrometry and instrumental neutron activation analysis for a wide range of naturally-occurring elements.

Analysis results are presented and converted to soil-to-plant transfer factors. These are compared to commonly used and internationally recommended values. Those determined for annual crops (e.g., alfalfa, grain (oats)) are very similar to commonly-used values; those determined for fruits and nuts differ from the generic recommendations in the literature. In most cases, the results of the transfer factors in fruits and nuts from this study are the only data available. Transfer factors for most macro- and micronutrients are slightly reduced in fruits from the generic recommendations; transfer factors for non-essential elements are reduced further. The results tend to support the use of chemical analogues for elements that are not homeostatically regulated (i.e., those for which internal levels are not regulated by the plant at optimal concentrations). These different findings may allow development of tree-fruit-specific transfer models.

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EXECUTIVE SUMMARY

Transfer of radionuclides from soils into plants is one of the key mechanisms for long-term contamination of the human food chain. Plants absorb nutrients through their roots and transport them via the phloem to active portions of the plant. Nearly all computer models that address soil-to-plant uptake of radionuclides use empirically-derived transfer factors to address this process. Essentially all available soil-to-plant transfer factors are based on measurements in annual crops. Very few measurements are available for tree fruits.

In order to address this limitation, a sampling of various “standard” crops and fruit and nut trees was made. Samples of alfalfa and oats (to compare with available transfer factors) and stems, leaves, and fruits and nuts of almond, apple, apricot, carob, fig, grape, nectarine, pecan, pistachio (natural and grafted), and pomegranate were collected, along with local surface soil. The samples were dried, ground, weighed, and analyzed for trace constituents through a combination of induction-coupled plasma mass spectrometry and instrumental neutron activation analysis for a wide range of naturally-occurring elements.

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1.0 INTRODUCTION

Transfer of radionuclides from soils into plants is one of the key mechanisms for long-term contamination of the human food chain. Plants absorb nutrients through their roots and transport them via the phloem to active portions of the plant. Nearly all computer models that address soil-to-plant uptake of radionuclides use empirically-derived transfer factors to address this process. Essentially all available soil-to-plant transfer factors are based on measurements in annual crops. Very few measurements are available for tree fruits. In order to address this limitation, a sampling of various “standard” crops and tree fruits, and the soils that they were growing in, were made from a single farm. Analyses of stable element concentrations were performed for the soils and the crops and various parts of the trees and fruits. The concentrations of numerous elements have been compared to provide soil-to-plant transfer factors for a range of fruits under-represented in the radioecological literature.

Section 2 of this report describes some key concepts in biosphere modeling including radionuclide behavior in soils and uptake from soil by plant roots. Each of these is an area addressed by research detailed in this report.

Section 3 of this report provides descriptions of the sampling location, sample collection and preparation, and sample analysis. Samples of several types of fruit trees, including branches, leaves, and fruits were collected and analyzed for stable element concentrations. The resulting concentration data are provided in Appendix A of this report.

Section 4 presents the results as soil-to-plant transfer factors for future use in radiological analyses. The results are compared to transfer factor values routinely used in radiological analyses, and observations are made related to uptakes of elements that are either nutrients or non-essential elements, as well as to the reliability of use of surrogate measures such as chemical similarity for chemically-similar but unmeasured materials.

The results are expected to be useful in:

- Supporting the development of regulatory criteria (e.g., guidance, technical positions) for food-chain pathway issues involving biosphere models
- Providing a basis for developing and evaluating biosphere and food-chain pathway data, information, analyses, conceptual models, and computer codes
- Providing data and information for resolving biosphere issues involving possible future development of predictive models for radionuclide uptake in fruits.

The results of the research program improve the understanding of the features and processes for some important long-lived radionuclides in biosphere modeling.

2.0 MODELING SOIL-TO-PLANT UPTAKE

The following discussion is adapted from a longer presentation in Napier (2006). There are a number of important features and processes that all biosphere models must address in some manner (UNSCEAR 2000). The primary inputs to estimating radiation doses to individuals and populations are the concentrations and availabilities of radionuclides in air, water, soil, and foods, and the level of exposure of the individuals or groups to each radionuclide in each medium. Because it is not possible to completely characterize the radiological environment, and because in many practical cases the concentration of radionuclides in the environment resulting from reactor operations is too low to measure, mathematical models are employed to go from what is known to what needs to be known. For terrestrial models, these include radionuclide behavior in soil and uptake from soil by plant roots.

2.1 Radionuclide Behavior in Soils and Plant Uptake

Terrestrial plants, as immobile organisms, have adapted to derive essential nutrients from their environments. Plants absorb nutrients through their roots and transport them via the phloem to active portions of the plant. Biotic factors are likely the source of much of the variability seen in concentrations of contaminants in plants. This variability results from the nature of the sessile terrestrial plant and its relationship with its environment: the need to compete and acquire specific nutrient species from soils (or to avoid uptake of excesses of potentially toxic materials), the need of individual plant types for specific levels of individual nutrients, and the use of certain metals in tissues as agents to discourage herbivory. Thus, the uptake is affected by the following biotic factors:

1. The plant-available concentration in soils within the rhizosphere (the soil zone that surrounds and is influenced by the roots of plants), which is governed by soil adsorption processes, chemical solubility, microbial/fungal activity, and stability of the chemical complexes;

2. The chemical nature and stability of the cation-anion/complex with respect to the plant's capability to metabolically alter and/or absorb the elemental form into the plant

3. A series of plant adaptive/evolutionary processes for survival; this can include, but not be limited to, protective root processes (exclusion or complexation of an ion for detoxification, sequestration within the plant to regulate both ion levels and for detoxification, redox to alter solubility and transport when necessary, organic complexation in the case of all but mono-cationic elements, and uptake capacity being dependent on metabolic needs).

Under these chemical and biotic constraints, uptake can be expected to vary based on source term, kinetics of solubilization/speciation, the relative ability of a plant to view a non-nutrient ion as an analogue to a nutrient species, and the relative need by the individual plant genus/species for specific levels of a particular ion.

Transfer of radionuclides from soils into plants is one of the key mechanisms for long-term contamination of the human food chain. There are several methods that may potentially be used to simulate this process in radioecological models; the most common is through the use of soil-to-plant transfer factors (or concentration ratios), but others may also be used.

2.2 Soil-to-Plant Transfer Factors

The concept of soil-to-plant transfer factors has a long history. The document series *Prediction of the Maximum Dosage to Man from the Fallout of Nuclear Devices* (Tamplin 1967; Ng and Thompson 1966; Burton and Pratt 1968; Ng et al. 1968) was intended to provide input in the design of nuclear explosives to minimize the impacts of fallout; a series of appendices to Ng et al. (1968) described how global average concentrations of stable elements in soils and plants could be ratioed to give an estimate of uptake of radionuclides in plants from contaminated soils. In this description, Ng used the symbol (C_P/C_S) for what he called the plant-to-soil concentration ratio. The data in this report became the basis for many later models and calculations, such as NRC Regulatory Guide 1.109 (NRC 1977).

The concept pioneered by Ng has been given many names over the years.

- *Plant-to-soil concentration ratio* – a generic term in ecology, used by Whicker and Schultz (1982), Peterson (1983), Faw and Shultis (1999), and others;
- *Soil-to-plant transfer factor* – used to describe the direction of radionuclide migration “from soil into plants”, adopted by Martin Frissell and the International Union of Radioecologists (1989), IAEA (1994), and others;
- *Vegetable/soil transfer factor* – used in documents related to the RESRAD family of computer codes (e.g., Yang, Biwer, and Yu 1993; Yu et al. 2001);
- *Soil-to-plant concentration ratio* – a variant used by NCRP (1984);
- *Soil-to-plant concentration factor* – a variant used by IAEA (1982), Ng, Colsher, and Thompson (1982);
- *Concentration factor* – a variant used by Soldat in Fletcher and Dotson (1971); Miller et al. (1980);
- *Transfer ratio* – Stannard (1988);
- *Concentration ratio* – a commonly-used variant (e.g., Cataldo, Wildung, and Garland 1983; Napier et al. 2012; numerous others);
- *Plant uptake factor* – Eisenbud (1987);
- *Relative ratio* – Dahlman and Van Voris (1976);
- *Uptake ratio* – Grummitt (1976);
- *Plant bioconcentration factor* – a definition more usually used for aquatic uptake processes, sometimes used with terrestrial vegetation (e.g., Wolterbeek, van der Meer, and Dielemans 2000);
- *Plant bioaccumulation factor* - a definition more usually used for aquatic uptake processes, sometimes used with terrestrial vegetation (e.g., Wolterbeek, van der Meer, and Dielemans 2000)
- *Discrimination factor* – the name sometimes given to the ratio of the steady state output to input of a compartment model, when applied to the ratio of concentration in soil to concentration in plant, also *accumulation factor* (Peterson 1983; Faw and Shultis 1999).

All of these concepts are the same; the notation generally used for the transfer factor is B_v and is the unitless ratio of the concentration of an element in a plant of interest to the concentration in the source soil. The transfer factor applies to long-term, chronic exposures and is ideally measured at equilibrium. Transfer factors are used in risk assessments to estimate the amount of radioactivity that could be present in a food crop based on the calculated concentration in the source soil. By calculating the concentration in the food, the total intake can be estimated and a dose calculated as a result of the annual intake. In terms of radionuclides, the transfer factor is used to calculate how many becquerels per kilogram of soil are transferred to the edible dry plant product (Bq per kg). Although the concept is occasionally questioned for some of its underlying assumptions (e.g., Centofani et al. 2005), it is the most commonly used approach in radiological environmental assessments.

The transfer factor depends on the radionuclide, the soil type (which may include soil chemistry and concentrations of nutrients and analogues), and the plant type. The transfer factors are empirically derived; they are based on measurements made for various chemical forms of the radionuclide on selected types of plant in selected soil types. Experimental data are not available for all elements for all food types. Frequently, a few measurements on a very limited number of plant types are used to infer a transfer factor for all crops. Often, when no referenceable documents are available, data are derived based on chemical groupings in the periodic table of the elements, such that chemically similar elements are assigned similar values.

Since the handbook prepared by Ng et al. (1968), numerous studies have been undertaken to quantify transfer factors (or concentration ratios) for specific chemical elements as a function of food type. These studies have been compiled in several publications. Most computer codes reference one or more of these compilations as the source of their transfer factors. Several frequently referenced compilations include the International Atomic Energy Agency's Technical Report Series #364, *Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environments* (IAEA 1994). This document encompasses a wide variety of plant types and is the result of extensive background investigations. It is based on data compiled by the International Union of Radioecologists. This document has recently been updated (IAEA 2009; IAEA 2010). A second frequently cited reference is the NUREG/CR-5512, *Residual Radioactive Contamination From Decommissioning: Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent* (Kennedy and Strenge 1992) because of its large set of data and traceable references. Other references include the National Council on Ionizing Radiation and Protection (NCRP) Report #123 (1996), *Screening Models for Releases of Radionuclides to Atmosphere, Surface Water, and Ground*, and the series of documents by Coughtrey and Thorne (1983), *Radionuclide Distribution and Transport in Terrestrial and Aquatic Ecosystems, Vols. 1-6*.

Root uptake is important for biologically active or mobile contaminants; other contaminants unused or toxic to plants (e.g., plutonium) are discriminated against by biological systems, and their root uptake is minimal.

It is important to remember that the modeling of transfer of radionuclides from soils to plants is based entirely on empirical observation. For combinations of other plant and soil types that have not been directly observed, any factor used is at best an approximation.

2.3 Potential Non-Linear Uptakes

A key assumption of the transfer-factor approach is that the transfer factor is a constant as a function of concentration; that is, the uptake is linear. This may not be true for contaminants that are nutrients or are chemical analogues for them. Non-linear responses may be possible if plants scavenge essential elements at low concentrations but maintain a homeostatic balance (i.e., an internal level regulated by the plant at optimal concentrations) at higher soil concentrations (Sheppard and Sheppard 1985). The assumption of linearity may be appropriate for elements that are not essential to biological function, are not analogues of such elements, or are not absorbed by organisms via nutrient pathways. These latter elements seldom exhibit linearity at very low environmental concentrations (Figure 2.1). For such elements (Table 2.1), organisms often are able to homeostatically regulate their tissue concentrations over a range of environmental concentrations. In some cases, these concentrations may be 40 to 200 times greater than the amount needed to sustain life (Förstner and Wittmann 1981). There is generally little information to evaluate this concept except for a few radionuclides such as cesium or strontium which are thought to biologically mimic potassium and calcium, respectively.

The differences in predicted effects between linear and homeostatic models can be substantial. Experience in assessing risks of metals in sediments and groundwater indicates that, for certain metals and species, the linear model can overestimate exposure by up to six orders of magnitude (DOE 1997).

To date, few models have been developed to deal with this problem. A possible alternative for radionuclides with this behavior would be to treat them with a specific-activity type model, wherein the atom ratio of the radioactive to stable atoms of an element are assumed to be the same in the plant as in the soil.

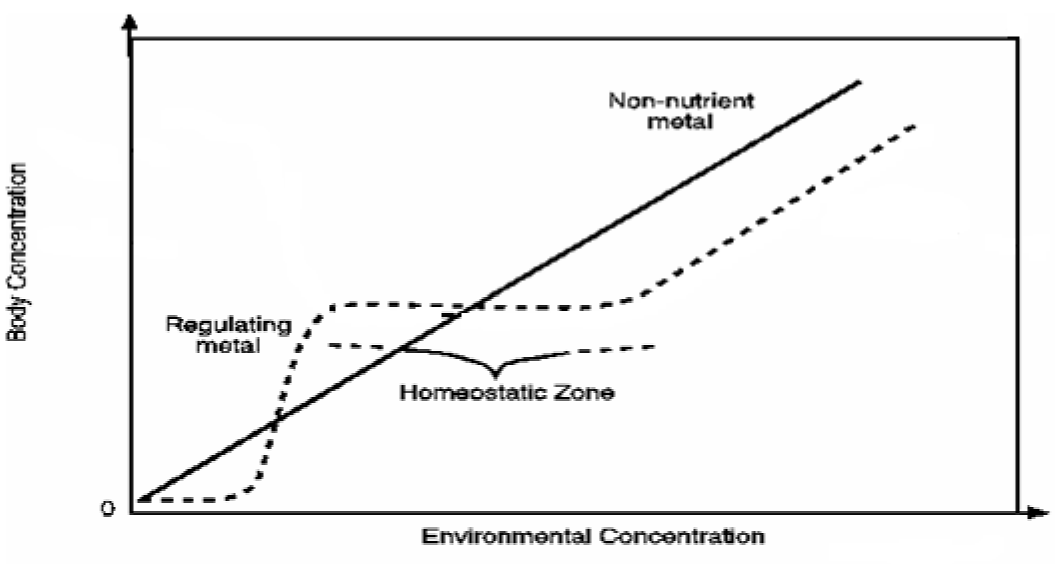

Figure 2.1. Relationships between Tissue Concentrations and Environmental Concentrations for Non-nutrient and Nutrient Compounds

Table 2.1. A Biological Classification of Metals: Shaded Cells are Non-nutrient Analogs; Bold Cells are Nonessential Metals.

Period	Macronutrient		Micronutrient					Non-essential	
3	Na	Mg							
4	K	Ca	Cr	Mn	Fe, Co, Ni	Cu	Zn		
5		**Sr**					**Cd**		
6	**Cs**							**Hg**	**Pb**
7								**Eu, U**	**Np**

(a) Period is from the Periodic Table of the Elements.

2.4 Uptake in Fruit Trees

The standard linear uptake model described above using transfer factors was originally developed for annual crops (leafy vegetables, root vegetables, forages, and grains). The vast majority of available observations, either laboratory or field studies, are for a limited number of crop types. In addition, observations are not available for all crop types for all chemical elements, and most compendiums of transfer factors use surrogates, relying on similar plant types, soil types, or chemical behavior to fill gaps in the knowledge (e.g., Staven et al. 2003; Yu et al. 2001).

The standard model is also used for perennial plants, including fruit trees. The model may not be appropriate for trees, considering their longer life and potential for accumulating contaminants in roots, trunks, and leaves, with transport to fruits possibly delayed for periods of over 1 year. The British Ministry of Agriculture, Fisheries, and Food (MAFF, since 2001 called the Department for Environment, Food, and Rural Affairs) has noted that such “models for fruit are extremely conservative… Extensive research is underway to produce more appropriate data. However, a review for MAFF concludes that no better fruit models currently exist” (MAFF 1999).

The International Union of Radioecologists and the International Atomic Energy Agency jointly prepared a major review of soil-to-plant transfer factors (IAEA 1994), which is used as a basic reference world-wide. In this review, soil-to-plant transfer factors are presented for many radionuclides and crop types. *None* of them refer to fruit or nut trees. A more recent compilation for tropical ecosystems does include some fruit trees (primarily apples), but the only nut is the coconut (Carini 2001). This state of affairs has been discussed in the international arena for several years; the IAEA’s Validation of Model Predictions (VAMP) Program Multiple Pathways Assessment Working Group noted in the early 1990s that many participants overestimated concentrations of ^{137}Cs in fruit trees, and that models for predicting the contamination of fruit were in need of further improvement (IAEA 1995). The sequel to VAMP, the IAEA’s Biosphere Modeling and Assessment (BIOMASS) Program, included a Fruits Working Group (IAEA 1996). As part of the work of the Fruits Working Group, a review was undertaken of the experimental, field and modeling information on the transfer of radionuclides to fruit. The results of this work were published as a special issue of the *Journal of Environmental Radiation* (Ventner et al. 2001).

In this special issue, Mitchell (2001) reports that there are three generic types of models that are applicable to fruit trees:

- Simple mathematical functions describing declining concentration in fruit, based on observations following deposition (e.g., Antonopoulos-Domis et al. 1990);
- Models that attempt to predict temporal distribution in soil-plant systems through descriptions of the processes involved; e.g. a model postulated by Frissell at the 1994 VAMP meeting in Vienna;
- Radiological dose assessment models that use a mixture of equilibrium and/or dynamic modeling approaches to predict concentrations in edible products; e.g. SPADE (Thorne and Coughtrey 1983).

Antonopoulos-Domis et al. (1990) developed a model structure for perennial fruit trees describing distribution, retention, transfer and rejection of radionuclides, based on experimental determinations of ^{137}Cs in apricot fruit trees. The original concept for the model was based on the fact that the leaves and fruits developing each year are only contaminated by a portion of the ^{137}Cs in the body of the tree. A fraction of this available reservoir is removed each year, part is lost from the tree through leaves and fruit and part becomes irretrievably associated with the body of the tree. This model requires knowledge of the contaminant inventory in the soil and the tree, as well as the deposition. The model is not immediately transferable to other types of trees, radionuclides, and locations, but it does indicate that at least two compartments are probably necessary to adequately describe the long-term accumulation and transfer of contaminants from trees into fruits.

A model for radiocesium transfer to tree fruit described by Frissel (1994) considers the homeostatic control of potassium within fruit trees. The model structure has four compartments and was designed to consider the long-term fate of cesium in soil as affected by changes in the supply of potassium to soil. The four compartments are soil, the easily accessible part of a tree, the poorly accessible woody part, and the fruit or leaf. The model is homeostatic; i.e., all cesium concentrations and fluxes are controlled by potassium concentrations and fluxes, respectively. In determining the various transfer parameters, it is assumed that there is no difference in the behavior of potassium and cesium, but that discrimination occurs between the compartments. The loss of plant material, termed debris by Frissel, via branches, leaf fall and fruit loss is included and returned to the soil, but because uptake is homeostatically controlled, this has minimal influence on the tree contents. Frissel (1994) concluded that the model was probably not sufficient to describe cesium transfer to fruit. In particular, the use of three compartments was not sufficient to model availability within the plant. The model results do indicate that important processes are likely to be the biological half time of cesium in wood, the discrimination between cesium and potassium, cycling of potassium (through falling leaves, etc.), and uptake of potassium.

The fruit plant model in the SPADE computer code (Thorne and Coughtrey 1983) has six compartments, representing internal leaf, external leaf, stem, fruit, storage organs and root. Movement of radionuclides within the plant model is controlled by empirically derived rate constants and parameters are derived for three broad categories of fruit plant: herbaceous, shrub and tree. Foliar absorption is represented by transfers between the external leaf and internal leaf compartments. Interception by plants takes account of changes in plant biomass with season. The original default parameters were based largely on data for cereals but were modified in the case of tree and shrub fruits to allow for more rapid transfer from stem to root so that the root store could serve as a reservoir through subsequent seasons. Loss of radionuclides from external plant surfaces to the soil is modeled as transfer to the surface layer of the soil model. The process of root uptake is modeled as the transfer of radionuclides from soil solution to the plant root compartment. The transfer rate is also assumed to vary with soil layer depth, both as a function of the root distribution throughout the soil profile and as a function of the deposit distribution in soil. Consequently, the transfer of radionuclides from the soil solution to root is represented by a discrete transfer from each of the 10 layers in the soil model. The soil solution to root rate constant in each soil layer is a function of the root uptake rate constant and the assumed distribution of root activity in each layer. Three plant absorption mechanisms are responsible for the transfer of radionuclides at the soil-root interface: plant-base absorption, main root system absorption and tap root absorption. The actual value of the soil solution to root transfer coefficient for each root layer corresponding to the soil layer of the soil model is calculated as the product of the specified rate coefficient and the normalized root shape modifier.

None of these models appears to be suitable for generic use in long-term radiological assessments without substantial modification and simplification, and all require additional development of parameters before general use. Again, it was noted that measurements of radionuclide uptake in trees were lacking (Carini 2001), and recommended that “There is a need for research on the behavior of radionuclides in fruit crops to drive model development, not simply to parameterize existing models. Research should focus on understanding the key processes” (Coughtrey et al. 2001). As a result of these recommendations, the IAEA initiated the Environmental Modeling for Radiation Safety (EMRAS) program in 2003. This program had a Working Group on Revision of IAEA Technical Report Series No. 364 “Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environments” and attempted to establish another Fruits Working Group. However, the participation in the Fruits group was so low that these participants joined with the Handbook group.

The IAEA handbook has recently been issued as Technical Reports Series Number 472 (IAEA 2009), supported with a larger compendium (IAEA 2010). These documents indicate that there remains a paucity of information about radionuclide uptake in fruits.

3.0 SAMPLING AND ANALYSIS OF SOIL AND FRUIT SAMPLES

Soil and vegetation samples were collected from a single farm in southern Nevada growing a wide variety of crops of interest. The soil samples were collected for use in plant radionuclide uptake studies. The information on soil in this section is a replication of that originally reported in Napier et al. (2005) so that the soil and transfer factor information could be easily found within a single reference.

The farm has been used for exploratory cultivation of a wide variety of tree species and other food crops. Standing crops include pistachio, almond, fig, carob, alfalfa, grapes, apples, pomegranate, pecan, field oats, apricots, and nectarines. All are irrigated from the underlying aquifer, using surface irrigation (not overhead sprinklers), and are registered as organic farm products (no pesticides or refined fertilizers). A sampling trip was taken to collect soil cores and up to six replicates of leaves, stems, and fruits of alfalfa, almond, apple, apricot, carob, fig, grape, nectarine, oats, pecan, pistachio, and pomegranate.

In addition to the soil and vegetation, samples were also taken of local groundwater used for irrigation and 1:1 soil-water extracts. Because these water samples were generally determined to have concentrations of materials too low for use in generation of transfer factors, they are not further discussed in this report.

3.1 Sampling and Analysis of Soil Samples

Uncontaminated soil samples were collected. The latitude and longitude position of each sampling location was recorded by using a global positioning system (GPS) unit to provide traceability and the opportunity to provide duplicate samples if required.

