Soil Mixes for Greenhouse and Nursery Growth of Desert Plants

a mini-symposium with contributions by

Greg Augustine, Desert Tree Nursery
John Augustine, Desert Tree Farm
Dan Bach, Bach's Cactus Greenhouse and Nursery
Ralph Backhaus, Arizona State University
Joe Corgan, New Mexico State University
Mark Dimmitt, Arizona-Sonora Desert Museum
George Fraser, Hines Wholesale Nurseries
Ron Gass, Mountain States Wholesale Nursery
Victor Gass, Desert Botanical Garden of Arizona
Dave Grigsby, Grigsby Cactus Gardens
LeMoyne Hogan, University of Arizona
Joan C. Johnson, Adams Nurseries
William Lipke and Maxine Rusche,
Northern Arizona University
Steve Pendleton, Native Plants, Inc.
Julie Schaller, New York Botanical Garden
Pat Williams, Tucson Plant Materials Center

Recently *Desert Plants* arranged a series of conferences with growers, partly by telephone and postal correspondence, in order to combine elements of theory and practice to explore soil mixes for desert plants in the format of a miniature journal symposium. The facts uncovered are reported in two sections, 1) theory and generalities, and 2) practice and specifics.

Theory and Generalities

To produce desert plants for revegetation purposes, for domestic or civic landscaping, for research, display or other purposes, it has been customary to raise the plants under greenhouse or nursery conditions, usually in containers (or in raised beds in the case of larger cacti) rather than in the open ground of cultivated fields. In such a greenhouse or container-nursery situation, the grower attempts to manipulate and improve conditions (which might have otherwise been less favorable) to effectively and economically produce healthy plants. The nursery stock, when grown in containers, can be manipulated more effectively and can readily be moved to market and/or to the site where the plants are to be used. The soil mix is more easily modified in a container situation than in the field and can easily be varied for different plant species.

Problems Associated with Container Plants. When desert plants are grown in containers, they are usually subjected to conditions quite different from those in nature where the plants grow without assistance from man. As an example, on the hot desert, the root system of a plant is rather well-insulated from the peak midday temperature. Not so with a container-plant where root and soil temperatures soar quickly on hot days and drop as precipitously with nightfall or when cold weather sets in. The result is a range of temperatures ordinarily not experienced by plant roots under natural conditions. Soil in containers dries out so quickly that the plants have to be frequently watered, often as much as once a day in mid-summer. The restricted soil volume of a container severely limits the natural spreading of plant roots so that the stress-buffering capabilities of a natural root system (with taproot, laterals and feeder roots intimately associated with physical features of the landmass) can not be achieved.

Growers of desert plants have been forced to develop special mixes for greenhouse and nursery growth of these plants. In practically no instance can soil be taken up from the desert and used without alteration as a successful medium for plant growth in containers in the greenhouse or nursery. Such soil may compact under nursery conditions or may have other undesirable qualities when placed in a container-situation. This is unfortunate because desert soils, having been subjected to little rainfall during the period of their formation, have generally not been leached of their nutrients to the extent that non-desert soils have been, and potentially represent some of the most fertile soils on earth.

There are three serious objections to using a heavy compactible soil for growing desert species in containers even when these same species seem capable of growing on such soil in nature. The timetable of watering, which results in repeated cycles of wetting and drying, can cause swelling, shrinkage and compaction of such soil, resulting in 1) poor wetting of soil if the soil ball shrinks away from the side of the container, 2) poor aeration resulting from compaction, and 3) poor drainage once the soil has been thoroughly saturated with water. The latter two conditions allow pathogenic organisms to multiply and harm or kill plants under nursery conditions. Many of the decisions a grower of desert plants makes concerning formulation of a soil mix are related to preventing the three possibilities listed above from ever happening.

Clays can be extremely important agriculturally because of the fertility resulting from their favorable cation exchange capacity (CEC) discussed