The sampling site is located in Nye County, Nevada, in a desert valley approximately 110 miles west of Las Vegas in the Amargosa Valley. The soil samples were collected from private land. The farmland was used to grow alfalfa for about 14 years up until about 1996, when it was allowed to turn to pasture. According to the land owner, the soil was originally conditioned using approximately 10 tons/acre of gypsum. No commercial fertilizer was used on the pasture. The soil was approximately 2.5 feet thick at the sample site, and consists of a light brown silty sand. Near the base, the occurrence of white streaks (calcareous materials) in the soil increased until the soil transitioned into broken-up calcrete.

3.1.1 Characterization and Analysis of Bulk Soil Samples

Detailed information about the soil is provided here, to provide background information for future researchers. In the following tables, analyses are listed for primary and duplicate samples. A duplicate sample is selected at random when a set of samples is submitted for analyses as part of the standard laboratory quality-assurance operating procedures used by the analytical laboratories in the PNNL Applied Geology and Geochemistry Group.

3.1.1.1 X-ray Diffraction

The primary crystalline minerals present in each bulk soil sample were identified using a Scintag X-ray powder diffraction (XRD) unit equipped with a Pelter thermoelectrically cooled detector and a copper X-ray tube. The diffractometer was operated at 45 kV and 40 mA. Individual scans were obtained from 2 to 65° 2θ with a dwell time of 2 seconds. Scans were collected electronically and processed using the JADE® XRD pattern-processing software. Identification of the mineral phases in the background-subtracted patterns was based on a comparison of the XRD patterns measured for the samples with the mineral powder diffraction files (PDF™) published by the Joint Committee on Powder Diffraction Standards (JCPDS) International Center for Diffraction Data (ICDD).

The background-subtracted XRD patterns for the soil sample are shown in Figure 3.1. Each XRD pattern is shown as a function of degrees 2θ based on Cu K_{α} radiation (λ=1.5406 Å). The vertical axis in each pattern represents the intensity in counts per second (cps) of the XRD peaks. In order to conveniently scale the XRD patterns on the vertical axes and visualize the minor XRD peaks, it was necessary to cutoff the intensity of the most intense XRD peak in each pattern. These intensity cutoffs are labeled on each XRD pattern, and correspond to the largest XRD peak for quartz.

At the bottom of the XRD pattern, schematic database PDF patterns considered for phase identification are also shown for comparison purposes. The height of each line in the schematic PDF patterns represents the relative intensity of an XRD peak (i.e., the most intense [the highest] peak has a relative intensity [I/I_o] of 100%). As noted previously, a crystalline phase typically must be present at greater than 5 wt% of the total sample mass (greater than 1 wt% under optimum conditions) to be readily detected by XRD.

The following minerals were identified in the soil sample: quartz, plagioclase feldspar, microcline feldspar, amphibole, zeolite, and mica. More detailed analyses would be required to refine the identities of the general mineral identifications (e.g., plagioclase, amphibole, zeolite, mica, etc.) to specific compositions. The soil sample appears to contain a zeolite mineral. Although the pattern for this soil sample (Figure 3.1) was a good match to the database pattern for clinoptilolite (PDF 47-1870), other compositions of zeolites may also match this pattern.

3.1.1.2 Elemental Analysis by X-ray Fluorescence

Elemental analysis of the bulk soil samples was determined by X-ray fluorescence (XRF). The XRF analyses were completed for PNNL by staff at the GeoAnalytical Laboratory in the Department of Geology at Washington State University using a Thermo-ARL Advant' XP+ automated spectrometer. The sequential, wavelength dispersive spectrometer contains a Rh-target X-ray tube operated at 60 kV, 60 mA. Samples were prepared for XRF analysis using a lithium tetraborate flux fusion method which includes double fusing (for homogeneity) in carbon crucibles at 1000°C. Preparation time and analytical time were both approximately one hour per sample. Except for now using diamond-impregnated metal disks to improve the lapping of specimen surfaces to flatness, the details of sample preparation are essentially those described in Johnson et al. (1999). Concentrations of major constituents are provided in Table 3.1; concentrations of trace elements are listed in Table 3.2.

3.1.1.3 Particle Size Distribution

American Society for Testing and Materials (ASTM) procedures ASTM D1140-00 (ASTM 2000) and D422-63 (ASTM 2003) were used for particle size analysis of the soil samples. In ASTM D422-63, a sedimentation process using a hydrometer is used to determine the distribution of particle sizes smaller than 75 µm, while sieving was used to measure the distribution of particle sizes larger than 53 µm (retained on a No. 270 sieve). A No. 10 sieve, which has sieve size openings of 2.00 mm, was first used to remove the fraction larger than "very coarse" prior to particle size analysis. Particle size results are shown in Table 3.3; the soil is essentially 99% sand.

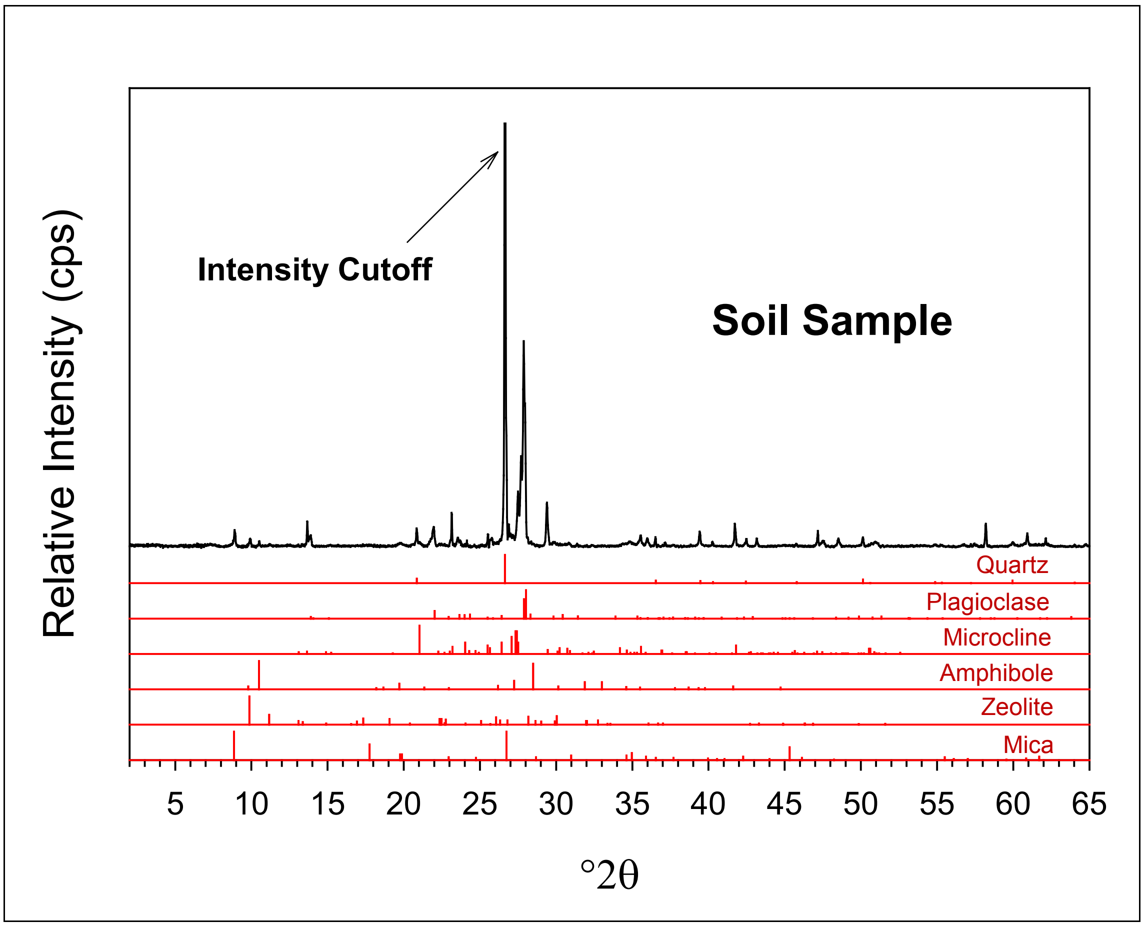

Figure 3.1. Background-Subtracted XRD Pattern for Nye County Soil Sample

Table 3.1. Concentrations of Major Elements in Bulk Soil Samples as Determined by XRF

Al_2O_3	CaO	FeO*	K_2O	MgO	MnO**	Na_2O	P_2O_5	SiO_2	TiO_2	Total
(wt% – dry basis, normalized to 100%)										
13.44	6.23	2.04	4.31	1.55	0.064	3	0.071	68.95	0.347	100

* Concentrations of total iron are normalized to FeO. XRF determines the concentrations of total iron and manganese, but does not provide any data regarding the oxidation states of such redox sensitive elements present in the sample.

** Concentrations of total manganese are normalized to MnO.

Table 3.2. Concentrations of Trace Elements in Bulk Soil Samples as Determined by XRF

Ba	Ce	Cr	Cu	Ga	La	Nb	Nd	Ni
(ppm)								
694	95	13	9	17	53	19	36	10
Pb	**Rb**	**Sc**	**Sr**	**Th**	**V**	**Y**	**Zn**	**Zr**
(ppm)								
24	136	6	413	19	24	27	53	256

Table 3.3. Particle Size Analysis of the Bulk Soil Samples

Gravel (x > 2 mm)	Sand (2 > x > 0.050 mm)	Silt/Clay (x < 0.050 mm)
(wt%)		
0.0	98.99	1.01

3.1.1.4 Moisture Content

Gravimetric water contents of the soil samples were determined using PNNL procedure PNL-MA-567-DO-1 (PNL 1990).[1] This procedure is based on the ASTM Method D2216-98 (ASTM 1998). One representative subsample of each soil sample was placed in tared containers, weighed, and dried in an oven at 105°C (221°F) until constant weight was achieved, which took at least 24 hours. The containers then were removed from the oven, sealed, cooled, and weighed. Two weighings, each after a 24-hour heating, were performed to ensure that all moisture was removed. The gravimetric water content shown in Table 3.4 was computed as the percentage change in soil weight before and after oven drying.

Table 3.4. Moisture Contents of the Bulk Soil Samples

Soils	Moisture (wt%)	
	First Weighing	Second Weighing
Primary	2.51	2.30
Duplicate	2.57	2.38

3.1.1.5 Cation Exchange Capacity

The cation exchange capacity (CEC) of each of the soil samples was determined using the method described in American Society of Agronomy (ASA) (1982). This method is particularly suited to arid land soils, including those containing carbonate, gypsum, and zeolites. This procedure involves two steps. The first step consists of saturation of the cation exchange sites with Na by reaction of the soil with pH 8.2, 60% ethanol solution of 0.4-*N* NaOAc–0.1 *N* NaCl. This is then followed by extraction of 0.5 *N* $MgNO_3$. The concentrations of dissolved Na and Cl are then measured in the extracted solution so that the dissolved Na from the excess saturation solution, carried over from the saturation step to the extraction step, is deducted from the total Na. This provides the amount of exchangeable Na, which is equivalent to the CEC. Results for three replicates are shown in Table 3.5.

Table 3.5. Cation Exchange Capacity (CEC) Values for the Soil Samples

CEC (meq/100 g)			
#1	#2	#3	Average
27.3	28.5	29.3	28.4

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1 PNL. 2000. "PNNL Technical Procedure SA-7. Water Content." Procedure approved in May 2000, in Procedures for Ground-Water Investigations, PNL-MA-567, Pacific Northwest National Laboratory, Richland, Washington.

3.1.1.6 Carbon Content

The total carbon and the inorganic carbon contents of the soil samples were measured using a Shimadzu Carbon Analyzer Model TOC-V csn. The method used to measure the carbon contents of the soil samples is similar to ASTM Method E1915-01 (ASTM 2001). Known quantities of calcium carbonate standards were analyzed to verify that the instrumentation was operating properly. Inorganic carbon content was determined through calculations performed using the microgram per-sample output data and sample weights. The organic carbon content of the soil samples was calculated by subtracting the inorganic carbon contents from the respective total carbon contents for each sample. Results are shown in Table 3.6.

Table 3.6. Carbon Contents of the Soil Samples

Soil	Total Carbon			Total Inorganic Carbon			Total Inorganic Carbon As $CaCO_3$	Total Organic Carbon (by difference)
	#1	#2	Ave	#1	#2	Ave	Ave	Ave
	(wt%)							
Primary	1.10	1.08	1.09	0.97	0.98	0.97	8.11	0.12
Duplicate	1.38	1.38	1.38	1.26	1.22	1.24	10.31	0.14

3.2 Sampling and Analysis of Crop and Fruit Samples

Up to six replicates were collected of leaves, stems, and fruits of alfalfa, almond, apple, apricot, carob, fig, grape, nectarine, oats, pecan, pistachio, and pomegranate. The sampled plants are shown in Figures 3.2 and 3.3.

The samples were collected July of 2004 at the farm, placed in paper bags, and shipped overnight to the Pacific Northwest National Laboratory. They were then unpacked, a fresh weight taken, the samples transferred to tared glass jars, and dried at 80°C for 72- to 96-h. Dry weights were then taken and the samples stored at room temperature in the closed jars.

The dried samples were then ground with a Wiley Mill (Sargent Welch, Inc. Philadelphia, PA) to a 20 mesh size. The samples were again stored at room temperature.

3.2.1 Methods for Analysis of Vegetation Samples

The primary interest was to obtain information about the concentrations of as many constituent elements in as many samples as possible, within budgetary constraints. Some initial range finding efforts were undertaken with mass spectrometry, these were followed up by a larger analysis using neutron activation analysis.

3.2.1.1 Mass Spectrometry

Based on soil sampling results, a small range finding effort was made to obtain leaf and fruit/nut concentrations for selected stable analogue and other specific chemical elements. This range finding was based on single replicates of those fruit and nut species for which both leaves and fruit/nuts were available. The elements selected for Induction-Coupled Argon Plasma Mass Spectrometry (ICAP) analysis were Cs, Co (+2, 3), Ga (+3 ion), I, Mg (+2 ion), Ni, P (+3, 5, -3), Se (+4, 6, -2), Ag (+1) and Sr. Selected samples (10-g aliquots) were sent to Huffman Labs, Inc. (Golden, Colorado) for wet digestion and ICAP analysis. The results are given in Table 3.7. These results verify the neutron activation analysis results discussed in Section 3.2.1.2; they were not used in the derivation of the transfer factors.

Table 3.7 Elemental Results from ICAP-MS analysis.

Element (μg/g)	Alfalfa Leaf/Stem	Almond Leaf	Almond Fruit	Apple Leaf	Apple Fruit	Apricot Leaf	Apricot Fruit
Cs	0.02	0.079	0.029	0.059	0.005	0.058	0.046
Co	0.13	0.15	0.05	0.12	0.01	0.11	0.07
Ga	0.03	0.12	0.05	0.11	0.02	0.1	0.09
I	0.3	0.4	0.5	0.4	<0.5	1	0.9
Mg	2630	5940	1260	2850	481	3430	877
Ni	1.5	1.5	5.7	2.4	3.2	0.6	2.3
P	212	903	1840	1350	945	2700	2640
Se	0.12	0.13	0.11	0.09	<0.05	0.07	0.06
Ag	0.02	0.03	<0.01	0.01	0.01	0.02	<0.01
Sr	107	117	14	81	1.9	91	6.8
Element (μg/g)	**Carob Leaf**	**Carob Fruit**	**Fig Leaf**	**Fig Fruit**	**Grape Leaf**	**Grape Fruit**	**Oat Leaf/Seed**
Cs	0.066	0.014	0.095	0.009	0.059	0.014	0.012
Co	0.14	0.04	0.19	0.36	0.16	0.03	0.13
Ga	0.11	0.04	0.16	0.03	0.12	0.04	0.04
I	1	1.3	0.7	0.3	1.3	<0.5	0.3
Mg	1840	1010	4380	1620	3760	1250	1610
Ni	1.4	1.8	1.9	1.8	0.7	0.2	3
P	1520	1810	1260	1660	3640	2350	2230
Se	0.14	0.06	0.19	0.06	0.12	<0.05	0.08
Ag	0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01
Sr	126	24	153	42	160	21	14

Grafted Pistachio

Natural Pistachio

Fig

Figure 3.2. Plants Sampled – Grafted and Natural Pistachio, Fig.

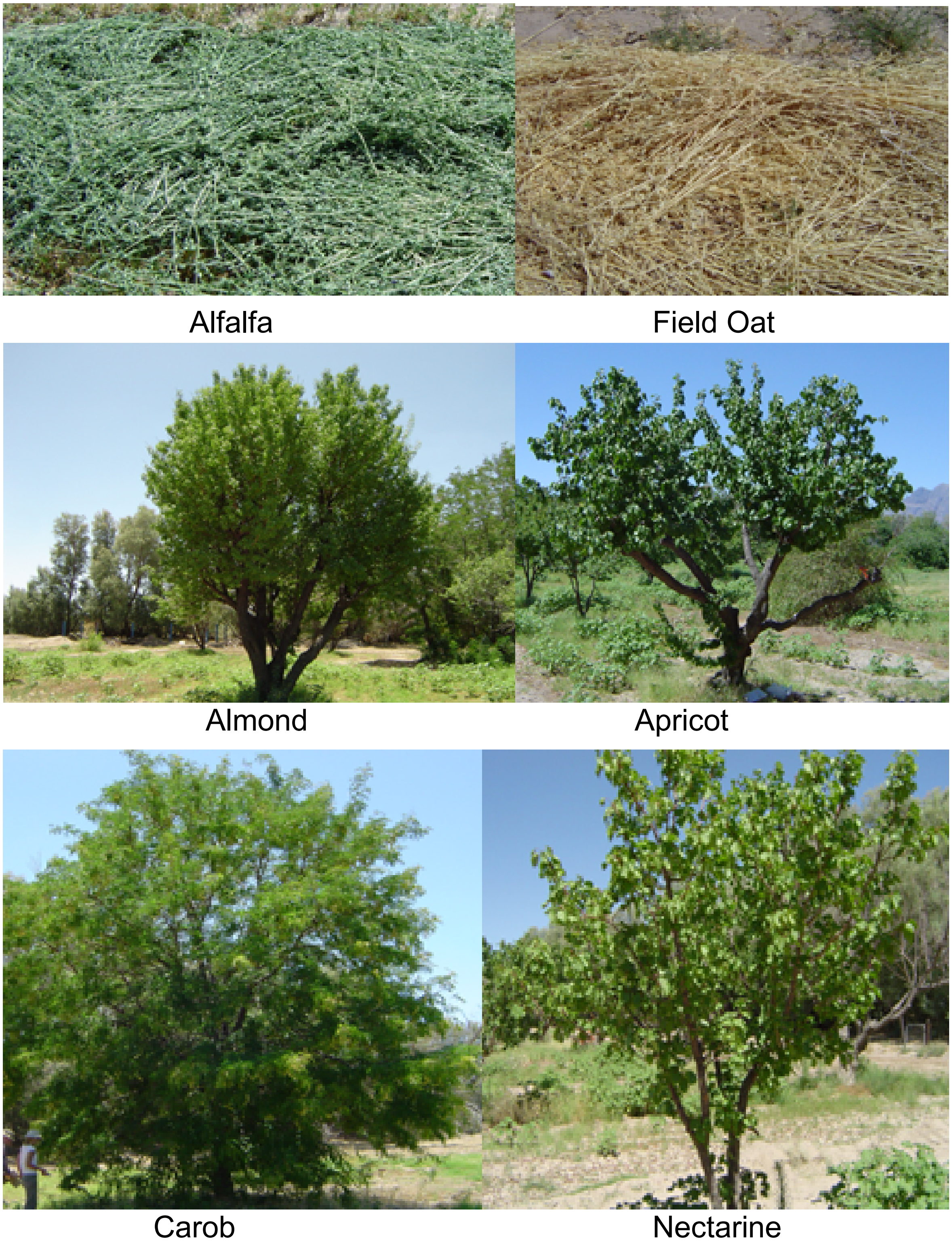

Figure 3.3. Plants Sampled – Field Crops Alfalfa and Oats, Fruits and Nuts Almond, Apricot, Carob, and Nectarine.

3.2.1.2 Instrumental Neutron Activation Analysis

A total of 93 botanical samples (tree branches, tree leaves, and tree fruit/nuts for several types of trees, along with samples of alfalfa and oats) were evaluated by instrumental neutron activation analysis (INAA) at the Radiation Center at Oregon State University. Neutron activation analysis is a non-destructive, highly precise and accurate analytical technique capable of determining up to 48 elements in almost all types of sample matrices. The INAA procedure involves irradiating the samples and appropriate standard reference materials with neutrons to produce unstable radioactive nuclides. Many of these radionuclides emit gamma-rays with characteristic energies that can be measured utilizing high-resolution semiconductor detectors. The rate that the gamma-rays are emitted from an element in the sample is directly proportional to its concentration. Detection limits are in the parts per million to parts per billion range depending on the element and sample matrix. Three aliquots of soil were also included.

Standard multi-element trace-element analysis typically includes three suites of elements: those with very short half-lives (ranging from minutes to less than about 15 hours), those with intermediate half-lives (15 hours to several days), and those with long half-lives (on the order of several weeks to years). Effective characterization therefore requires a minimum of two irradiations, each followed by several counts of resultant gamma activity. These protocols are tailored to the type of material and the overall sample activity expected, and thus differ between botanical and soil samples.

Botanical Samples. Botanical samples have notoriously low concentrations of many elements, and thus are a challenge for multi-element analysis. One common solution is to dry ash the materials in order to reduce both the mass and volume of organic compounds and pre-concentrate other elements, resulting in increased analytical sensitivity (Harju *et al.* 2004; Koh *et al.* 1999). However, a number of elements of interest - including Br and Cl - are highly volatile and can be lost in the ashing process. The solution advanced here was to analyze both unashed material and ashed materials, for different suites of elements as appropriate.

To dry ash the samples, approximately 5-25 g of plant material (depending on availability) was placed in a covered porcelain crucible, and heated to 550° C in a muffle furnace, using a slow ramp of about 200° C per hour and a soak time of 20 hours. As soon as samples were cool enough to handle, the ash was lightly ground and homogenized using a ceramic mortar and pestle, and transferred to tightly-capped liquid scintillation vials to prevent re-hydration. Concentration factors were determined from the ratio of pre-fire to post-fire mass, and used to determine the equivalent mass of unashed plant material that was irradiated. The standard reference material NIST1571 (orchard leaves) was similarly subjected to the ashing process, and both ashed and unashed aliquots of this standard reference material were included in the analysis to track the effects of ashing on element concentrations.

Analyses of elements analyzed via short half-life isotopes utilized unashed plant material. Approximately 700-850 mg of sample plant material was packed into high-purity polyethylene 4/5 D vials, weighed to the neared 0.1 mg, and then heat-sealed to ensure closure. Samples were irradiated for 60 s at 1 MW_{th} using the OSU TRIGA reactor pneumatic tube system, which delivers samples to an in-core location with a thermal flux of 10^{13} n $cm^{-2} \cdot s^{-1}$. Following a decay of 14 minutes, each sample was then placed on a 25% relative efficiency HPGe detector at a distance of 14 cm from the detector face. Gamma activity was recorded for a period of 500 s (real time).

Element concentrations were determined using the direct comparison method, with values calculated on a weight ratio basis relative to activities obtained in the standard reference material NIST1571 (orchard leaves). Three replicates of NIST1571 were included with every batch of 20-25 samples; a fourth replicate of NIST1571 was included in each batch as a check-standard and treated as an unknown, in order to evaluate precision and accuracy of results. All data reductions were based on consensus values for the standard reference materials as reported in Glascock 2006 (Appendix B). These protocols resulted in data on concentrations of Al, Br, Ca, Cl, Cu, Dy, K, Mg, Mn, Na, Ti, and V. However, Cu and Ti were consistently below detection limits in the NIST1571 standards, resulting in missing data for these elements in the botanical samples.

Dry-ashed material was utilized for analysis of elements determined through longer half-life isotopes. Ashed materials were encapsulated as above in high-purity polyethylene vials. In this case, encapsulated sample masses ranged from 0.5 to 1.0 g of ashed material, a range equivalent to 2-18 g of unashed material, depending on the concentration factor. The materials were organized in batches of ca. 25 samples, and subjected to a 21-hr irradiation in the rotating rack of the OSU TRIGA reactor, a location which experiences a nominal thermal neutron flux of 3×10^{12} n cm^{-2} s^{-1}. Two separate counts of gamma activity were made using a 32-38% relative efficiency detector, and a counting geometry of 3 inches. The first count of 5000 s (live-time) began 5 days after the end of irradiation, while the second count for 15,000 s followed a 4-week decay. These two counts provided data on As, Ba, La, Lu, K, Na, Sm, U, Yb, and Ce, Co, Cr, Cs, Eu, Fe, Hf, Nd, Rb, Sb, Sc, Ta, Tb, Th, Zn, and Zr, respectively.

As above, element concentrations were determined via the direct comparison method. Three replicates of the standard reference material NIST1633a (coal fly ash) were included as standards. All data reductions were based on consensus values for the standard reference materials as reported in Glascock (2006). NIST1571 (orchard leaves) and NIST1570 (spinach) were included as check standards to verify accuracy and precision of results.

Soil Samples. Soils were irradiated and analyzed using standard protocols for the analysis of mineral samples. Approximately 250 mg of material was placed in a 400 µL polyvial, weighed to the nearest 0.1 mg, and then heat-sealed to ensure closure. The samples were then subjected to two irradiations, both followed by two separate counts of gamma activity. In this case, the data for short half-live isotopes (Al, Ca, Cu, Ti, V, K, Mn, Na) result from a 7 s irradiation delivered via pneumatic tube to an in-core location with an average thermal flux of 10^{13} n cm^{-2} s^{-1}. Two separate counts were necessary, one after a 15-minute decay (for Al, Br, Ca, Cu, Ti, and V) using a 28% relative efficiency HPGe detector, and a second count after 2-hr decay (for K, Mn, and Na) on a 38% relative efficiency HPGe detector. Both counts were for 540 seconds (real time).

The concentrations of most elements were determined based on comparison with three replicates of the standard reference material NIST1633A (coal fly ash). In addition, the determination of Ca content was based on NIST688 (basalt rock), while Br content was evaluated relative to NIST1648 (urban particulate). All data reductions were based on consensus values for the standard reference materials as reported in Glascock (2006).

In contrast, the data for elements with intermediate and long half-life isotopes (including As, Ba, La, Lu, K, Na, Sm, U, Yb, Ce, Co, Cr, Cs, Eu, Fe, Hf, Nd, Rb, Sc, Sr, Ta, Tb, Th, Zn, Zr), result from an extended (7 hr) irradiation in the rotating rack, which experiences an average thermal neutron flux of 2×10^{12} n cm^{-2} s^{-1}. Following irradiation, two separate counts of gamma activity were recorded using a 32% relative efficiency HPGe detector. These include a 5000-second count (live time) of each sample after a 1-week decay period, and a 10,000-second count (live time) after a period of 4 weeks decay.

4.0 SOIL-TO-PLANT TRANSFER FACTORS

Soil-to-plant transfer factors for the nine crops, fruits, and nuts are estimated from the data prepared by this study. The transfer factors were evaluated from ratio of the arithmetic means of the concentrations of the available samples to the average concentrations of the three soil replicates. Uncertainties were propagated assuming that the measurements are uncorrelated (i.e., that there are no covariance terms).

In a few instances, the INAA analysis of the soil samples reported concentration values less than the reliable detection level. The INAA method was insufficiently sensitive for measuring Br, Cl, and Ni in soil samples. The x-ray fluorescence measurements of soil provide a more-sensitive measure for these elements, so these measurements were used for the estimation of transfer factors. A generic uncertainty of 10% was assumed for the x-ray fluorescence measurements for this purpose as a conservative approximation (IAEA 2004).

For several elements, there were a large number of less-than or zero measurements in the vegetation samples. The elements for which this occurred include Ti, V, Lu, U, Yb, Nd, Ta, Tb, and Zr. These are all trace elements with no known biological function. The less-than values were not used in the estimation of the transfer factors, and as a result there are several plant types for these elements for which no transfer factors are reported.

The transfer factors derived from the data discussed in Section 3 are presented in Tables 4.1 through 4.14. The transfer factors (soil-to-plant concentration ratios) are calculated by dividing the average measured concentration of the element in the plant portion by the average measured concentration in the soil. The uncertainties presented incorporate the variability in the plant and soil measurements and the measurement errors. The measurement uncertainties reflect counting uncertainty for net peak areas. The measurements of the plant concentration and the soil concentration are assumed to be uncorrelated (the covariance is assumed to be zero.) The reported uncertainty in the concentration ratio is then estimated as:

$$\frac{\sigma_{CR}^2}{CR} = \frac{\sigma_P^2}{C_P} + \frac{\sigma_S^2}{Cs}$$

Where CR = concentration ratio
C_P = concentration in plant
C_S = concentration in soil
σ_{CR}^2 = variance of the concentration ratio
σ_P^2 = variance of the concentration in the plant
σ_S^2 = variance of the concentration in the soil.

Table 4.1 presents transfer factors for a forage (alfalfa) and a grain (oats) developed in this report. These are compared with similar transfer factors used in environmental modeling; the complete set of transfer factors used in the GENII Version 2.10 model (Napier et al. 2012) which are primarily based upon the International Atomic Energy Agency's (IAEA) Technical Report Series No. 364 (IAEA 1994). These are also compared with the newer values for temperate environments for all soil types compiled in IAEA Technical Reports Series No. 472 (IAEA 2009), supported with a larger compendium (IAEA 2010). It can be seen in Table 4.1 that the values found for this one location in Nevada are of the same general magnitude as the IAEA recommendations, although generally slightly lower as might be expected for a site-specific, rather than conservatively generic, analysis.

Tables 4.2 through 4.13 present the results for the specific fruit and nut trees evaluated herein – almond, apple, apricot, carob, figs, grapes, nectarines, pecans, pistachios, and pomegranates. The results for pistachios are given for natural pistachios, grafted pistachios, and the two combined (there are minor differences – the uptake appears to be generally a little greater in the grafted variety). Table 4.14 presents a summary of the average of these fruits and nuts as generic transfer factors, which may be more appropriate for most general environmental analyses.

In the following tables, a double dash (--) indicates a combination for which there was insufficient data above detection limits to make an estimate.

Table 4.1 Soil-to-Plant Transfer Values for Forage and Grain from this Study, Compared to Those in Current Use (unitless)

	Current Study Values				TRS-364 Values			TRS-472 Values		
Element	**Forage**	**± 1σ**	**Grain**	**± 1σ**	**Forage**	**Grain**	**Fruit**	**Forage**	**Grain**	**Fruit**
Al	0.002	0.001	0.004	0.002	0.00018	0.00018	0.00018			
Br	0.002	0.001	0.004	0.002	1.5	1.5	1.5			
Ca	0.495	0.152	0.108	0.031	3.5	0.35	0.35	8.7	20	
Cl	0.514	0.206	0.302	0.107	70	70	70		0.36	
Mg	0.342	0.187	0.231	0.113	1	0.55	0.55			
Mn	0.098	0.015	0.149	0.019	0.7	0.3	0.05	1.5	0.28	0.31
K	1.073	0.298	0.278	0.071	1	0.55	0.55	0.74	0.74	
Na	0.041	0.012	0.044	0.010	0.3	0.3	0.3	0.1	0.01	0.03
Ti	--	--	--	--	5.40E-05	5.40E-05	5.40E-05			
V	--	--	--	--	0.0013	0.0013	0.0013			
As	0.028	0.006	--	--	0.04	0.006	0.006			
La	0.002	0.0001	0.002	0.0001	0.0052	0.004	0.004	0.02	0.00002	0.006
Lu	--	--	--	--	0.02	0.02	0.02			
Sm	0.002	0.001	0.002	0.0004	0.02	0.02	0.02			
Na	0.042	0.004	0.047	0.004	0.3	0.3	0.3			
U	--	--	--	--	0.0083	0.0013	0.004	0.015	0.0062	0.015
Yb	--	--	--	--	0.02	0.02	0.02			
Sb	0.074	0.028	0.043	0.014	0.00013	0.03	8.00E-05	0.007	0.0018	0.00013
Ba	0.007	0.003	0.005	0.002	0.15	0.015	0.015	0.91	0.001	0.005
Ce	0.002	0.0004	0.002	0.001	0.02	0.02	0.02	0.008	0.003	
Cs	0.003	0.001	0.003	0.001	0.46	0.026	0.22	0.16	0.029	0.021
Cr	0.010	0.004	0.025	0.006	0.0075	0.0045	0.0045	0.002	0.0002	0.001
Co	0.027	0.003	0.022	0.002	0.23	0.0037	0.007	0.066	0.0085	0.14
Eu	0.001	--	0.002	0.001	0.02	0.02	0.02			
Hf	0.001	0.0004	0.002	0.001	0.001	0.001	0.001			
Fe	0.005	0.0003	0.004	0.0003	0.05	0.05	0.05	0.002	0.0002	0.001
Nd	--	--	--	--	0.02	0.02	0.02			
Ni	0.102	0.060	0.309	0.155	0.28	0.03	0.06	0.4	0.027	
Rb	0.124	0.023	0.052	0.009	0.9	0.9	0.9	0.61	0.9	
Sc	0.002	0.0002	0.003	0.0002	0.006	0.001	0.001			
Sr	0.277	0.131	0.049	0.022	3	0.21	0.2	3.7	0.11	0.36
Ta	0.003	0.0004	0.002	0.001	0.025	0.025	0.025			
Tb	--	--	--	--	0.02	0.02	0.02			
Th	0.001	0.0002	0.002	0.0003	0.0018	3.40E-05	0.00025	0.0026	0.0021	0.00078
Zn	0.159	0.032	0.211	0.039	1.3	1.6	0.9	1	1.8	0.42
Zr	--	--	--	--	0.001	0.001	0.001	0.01	0.001	0.004

Table 4.2 Transfer Factors for Almonds (unitless)

Element	Leaf	± 1σ	Stem	± 1σ	Nut	± 1σ
Al	0.007	0.003	0.001	0.0005	0.003	0.002
Br	--	--	--	--	--	--
Ca	1.588	0.309	0.734	0.156	0.105	0.033
Cl	0.022	0.006	0.008	0.002	0.016	0.006
Mg	0.680	0.238	0.084	0.029	0.142	0.079
Mn	0.048	0.005	0.022	0.002	0.019	0.003
K	0.712	0.125	0.146	0.026	0.793	0.218
Na	0.118	0.023	0.022	0.005	0.027	0.007
Ti	0.005	0.005	--	--	0.004	0.003
V	0.013	0.006	--	--	0.011	0.008
As	0.176	0.043	0.163	0.043	0.024	0.010
La	0.008	0.0002	0.002	0.0001	0.004	0.0002
Lu	0.008	0.002	0.002	0.001	0.003	0.002
Sm	0.011	0.001	0.002	0.0002	0.005	0.001
Na	0.128	0.009	0.022	0.002	0.024	0.003
U	0.015	0.005	--	--	0.004	--
Yb	0.015	0.004	--	--	0.009	0.003
Sb	0.035	0.008	0.176	0.038	0.098	0.033
Ba	0.016	0.003	0.004	0.001	0.005	0.002
Ce	0.009	0.0004	0.002	0.0001	0.004	0.0004
Cs	0.013	0.001	0.003	0.0003	0.005	0.001
Cr	0.055	0.008	0.012	0.002	0.028	0.007
Co	0.023	0.002	0.006	0.0004	0.010	0.001
Eu	0.009	0.001	0.002	0.0003	0.005	0.001
Hf	0.009	0.001	0.002	0.0002	0.006	0.001
Fe	0.018	0.001	0.004	0.0002	0.007	0.0005
Nd	0.008	0.003	--	--	--	--
Ni	0.288	0.070	0.271	0.111	0.295	0.165
Rb	0.077	0.009	0.016	0.002	0.122	0.022
Sc	0.017	0.001	0.003	0.0001	0.006	0.001
Sr	0.494	0.148	0.344	0.110	0.045	0.022
Ta	0.010	0.002	0.002	0.0004	0.004	0.001
Tb	0.008	0.003	--	--	0.004	0.002
Th	0.010	0.0004	0.002	0.0001	0.005	0.0003
Zn	0.099	0.013	0.051	0.007	0.118	0.024
Zr	0.010	0.005	--	--	0.006	0.004

Table 4.3 Transfer Factors for Apples (unitless)

Element	Leaf	± 1σ	Stem	± 1σ	Fruit	± 1σ
Al	0.009	0.003	0.001	0.0004	0.001	0.0002
Br	0.001	0.00002	--	--	--	--
Ca	0.687	0.141	0.793	0.154	0.015	0.003
Cl	0.039	0.011	0.005	0.002	0.003	0.001
Mg	0.381	0.131	0.122	0.042	0.059	0.020
Mn	0.101	0.009	0.032	0.003	0.006	0.001
K	0.700	0.122	0.190	0.034	0.468	0.081
Na	0.017	0.003	0.004	0.001	0.002	0.0004
Ti	--	--	--	--	--	--
V	0.023	0.012	--	--	--	--
As	0.160	0.038	0.035	0.009	0.033	0.008
La	0.009	0.0002	0.001	0.00004	0.001	0.00004
Lu	0.007	0.002	--	--	--	--
Sm	0.010	0.001	0.001	0.0001	0.001	0.0001
Na	0.016	0.001	0.004	0.0003	0.002	0.0002
U	0.012	0.006	--	--	--	--
Yb	0.012	0.004	--	--	--	--
Sb	0.047	0.010	0.045	0.010	0.090	0.021
Ba	0.017	0.004	0.011	0.002	--	--
Ce	0.010	0.0004	0.001	0.0002	0.001	0.0002
Cs	0.013	0.001	0.002	0.0003	0.002	0.0003
Cr	0.096	0.014	0.010	0.002	0.011	0.002
Co	0.028	0.002	0.007	0.0004	0.003	0.0003
Eu	0.011	0.001	0.001	0.0003	0.002	0.0003
Hf	0.010	0.001	0.001	0.0002	0.001	0.0001
Fe	0.019	0.001	0.003	0.0001	0.001	0.0001
Nd	0.017	0.005	--	--	--	--
Ni	--	--	0.083	0.033	0.126	0.054
Rb	0.136	0.016	0.046	0.005	0.139	0.017
Sc	0.018	0.001	0.002	0.0001	0.001	0.0001
Sr	0.232	0.075	0.286	0.089	0.004	0.002
Ta	0.010	0.002	0.001	0.0003	--	--
Tb	0.009	0.003	--	--	--	--
Th	0.009	0.0003	0.001	0.0001	0.0008	0.0001
Zn	0.171	0.022	0.225	0.033	0.022	0.003
Zr	0.008	0.005	--	--	--	--

Table 4.4 Transfer Factors for Apricots (unitless)

Element	Leaf	± 1σ	Stem	± 1σ	Fruit	± 1σ
Al	0.001	0.0002	0.003	0.001	0.001	0.001
Br	--	--	--	--	--	--
Ca	0.617	0.084	0.662	0.135	0.323	0.009
Cl	0.006	0.001	0.017	0.005	0.006	0.002
Mg	0.144	0.035	0.258	0.103	0.109	0.030
Mn	0.040	0.003	0.079	0.009	0.024	0.001
K	0.163	0.020	0.832	0.182	0.502	0.148
Na	0.003	0.0003	0.005	0.001	0.003	0.001
Ti	--	--	--	--	--	--
V	--	--	0.019	0.008	--	--
As	0.050	0.009	0.060	0.016	0.035	0.006
La	0.001	0.00005	0.003	0.0001	0.001	0.0001
Lu	--	--	0.004	0.001	--	--
Sm	0.001	0.0001	0.004	0.0003	0.002	0.0004
Na	0.003	0.0002	0.005	0.0004	0.003	0.0004
U	--	--	0.005	0.000	--	--
Yb	--	--	0.012	0.003	--	--
Sb	0.026	0.004	0.075	0.017	0.032	0.009
Ba	0.005	0.001	0.007	0.002	0.005	0.001
Ce	0.001	0.0002	0.004	0.0003	0.001	0.0004
Cs	0.002	0.0002	0.006	0.001	0.002	0.001
Cr	0.009	0.001	0.026	0.005	0.009	0.003
Co	0.005	0.0003	0.010	0.001	0.006	0.001
Eu	0.002	0.0002	0.004	0.001	0.002	0.001
Hf	0.001	0.0002	0.003	0.0004	0.001	0.001
Fe	0.003	0.0001	0.008	0.0004	0.003	0.0003
Nd	--	--	--	--	--	--
Ni	0.063	0.019	--	--	0.112	0.061
Rb	0.044	0.004	0.140	0.019	0.144	0.036
Sc	0.002	0.0001	0.007	0.0004	0.002	0.0003
Sr	0.249	0.053	0.182	0.056	0.133	0.006
Ta	--	--	0.007	0.001	--	--
Tb	--	--	--	--	--	--
Th	0.001	0.0001	0.003	0.0002	0.001	0.0002
Zn	0.189	0.017	0.128	0.017	0.133	0.015
Zr	--	--	--	--	--	--

Table 4.5 Transfer Factors for Carob (unitless)

Element	Leaf	± 1σ	Stem	± 1σ	Fruit	± 1σ
Al	0.004	0.001	0.002	0.001	0.001	0.001
Br	0.002	0.001	--	--	--	--
Ca	0.668	0.132	0.409	0.082	0.225	0.063
Cl	0.106	0.027	0.025	0.006	0.057	0.020
Mg	0.254	0.088	0.075	0.027	0.139	0.068
Mn	0.092	0.009	0.014	0.001	0.031	0.004
K	0.409	0.071	0.134	0.025	0.559	0.137
Na	0.007	0.001	0.004	0.001	0.001	0.0002
Ti	--	--	--	--	--	--
V	--	--	--	--	--	--
As	0.036	0.011	0.016	0.004	--	--
La	0.003	0.0001	0.002	0.0001	0.001	0.0001
Lu	0.003	0.001	0.002	0.001	0.001	0.001
Sm	0.005	0.0003	0.003	0.0002	0.001	0.0002
Na	0.007	0.001	0.004	0.0003	0.001	0.0002
U	0.002	--	--	--	--	--
Yb	0.005	0.002	--	--	--	--
Sb	0.029	0.007	0.150	0.032	0.022	0.007
Ba	0.009	0.002	0.005	0.001	0.003	0.001
Ce	0.004	0.0003	0.002	0.0002	0.001	0.0003
Cs	0.007	0.001	0.003	0.0004	0.002	0.001
Cr	0.044	0.006	0.014	0.002	0.020	0.005
Co	0.014	0.001	0.007	0.001	0.007	0.001
Eu	0.005	0.0005	0.004	0.0004	0.002	0.001
Hf	0.004	0.0004	0.002	0.0003	0.001	0.0003
Fe	0.010	0.0004	0.004	0.0002	0.003	0.0002
Nd	--	--	--	--	--	--
Ni	0.141	0.038	0.253	0.113	0.242	0.129
Rb	0.093	0.011	0.026	0.003	0.135	0.023
Sc	0.008	0.0004	0.004	0.0002	0.002	0.0002
Sr	0.173	0.055	0.173	0.057	0.073	0.032
Ta	0.004	0.001	0.003	0.0005	0.001	0.0004
Tb	0.004	0.002	--	--	--	--
Th	0.004	0.0002	0.002	0.0001	0.001	0.0002
Zn	0.168	0.022	0.104	0.014	0.222	0.041
Zr	--	--	--	--	--	--

Table 4.6 Transfer Factors for Figs (unitless)

Element	Leaf	± 1σ	Stem	± 1σ	Fruit	± 1σ
Al	0.017	0.005	0.002	0.001	0.001	0.001
Br	0.001	0.0004	0.001	0.0003	0.001	0.0005
Ca	0.908	0.174	0.631	0.121	0.317	0.101
Cl	0.174	0.044	0.150	0.042	0.171	0.068
Mg	0.534	0.183	0.255	0.092	0.248	0.140
Mn	0.098	0.009	0.044	0.004	0.026	0.004
K	0.691	0.120	0.405	0.073	0.520	0.144
Na	0.045	0.007	0.013	0.002	0.013	0.003
Ti	--	--	--	--	--	--
V	0.030	0.015	--	--	--	--
As	0.050	0.010	0.010	0.003	--	--
La	0.021	0.0005	0.002	0.00005	0.001	0.0001
Lu	0.025	0.004	--	--	--	--
Sm	0.024	0.001	0.002	0.0001	0.001	0.0002
Na	0.060	0.004	0.013	0.001	0.014	0.001
U	0.031	0.013	0.001	--	--	--
Yb	0.034	0.010	0.002	0.001	--	--
Sb	0.066	0.015	0.043	0.010	0.119	0.042
Ba	0.027	0.006	0.006	0.001	0.003	0.002
Ce	0.022	0.001	0.002	0.0002	0.001	0.0002
Cs	0.023	0.002	0.002	0.0002	0.002	0.001
Cr	0.079	0.011	0.010	0.002	0.010	0.003
Co	0.044	0.003	0.008	0.001	0.007	0.001
Eu	0.024	0.002	0.001	0.0002	0.001	0.0004
Hf	0.025	0.002	0.002	0.0002	0.001	0.0003
Fe	0.035	0.001	0.003	0.0001	0.003	0.0002
Nd	0.021	0.008	--	--	--	--
Ni	1.049	0.259	0.110	0.041	0.266	0.164
Rb	0.106	0.013	0.051	0.006	0.080	0.015
Sc	0.032	0.002	0.002	0.0001	0.001	0.0001
Sr	0.346	0.104	0.261	0.078	0.109	0.053
Ta	0.022	0.003	0.001	0.0003	0.004	0.001
Tb	0.024	0.006	0.001	0.001	--	--
Th	0.021	0.001	0.001	0.0001	0.001	0.0002
Zn	0.200	0.026	0.101	0.013	0.165	0.034
Zr	0.020	0.014	--	--	--	--

Table 4.7 Transfer Factors for Grapes (unitless)

Element	Leaf	± 1σ	Stem	± 1σ	Fruit	± 1σ
Al	0.007	0.002	0.001	0.0004	0.001	0.0003
Br	0.001	0.001	0.003	0.001	0.001	0.001
Ca	1.045	0.200	0.352	0.083	0.241	0.061
Cl	0.103	0.026	0.321	0.104	0.160	0.072
Mg	0.398	0.138	0.206	0.092	0.175	0.076
Mn	0.179	0.016	0.067	0.007	0.044	0.005
K	0.265	0.047	0.541	0.122	0.679	0.144
Na	0.026	0.004	0.217	0.045	0.093	0.028
Ti	--	--	--	--	--	--
V	--	--	--	--	--	--
As	0.164	0.040	0.088	0.029	0.064	0.023
La	0.006	0.0001	0.001	0.00005	0.001	0.0001
Lu	--	--	--	--	--	--
Sm	0.007	0.0004	0.001	0.0001	0.001	0.0002
Na	0.028	0.002	0.242	0.018	0.101	0.011
U	--	--	--	--	--	--
Yb	--	--	--	--	--	--
Sb	0.072	0.015	0.260	0.101	0.110	0.037
Ba	0.012	0.003	0.004	0.001	0.004	0.002
Ce	0.006	0.0004	0.001	0.0002	0.001	0.0002
Cs	0.009	0.001	0.002	0.001	0.002	0.0004
Cr	0.025	0.004	0.017	0.004	0.012	0.003
Co	0.023	0.001	0.016	0.001	0.007	0.001
Eu	0.006	0.001	0.002	0.0002	-	--
Hf	0.005	0.001	0.001	0.0002	0.001	0.0003
Fe	0.014	0.001	0.002	0.0002	0.003	0.0002
Nd	--	--	--	--	--	--
Ni	--	--	0.222	0.089	0.174	0.068
Rb	0.047	0.006	0.151	0.024	0.154	0.022
Sc	0.012	0.001	0.001	0.0001	0.001	0.0001
Sr	0.373	0.111	0.178	0.065	0.111	0.047
Ta	0.006	0.001	0.002	0.0003	--	--
Tb	0.005	0.001	--	--	--	--
Th	0.006	0.0003	0.001	0.0001	0.001	0.0002
Zn	0.198	0.025	0.314	0.050	0.144	0.026
Zr	--	--	--	--	--	--

Table 4.8 Transfer Factors for Nectarines (unitless)

Element	Leaf	± 1σ	Stem	± 1σ	Fruit	± 1σ
Al	0.006	0.002	0.001	0.0003	0.001	0.0002
Br	0.001	0.0002	--	--	--	--
Ca	0.554	0.107	0.754	0.155	0.049	0.007
Cl	0.057	0.015	0.007	0.002	0.006	0.001
Mg	0.378	0.131	0.124	0.043	0.110	0.027
Mn	0.132	0.012	0.058	0.006	0.020	0.001
K	1.239	0.214	0.148	0.028	0.653	0.080
Na	0.006	0.001	0.002	0.0004	0.001	0.0002
Ti	--	--	--	--	--	--
V	--	--	--	--	--	--
As	0.062	0.015	0.034	0.009	0.005	0.001
La	0.006	0.0001	0.001	0.00004	0.002	0.00003
Lu	0.005	0.002	0.002	0.0004	--	--
Sm	0.007	0.0005	0.002	0.0001	0.001	0.0001
Na	0.006	0.0003	0.002	0.0001	0.001	0.00005
U	0.011	0.005	--	--	--	--
Yb	0.012	0.004	--	--	--	--
Sb	0.051	0.011	0.138	0.029	0.167	0.025
Ba	0.011	0.003	0.004	0.001	--	--
Ce	0.007	0.0003	0.001	0.0001	0.002	0.0002
Cs	0.012	0.001	0.002	0.0002	0.002	0.0003
Cr	0.063	0.009	0.011	0.002	0.008	0.001
Co	0.020	0.001	0.005	0.0004	0.005	0.0003
Eu	0.007	0.001	0.001	0.0003	0.001	0.0002
Hf	0.005	0.001	0.001	0.0002	0.001	0.0002
Fe	0.015	0.001	0.003	0.0001	0.003	0.0001
Nd	--	--	--	--	--	--
Ni	0.141	0.042	0.260	0.112	0.375	0.095
Rb	0.293	0.034	0.054	0.007	0.302	0.025
Sc	0.014	0.001	0.002	0.0001	0.002	0.0001
Sr	0.136	0.041	0.251	0.080	0.013	0.003
Ta	0.007	0.001	0.003	0.0004	--	--
Tb	0.007	0.002	--	--	--	--
Th	0.007	0.0003	0.001	0.0001	0.001	0.0001
Zn	0.134	0.017	0.155	0.023	0.123	0.011
Zr	--	--	--	--	--	--

Table 4.9 Transfer Factors for Pecans (unitless)

Element	Leaf	± 1σ	Stem	± 1σ	Fruit	± 1σ
Al	0.003	0.001	0.001	0.0002	--	--
Br	0.003	0.001	--	--	--	--
Ca	0.734	0.099	0.504	0.068	0.042	0.006
Cl	0.553	0.098	0.083	0.015	0.066	0.012
Mg	0.358	0.087	0.087	0.021	0.060	0.015
Mn	0.088	0.006	0.024	0.002	0.009	0.001
K	0.724	0.089	0.193	0.024	0.397	0.049
Na	0.004	0.001	0.003	0.0004	0.0005	0.0001
Ti	--	--	--	--	--	--
V	--	--	--	--	--	--
As	0.020	0.004	0.077	0.013	--	--0
La	0.003	0.0001	0.001	0.00000	0.0002	0.00001
Lu	--	--	--	--	--	--
Sm	0.004	0.0002	0.002	0.0001	--	--
Na	0.005	0.0002	0.004	0.00010	0.001	0.00005
U	--	--	--	--	--	--
Yb	--	--	--	--	--	--
Sb	0.023	0.004	0.935	0.137	0.060	0.009
Ba	0.005	0.001	0.003	0.001	--	--
Ce	0.004	0.0002	0.002	0.0001	--	--
Cs	0.006	0.0004	0.002	0.0002	--	--
Cr	0.026	0.003	0.016	0.002	0.003	0.001
Co	0.011	0.0005	0.005	0.0003	0.002	0.0002
Eu	0.004	0.0003	--	--	--	--
Hf	0.003	0.0002	0.001	0.0001	--	--
Fe	0.009	0.0003	0.003	0.0001	0.001	0.0001
Nd	--	--	--	--	--	--
Ni	--	--	0.191	0.049	0.275	0.069
Rb	0.088	0.007	0.031	0.003	0.085	0.007
Sc	0.008	0.0003	0.003	0.0001	0.0002	0.0000
Sr	0.208	0.044	0.208	0.044	0.015	0.003
Ta	0.004	0.0004	--	--	--	--
Tb	0.004	0.001	--	--	--	--
Th	0.004	0.0001	0.001	0.0001	--	--
Zn	0.193	0.017	0.121	0.011	0.211	0.019
Zr	0.003	0.001	0.002	0.001	0.002	0.001

Table 4.10 Transfer Factors for Grafted Pistachios (unitless)

Element	Leaf	± 1σ	Stem	± 1σ	Nut	± 1σ
Al	0.005	0.002	0.005	0.002	0.0004	0.0002
Br	0.003	0.001	--	--	--	--
Ca	0.893	0.244	0.586	0.164	0.034	0.010
Cl	0.364	0.133	0.015	0.006	0.035	0.013
Mg	0.640	0.314	0.116	0.057	0.070	0.034
Mn	0.117	0.015	0.067	0.009	0.009	0.001
K	0.608	0.150	0.207	0.053	0.481	0.118
Na	0.008	0.002	0.007	0.002	0.001	0.0003
Ti	--	--	--	--	--	--
V	--	--	0.013	0.008	--	--
As	0.142	0.050	0.021	0.008	0.020	0.008
La	0.006	0.0002	0.006	0.0003	0.0004	0.0003
Lu	0.005	0.002	0.008	0.002	--	--
Sm	0.007	0.001	0.007	0.001	0.0005	0.0002
Na	0.008	0.001	0.007	0.001	0.001	0.0001
U	0.010	0.004	0.007	0.005	--	--
Yb	0.013	0.003	0.012	0.004	--	--
Sb	0.061	0.021	0.179	0.066	0.209	0.064
Ba	0.016	0.005	0.011	0.004	--	--
Ce	0.006	0.001	0.007	0.0005	0.001	0.0002
Cs	0.010	0.001	0.008	0.001	0.002	0.0004
Cr	0.056	0.011	0.034	0.008	0.009	0.003
Co	0.015	0.001	0.014	0.002	0.003	0.001
Eu	0.006	0.001	0.006	0.001	0.002	0.001
Hf	0.005	0.001	0.006	0.001	0.0008	0.0002
Fe	0.012	0.001	0.011	0.001	0.002	0.0002
Nd	--	--	0.009	0.004	--	--
Ni	0.052	0.025	0.040	0.021	0.489	0.258
Rb	0.075	0.013	0.030	0.005	0.094	0.016
Sc	0.011	0.001	0.010	0.001	0.001	0.0001
Sr	0.347	0.154	0.300	0.133	0.018	0.009
Ta	0.006	0.002	0.005	0.002	--	--
Tb	0.007	0.003	0.008	0.004	--	--
Th	0.007	0.0004	0.006	0.0004	0.0004	0.0001
Zn	0.148	0.028	0.115	0.022	0.140	0.027
Zr	--	--	0.019	0.011	--	--

Table 4.11 Transfer Factors for Natural Pistachios (unitless)

Element	Leaf	± 1σ	Stem	± 1σ	Nut	± 1σ
Al	0.005	0.002	0.006	0.002	0.001	0.0004
Br	0.002	0.001	--	--	0.001	0.0002
Ca	0.573	0.139	0.788	0.186	0.086	0.021
Cl	0.138	0.044	0.022	0.007	0.077	0.024
Mg	0.476	0.206	0.175	0.074	0.121	0.052
Mn	0.093	0.010	0.057	0.006	0.018	0.002
K	0.344	0.074	0.252	0.055	0.559	0.119
Na	0.007	0.001	0.005	0.001	0.002	0.0004
Ti	--	--	--	--	--	--
V	0.014	0.005	0.016	0.007	--	--
As	0.087	0.029	0.026	0.009	0.028	0.010
La	0.004	0.0001	0.007	0.0002	0.001	0.00005
Lu	0.006	0.001	0.008	0.002	--	--
Sm	0.006	0.0005	0.009	0.001	0.001	0.0002
Na	0.005	0.0004	0.004	0.0004	0.001	0.0001
U	0.006	0.004	0.006	0.004	--	--
Yb	0.007	0.003	0.007	0.003	--	--
Sb	0.047	0.013	0.062	0.018	0.054	0.016
Ba	0.019	0.004	0.019	0.005	--	--
Ce	0.005	0.0004	0.008	0.0004	0.001	0.0003
Cs	0.008	0.001	0.009	0.001	0.002	0.0004
Cr	0.023	0.005	0.023	0.005	0.006	0.002
Co	0.015	0.001	0.017	0.001	0.004	0.0005
Eu	0.008	0.001	0.008	0.001	0.002	0.0003
Hf	0.004	0.001	0.005	0.001	0.001	0.0003
Fe	0.010	0.001	0.011	0.001	0.003	0.0002
Nd	0.011	0.004	0.005	0.003	--	--
Ni	0.275	0.138	0.070	0.027	0.156	0.075
Rb	0.099	0.017	0.045	0.007	0.101	0.016
Sc	0.010	0.001	0.010	0.001	0.002	0.0001
Sr	0.156	0.071	0.362	0.136	0.027	0.012
Ta	0.007	0.001	0.006	0.002	--	--
Tb	0.006	0.002	0.008	0.003	--	--
Th	0.005	0.0003	0.007	0.0003	0.001	0.0002
Zn	0.114	0.018	0.049	0.009	0.089	0.016
Zr	0.004	0.002	--	--	--	--

Table 4.12 Transfer Factors for Pistachios (Natural + Grafted) (unitless)

Element	Leaf	± 1σ	Stem	± 1σ	Nut	± 1σ
Al	0.005	0.003	0.005	0.003	0.001	0.0004
Br	0.003	0.002	--	--	--	--
Ca	0.733	0.281	0.687	0.248	0.060	0.023
Cl	0.251	0.140	0.018	0.009	0.056	0.027
Mg	0.558	0.376	0.145	0.093	0.095	0.062
Mn	0.105	0.018	0.062	0.011	0.014	0.002
K	0.476	0.168	0.229	0.076	0.520	0.167
Na	0.007	0.002	0.006	0.002	0.001	0.0005
Ti	--	--	--	--	--	--
V	0.014	0.005	0.015	0.010	--	--
As	0.115	0.058	0.023	0.012	0.024	0.013
La	0.005	0.0003	0.007	0.0003	0.001	0.0001
Lu	0.005	0.003	0.008	0.003	--	--
Sm	0.006	0.001	0.008	0.001	0.001	0.0002
Na	0.006	0.001	0.005	0.001	0.001	0.0001
U	0.008	0.006	0.007	0.007	--	--
Yb	0.010	0.004	0.009	0.005	--	--
Sb	0.054	0.025	0.121	0.068	0.132	0.066
Ba	0.018	0.007	0.015	0.006	--	--
Ce	0.006	0.001	0.007	0.001	0.001	0.0003
Cs	0.009	0.002	0.008	0.002	0.002	0.001
Cr	0.039	0.012	0.028	0.009	0.007	0.004
Co	0.015	0.002	0.016	0.002	0.004	0.001
Eu	0.007	0.001	0.007	0.002	0.002	0.001
Hf	0.005	0.001	0.006	0.001	0.001	0.0003
Fe	0.011	0.001	0.011	0.001	0.003	0.0003
Nd	0.011	0.004	0.007	0.005	--	--
Ni	0.164	0.140	0.055	0.034	0.322	0.269
Rb	0.087	0.022	0.038	0.009	0.097	0.022
Sc	0.010	0.001	0.010	0.001	0.001	0.0002
Sr	0.251	0.169	0.331	0.191	0.023	0.015
Ta	0.006	0.002	0.006	0.003	--	--
Tb	0.007	0.004	0.008	0.005	--	--
Th	0.006	0.001	0.007	0.001	0.001	0.0002
Zn	0.131	0.033	0.082	0.024	0.114	0.031
Zr	0.004	0.002	0.019	0.011	--	--

Table 4.13 Transfer Factors for Pomegranates (unitless)

Element	Leaf	± 1σ	Stem	± 1σ	Fruit	± 1σ
Al	0.003	0.001	0.002	0.0005	--	--
Br	0.005	0.002	0.001	0.001	0.002	0.001
Ca	0.830	0.197	0.566	0.132	0.090	0.022
Cl	0.531	0.165	0.192	0.060	0.318	0.097
Mg	0.253	0.107	0.088	0.038	0.093	0.040
Mn	0.078	0.009	0.023	0.003	0.013	0.001
K	0.367	0.080	0.236	0.051	0.521	0.110
Na	0.004	0.001	0.006	0.001	0.004	0.001
Ti	--	--	--	--	--	--
V	--	--	--	--	--	--
As	0.061	0.019	0.011	0.004	--	--
La	0.004	0.0001	0.002	0.0001	--	--
Lu	0.003	--	0.001	0.001	--	--
Sm	0.005	0.0004	0.003	0.0002	--	--
Na	0.004	0.0003	0.006	0.0004	0.004	0.0004
U	--	--	0.001	--	--	--
Yb	--	--	0.002	0.001	--	--
Sb	0.039	0.011	0.173	0.049	0.133	0.036
Ba	0.010	0.003	0.007	0.002	--	--
Ce	0.004	0.0004	0.002	0.0003	--	--
Cs	0.008	0.001	0.003	0.0005	0.001	0.0003
Cr	0.031	0.006	0.021	0.004	0.009	0.003
Co	0.014	0.001	0.010	0.001	0.004	0.001
Eu	0.004	0.001	0.002	0.001	--	--
Hf	0.003	0.0005	0.002	0.0003	--	--
Fe	0.009	0.0005	0.004	0.0002	0.001	0.0001
Nd	--	--	--	--	--	--
Ni	0.067	0.020	0.062	0.032	0.587	0.272
Rb	0.037	0.006	0.024	0.004	0.059	0.009
Sc	0.008	0.0005	0.004	0.0002	0.00009	0.00002
Sr	0.340	0.129	0.291	0.110	0.034	0.013
Ta	0.004	0.001	0.003	0.0004	--	--
Tb	0.006	0.002	0.003	0.001	--	--
Th	0.004	0.0002	0.002	0.0002	--	--
Zn	0.123	0.020	0.142	0.023	0.151	0.024
Zr	--	--	--	--	--	--

Table 4.14 Transfer Factors for Generic Fruit and Nut Trees (unitless)

	Generic Fruit						Generic Nut					
Element	**Leaf**	**± 1σ**	**Stem**	**± 1σ**	**Fruit**	**± 1σ**	**Leaf**	**± 1σ**	**Stem**	**± 1σ**	**Nut**	**± 1σ**
Al	0.007	0.006	0.002	0.002	0.001	0.002	0.005	0.0038	0.0026	0.0031	0.0021	0.0017
Br	0.002	0.001	0.001	0.001	0.001	0.001	0.0018	0.0016	0.0003	0.0002	0.0002	0.0003
Ca	0.759	0.344	0.595	0.270	0.180	0.134	1.0183	0.4294	0.6418	0.3007	0.0689	0.0408
Cl	0.145	0.062	0.102	0.112	0.103	0.101	0.2754	0.1706	0.0364	0.0174	0.0457	0.0301
Mg	0.334	0.283	0.161	0.173	0.133	0.177	0.532	0.4533	0.1052	0.1001	0.0989	0.1012
Mn	0.103	0.022	0.045	0.012	0.023	0.008	0.0802	0.0193	0.0358	0.0112	0.0139	0.0036
K	0.548	0.196	0.355	0.235	0.557	0.299	0.6372	0.2274	0.1892	0.0842	0.5701	0.2789
Na	0.015	0.009	0.036	0.045	0.017	0.028	0.043	0.0233	0.0103	0.0049	0.0095	0.0069
Ti	--	--	--	--	--	--	0.0054	0.0047	--	--	0.0035	0.003
V	0.026	0.019	0.019	0.008	--	--	0.0136	0.0074	0.0145	0.0103	0.0111	0.0076
As	0.083	0.058	0.036	0.035	0.034	0.025	0.1035	0.0719	0.0875	0.0464	0.0238	0.0163
La	0.007	0.001	0.002	0.0001	0.001	0.0002	0.0055	0.0004	0.0031	0.0003	0.0016	0.0002
Lu	0.007	0.005	0.002	0.001	0.001	0.001	0.0068	0.0034	0.0046	0.0028	0.0033	0.0016
Sm	0.009	0.002	0.002	0.001	0.001	0.001	0.0072	0.0011	0.004	0.0009	0.0027	0.0006
Na	0.018	0.004	0.039	0.018	0.018	0.011	0.0463	0.0086	0.0102	0.0018	0.0088	0.0025
U	0.014	0.014	0.003	--	--	--	0.0114	0.0076	0.0068	0.0065	0.0042	--
Yb	0.016	0.011	0.005	0.003	--	--	0.0121	0.0057	0.0092	0.005	0.009	0.0026
Sb	0.047	0.025	0.126	0.109	0.096	0.061	0.0371	0.026	0.4106	0.1575	0.0964	0.0743
Ba	0.013	0.008	0.006	0.004	0.004	0.003	0.0129	0.0074	0.0073	0.0062	0.005	0.0023
Ce	0.008	0.001	0.002	0.001	0.001	0.001	0.0061	0.0007	0.0035	0.0007	0.0024	0.0005
Cs	0.010	0.002	0.003	0.001	0.002	0.001	0.0095	0.002	0.0043	0.0016	0.0035	0.001
Cr	0.050	0.020	0.016	0.007	0.011	0.008	0.0402	0.0151	0.019	0.0093	0.0128	0.0077
Co	0.021	0.004	0.009	0.002	0.006	0.002	0.0164	0.0025	0.0088	0.0022	0.0052	0.0013
Eu	0.008	0.002	0.002	0.001	0.002	0.001	0.0067	0.0017	0.0045	0.0018	0.0033	0.001
Hf	0.008	0.002	0.002	0.001	0.001	0.001	0.0057	0.0014	0.0029	0.0013	0.0033	0.0009
Fe	0.015	0.002	0.004	0.001	0.002	0.0005	0.0127	0.0012	0.0059	0.0009	0.0035	0.0005

Table 4.14 Transfer Factors for Generic Fruit and Nut Trees (unitless) (Continued)

	Generic Fruit						Generic Nut					
Element	**Leaf**	**± 1σ**	**Stem**	**± 1σ**	**Fruit**	**± 1σ**	**Leaf**	**± 1σ**	**Stem**	**± 1σ**	**Nut**	**± 1σ**
Nd	0.019	0.01	--	--	--	--	0.0095	0.0051	0.007	0.0049	--	--
Ni	0.292	0.263	0.165	0.153	0.269	0.249	0.2261	0.1567	0.1721	0.1261	0.2974	0.3231
Rb	0.108	0.025	0.07	0.032	0.145	0.053	0.0842	0.0247	0.0283	0.0095	0.1012	0.0324
Sc	0.013	0.002	0.003	0.0005	0.001	0.0004	0.0114	0.0013	0.0051	0.001	0.0026	0.0005
Sr	0.264	0.188	0.232	0.16	0.068	0.078	0.3177	0.2287	0.2944	0.2242	0.0277	0.0268
Ta	0.009	0.004	0.003	0.001	0.002	0.001	0.0067	0.0025	0.0037	0.0025	0.0044	0.0012
Tb	0.009	0.007	0.002	0.001	--	--	0.0063	0.0047	0.008	0.0046	0.0043	0.0019
Th	0.008	0.001	0.002	0.0003	0.0009	0.0004	0.0065	0.0006	0.0031	0.0006	0.0026	0.0004
Zn	0.169	0.051	0.167	0.065	0.137	0.062	0.1411	0.0395	0.0845	0.0267	0.1476	0.0437
Zr	0.014	0.015	--	--	--	--	0.0069	0.0052	0.019	0.0108	0.006	0.0041

5.0 SUMMARY AND CONCLUSIONS

Several of the elements reported in the tables in Section 4 (Ca, Cl, Mg, K, Na) are well known macronutrients. These have relatively high transfer factors (with the exception of Na); however, these may all be homeostatically regulated as discussed in Section 2.2. It is apparent that these macronutrients are preferentially taken up from soils. Several other elements (Mn, Cr, Co, Fe, Ni, Zn) are micronutrients. The average uptake of the micronutrients is about one-fifth that of the average macronutrient. Both sets of nutrient classes have higher uptakes than those of the remaining trace elements, as would be expected. In addition, for the macronutrients and micronutrients, the average uptakes in leaves are greater than in stems, which in turn are greater than in fruits/nuts. In the other non-essential elements, the uptake in leaves and stems are about equal, but both are still greater than in fruits/nuts. Thus, it appears that the plants are using the nutrients in photosynthesis and respiration, but not storing them in the fruits.

Some observations may be made about the use of ‘surrogate’ elements for others with few or no measurements. It is often asserted that strontium can be expected to mimic calcium and that cesium can be expected to mimic potassium. In this series of measurements, the transfer factors for cesium are quite unlike those for potassium. Potassium uptake factors are high and very similar across the plant compartments, but the cesium uptake factors are much lower (nearly a factor of 50) and show non-essential-element discrimination between leaves, stems, and fruits. (The transfer factors for sodium, also a member of period I-A of the periodic table, are not comparable to potassium and cesium.) The transfer of calcium is also high and shows slight decrease from leaf to stem to fruit; strontium has the same pattern but the transfer is lower than that for calcium by about a factor of 4. (The transfer factors for magnesium, also a member of periodic table II-A, are more similar to strontium than to calcium.) The limited information about chemical periods V-B (As and Sb) and VIII-A (Fe, Co, and Ni) also does not indicate a strong influence of chemical similarity, although this may be because of the mixed influences of the micronutrients in these categories.

The members of the lanthanide series are also assumed to behave similarly because of chemical similarity. For instance, in the GENII computer code data library (Napier et al. 2012), many lanthanide transfer factors are assumed to parallel that of cerium, and in these experiments that assumption appears to be more defensible. The measurements for Nd, Sm, Eu, Tb, Yb, and Lu are all relatively similar. The only actinide elements in this experimental series are Th and U, and the lack of significance of the U measurements makes any comparison difficult. Overall, chemical similarity may be appropriate for larger-atomic-radius, non-essential elements, but potentially misleading for analogues for homeostatically-controlled nutrients.

The generic transfer factors developed in this report may be implemented in radioecological and biosphere models, such as GENII (Napier et al. 2012). The transfer factors for various specific fruit and nut varieties developed in this report may be useful in the development of models for tree fruits. The results indicate that, overall, transfer is highest to leaves, medium to the woody stems, and lowest to fruits and nuts.

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APPENDIX A. RESULTS OF ANALYSES AND CHARACTERIZATION OF SOIL, CROP, AND FRUIT SAMPLES

Instrumental Neutron Activation Analysis (INAA) was used to determine the concentrations of trace elements in the samples. Concentrations for 35 elements (Al, As, Ba, Br, Ca, Ce, Cl, Co, Cr, Cs, Eu, Fe, Hf, K, La, Lu, Mg, Mn, Na, Nd, Ni, Rb, Sb, Sc, Sm, Sr, Ta, Tb, Th, Ti, U, V, Yb, Zn, and Zr) are presented in Table A.1. All values are reported in parts per million (ppm); associated error values reflect counting uncertainty (± 1 sigma) for net peak areas. Note that less-than (<) values indicate concentrations below detection limits; the value given represents the minimum detectable concentration (MDC) and varies according to the continuum or background in the region of the peak in question, which in turn is a function of sample matrix composition.

Detection limits vary strongly by isotope, and are a function of activation yield and gamma branching ratios. In spite of the preconcentration via dry ashing, many elements were below detection limits for a significant number of cases. Only 17 elements were detected in at least 90% of the cases, while two others were detected in 87% of cases; this suite includes Al, Ca, Cl, Co, Cr, Cs, Fe, K, La, Mg, Mn, Na, Rb, Sb, Sc, Sm, Sr, Th, and Zn.

The soils were also characterized earlier with use of X-ray Fluorescence (Section 3.1.1.2). The results of the XRF determination are shown in the last line of Table A.1 for comparison. Three of the XRF values were also used in the determination of transfer factors because the INAA methods were insufficiently sensitive for Br, Cl, and Ni. For that analysis, the uncertainty on each XRF measurement was assumed to be 10 percent.

Because of the number of elements reported, Table A.1 is divided into 8 parts. The following elements are reported alphabetically in each part:

Part 1: Al, As, Sb, Ba, Br

Part 2: Ca, Ce, Cs, Cl, Cr

Part 3: Co, Eu, Hf, Fe, La

Part 4: Lu, Mg, Mn, Ni, Nd

Part 5: K, Ru, Sm, Sc, Na (from unashed samples)

Part 6: Na (from ashed samples), Sr, Ta, Tb, Th

Part 7: Ti, U (from 228 keV emission), U (from 277 keV emission), V

Part 8: Yb, Zn, Zr

Table A.1, Part 1. Concentrations of Elements in Botanical and Soil Samples (ppm)

Sample Code	Crop/Fruit	Aluminum	± 1σ	Arsenic	± 1σ	Antimony	± 1σ	Barium	± 1σ	Bromine	± 1σ
AF1	Alfalfa	42	15	<0.09	0	0.042	0.002	6.83	0.66	15.16	1.91
AF2	Alfalfa	205	54	0.13	0.02	0.057	0.002	4.79	0.68	11.7	1.45
AF3	Alfalfa	<39	10	<0.06	0	0.09	0.003	4.91	0.63	8.85	1.2
AF4	Alfalfa	<38	9	<0.08	0	0.042	0.002	5.54	0.71	12.42	1.57
AF5	Alfalfa	<42	10	<0.08	0	0.006	0.001	4.92	0.66	17.83	2.06
ALL1	Almond Tree 1	316	78	0.94	0.03	0.016	0.001	10.41	0.87	0.65	0.5
ALS1	Almond Tree 1	110	28	1.16	0.02	0.141	0.004	3.51	0.49	<1.00	0.1
ALF1	Almond Tree 1	152	38	0.09	0.01	0.073	0.003	3.13	0.62	0.21	0.28
ALL2	Almond Tree 2	603	150	0.75	0.04	0.029	0.002	13.04	1.15	<1.66	0.17
ALS2	Almond Tree 2	72	15	0.41	0.01	0.086	0.002	2.29	0.27	<0.70	0.06
ALF2	Almond Tree 2	332	67	0.12	0.01	0.074	0.002	4.96	0.67	<0.92	0.08
ALF4	Almond Tree 4	265	54	0.11	0.01	0.051	0.002	4.1	0.66	<0.89	0.08
ALF5	Almond Tree 5	232	47	0.11	0.01	0.04	0.002	3.53	0.53	<0.87	0.08
ALF6	Almond Tree 6	155	32	0.13	0.01	0.077	0.002	2.5	0.49	<0.86	0.08
APL1	Apple Tree 1	424	86	0.83	0.02	0.028	0.001	13.17	0.87	<1.64	0.14
APS1	Apple Tree 1	58	12	0.21	0.01	0.027	0.001	7.13	0.61	<0.90	0.08
APF1	Apple Tree 1	9	2	0.17	0.01	0.029	0.002	<0.8	0.03	<0.49	0.04
APL2	Apple Tree 2	786	159	0.71	0.03	0.032	0.002	11.63	1.22	3.08	0.81
APS2	Apple Tree 2	99	21	0.13	0.01	0.031	0.002	8.63	0.63	<0.87	0.08
APF2	Apple Tree 2	59	12	0.15	0.01	0.087	0.003	<0.92	0.05	<0.53	0.05
ARS4	Apricot Tree 4	50	11	0.17	0.01	0.029	0.001	2.06	0.38	<0.81	0.07
ARF4	Apricot Tree 4	415	84	0.12	0.01	0.023	0.002	4.86	0.78	<0.76	0.07
ARL5	Apricot Tree 5	60	13	0.24	0.01	0.017	0.001	3.4	0.49	<0.92	0.08
ARS5	Apricot Tree 5	395	80	0.41	0.02	0.068	0.003	8.31	1.21	<1.72	0.15
ARF5	Apricot Composite	81	17	0.09	0.01	0.024	0.002	<1.36	0.06	<0.61	0.05
CRL1	Carob Tree 1	266	54	0.19	0.02	0.023	0.001	8.66	0.81	10.83	1.26
CRS1	Carob Tree 1	132	27	0.09	0.01	0.072	0.003	4.4	0.62	0.94	0.25
CRF1a	Carob Tree 1	136	28	<0.03	0	0.015	0.001	3.67	0.62	<0.98	0.09
CRF1b	Carob Tree 1	95	20	<0.03	0	0.014	0.001	2.5	0.55	<1.00	0.09
CRL2	Carob Tree 2	232	47	0.16	0.02	0.014	0.001	4.56	0.68	8.99	1
CRS2	Carob Tree 2	100	21	0.07	0.01	0.12	0.004	2.19	0.43	<0.69	0.06
CRF2a	Carob Tree 2	27	7	<0.02	0	0.014	0.001	<1.57	0.08	0.96	0.32
CRF2b	Carob Tree 2	31	7	<0.01	0	0.012	0.001	1.33	0.39	0.78	0.31
FIL	Fig Tree 1	1095	220	<0.09	0	0.035	0.003	18.65	1.85	7.55	1
FIS	Fig Tree 1	75	17	0.06	0.01	0.039	0.001	4.72	0.47	8.4	0.93
FIF	Fig Tree 1	84	18	<0.03	0	0.09	0.003	2.16	0.5	7.38	0.86
FIL	Fig Tree 3	1250	252	0.24	0.03	0.05	0.003	20.38	1.84	3.86	0.86
FIS	Fig Tree 3	164	34	0.04	0.01	0.015	0.001	4.55	0.4	2.28	0.44
FIF	Fig Tree 3	54	12	<0.02	0	0.038	0.002	1.18	0.4	4.02	0.55
FIF	Fig Tree 2	76	17	<0.03	0	0.044	0.002	3.52	0.55	4.83	0.69
FIF	Fig Tree 4	31	8	<0.03	0	0.109	0.004	2.29	0.7	6.74	0.74
FIF	Fig Tree 5	124	26	<0.03	0	0.102	0.003	2.52	0.55	4.19	0.58

Table A.1, Part 1. Concentrations of Elements in Botanical and Soil Samples (ppm)

Sample Code	Crop/Fruit	Aluminum	± 1σ	Arsenic	± 1σ	Antimony	± 1σ	Barium	± 1σ	Bromine	± 1σ
GRL1	Grape Vine 1	465	94	0.63	0.02	0.038	0.002	9.69	1.15	6.45	1.08
GRS1	Grape Vine 1	74	17	0.28	0.01	0.014	0.001	4	0.56	4.86	0.81
GRF1	Grape Vine 1	73	19	0.57	0.03	0.153	0.005	3.55	0.84	18.96	1.95
GRL2	Grape Vine 2	422	86	0.94	0.02	0.054	0.002	8.29	0.96	3.87	0.89
GRS2.3	Grape Vine 2	69	21	0.52	0.04	0.046	0.002	2.29	0.61	19.97	2.07
GRS2.4	Grape Vine 2	25	11	0.47	0.04	0.441	0.012	<2.46	0.11	16.33	1.74
GRF2.2	Grape Vine 2	31	7	0.13	0.01	0.035	0.002	1.78	0.48	1.93	0.44
GRF2.3	Grape Vine 2	50	11	0.22	0.01	0.024	0.002	<1.39	0.06	1.9	0.45
NCL1	Nectarine Tree 1	430	87	0.34	0.01	0.026	0.001	8.5	1.08	3.41	0.71
NCS1	Nectarine Tree 1	75	16	0.22	0.01	0.108	0.003	3.59	0.45	<1.23	0.11
NCF1	Nectarine Tree 1	64	13	0.02	0.003	0.107	0.003	<1.19	0.05	<0.73	0.06
NCL3	Nectarine Tree 3	421	85	0.26	0.01	0.04	0.002	7.69	0.73	<1.80	0.16
NCS3	Nectarine Tree 3	48	10	0.11	0.004	0.069	0.002	2.03	0.31	<0.93	0.08
FO1	Feed Oats	266	54	<0.08	0	0.045	0.002	3.93	0.64	19.71	1.95
FO4	Feed Oats	267	55	<0.10	0	0.025	0.002	3.98	0.78	24.01	2.29
FO6	Feed Oats	258	53	<0.09	0	0.038	0.002	3.47	0.74	17.69	1.85
FO8	Feed Oats	241	50	<0.10	0	0.022	0.002	3.71	0.84	26.27	2.49
PCL	Pecan	211	44	0.1	0.01	0.015	0.001	3.75	0.59	14.61	1.58
PCS	Pecan	66	15	0.37	0.01	0.602	0.014	1.92	0.38	1.53	0.36
PCF	Pecan	<7	1	<0.01	0	0.039	0.002	<0.86	0.04	0.83	0.31
GPL1	Graft Pist. Tree 1	290	59	0.82	0.03	0.016	0.001	7.94	0.87	20.55	2
GPS1	Graft Pist. Tree 1	59	12	0.07	0	0.255	0.007	4.31	0.54	0.52	0.36
GPF1	Graft Pist. Tree 1	28	7	0.12	0.01	0.173	0.005	<1.24	0.06	1.5	0.31
GPL2	Graft Pist. Tree 2	250	51	0.66	0.03	0.062	0.003	8.01	0.91	23.03	2.23
GPS2	Graft Pist. Tree 2	498	100	0.16	0.01	0.11	0.005	11.73	1.25	0.87	0.45
GPF2	Graft Pist. Tree 2	28	6	0.11	0.01	0.097	0.004	<1.15	0.06	1.71	0.3
GPL3	Graft Pist. Tree 3	294	60	0.54	0.03	0.026	0.002	11.96	1.11	17.79	1.8
GPS3	Graft Pist. Tree 3	219	44	0.07	0.004	0.025	0.002	4.79	0.54	<1.07	0.09
GPF3	Graft Pist. Tree 3	21	5	0.06	0.01	0.101	0.004	<1.25	0.06	1.01	0.27
GPL4	Graft Pist. Tree 4	517	104	0.73	0.03	0.052	0.003	20.41	1.51	7.8	1.08
GPS4	Graft Pist. Tree 4	564	113	0.11	0.01	0.071	0.003	12.16	1.06	<1.45	0.13
GPF4	Graft Pist. Tree 4	38	8	0.1	0.01	0.166	0.005	<1.16	0.06	<0.69	0.06
NPL1	Natural Pist. Tree 1	362	73	0.11	0.01	0.046	0.002	<1.23	0.06	14.27	1.45
NPS1	Natural Pist. Tree 1	420	85	0.12	0.01	0.021	0.002	11.59	1.12	1.36	0.43
NPF1	Natural Pist. Tree 1	52	11	0.04	0	0.012	0.001	<0.39	0.02	2.71	0.44
NPL2	Natural Pist. Tree 2	387	78	0.62	0.02	0.024	0.002	10.18	1.11	8.74	1
NPS2	Natural Pist. Tree 2	466	94	0.12	0.01	0.046	0.002	14.39	1.03	2.14	0.49
NPF2	Natural Pist. Tree 2	99	18	0.23	0.01	0.05	0.002	<1.33	0.07	3.97	0.5
NPL3	Natural Pist. Tree 3	347	61	0.52	0.02	0.02	0.001	17.89	1.23	5.62	0.86
NPS3	Natural Pist. Tree 3	321	56	0.13	0.01	0.052	0.003	16.58	1.35	<1.28	0.1
NPF3	Natural Pist. Tree 3	94	17	0.13	0.01	0.043	0.002	<1.54	0.08	1.45	0.31
POL1	Pomegranate Tree 1	265	47	0.3	0.03	0.04	0.002	8.38	0.91	48.74	3.76

Table A.1, Part 1. Concentrations of Elements in Botanical and Soil Samples (ppm)

Sample Code	Crop/Fruit	Aluminum	± 1σ	Arsenic	± 1σ	Antimony	± 1σ	Barium	± 1σ	Bromine	± 1σ
POS1	Pomegranate Tree 1	128	23	0.05	0.01	0.181	0.005	5.38	0.59	11.21	0.98
POF1	Pomegranate Tree 1	<13	2	<0.07	0	0.06	0.004	<1.75	0.09	18.67	1.49
POL4	Pomegranate Tree 4	210	39	0.27	0.02	0.02	0.001	6.54	0.82	20.69	1.79
POS4	Pomegranate Tree 4	103	20	0.05	0.01	0.066	0.003	5.71	0.59	3.94	0.54
POF4	Pomegranate Tree 4	<15	3	<0.05	0	0.113	0.005	<1.79	0.09	5.54	0.68
POL5	Pomegranate Tree 5	176	33	0.31	0.02	0.015	0.001	6.49	0.76	17	1.52
POS5	Pomegranate Tree 5	66	13	0.05	0.01	0.086	0.003	4.72	0.62	5.72	0.7
POF5	Pomegranate Tree 5	<15	3	<0.03	0	0.085	0.003	<1.4	0.07	6.44	0.68
NYE	County Soil 1	69024	491	4.57	0.46	0.605	0.048	760.82	49.33	<21.05	1.23
NYE	County Soil 2	68071	480	4.94	0.48	0.725	0.056	727.76	50.49	<21.03	1.23
NYE	County Soil 3	66689	483	4.95	0.46	0.6	0.057	714.95	48.77	<20.07	1.17
Soil XRF		71000						694		54000	

Table A.1, Part 2. Concentrations of Elements in Botanical and Soil Samples (ppm)

Sample Code	Crop/Fruit	Calcium	± 1σ	Cerium	± 1σ	Cesium	± 1σ	Chlorine	± 1σ	Chromium	± 1σ
AF1	Alfalfa	15070	688	0.13	0.01	0.013	0.001	5812	235	0.08	0.02
AF2	Alfalfa	14355	635	0.37	0.02	0.03	0.002	3978	159	0.23	0.02
AF3	Alfalfa	15426	681	0.09	0.01	0.011	0.001	4777	191	0.17	0.02
AF4	Alfalfa	15756	694	0.13	0.02	0.016	0.001	4149	166	0.1	0.02
AF5	Alfalfa	15508	685	0.13	0.01	0.015	0.001	5172	207	0.2	0.02
ALL1	Almond Tree 1	53327	2303	0.42	0.02	0.044	0.002	97	7	0.48	0.02
ALS1	Almond Tree 1	32702	1424	0.2	0.01	0.018	0.001	37	4	0.17	0.01
ALF1	Almond Tree 1	2347	142	0.26	0.02	0.022	0.002	137	7	0.23	0.02
ALL2	Almond Tree 2	44392	1898	1.23	0.02	0.104	0.003	308	14	1.25	0.03
ALS2	Almond Tree 2	12470	472	0.11	0.01	0.012	0.001	109	5	0.22	0.01
ALF2	Almond Tree 2	3673	168	0.57	0.02	0.039	0.002	144	7	0.63	0.02
ALF4	Almond Tree 4	2950	133	0.42	0.02	0.033	0.002	169	7	0.35	0.02
ALF5	Almond Tree 5	3932	173	0.35	0.01	0.032	0.001	141	6	0.47	0.02
ALF6	Almond Tree 6	3215	151	0.25	0.01	0.024	0.001	142	7	0.55	0.02
APL1	Apple Tree 1	29577	1067	0.66	0.02	0.061	0.002	197	10	0.85	0.03
APS1	Apple Tree 1	28344	1025	0.12	0.01	0.011	0.001	57	5	0.14	0.01
APF1	Apple Tree 1	425	34	0.13	0.01	0.007	0.001	10	1	0.12	0.01
APL2	Apple Tree 2	12669	488	1.17	0.03	0.089	0.004	526	19	2.2	0.05
APS2	Apple Tree 2	20462	750	0.09	0.01	0.011	0.001	42	4	0.18	0.01
APF2	Apple Tree 2	488	40	0.08	0.01	0.012	0.001	47	3	0.23	0.02
ARS4	Apricot Tree 4	12905	488	0.1	0.01	0.01	0.001	92	5	0.11	0.01
ARF4	Apricot Tree 4	1623	87	0.65	0.03	0.038	0.003	54	4	0.32	0.03
ARL5	Apricot Tree 5	18980	700	0.12	0.02	0.011	0.001	58	4	0.14	0.02
ARS5	Apricot Tree 5	27817	1004	0.6	0.03	0.061	0.003	226	10	0.7	0.03
ARF5	Apricot Composite	864	61	0.13	0.02	0.014	0.002	54	3	0.14	0.02
CRL1	Carob Tree 1	26178	945	0.38	0.02	0.041	0.002	847	30	0.73	0.03
CRS1	Carob Tree 1	16455	613	0.25	0.01	0.019	0.001	287	11	0.22	0.02
CRF1a	Carob Tree 1	9185	362	0.19	0.02	0.017	0.001	551	19	0.46	0.02
CRF1b	Carob Tree 1	7797	307	0.09	0.02	0.013	0.001	413	15	0.43	0.03
CRL2	Carob Tree 2	14899	553	0.34	0.02	0.033	0.002	1123	38	0.67	0.02
CRS2	Carob Tree 2	8726	344	0.16	0.01	0.014	0.001	176	7	0.22	0.02
CRF2a	Carob Tree 2	5900	243	<0.06	0	0.007	0.002	575	20	0.24	0.02
CRF2b	Carob Tree 2	4804	202	0.04	0.01	0.006	0.001	577	20	0.14	0.01
FIL	Fig Tree 1	29387	1051	1.66	0.03	0.104	0.004	1793	60	1.04	0.04
FIS	Fig Tree 1	17400	637	0.12	0.01	0.01	0.001	2096	70	0.13	0.01
FIF	Fig Tree 1	13704	510	0.08	0.01	0.011	0.001	1770	59	0.16	0.02
FIL	Fig Tree 3	26505	952	2.34	0.04	0.153	0.005	1442	49	1.46	0.05
FIS	Fig Tree 3	21400	777	0.18	0.01	0.012	0.001	689	24	0.2	0.01
FIF	Fig Tree 3	5891	235	0.03	0.01	0.007	0.001	1267	43	0.19	0.02
FIF	Fig Tree 2	12683	473	<0.03	0	0.014	0.001	1932	64	0.11	0.01
FIF	Fig Tree 4	8010	314	<0.05	0	0.007	0.002	1597	54	0.16	0.02
FIF	Fig Tree 5	8503	330	0.1	0.02	0.012	0.002	1388	47	0.19	0.02

Table A.1, Part 2. Concentrations of Elements in Botanical and Soil Samples (ppm)

Sample Code	Crop/Fruit	Calcium	± 1σ	Cerium	± 1σ	Cesium	± 1σ	Chlorine	± 1σ	Chromium	± 1σ
GRL1	Grape Vine 1	32953	1174	0.55	0.03	0.057	0.002	998	34	0.27	0.03
GRS1	Grape Vine 1	12527	480	0.13	0.01	0.016	0.001	1533	52	0.41	0.02
GRF1	Grape Vine 1	11358	443	0.08	0.02	0.016	0.001	3738	124	0.23	0.02
GRL2	Grape Vine 2	31368	1126	0.48	0.02	0.043	0.002	914	32	0.52	0.03
GRS2.3	Grape Vine 2	10102	410	0.07	0.01	0.009	0.001	3698	123	0.16	0.02
GRS2.4	Grape Vine 2	9856	393	<0.06	0	0.01	0.002	3711	123	0.23	0.03
GRF2.2	Grape Vine 2	5473	225	<0.04	0	0.01	0.001	350	13	0.11	0.02
GRF2.3	Grape Vine 2	5379	221	<0.05	0	0.013	0.001	372	14	0.24	0.02
NCL1	Nectarine Tree 1	19284	703	0.63	0.02	0.068	0.003	719	25	0.9	0.03
NCS1	Nectarine Tree 1	32240	1152	0.18	0.01	0.009	0.001	83	6	0.21	0.01
NCF1	Nectarine Tree 1	1505	83	0.13	0.01	0.013	0.002	53	3	0.12	0.02
NCL3	Nectarine Tree 3	14822	551	0.6	0.02	0.064	0.002	334	13	1.1	0.03
NCS3	Nectarine Tree 3	14159	536	0.09	0.01	0.009	0.001	41	4	0.13	0.01
FO1	Feed Oats	4349	192	0.12	0.02	0.011	0.001	2609	87	0.34	0.02
FO4	Feed Oats	2601	139	0.25	0.02	0.02	0.002	3025	101	0.42	0.03
FO6	Feed Oats	2949	156	0.13	0.02	0.013	0.002	2475	83	0.47	0.03
FO8	Feed Oats	3441	160	0.11	0.02	0.017	0.002	3137	105	0.33	0.03
PCL	Pecan	22568	827	0.35	0.01	0.036	0.002	5144	171	0.42	0.02
PCS	Pecan	15503	589	0.14	0.01	0.013	0.001	772	27	0.26	0.01
PCF	Pecan	1297	81	<0.03	0	<0.002	0	610	21	0.05	0.01
GPL1	Graft Pist. Tree 1	24734	902	0.46	0.02	0.054	0.002	3553	118	0.63	0.03
GPS1	Graft Pist. Tree 1	10796	422	0.12	0.01	0.011	0.001	197	8	0.65	0.02
GPF1	Graft Pist. Tree 1	816	64	<0.04	0	0.009	0.001	331	12	0.17	0.02
GPL2	Graft Pist. Tree 2	27226	988	0.42	0.02	0.038	0.002	4012	133	0.76	0.03
GPS2	Graft Pist. Tree 2	22377	824	1.37	0.02	0.089	0.004	97	7	0.8	0.04
GPF2	Graft Pist. Tree 2	1062	71	0.06	0.02	0.008	0.001	340	12	0.16	0.02
GPL3	Graft Pist. Tree 3	34174	1228	0.5	0.02	0.049	0.002	4082	136	1.22	0.04
GPS3	Graft Pist. Tree 3	16663	629	0.3	0.01	0.026	0.001	172	8	0.23	0.02
GPF3	Graft Pist. Tree 3	1216	76	<0.05	0	0.007	0.001	402	14	0.08	0.02
GPL4	Graft Pist. Tree 4	23789	871	0.9	0.02	0.08	0.003	1909	64	0.93	0.03
GPS4	Graft Pist. Tree 4	22268	822	0.67	0.02	0.05	0.002	93	6	0.46	0.02
GPF4	Graft Pist. Tree 4	1026	74	0.08	0.01	0.01	0.001	226	9	0.12	0.02
NPL1	Natural Pist. Tree 1	12701	489	0.08	0.01	0.015	0.001	1702	57	0.2	0.02
NPS1	Natural Pist. Tree 1	21191	784	0.75	0.02	0.045	0.003	301	12	0.35	0.03
NPF1	Natural Pist. Tree 1	1854	105	0.03	0	0.004	0	752	26	0.05	0.01
NPL2	Natural Pist. Tree 2	15350	574	0.72	0.02	0.075	0.003	1265	43	0.45	0.03
NPS2	Natural Pist. Tree 2	22547	832	0.71	0.02	0.046	0.002	167	7	0.32	0.02
NPF2	Natural Pist. Tree 2	3220	142	0.12	0.02	0.014	0.001	883	26	0.11	0.02
NPL3	Natural Pist. Tree 3	24812	797	0.55	0.02	0.054	0.002	886	27	0.44	0.02
NPS3	Natural Pist. Tree 3	29025	929	0.8	0.02	0.053	0.003	138	7	0.41	0.03
NPF3	Natural Pist. Tree 3	2876	127	0.1	0.02	0.014	0.001	503	16	0.12	0.02
POL1	Pomegranate Tree 1	32672	1033	0.46	0.02	0.049	0.002	3487	100	0.56	0.03

Table A.1, Part 2. Concentrations of Elements in Botanical and Soil Samples (ppm)

Sample Code	Crop/Fruit	Calcium	± 1σ	Cerium	± 1σ	Cesium	± 1σ	Chlorine	± 1σ	Chromium	± 1σ
POS1	Pomegranate Tree 1	18007	595	0.31	0.01	0.022	0.001	1295	38	0.46	0.02
POF1	Pomegranate Tree 1	3857	158	<0.06	0	0.007	0.001	2579	74	0.07	0.02
POL4	Pomegranate Tree 4	22618	728	0.33	0.02	0.041	0.002	5966	171	0.41	0.02
POS4	Pomegranate Tree 4	16907	560	0.2	0.02	0.018	0.001	1941	56	0.33	0.02
POF4	Pomegranate Tree 4	2056	108	<0.06	0	<0.004	0	3132	90	0.15	0.03
POL5	Pomegranate Tree 5	21341	690	0.34	0.02	0.037	0.002	5347	153	0.5	0.02
POS5	Pomegranate Tree 5	17283	568	0.13	0.01	0.012	0.001	2117	61	0.22	0.02
POF5	Pomegranate Tree 5	2419	110	<0.05	0	<0.003	0	3169	91	0.2	0.02
NYE	County Soil 1	30345	2258	97.69	0.89	5.793	0.152	<240	15	14.99	0.8
NYE	County Soil 2	30901	2261	92.99	0.86	5.638	0.153	<246	15	15.71	0.85
NYE	County Soil 3	31042	2414	86.74	0.82	5.542	0.148	<244	15	16.72	0.89
Soil XRF				95				9300		13	

Table A.1, Part 3. Concentrations of Elements in Botanical and Soil Samples (ppm)

Sample Code	Crop/Fruit	Cobalt	± 1σ	Europium	± 1σ	Hafnium	± 1σ	Iron	± 1σ	Lawrencium	± 1σ
AF1	Alfalfa	0.1	0	<0.001	0	0.008	0.001	55	1	0.067	0.002
AF2	Alfalfa	0.12	0	0.003	0	0.023	0.001	106	2	0.189	0.003
AF3	Alfalfa	0.1	0	0.001	0	0.004	0.001	55	1	0.049	0.002
AF4	Alfalfa	0.09	0	0.001	0	0.003	0.001	61	1	0.059	0.002
AF5	Alfalfa	0.11	0	0.001	0	0.006	0.001	62	1	0.063	0.002
ALL1	Almond Tree 1	0.05	0	0.005	0	0.029	0.002	155	2	0.207	0.004
ALS1	Almond Tree 1	0.02	0	0.002	0	0.015	0.001	64	1	0.105	0.002
ALF1	Almond Tree 1	0.03	0	0.004	0	0.027	0.002	74	2	0.134	0.003
ALL2	Almond Tree 2	0.13	0	0.012	0	0.101	0.003	363	5	0.611	0.007
ALS2	Almond Tree 2	0.02	0	0.001	0	0.008	0.001	42	1	0.054	0.001
ALF2	Almond Tree 2	0.05	0	0.006	0	0.061	0.002	148	2	0.305	0.003
ALF4	Almond Tree 4	0.04	0	0.005	0	0.046	0.002	119	2	0.206	0.003
ALF5	Almond Tree 5	0.03	0	0.004	0	0.039	0.002	95	2	0.17	0.002
ALF6	Almond Tree 6	0.03	0	0.004	0	0.025	0.002	79	1	0.125	0.002
APL1	Apple Tree 1	0.09	0	0.007	0	0.05	0.002	234	3	0.327	0.003
APS1	Apple Tree 1	0.03	0	0.002	0	0.009	0.001	41	1	0.059	0.001
APF1	Apple Tree 1	0.01	0	<0.001	0	<0.002	0	7	1	0.053	0.001
APL2	Apple Tree 2	0.13	0	0.012	0.001	0.085	0.003	323	5	0.582	0.006
APS2	Apple Tree 2	0.02	0	0.001	0	0.008	0.001	41	1	0.049	0.001
APF2	Apple Tree 2	0.01	0	0.002	0	0.007	0.001	23	1	0.036	0.001
ARS4	Apricot Tree 4	0.01	0	0.001	0	0.006	0.001	34	1	0.045	0.001
ARF4	Apricot Tree 4	0.04	0	0.007	0	0.063	0.003	120	2	0.327	0.004
ARL5	Apricot Tree 5	0.02	0	0.001	0	0.007	0.001	41	1	0.054	0.001
ARS5	Apricot Tree 5	0.07	0	0.006	0.001	0.029	0.002	195	3	0.264	0.004
ARF5	Apricot Composite	0.03	0	0.002	0	0.011	0.002	43	1	0.054	0.002
CRL1	Carob Tree 1	0.06	0	0.005	0	0.027	0.002	167	3	0.184	0.003
CRS1	Carob Tree 1	0.03	0	0.003	0	0.019	0.001	78	2	0.13	0.002
CRF1a	Carob Tree 1	0.04	0	0.002	0	0.016	0.001	71	1	0.077	0.002
CRF1b	Carob Tree 1	0.03	0	0.002	0	0.011	0.001	57	1	0.062	0.001
CRL2	Carob Tree 2	0.05	0	0.004	0	0.025	0.001	126	2	0.152	0.002
CRS2	Carob Tree 2	0.03	0	<0.001	0	0.009	0.001	52	1	0.075	0.001
CRF2a	Carob Tree 2	0.02	0	0.001	0	<0.003	0	28	1	0.014	0.001
CRF2b	Carob Tree 2	0.02	0	0.001	0	0.003	0.001	25	1	0.02	0.001
FIL	Fig Tree 1	0.14	0	0.019	0.001	0.136	0.005	439	6	0.873	0.009
FIS	Fig Tree 1	0.04	0	0.001	0	0.009	0.001	45	1	0.064	0.001
FIF	Fig Tree 1	0.04	0	0.001	0	0.012	0.001	47	1	0.043	0.001
FIL	Fig Tree 3	0.2	0	0.026	0.001	0.217	0.007	590	8	1.221	0.011
FIS	Fig Tree 3	0.03	0	0.002	0	0.012	0.001	48	1	0.086	0.001
FIF	Fig Tree 3	0.02	0	0	0	0.006	0.001	33	1	0.021	0.001
FIF	Fig Tree 2	0.03	0	0.001	0	0.005	0.001	40	1	0.029	0.001
FIF	Fig Tree 4	0.02	0	<0.001	0	<0.003	0	41	1	0.02	0.002
FIF	Fig Tree 5	0.03	0	0.002	0	0.011	0.001	47	1	0.051	0.002
GRL1	Grape Vine 1	0.08	0	0.006	0	0.036	0.002	201	3	0.277	0.004

Table A.1, Part 3. Concentrations of Elements in Botanical and Soil Samples (ppm)

Sample Code	Crop/Fruit	Cobalt	± 1σ	Europium	± 1σ	Hafnium	± 1σ	Iron	± 1σ	Lawrencium	± 1σ
GRS1	Grape Vine 1	0.05	0	0.002	0	0.011	0.001	49	1	0.072	0.002
GRF1	Grape Vine 1	0.04	0	<0.001	0	0.011	0.001	47	1	0.06	0.004
GRL2	Grape Vine 2	0.09	0	0.006	0	0.035	0.002	197	3	0.264	0.003
GRS2.3	Grape Vine 2	0.06	0	<0.001	0	0.003	0.001	23	1	<0.009	0
GRS2.4	Grape Vine 2	0.07	0	<0.002	0	<0.005	0	26	2	<0.015	0
GRF2.2	Grape Vine 2	0.02	0	0	0	<0.002	0	28	1	0.021	0.001
GRF2.3	Grape Vine 2	0.02	0	<0.001	0	0.005	0.001	39	1	0.029	0.001
NCL1	Nectarine Tree 1	0.08	0	0.007	0	0.037	0.002	220	3	0.317	0.003
NCS1	Nectarine Tree 1	0.02	0	0.002	0	0.007	0.001	44	1	0.082	0.001
NCF1	Nectarine Tree 1	0.02	0	0.001	0	0.008	0.001	36	1	0.075	0.001
NCL3	Nectarine Tree 3	0.08	0	0.006	0	0.038	0.002	219	3	0.303	0.003
NCS3	Nectarine Tree 3	0.01	0	0.001	0	0.004	0.001	34	1	0.045	0.001
FO1	Feed Oats	0.06	0	0.002	0	0.009	0.001	51	1	0.062	0.002
FO4	Feed Oats	0.08	0	0.002	0	0.025	0.002	82	2	0.12	0.003
FO6	Feed Oats	0.11	0	0.002	0	0.018	0.002	62	2	0.082	0.003
FO8	Feed Oats	0.09	0	<0.001	0	0.006	0.001	43	2	0.042	0.003
PCL	Pecan	0.04	0	0.004	0	0.022	0.001	136	2	0.165	0.002
PCS	Pecan	0.02	0	<0.001	0	0.009	0.001	50	1	0.065	0.001
PCF	Pecan	0.01	0	0	0	<0.002	0	16	1	0.01	0.001
GPL1	Graft Pist. Tree 1	0.05	0	0.005	0	0.027	0.002	158	3	0.217	0.003
GPS1	Graft Pist. Tree 1	0.01	0	0.002	0	0.007	0.001	46	1	0.057	0.001
GPF1	Graft Pist. Tree 1	0.02	0	0.002	0	0.005	0.001	32	1	0.018	0.001
GPL2	Graft Pist. Tree 2	0.05	0	0.004	0	0.028	0.002	147	2	0.197	0.003
GPS2	Graft Pist. Tree 2	0.11	0	0.013	0.001	0.106	0.004	334	5	0.652	0.007
GPF2	Graft Pist. Tree 2	0.01	0	<0.001	0	<0.003	0	29	1	0.018	0.001
GPL3	Graft Pist. Tree 3	0.06	0	0.005	0	0.031	0.002	169	3	0.221	0.003
GPS3	Graft Pist. Tree 3	0.03	0	0.002	0	0.017	0.001	84	2	0.137	0.002
GPF3	Graft Pist. Tree 3	0.01	0	0.001	0	<0.003	0	34	1	0.012	0.001
GPL4	Graft Pist. Tree 4	0.08	0	0.008	0	0.059	0.003	240	4	0.436	0.005
GPS4	Graft Pist. Tree 4	0.06	0	0.007	0	0.044	0.002	164	3	0.317	0.003
GPF4	Graft Pist. Tree 4	0.01	0	0.001	0	<0.003	0	29	1	0.027	0.001
NPL1	Natural Pist. Tree 1	0.02	0	0.01	0	0.005	0.001	43	1	0.038	0.001
NPS1	Natural Pist. Tree 1	0.06	0	0.008	0.001	0.036	0.002	161	3	0.336	0.005
NPF1	Natural Pist. Tree 1	0.01	0	0.003	0	<0.001	0	13	0	0.012	0
NPL2	Natural Pist. Tree 2	0.08	0	0.008	0	0.042	0.002	234	4	0.319	0.004
NPS2	Natural Pist. Tree 2	0.06	0	0.006	0	0.035	0.002	152	3	0.321	0.003
NPF2	Natural Pist. Tree 2	0.02	0	0.001	0	0.007	0.001	59	1	0.061	0.001
NPL3	Natural Pist. Tree 3	0.07	0	0.006	0	0.039	0.002	184	3	0.254	0.003
NPS3	Natural Pist. Tree 3	0.07	0	0.007	0.001	0.04	0.002	160	3	0.368	0.005
NPF3	Natural Pist. Tree 3	0.02	0	<0.001	0	0.009	0.001	52	1	0.051	0.001
POL1	Pomegranate Tree 1	0.06	0	0.005	0	0.029	0.002	159	3	0.21	0.003
POS1	Pomegranate Tree 1	0.04	0	0.003	0	0.017	0.001	79	1	0.139	0.002
POF1	Pomegranate Tree 1	0.01	0	<0.001	0	<0.004	0	16	1	<0.003	0

Table A.1, Part 3. Concentrations of Elements in Botanical and Soil Samples (ppm)

Sample Code	Crop/Fruit	Cobalt	± 1σ	Europium	± 1σ	Hafnium	± 1σ	Iron	± 1σ	Lawrencium	± 1σ
POL4	Pomegranate Tree 4	0.05	0	0.003	0	0.02	0.002	120	2	0.151	0.002
POS4	Pomegranate Tree 4	0.05	0	0.002	0	0.009	0.001	60	1	0.097	0.002
POF4	Pomegranate Tree 4	0.02	0	<0.001	0	<0.004	0	13	1	<0.003	0
POL5	Pomegranate Tree 5	0.05	0	0.004	0	0.021	0.002	121	2	0.156	0.002
POS5	Pomegranate Tree 5	0.03	0	0.001	0	0.007	0.001	46	1	0.061	0.001
POF5	Pomegranate Tree 5	0.01	0	<0.001	0	<0.003	0	16	1	<0.002	0
NYE	County Soil 1	4.08	0.09	0.975	0.026	7.392	0.2	15269	207	49.91	0.374
NYE	County Soil 2	3.9	0.08	0.926	0.026	6.651	0.183	15043	204	50.279	0.378
NYE	County Soil 3	3.59	0.08	0.921	0.024	6.838	0.187	13986	191	46.379	0.357
Soil XRF								15900		53	

Table A.1, Part 4. Concentrations of Elements in Botanical and Soil Samples (ppm)

Sample Code	Crop/Fruit	Lutetium	± 1σ	Magnesium	± 1σ	Manganese	± 1σ	Nickel	± 1σ	Neodymium	± 1σ
AF1	Alfalfa	<0.001	0	2711	144	49.67	1.99	0.47	0.16	<0.32	0.01
AF2	Alfalfa	<0.001	0	3025	149	51.44	2.05	1.51	0.3	<0.31	0.01
AF3	Alfalfa	<0.001	0	2664	136	40.22	1.61	1.29	0.26	<0.3	0.01
AF4	Alfalfa	<0.001	0	2811	139	47.8	1.91	<0.41	0.07	<0.34	0.01
AF5	Alfalfa	<0.001	0	2897	148	45.19	1.8	0.83	0.19	<0.31	0.01
ALL1	Almond Tree 1	0.001	0	4611	215	21.85	0.88	2.88	0.49	<0.25	0.01
ALS1	Almond Tree 1	0.001	0	672	42	13.21	0.53	0.79	0.16	<0.16	0.01
ALF1	Almond Tree 1	0	0	1059	54	7.41	0.3	3.84	0.64	<0.27	0.01
ALL2	Almond Tree 2	0.005	0	6618	303	23.76	0.95	<0.63	0.1	0.29	0.1
ALS2	Almond Tree 2	0	0	707	33	7.84	0.26	4.62	0.74	<0.09	0
ALF2	Almond Tree 2	0.002	0	1544	64	12.24	0.41	2.38	0.42	<0.25	0.01
ALF4	Almond Tree 4	0.002	0	927	43	9.06	0.3	2.39	0.43	<0.28	0.01
ALF5	Almond Tree 5	0.001	0	1147	50	8.3	0.28	2.35	0.41	<0.2	0.01
ALF6	Almond Tree 6	<0.001	0	1178	51	7.25	0.25	3.81	0.64	<0.22	0.01
APL1	Apple Tree 1	0.002	0	3124	124	51.86	1.69	<0.47	0.08	<0.21	0.01
APS1	Apple Tree 1	<0.001	0	889	40	16.46	0.54	1.04	0.21	<0.22	0.01
APF1	Apple Tree 1	<0.001	0	485	23	2.85	0.1	2.07	0.37	<0.18	0.01
APL2	Apple Tree 2	0.003	0	3165	126	44.56	1.46	<0.70	0.12	0.61	0.16
APS2	Apple Tree 2	0	0	1131	47	14.13	0.47	0.63	0.15	<0.24	0.02
APF2	Apple Tree 2	0	0	484	23	3.1	0.11	0.45	0.16	<0.25	0.02
ARS4	Apricot Tree 4	<0.001	0	868	40	12.48	0.41	<0.26	0.04	<0.31	0.02
ARF4	Apricot Tree 4	0.002	0	822	37	8.52	0.29	1.4	0.36	<0.48	0.03
ARL5	Apricot Tree 5	<0.001	0	1190	50	18.95	0.62	0.62	0.15	<0.35	0.02
ARS5	Apricot Tree 5	0.002	0	3386	135	62.99	2.05	<0.62	0.1	<0.54	0.04
ARF5	Apricot Composite	<0.001	0	604	28	4.15	0.14	1.62	0.33	<0.3	0.01
CRL1	Carob Tree 1	0.001	0	2398	100	58.51	1.91	1.41	0.29	<0.39	0.03
CRS1	Carob Tree 1	0.001	0	770	36	6.23	0.21	0.53	0.16	<0.25	0.02
CRF1a	Carob Tree 1	0	0	1376	57	15.11	0.5	3.41	0.6	<0.39	0.03
CRF1b	Carob Tree 1	<0.001	0	1172	53	18.01	0.59	2.84	0.52	<0.4	0.03
CRL2	Carob Tree 2	<0.001	0	1786	75	29.05	0.95	<0.36	0.06	<0.34	0.02
CRS2	Carob Tree 2	0	0	459	25	7.22	0.24	4.52	0.79	<0.22	0.01
CRF2a	Carob Tree 2	<0.001	0	1032	47	13.93	0.46	2.27	0.44	<0.45	0.03
CRF2b	Carob Tree 2	<0.001	0	1011	45	11.63	0.39	1.17	0.24	<0.21	0.01
FIL	Fig Tree 1	0.007	0.001	4247	165	35.33	1.16	<0.89	0.15	0.65	0.2
FIS	Fig Tree 1	<0.001	0	2786	110	26.7	0.88	1.31	0.25	<0.2	0.01
FIF	Fig Tree 1	<0.001	0	2876	112	18.85	0.62	1.51	0.29	<0.25	0.01
FIL	Fig Tree 3	0.011	0.001	4572	179	58.43	1.91	10.48	1.85	0.85	0.16
FIS	Fig Tree 3	0	0	1425	62	15.26	0.5	0.89	0.18	<0.14	0.01
FIF	Fig Tree 3	<0.001	0	1446	60	9.08	0.31	2.13	0.38	<0.18	0.01
FIF	Fig Tree 2	<0.001	0	2520	99	15.97	0.53	1.94	0.36	<0.24	0.01
FIF	Fig Tree 4	<0.001	0	1562	64	4.96	0.17	2.44	0.51	<0.32	0.01
FIF	Fig Tree 5	<0.001	0	1840	74	12.66	0.42	5.26	0.87	<0.26	0.01

Table A.1, Part 4. Concentrations of Elements in Botanical and Soil Samples (ppm)

Sample Code	Crop/Fruit	Lutetium	± 1σ	Magnesium	± 1σ	Manganese	± 1σ	Nickel	± 1σ	Neodymium	± 1σ
GRL1	Grape Vine 1	<0.001	0	3683	149	78.58	2.56	<0.62	0.1	<0.47	0.02
GRS1	Grape Vine 1	<0.001	0	2441	102	29.75	0.98	1.1	0.24	<0.25	0.01
GRF1	Grape Vine 1	<0.002	0	1919	94	25.42	0.84	<0.54	0.09	<0.38	0.01
GRL2	Grape Vine 2	<0.001	0	2883	134	92.2	3	<0.59	0.1	<0.38	0.01
GRS2.3	Grape Vine 2	<0.001	0	1322	96	33.6	1.11	3.35	0.6	<0.31	0.01
GRS2.4	Grape Vine 2	<0.002	0	1345	92	32.42	1.07	<0.84	0.14	<0.45	0.02
GRF2.2	Grape Vine 2	<0.001	0	1209	54	18.78	0.62	1.65	0.33	<0.28	0.01
GRF2.3	Grape Vine 2	<0.001	0	1192	54	19.01	0.63	1.83	0.41	<0.33	0.01
NCL1	Nectarine Tree 1	0.002	0	3584	142	58.13	1.9	1.41	0.34	<0.33	0.01
NCS1	Nectarine Tree 1	0.001	0	1165	59	36.92	1.21	4.49	0.78	<0.16	0.01
NCF1	Nectarine Tree 1	<0.001	0	908	40	9.66	0.32	3.75	0.69	<0.24	0.01
NCL3	Nectarine Tree 3	0.002	0	2648	111	67.31	2.19	<0.58	0.1	<0.26	0.01
NCS3	Nectarine Tree 3	0	0	887	40	18.82	0.62	0.72	0.15	<0.13	0
FO1	Feed Oats	<0.001	0	1810	93	66.29	2.16	3.13	0.54	<0.36	0.01
FO4	Feed Oats	<0.002	0	1716	89	56.49	1.84	3.52	0.6	<0.35	0.01
FO6	Feed Oats	<0.002	0	2064	96	82.02	2.67	3.44	0.59	<0.4	0.01
FO8	Feed Oats	<0.001	0	2030	104	79.43	2.59	2.3	0.47	<0.56	0.04
PCL	Pecan	<0.001	0	2952	122	41.9	1.37	<0.44	0.07	<0.25	0.01
PCS	Pecan	<0.001	0	716	37	11.2	0.37	1.91	0.37	<0.14	0.01
PCF	Pecan	<0.001	0	491	26	4.48	0.15	2.75	0.5	<0.2	0.01
GPL1	Graft Pist. Tree 1	0.001	0	4083	160	52.24	1.71	<0.38	0.06	<0.43	0.03
GPS1	Graft Pist. Tree 1	0	0	1018	45	19.57	0.64	<0.24	0.04	<0.21	0.01
GPF1	Graft Pist. Tree 1	<0.001	0	557	26	4.82	0.17	9.04	1.41	<0.39	0.03
GPL2	Graft Pist. Tree 2	0.001	0	5246	203	57.31	1.87	0.41	0.13	<0.38	0.03
GPS2	Graft Pist. Tree 2	0.005	0	1034	57	40.2	1.31	<0.82	0.14	0.42	0.1
GPF2	Graft Pist. Tree 2	<0.001	0	544	25	3.68	0.13	3.37	0.54	<0.35	0.02
GPL3	Graft Pist. Tree 3	0.002	0	6508	248	53.88	1.76	0.63	0.17	<0.42	0.03
GPS3	Graft Pist. Tree 3	0.001	0	781	42	22.11	0.73	0.41	0.12	<0.21	0.01
GPF3	Graft Pist. Tree 3	<0.001	0	614	28	4.08	0.14	2.19	0.37	<0.4	0.03
GPL4	Graft Pist. Tree 4	0.002	0	5283	203	59.66	1.95	<0.52	0.08	<0.43	0.03
GPS4	Graft Pist. Tree 4	0.002	0	981	57	45.55	1.49	0.38	0.14	0.24	0.09
GPF4	Graft Pist. Tree 4	<0.001	0	592	28	5.22	0.18	4.94	0.77	<0.37	0.03
NPL1	Natural Pist. Tree 1	<0.001	0	2837	111	39.48	1.29	2.09	0.35	<0.3	0.02
NPS1	Natural Pist. Tree 1	0.003	0	1535	65	29.41	0.96	<0.68	0.11	<0.29	0.02
NPF1	Natural Pist. Tree 1	0	0	672	32	6.38	0.22	0.66	0.11	<0.1	0.01
NPL2	Natural Pist. Tree 2	0.002	0	3766	146	41.04	1.34	0.8	0.2	0.38	0.14
NPS2	Natural Pist. Tree 2	0.002	0	1353	60	22.09	0.73	<0.34	0.05	0.17	0.08
NPF2	Natural Pist. Tree 2	<0.001	0	1213	47	9.62	0.28	1.9	0.33	<0.36	0.02
NPL3	Natural Pist. Tree 3	0.002	0	5176	175	52.16	1.48	5.37	0.85	<0.29	0.02
NPS3	Natural Pist. Tree 3	0.003	0	1450	64	30.23	0.86	0.7	0.24	<0.3	0.02
NPF3	Natural Pist. Tree 3	<0.001	0	1098	42	10.06	0.29	2.1	0.43	<0.41	0.03
POL1	Pomegranate Tree 1	<0.001	0	2360	90	48.5	1.37	<0.32	0.05	<0.41	0.03

Table A.1, Part 4. Concentrations of Elements in Botanical and Soil Samples (ppm)

Sample Code	Crop/Fruit	Lutetium	± 1σ	Magnesium	± 1σ	Manganese	± 1σ	Nickel	± 1σ	Neodymium	± 1σ
POS1	Pomegranate Tree 1	0.001	0	631	35	9.36	0.27	0.74	0.14	<0.23	0.02
POF1	Pomegranate Tree 1	<0.001	0	873	40	6.91	0.21	6.49	1.14	<0.51	0.03
POL4	Pomegranate Tree 4	0.001	0	1884	79	38.43	1.09	0.67	0.17	<0.43	0.03
POS4	Pomegranate Tree 4	0	0	770	40	13.69	0.4	0.88	0.18	<0.29	0.02
POF4	Pomegranate Tree 4	<0.001	0	649	33	5.23	0.16	8.6	1.49	<0.5	0.03
POL5	Pomegranate Tree 5	0.001	0	2007	78	24.63	0.71	<0.28	0.04	<0.42	0.03
POS5	Pomegranate Tree 5	<0.001	0	787	36	10.37	0.3	0.24	0.1	<0.29	0.02
POF5	Pomegranate Tree 5	<0.001	0	788	40	5.95	0.18	2.52	0.41	<0.44	0.03
NYE	County Soil 1	0.39	0.017	7578	1048	490.8	15.3	<27.19	4.57	40.59	2.87
NYE	County Soil 2	0.362	0.017	7534	1116	479	15	<27.26	4.58	35.54	2.63
NYE	County Soil 3	0.311	0.017	9643	1249	461.1	14.4	<26.13	4.39	29.75	2.38
Soil XRF				495		33000		10		36	

Table A.1, Part 5. Concentrations of Elements in Botanical and Soil Samples (ppm)

Sample Code	Crop/Fruit	Potassium	± 1σ	Rubidium	± 1σ	Samarium	± 1σ	Scandium	± 1σ	Sodium(1)	± 1σ
AF1	Alfalfa	36344	1491	16.02	0.54	0.009	0.001	0.005	0	1035	131
AF2	Alfalfa	36498	1418	16.42	0.56	0.024	0.001	0.02	0	853	106
AF3	Alfalfa	35244	1353	16.07	0.54	0.007	0.001	0.004	0	643	80
AF4	Alfalfa	33995	1307	16.02	0.54	0.008	0.001	0.005	0	701	88
AF5	Alfalfa	33788	1303	15.61	0.53	0.009	0.001	0.006	0	824	103
ALL1	Almond Tree 1	24011	972	10.77	0.37	0.036	0.001	0.041	0.001	1400	177
ALS1	Almond Tree 1	4104	227	2.16	0.08	0.016	0.001	0.017	0	665	84
ALF1	Almond Tree 1	25723	1015	16.94	0.58	0.018	0.001	0.02	0	433	55
ALL2	Almond Tree 2	22646	877	9.14	0.32	0.086	0.003	0.105	0.002	3286	408
ALS2	Almond Tree 2	5452	223	1.99	0.07	0.008	0	0.01	0	195	20
ALF2	Almond Tree 2	25614	826	12.98	0.44	0.035	0.002	0.04	0.001	425	44
ALF4	Almond Tree 4	28633	913	16.27	0.55	0.029	0.001	0.032	0.001	561	58
ALF5	Almond Tree 5	23996	774	15.48	0.52	0.024	0.001	0.025	0	581	60
ALF6	Almond Tree 6	26078	837	17.09	0.58	0.02	0.001	0.02	0	683	70
APL1	Apple Tree 1	25799	857	19.4	0.65	0.043	0.001	0.064	0.001	191	20
APS1	Apple Tree 1	6801	261	6.68	0.23	0.008	0.001	0.008	0	76	8
APF1	Apple Tree 1	14804	482	17.13	0.58	<0.001	0	0.001	0	9	2
APL2	Apple Tree 2	20106	692	15.81	0.68	0.072	0.003	0.091	0.002	466	48
APS2	Apple Tree 2	5674	230	5.17	0.22	0.007	0	0.009	0	77	8
APF2	Apple Tree 2	15865	518	18.89	0.8	0.005	0	0.005	0	59	6
ARS4	Apricot Tree 4	6119	241	9.94	0.42	0.007	0.001	0.008	0	73	8
ARF4	Apricot Tree 4	28477	907	45.6	1.92	0.032	0.002	0.032	0.001	189	20
ARL5	Apricot Tree 5	5342	226	5.71	0.25	0.008	0.001	0.009	0	51	6
ARS5	Apricot Tree 5	48417	1532	26.26	1.11	0.042	0.001	0.051	0.001	127	14
ARF5	Apricot Composite	27552	874	31.45	1.06	0.009	0.001	0.01	0	54	6
CRL1	Carob Tree 1	14379	524	11.95	0.51	0.028	0.001	0.041	0.001	156	17
CRS1	Carob Tree 1	5793	226	3.69	0.17	0.021	0.001	0.022	0	88	10
CRF1a	Carob Tree 1	20473	674	14.88	0.63	0.012	0.001	0.016	0	55	7
CRF1b	Carob Tree 1	19698	651	16.66	0.71	0.009	0.001	0.012	0	44	6
CRL2	Carob Tree 2	12408	449	12.01	0.51	0.023	0.001	0.033	0.001	118	13
CRS2	Carob Tree 2	3004	162	2.93	0.14	0.011	0	0.011	0	57	6
CRF2a	Carob Tree 2	15891	534	20.28	0.86	0.001	0.001	0.003	0	<6	1
CRF2b	Carob Tree 2	17187	573	17.97	0.63	0.002	0	0.003	0	15	4
FIL	Fig Tree 1	21982	763	9.91	0.45	0.109	0.004	0.125	0.002	835	86
FIS	Fig Tree 1	17048	592	8.63	0.3	0.007	0	0.008	0	147	16
FIF	Fig Tree 1	19195	637	12.71	0.45	0.006	0.001	0.007	0	280	29
FIL	Fig Tree 3	23306	802	17.38	0.63	0.16	0.004	0.161	0.003	963	99
FIS	Fig Tree 3	9510	368	4.62	0.17	0.012	0	0.011	0	359	37
FIF	Fig Tree 3	13556	470	9.08	0.32	0.002	0	0.003	0	222	23
FIF	Fig Tree 2	18062	633	10.93	0.38	0.003	0	0.005	0	375	39
FIF	Fig Tree 4	16368	556	9.43	0.35	0.002	0.001	0.004	0	209	22
FIF	Fig Tree 5	18046	601	9.37	0.32	0.006	0.001	0.008	0	244	25

Table A.1, Part 5. Concentrations of Elements in Botanical and Soil Samples (ppm)

Sample Code	Crop/Fruit	Potassium	± 1σ	Rubidium	± 1σ	Samarium	± 1σ	Scandium	± 1σ	Sodium(1)	± 1σ
GRL1	Grape Vine 1	8641	377	5.66	0.22	0.04	0.001	0.053	0.001	471	49
GRS1	Grape Vine 1	9707	431	5.82	0.21	0.01	0.001	0.012	0	1515	155
GRF1	Grape Vine 1	22322	818	18.65	0.66	0.01	0.001	0.009	0	5106	523
GRL2	Grape Vine 2	8706	402	6.37	0.24	0.038	0.001	0.052	0.001	546	56
GRS2.3	Grape Vine 2	22003	829	27.09	0.94	<0.003	0	0.004	0	5389	552
GRS2.4	Grape Vine 2	21528	824	25.7	0.91	<0.004	0	0.003	0	6048	619
GRF2.2	Grape Vine 2	21840	711	20.78	0.72	0.003	0	0.004	0	218	23
GRF2.3	Grape Vine 2	22590	730	20.37	0.72	0.003	0.001	0.005	0	223	23
NCL1	Nectarine Tree 1	41952	1340	36.68	1.27	0.041	0.002	0.06	0.001	117	13
NCS1	Nectarine Tree 1	3085	197	4.38	0.16	0.017	0	0.01	0	61	7
NCF1	Nectarine Tree 1	21403	688	38.97	1.35	0.006	0	0.007	0	27	3
NCL3	Nectarine Tree 3	39257	1254	38.97	1.35	0.04	0.001	0.061	0.001	115	13
NCS3	Nectarine Tree 3	6616	253	9.59	0.34	0.006	0	0.006	0	30	4
FO1	Feed Oats	7808	375	7.49	0.27	0.012	0.001	0.01	0	863	89
FO4	Feed Oats	10794	459	7.71	0.27	0.015	0.001	0.018	0	1024	106
FO6	Feed Oats	8042	408	6.12	0.23	0.01	0.001	0.014	0	770	80
FO8	Feed Oats	9850	438	5.34	0.25	0.006	0.001	0.009	0	878	91
PCL	Pecan	23751	847	11.42	0.4	0.024	0.001	0.034	0.001	82	11
PCS	Pecan	6322	282	4.02	0.15	0.01	0	0.011	0	67	8
PCF	Pecan	13012	439	10.91	0.38	<0.001	0	0.001	0	9	2
GPL1	Graft Pist. Tree 1	19513	714	6.59	0.29	0.035	0.001	0.042	0.001	101	12
GPS1	Graft Pist. Tree 1	8448	307	3.43	0.16	0.008	0	0.008	0	44	6
GPF1	Graft Pist. Tree 1	14748	491	11.33	0.48	0.003	0	0.003	0	15	3
GPL2	Graft Pist. Tree 2	16949	631	7.89	0.34	0.03	0.001	0.036	0.001	82	10
GPS2	Graft Pist. Tree 2	5045	292	3.27	0.19	0.093	0.002	0.096	0.002	150	16
GPF2	Graft Pist. Tree 2	16284	535	10.96	0.47	0.003	0	0.004	0	9	2
GPL3	Graft Pist. Tree 3	22504	800	11.02	0.48	0.035	0.001	0.044	0.001	127	15
GPS3	Graft Pist. Tree 3	7577	292	4.07	0.18	0.02	0.001	0.02	0	113	12
GPF3	Graft Pist. Tree 3	16237	533	13.09	0.56	0.001	0	0.002	0	11	2
GPL4	Graft Pist. Tree 4	20704	715	13.33	0.58	0.059	0.002	0.07	0.001	294	31
GPS4	Graft Pist. Tree 4	6037	275	4.94	0.23	0.044	0.001	0.045	0.001	245	26
GPF4	Graft Pist. Tree 4	15827	517	13.07	0.55	0.004	0	0.004	0	25	3
NPL1	Natural Pist. Tree 1	12511	469	24.21	1.02	0.006	0	0.008	0	118	13
NPS1	Natural Pist. Tree 1	9228	355	8.52	0.38	0.05	0.001	0.045	0.001	103	11
NPF1	Natural Pist. Tree 1	15121	505	7.92	0.33	0.002	0	0.002	0	18	4
NPL2	Natural Pist. Tree 2	10212	409	7.32	0.33	0.048	0.002	0.066	0.001	141	15
NPS2	Natural Pist. Tree 2	6124	262	4	0.19	0.05	0.001	0.043	0.001	112	12
NPF2	Natural Pist. Tree 2	19007	554	17.13	0.72	0.01	0.001	0.012	0	40	5
NPL3	Natural Pist. Tree 3	11092	384	6.77	0.3	0.038	0.001	0.052	0.001	141	14
NPS3	Natural Pist. Tree 3	9392	347	4.86	0.23	0.053	0.001	0.048	0.001	84	8
NPF3	Natural Pist. Tree 3	20871	602	14.02	0.6	0.008	0.001	0.01	0	35	4
POL1	Pomegranate Tree 1	10203	429	3.85	0.18	0.031	0.001	0.043	0.001	94	11

Table A.1, Part 5. Concentrations of Elements in Botanical and Soil Samples (ppm)

Sample Code	Crop/Fruit	Potassium	± 1σ	Rubidium	± 1σ	Samarium	± 1σ	Scandium	± 1σ	Sodium(1)	± 1σ
POS1	Pomegranate Tree 1	6901	273	2.86	0.13	0.021	0	0.021	0	133	13
POF1	Pomegranate Tree 1	16892	540	7.23	0.33	<0.003	0	0	0	41	6
POL4	Pomegranate Tree 4	14728	557	6.04	0.27	0.022	0.001	0.029	0.001	78	10
POS4	Pomegranate Tree 4	8515	337	3.57	0.17	0.015	0	0.015	0	126	12
POF4	Pomegranate Tree 4	16565	521	7.56	0.34	<0.002	0	0	0	113	11
POL5	Pomegranate Tree 5	11200	428	4.31	0.2	0.025	0.001	0.03	0.001	70	9
POS5	Pomegranate Tree 5	7832	306	2.89	0.14	0.01	0	0.01	0	116	12
POF5	Pomegranate Tree 5	17808	552	8.17	0.36	<0.001	0	0	0	82	9
NYE	County Soil 1	35493	2345	129.58	5.5	5.766	0.096	4.553	0.077	19979	392
NYE	County Soil 2	31258	2016	129.04	5.52	5.593	0.098	4.567	0.077	20075	394
NYE	County Soil 3	31609	2316	128.87	5.57	5.443	0.095	4.134	0.07	19639	386
Soil XRF		20000		136				6		2100	

1) Sodium measured in unashed samples

Table A.1, Part 6. Concentrations of Elements in Botanical and Soil Samples (ppm)

Sample Code	Crop/Fruit	Sodium[2]	± 1σ	Strontium	± 1σ	Tantalum	± 1σ	Terbium	± 1σ	Thorium	± 1σ
AF1	Alfalfa	1068	29	130.45	9.04	<0.001	0	<0.001	0	0.011	0.001
AF2	Alfalfa	820	23	132.5	9.18	0.003	0	<0.002	0	0.05	0.002
AF3	Alfalfa	750	21	119.85	8.3	<0.001	0	<0.001	0	0.009	0.001
AF4	Alfalfa	713	20	136.02	9.43	<0.001	0	<0.002	0	0.01	0.002
AF5	Alfalfa	754	21	136.58	9.45	<0.001	0	<0.001	0	0.011	0.001
ALL1	Almond Tree 1	1556	42	232.93	16.08	0.007	0.001	0.004	0.001	0.075	0.002
ALS1	Almond Tree 1	678	19	222.54	15.36	0.003	0	<0.001	0	0.032	0.001
ALF1	Almond Tree 1	419	12	15.4	1.36	0.004	0	<0.002	0	0.044	0.002
ALL2	Almond Tree 2	3474	94	234.03	16.23	0.019	0.001	0.008	0.001	0.238	0.003
ALS2	Almond Tree 2	179	5	102.38	7.07	0.002	0	<0.001	0	0.02	0.001
ALF2	Almond Tree 2	393	11	21.5	1.62	0.008	0.001	0.005	0.001	0.125	0.002
ALF4	Almond Tree 4	454	12	20.8	1.64	0.006	0.001	0.003	0.001	0.083	0.002
ALF5	Almond Tree 5	529	14	26.93	2	0.005	0.001	0.002	0.001	0.058	0.002
ALF6	Almond Tree 6	605	16	21.85	1.65	0.004	0.001	<0.002	0	0.053	0.001
APL1	Apple Tree 1	188	5	151.39	10.47	0.01	0.001	0.005	0.001	0.114	0.002
APS1	Apple Tree 1	74	2	173.12	11.95	0.001	0	<0.001	0	0.019	0.001
APF1	Apple Tree 1	8	0	2.29	0.54	<0.001	0	<0.001	0	<0.002	0
APL2	Apple Tree 2	429	19	67.92	5.48	0.015	0.001	0.01	0.001	0.192	0.003
APS2	Apple Tree 2	67	3	97.46	7.65	<0.001	0	<0.001	0	0.018	0.001
APF2	Apple Tree 2	65	3	1.59	0.38	<0.001	0	<0.001	0	0.013	0.001
ARS4	Apricot Tree 4	65	3	69.39	5.46	<0.001	0	<0.001	0	0.015	0.001
ARF4	Apricot Tree 4	149	7	8.1	1.2	0.007	0.001	0.006	0.001	0.106	0.003
ARL5	Apricot Tree 5	56	3	117.45	9.23	<0.001	0	<0.002	0	0.018	0.002
ARS5	Apricot Tree 5	124	6	102.58	8.16	0.009	0.001	<0.003	0	0.096	0.003
ARF5	Apricot Composite	45	1	7.77	1.04	<0.002	0	<0.002	0	0.019	0.002
CRL1	Carob Tree 1	145	7	105.41	8.29	0.006	0.001	0.003	0.001	0.07	0.002
CRS1	Carob Tree 1	86	4	115.66	9.11	0.004	0.001	<0.002	0	0.041	0.001
CRF1a	Carob Tree 1	48	2	48.01	3.84	0.002	0	<0.002	0	0.038	0.002
CRF1b	Carob Tree 1	41	2	34.28	2.81	<0.001	0	<0.002	0	0.025	0.002
CRL2	Carob Tree 2	111	5	57.73	4.62	0.005	0.001	0.002	0.001	0.057	0.002
CRS2	Carob Tree 2	53	2	47.46	3.78	<0.001	0	<0.002	0	0.023	0.001
CRF2a	Carob Tree 2	11	1	29.7	2.51	<0.002	0	<0.002	0	<0.004	0
CRF2b	Carob Tree 2	11	0	25.24	1.75	<0.001	0	<0.001	0	0.004	0.001
FIL	Fig Tree 1	898	39	152.56	12.11	0.021	0.002	0.016	0.002	0.278	0.005
FIS	Fig Tree 1	165	3	106.85	6.99	0.002	0	<0.001	0	0.015	0.001
FIF	Fig Tree 1	284	5	68.16	4.5	0.001	0	<0.001	0	0.016	0.001
FIL	Fig Tree 3	1474	27	174.03	11.5	0.034	0.002	0.02	0.002	0.392	0.006
FIS	Fig Tree 3	351	6	140.02	9.14	0.002	0	0.001	0	0.022	0.001
FIF	Fig Tree 3	221	4	29.43	1.99	<0.001	0	<0.001	0	0.007	0.001
FIF	Fig Tree 2	396	7	65.39	4.31	<0.001	0	<0.001	0	0.011	0.001
FIF	Fig Tree 4	221	4	52.33	3.61	<0.002	0	<0.002	0	0.008	0.002
FIF	Fig Tree 5	228	6	41.08	2.95	0.007	0.001	<0.002	0	0.019	0.002

Table A.1, Part 6. Concentrations of Elements in Botanical and Soil Samples (ppm)

Sample Code	Crop/Fruit	Sodium(2)	± 1σ	Strontium	± 1σ	Tantalum	± 1σ	Terbium	± 1σ	Thorium	± 1σ
GRL1	Grape Vine 1	543	10	188.38	12.34	0.008	0.001	<0.002	0	0.101	0.003
GRS1	Grape Vine 1	1591	29	95.83	6.29	0.002	0	<0.001	0	0.023	0.001
GRF1	Grape Vine 1	5490	100	94.29	6.23	<0.001	0	<0.002	0	0.019	0.002
GRL2	Grape Vine 2	555	10	164.35	10.78	0.008	0.001	0.004	0.001	0.093	0.002
GRS2.3	Grape Vine 2	6016	110	76.81	5.08	<0.001	0	<0.002	0	0.007	0.001
GRS2.4	Grape Vine 2	6679	121	79.05	5.38	<0.002	0	<0.003	0	<0.006	0
GRF2.2	Grape Vine 2	218	4	30.84	2.13	<0.001	0	<0.001	0	0.007	0.001
GRF2.3	Grape Vine 2	238	4	32.12	2.28	<0.001	0	<0.002	0	0.01	0.002
NCL1	Nectarine Tree 1	126	2	70.3	4.7	0.009	0.001	0.005	0.001	0.121	0.002
NCS1	Nectarine Tree 1	61	1	165.6	10.82	0.003	0	<0.001	0	0.023	0.001
NCF1	Nectarine Tree 1	22	0	6.29	0.84	<0.001	0	<0.002	0	0.012	0.001
NCL3	Nectarine Tree 3	118	2	57.78	3.86	0.009	0.001	0.005	0.001	0.115	0.002
NCS3	Nectarine Tree 3	26	0	71.37	4.68	<0.001	0	<0.001	0	0.014	0.001
FO1	Feed Oats	861	24	25.09	1.95	<0.001	0	<0.002	0	0.024	0.002
FO4	Feed Oats	1120	31	20	1.65	0.003	0.001	<0.002	0	0.041	0.002
FO6	Feed Oats	969	26	30.08	2.4	0.003	0.001	<0.002	0	0.037	0.002
FO8	Feed Oats	750	33	16.74	1.57	<0.002	0	<0.002	0	0.017	0.002
PCL	Pecan	95	2	98.26	6.45	0.005	0	0.003	0.001	0.064	0.002
PCS	Pecan	68	1	98.48	6.45	<0.001	0	<0.001	0	0.022	0.001
PCF	Pecan	19	0	7.15	0.73	<0.001	0	<0.001	0	<0.003	0
GPL1	Graft Pist. Tree 1	97	3	135.94	11.91	0.005	0.001	0.004	0.001	0.087	0.002
GPS1	Graft Pist. Tree 1	40	1	90.61	7.92	0.001	0	<0.001	0	0.019	0.001
GPF1	Graft Pist. Tree 1	15	0	10.62	1.55	<0.001	0	<0.001	0	0.006	0.001
GPL2	Graft Pist. Tree 2	84	2	161.37	14.12	0.005	0.001	0.004	0.001	0.076	0.002
GPS2	Graft Pist. Tree 2	188	8	167.8	13.3	0.013	0.002	0.013	0.002	0.219	0.004
GPF2	Graft Pist. Tree 2	18	0	10.34	1.42	<0.001	0	<0.001	0	0.007	0.001
GPL3	Graft Pist. Tree 3	128	3	210.43	18.35	0.006	0.001	<0.003	0	0.087	0.002
GPS3	Graft Pist. Tree 3	96	2	153.72	13.4	0.003	0.001	0.002	0.001	0.05	0.002
GPF3	Graft Pist. Tree 3	14	0	6.3	0.93	<0.001	0	<0.002	0	0.002	0.001
GPL4	Graft Pist. Tree 4	288	7	147.26	12.94	0.013	0.001	0.008	0.001	0.172	0.003
GPS4	Graft Pist. Tree 4	217	5	155.76	13.59	0.008	0.001	0.004	0.001	0.108	0.002
GPF4	Graft Pist. Tree 4	24	1	7.42	0.99	<0.001	0	<0.001	0	0.007	0.001
NPL1	Natural Pist. Tree 1	23	1	11.16	1.26	<0.001	0	<0.002	0	0.016	0.001
NPS1	Natural Pist. Tree 1	78	4	145.35	11.51	0.008	0.001	<0.003	0	0.111	0.003
NPF1	Natural Pist. Tree 1	8	0	3.65	0.41	0	0	<0.001	0	0.005	0
NPL2	Natural Pist. Tree 2	139	3	78.02	6.95	0.009	0.001	0.005	0.001	0.132	0.003
NPS2	Natural Pist. Tree 2	77	2	185.64	16.2	0.008	0.001	0.007	0.001	0.105	0.002
NPF2	Natural Pist. Tree 2	36	1	21.1	2.01	<0.001	0	<0.002	0	0.022	0.001
NPL3	Natural Pist. Tree 3	127	3	131.55	11.47	0.008	0.001	0.005	0.001	0.106	0.002
NPS3	Natural Pist. Tree 3	82	4	182.02	14.38	0.007	0.001	0.005	0.001	0.119	0.003
NPF3	Natural Pist. Tree 3	29	1	14.04	1.41	<0.002	0	<0.002	0	0.022	0.002
POL1	Pomegranate Tree 1	96	3	180.96	15.78	0.006	0.001	0.004	0.001	0.078	0.002

Table A.1, Part 6. Concentrations of Elements in Botanical and Soil Samples (ppm)

Sample Code	Crop/Fruit	Sodium[2]	± 1σ	Strontium	± 1σ	Tantalum	± 1σ	Terbium	± 1σ	Thorium	± 1σ
POS1	Pomegranate Tree 1	132	3	130.19	11.34	0.004	0	0.002	0.001	0.044	0.001
POF1	Pomegranate Tree 1	39	2	19.47	1.84	<0.002	0	<0.002	0	<0.005	0
POL4	Pomegranate Tree 4	74	2	161.42	14.13	0.004	0.001	0.005	0.001	0.059	0.002
POS4	Pomegranate Tree 4	121	3	153.09	13.35	<0.001	0	<0.002	0	0.035	0.002
POF4	Pomegranate Tree 4	106	5	12.07	1.32	<0.002	0	<0.002	0	<0.005	0
POL5	Pomegranate Tree 5	67	2	139.39	12.17	0.005	0.001	<0.002	0	0.06	0.002
POS5	Pomegranate Tree 5	109	2	129.1	11.27	<0.001	0	<0.002	0	0.023	0.001
POF5	Pomegranate Tree 5	77	2	16.54	1.72	<0.001	0	<0.002	0	<0.004	0
NYE	County Soil 1	19603	395	509.45	56.63	1.299	0.058	0.714	0.057	17.002	0.176
NYE	County Soil 2	20500	413	476.53	54.69	1.254	0.056	0.843	0.07	15.912	0.168
NYE	County Soil 3	18916	383	431.72	52.19	1.233	0.057	0.737	0.063	15.935	0.168
Soil XRF		20000		413						19	

2) Sodium measured in ashed samples

Table A.1, Part 7. Concentrations of Elements in Botanical and Soil Samples (ppm)

Sample Code	Crop/Fruit	Titanium	± 1σ	Uranium[(a)]	± 1σ	Uranium[(b)]	± 1σ	Vanadium	± 1σ
AF1	Alfalfa	<33	17	<0.029	0.001	<0.029	0.001	<0.45	0.1
AF2	Alfalfa	0	0	<0.027	0.001	<0.027	0.001	<0.44	0.14
AF3	Alfalfa	0	0	<0.025	0.001	<0.024	0.001	<0.46	0.15
AF4	Alfalfa	0	0	<0.029	0.001	<0.029	0.001	<0.44	0.14
AF5	Alfalfa	0	0	<0.027	0.001	<0.027	0.001	<0.49	0.16
ALL1	Almond Tree 1	11	9	<0.021	0.001	<0.021	0.001	0.31	0.12
ALS1	Almond Tree 1	<15	8	<0.013	0	<0.013	0	<0.14	0.03
ALF1	Almond Tree 1	7	6	<0.018	0.001	<0.017	0	0.21	0.07
ALL2	Almond Tree 2	0	0	0.057	0.011	0.045	0.01	<0.31	0.1
ALS2	Almond Tree 2	0	0	<0.007	0	<0.007	0	<0.08	0.02
ALF2	Almond Tree 2	0	0	0.03	0.006	<0.016	0	0.34	0.11
ALF4	Almond Tree 4	0	0	<0.018	0.001	0.028	0.007	0.23	0.08
ALF5	Almond Tree 5	0	0	<0.014	0	<0.014	0	<0.12	0.03
ALF6	Almond Tree 6	0	0	<0.015	0	<0.014	0	<0.11	0.03
APL1	Apple Tree 1	0	0	0.035	0.006	0.034	0.005	0.48	0.15
APS1	Apple Tree 1	0	0	<0.012	0	<0.012	0	<0.10	0.03
APF1	Apple Tree 1	0	0	<0.011	0	<0.010	0	<0.05	0.01
APL2	Apple Tree 2	0	0	0.06	0.01	0.039	0.008	0.58	0.18
APS2	Apple Tree 2	0	0	<0.009	0	<0.009	0	<0.10	0.03
APF2	Apple Tree 2	0	0	<0.010	0	<0.009	0	<0.06	0.02
ARS4	Apricot Tree 4	0	0	<0.012	0	<0.011	0	<0.09	0.02
ARF4	Apricot Tree 4	0	0	0.053	0.008	0.047	0.007	0.24	0.08
ARL5	Apricot Tree 5	0	0	<0.014	0	<0.013	0	<0.10	0.03
ARS5	Apricot Tree 5	0	0	<0.024	0.001	0.037	0.006	0.45	0.15
ARF5	Apricot Composite	0	0	<0.017	0.001	<0.016	0	<0.08	0.02
CRL1	Carob Tree 1	0	0	<0.022	0.001	<0.021	0.001	<0.20	0.05
CRS1	Carob Tree 1	0	0	<0.011	0	<0.011	0	<0.11	0.03
CRF1a	Carob Tree 1	0	0	<0.016	0.001	<0.015	0	<0.14	0.04
CRF1b	Carob Tree 1	0	0	<0.016	0.001	<0.015	0	<0.12	0.03
CRL2	Carob Tree 2	0	0	<0.018	0.001	0.014	0.006	<0.21	0.04
CRS2	Carob Tree 2	0	0	<0.009	0	<0.009	0	<0.11	0.02
CRF2a	Carob Tree 2	0	0	<0.017	0.001	<0.016	0.001	<0.14	0.03
CRF2b	Carob Tree 2	0	0	<0.010	0	<0.009	0	<0.14	0.03
FIL	Fig Tree 1	0	0	0.09	0.014	0.076	0.012	0.75	0.19
FIS	Fig Tree 1	0	0	<0.014	0	<0.014	0	<0.24	0.05
FIF	Fig Tree 1	0	0	<0.017	0	<0.016	0	<0.22	0.05
FIL	Fig Tree 3	0	0	0.125	0.015	0.137	0.015	0.67	0.19
FIS	Fig Tree 3	0	0	<0.010	0	0.007	0.003	<0.18	0.04
FIF	Fig Tree 3	0	0	<0.012	0	<0.012	0	<0.18	0.04
FIF	Fig Tree 2	0	0	<0.015	0	<0.014	0	<0.23	0.05
FIF	Fig Tree 4	0	0	<0.022	0.001	<0.022	0.001	<0.19	0.04
FIF	Fig Tree 5	0	0	<0.018	0.001	<0.018	0.001	<0.20	0.04

Table A.1, Part 7. Concentrations of Elements in Botanical and Soil Samples (ppm)

Sample Code	Crop/Fruit	Titanium	± 1σ	Uranium[(a)]	± 1σ	Uranium[(b)]	± 1σ	Vanadium	± 1σ
GRL1	Grape Vine 1	0	0	<0.027	0.001	<0.026	0.001	<0.27	0.06
GRS1	Grape Vine 1	0	0	<0.018	0	<0.018	0	<0.26	0.06
GRF1	Grape Vine 1	0	0	<0.038	0.001	<0.038	0.001	<0.41	0.09
GRL2	Grape Vine 2	0	0	<0.023	0.001	<0.022	0.001	<0.32	0.07
GRS2.3	Grape Vine 2	0	0	<0.034	0.001	<0.033	0.001	<0.45	0.09
GRS2.4	Grape Vine 2	0	0	<0.053	0.001	<0.053	0.001	<0.42	0.09
GRF2.2	Grape Vine 2	0	0	<0.015	0	<0.014	0	<0.14	0.03
GRF2.3	Grape Vine 2	0	0	<0.018	0	<0.017	0	<0.14	0.03
NCL1	Nectarine Tree 1	0	0	0.043	0.007	0.048	0.008	<0.24	0.05
NCS1	Nectarine Tree 1	0	0	<0.009	0	<0.009	0	<0.15	0.03
NCF1	Nectarine Tree 1	0	0	<0.012	0	<0.011	0	<0.09	0.02
NCL3	Nectarine Tree 3	0	0	0.032	0.006	0.029	0.006	<0.25	0.05
NCS3	Nectarine Tree 3	0	0	<0.007	0	<0.006	0	<0.08	0.01
FO1	Feed Oats	0	0	<0.032	0.001	<0.033	0.001	<0.22	0.04
FO4	Feed Oats	0	0	<0.035	0.001	<0.036	0.001	<0.23	0.04
FO6	Feed Oats	0	0	<0.037	0.001	<0.038	0.001	<0.22	0.03
FO8	Feed Oats	0	0	<0.035	0.001	<0.035	0.001	<0.24	0.04
PCL	Pecan	0	0	<0.020	0	<0.020	0.001	<0.27	0.04
PCS	Pecan	0	0	<0.009	0	<0.009	0	<0.11	0.02
PCF	Pecan	0	0	<0.010	0	<0.010	0	<0.09	0.01
GPL1	Graft Pist. Tree 1	0	0	<0.025	0.001	<0.026	0.001	<0.24	0.04
GPS1	Graft Pist. Tree 1	0	0	<0.007	0	<0.007	0	<0.09	0.01
GPF1	Graft Pist. Tree 1	0	0	<0.012	0	<0.011	0	<0.07	0.01
GPL2	Graft Pist. Tree 2	0	0	<0.022	0.001	<0.023	0.001	<0.25	0.04
GPS2	Graft Pist. Tree 2	0	0	0.041	0.007	0.047	0.007	0.35	0.08
GPF2	Graft Pist. Tree 2	0	0	<0.010	0	<0.010	0	<0.07	0.01
GPL3	Graft Pist. Tree 3	0	0	<0.024	0.001	<0.026	0.001	<0.25	0.04
GPS3	Graft Pist. Tree 3	0	0	0.008	0.003	<0.008	0	0.14	0.06
GPF3	Graft Pist. Tree 3	0	0	<0.011	0	<0.011	0	<0.08	0.01
GPL4	Graft Pist. Tree 4	0	0	0.028	0.007	0.039	0.007	<0.21	0.03
GPS4	Graft Pist. Tree 4	0	0	0.027	0.005	0.025	0.004	0.44	0.09
GPF4	Graft Pist. Tree 4	0	0	<0.011	0	<0.010	0	<0.07	0.01
NPL1	Natural Pist. Tree 1	0	0	<0.011	0	<0.011	0	<0.18	0.03
NPS1	Natural Pist. Tree 1	0	0	0.02	0.006	0.02	0.005	0.41	0.09
NPF1	Natural Pist. Tree 1	0	0	<0.004	0	<0.004	0	<0.10	0.02
NPL2	Natural Pist. Tree 2	0	0	0.023	0.006	0.018	0.006	0.33	0.09
NPS2	Natural Pist. Tree 2	0	0	0.02	0.003	0.018	0.003	0.33	0.07
NPF2	Natural Pist. Tree 2	0	0	<0.013	0	<0.013	0	<0.23	0.04
NPL3	Natural Pist. Tree 3	0	0	0.018	0.004	0.024	0.005	<0.33	0.06
NPS3	Natural Pist. Tree 3	0	0	0.028	0.005	0.026	0.006	<0.24	0.04
NPF3	Natural Pist. Tree 3	0	0	<0.017	0.001	<0.016	0.001	<0.16	0.03
POL1	Pomegranate Tree 1	0	0	<0.024	0.001	<0.026	0.001	<0.46	0.09

Table A.1, Part 7. Concentrations of Elements in Botanical and Soil Samples (ppm)

Sample Code	Crop/Fruit	Titanium	± 1σ	Uranium[(a)]	± 1σ	Uranium[(b)]	± 1σ	Vanadium	± 1σ
POS1	Pomegranate Tree 1	0	0	<0.010	0	0.007	0.004	<0.27	0.05
POF1	Pomegranate Tree 1	0	0	<0.029	0.001	<0.029	0.001	<0.33	0.06
POL4	Pomegranate Tree 4	0	0	<0.021	0.001	<0.022	0.001	<0.56	0.1
POS4	Pomegranate Tree 4	0	0	<0.011	0	<0.011	0	<0.32	0.06
POF4	Pomegranate Tree 4	0	0	<0.023	0.001	<0.023	0.001	<0.37	0.07
POL5	Pomegranate Tree 5	0	0	<0.018	0	<0.019	0	<0.52	0.09
POS5	Pomegranate Tree 5	0	0	<0.011	0	<0.011	0	<0.32	0.06
POF5	Pomegranate Tree 5	0	0	<0.016	0	<0.016	0	<0.37	0.07
NYE	County Soil 1	1995.7	284.5	3.732	0.334	3.131	0.257	24.4	2.9
NYE	County Soil 2	2423.2	364	3.799	0.354	3.025	0.276	23.5	2.7
NYE	County Soil 3	1834.2	314.5	3.658	0.329	3.204	0.297	22.9	3.1
Soil XRF								24	

Uranium concentrations estimated on the basis of 2 decay energy peaks: a) 228 and b) 277 keV.

Table A.1, Part 8. Concentrations of Elements in Botanical and Soil Samples (ppm)

Sample Code	Crop/Fruit	Ytterbium	± 1σ	Zinc	± 1σ	Zirconium	± 1σ
AF1	Alfalfa	<0.007	0	9.08	0.28	<0.81	
AF2	Alfalfa	<0.007	0	8.56	0.26	<0.92	
AF3	Alfalfa	<0.006	0	9.63	0.3	<0.78	
AF4	Alfalfa	<0.007	0	7.95	0.25	<0.89	
AF5	Alfalfa	<0.007	0	8.92	0.27	<0.78	
ALL1	Almond Tree 1	0.007	0.002	4.94	0.16	<0.99	
ALS1	Almond Tree 1	0.006	0.001	2.56	0.09	<0.58	
ALF1	Almond Tree 1	0.007	0.002	5.62	0.18	<0.98	
ALL2	Almond Tree 2	0.032	0.004	6.1	0.2	2.35	0.66
ALS2	Almond Tree 2	0.003	0.001	3.11	0.1	<0.40	
ALF2	Almond Tree 2	0.014	0.002	8.63	0.26	1.55	0.42
ALF4	Almond Tree 4	0.009	0.002	8.1	0.25	1.3	0.43
ALF5	Almond Tree 5	0.011	0.002	5.08	0.16	<0.85	
ALF6	Almond Tree 6	0.006	0.001	5.29	0.17	<0.85	
APL1	Apple Tree 1	0.013	0.002	9.62	0.3	<1.08	
APS1	Apple Tree 1	<0.003	0	19.54	0.59	<0.66	
APF1	Apple Tree 1	<0.003	0	1.23	0.05	<0.70	
APL2	Apple Tree 2	0.024	0.003	9.38	0.32	1.94	1.04
APS2	Apple Tree 2	0.002	0.001	5.53	0.18	<0.66	
APF2	Apple Tree 2	<0.002	0	1.17	0.05	<0.81	
ARS4	Apricot Tree 4	<0.003	0	6.61	0.22	<0.68	
ARF4	Apricot Tree 4	0.01	0.002	8.24	0.28	<1.90	
ARL5	Apricot Tree 5	0.002	0.001	10.5	0.34	<0.88	
ARS5	Apricot Tree 5	0.009	0.002	7.63	0.26	<1.66	
ARF5	Apricot Composite	<0.004	0	4.26	0.14	<1.19	
CRL1	Carob Tree 1	0.009	0.002	10.99	0.36	<1.10	
CRS1	Carob Tree 1	0.009	0.001	7.14	0.24	<0.97	
CRF1a	Carob Tree 1	0.006	0.001	16.94	0.55	<1.01	
CRF1b	Carob Tree 1	<0.004	0	11.97	0.39	<1.11	
CRL2	Carob Tree 2	0.009	0.002	7.71	0.25	<0.97	
CRS2	Carob Tree 2	0.003	0.001	4.42	0.15	<0.84	
CRF2a	Carob Tree 2	<0.004	0	10.98	0.36	<1.24	
CRF2b	Carob Tree 2	<0.003	0	9.52	0.29	<0.51	
FIL	Fig Tree 1	0.055	0.004	11.63	0.39	4.14	1.84
FIS	Fig Tree 1	<0.004	0	5.79	0.18	<0.40	
FIF	Fig Tree 1	<0.005	0	7.25	0.22	<0.52	
FIL	Fig Tree 3	0.059	0.006	10.65	0.33	5.26	1.03
FIS	Fig Tree 3	0.004	0.001	5.47	0.17	<0.37	
FIF	Fig Tree 3	<0.004	0	6.3	0.19	<0.44	
FIF	Fig Tree 2	<0.004	0	9.17	0.28	<0.48	
FIF	Fig Tree 4	<0.008	0	11.3	0.35	<0.89	
FIF	Fig Tree 5	<0.005	0	11.86	0.37	<0.92	

Table A.1, Part 8. Concentrations of Elements in Botanical and Soil Samples (ppm)

Sample Code	Crop/Fruit	Ytterbium	± 1σ	Zinc	± 1σ	Zirconium	± 1σ
GRL1	Grape Vine 1	0.018	0.003	11.81	0.36	<1.02	
GRS1	Grape Vine 1	<0.005	0	21.79	0.65	<0.59	
GRF1	Grape Vine 1	<0.010	0	14.6	0.44	<0.81	
GRL2	Grape Vine 2	0.013	0.003	10.22	0.31	<0.95	
GRS2.3	Grape Vine 2	<0.008	0	13.47	0.4	<0.70	
GRS2.4	Grape Vine 2	<0.015	0	17.18	0.53	<1.18	
GRF2.2	Grape Vine 2	<0.004	0	5	0.15	<0.59	
GRF2.3	Grape Vine 2	<0.005	0	4.45	0.14	<0.76	
NCL1	Nectarine Tree 1	0.016	0.002	6.18	0.19	<1.06	
NCS1	Nectarine Tree 1	0.004	0.001	13.57	0.41	<0.56	
NCF1	Nectarine Tree 1	<0.003	0	6.84	0.21	<0.80	
NCL3	Nectarine Tree 3	0.015	0.002	8.75	0.26	<0.88	
NCS3	Nectarine Tree 3	<0.002	0	3.62	0.11	<0.37	
FO1	Feed Oats	<0.009	0	13.56	0.42	<1.01	
FO4	Feed Oats	<0.010	0	10.77	0.33	<1.06	
FO6	Feed Oats	<0.011	0	13.15	0.41	<1.14	
FO8	Feed Oats	<0.010	0	9.43	0.32	<1.26	
PCL	Pecan	0.009	0.002	10.75	0.32	<0.67	
PCS	Pecan	<0.003	0	6.72	0.2	<0.44	
PCF	Pecan	<0.003	0	11.74	0.35	<0.54	
GPL1	Graft Pist. Tree 1	0.012	0.003	8.41	0.28	<1.21	
GPS1	Graft Pist. Tree 1	0.003	0.001	7.5	0.25	<0.67	
GPF1	Graft Pist. Tree 1	<0.003	0	10.67	0.35	<0.76	
GPL2	Graft Pist. Tree 2	0.009	0.003	7.99	0.26	<1.06	
GPS2	Graft Pist. Tree 2	0.032	0.003	4.58	0.19	4.56	1.92
GPF2	Graft Pist. Tree 2	<0.004	0	4.78	0.16	<0.81	
GPL3	Graft Pist. Tree 3	0.016	0.003	5.94	0.21	<1.37	
GPS3	Graft Pist. Tree 3	0.008	0.001	4.73	0.16	<0.85	
GPF3	Graft Pist. Tree 3	<0.004	0	6.04	0.2	<0.84	
GPL4	Graft Pist. Tree 4	0.021	0.003	10.68	0.36	<1.68	
GPS4	Graft Pist. Tree 4	0.018	0.002	8.72	0.29	<1.23	
GPF4	Graft Pist. Tree 4	<0.003	0	9.56	0.31	<0.72	
NPL1	Natural Pist. Tree 1	<0.004	0	5.44	0.18	<0.95	
NPS1	Natural Pist. Tree 1	0.018	0.002	1.66	0.1	<1.87	
NPF1	Natural Pist. Tree 1	<0.001	0	1.65	0.06	<0.30	
NPL2	Natural Pist. Tree 2	0.016	0.003	5.96	0.21	<1.47	
NPS2	Natural Pist. Tree 2	0.018	0.001	2.13	0.09	<1.10	
NPF2	Natural Pist. Tree 2	<0.004	0	5.45	0.18	<0.85	
NPL3	Natural Pist. Tree 3	0.014	0.002	7.58	0.25	0.98	0.41
NPS3	Natural Pist. Tree 3	0.019	0.002	4.41	0.18	<1.78	
NPF3	Natural Pist. Tree 3	<0.004	0	7.78	0.26	<1.20	
POL1	Pomegranate Tree 1	0.015	0.003	7.6	0.25	<1.03	

Table A.1, Part 8. Concentrations of Elements in Botanical and Soil Samples (ppm)

Sample Code	Crop/Fruit	Ytterbium	± 1σ	Zinc	± 1σ	Zirconium	± 1σ
POS1	Pomegranate Tree 1	0.007	0.001	6.8	0.22	<0.69	
POF1	Pomegranate Tree 1	<0.009	0	8.5	0.29	<1.27	
POL4	Pomegranate Tree 4	0.007	0.002	7.55	0.25	<1.01	
POS4	Pomegranate Tree 4	<0.004	0	8.15	0.27	<0.87	
POF4	Pomegranate Tree 4	<0.006	0	8.24	0.29	<1.30	
POL5	Pomegranate Tree 5	0.007	0.002	5.43	0.18	<0.89	
POS5	Pomegranate Tree 5	<0.004	0	8.72	0.29	<0.79	
POF5	Pomegranate Tree 5	<0.006	0	8.49	0.28	<0.92	
NYE	County Soil 1	2.493	0.087	53.15	2.76	296.28	62.2
NYE	County Soil 2	2.256	0.085	56.12	2.67	215.76	47.7
NYE	County Soil 3	2.167	0.079	57.68	2.74	206.34	46.4
Soil XRF				53		256	

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10. SUPPLEMENTARY NOTES
P. R. Reed, NRC Project Manager

11. ABSTRACT *(200 words or less)*

Transfer of radionuclides from soils into plants is one of the key mechanisms for long-term contamination of the human food chain. Nearly all computer models that address soil-to-plant uptake of radionuclides use empirically-derived transfer factors to address this process. Essentially all available soil-to-plant transfer factors are based on measurements in annual crops. Because very few measurements are available for tree fruits, samples were taken of alfalfa and oats and the stems, leaves, and fruits and nuts of almond, apple, apricot, carob, fig, grape, nectarine, pecan, pistachio (natural and grafted), and pomegranate, along with local surface soil. The samples were dried, ground, weighed, and analyzed for trace constituents through a combination of induction-coupled plasma mass spectrometry and instrumental neutron activation analysis for a wide range of naturally-occurring elements. Analysis results are presented and converted to soil-to-plant transfer factors. These are compared to commonly used and internationally recommended values. Those determined for annual crops are very similar to commonly-used values; those determined for tree fruits show interesting differences. Most macro- and micronutrients are slightly reduced in fruits; non-essential elements are reduced further. These findings may be used in existing computer models and may allow development of tree-fruit-specific transfer models.

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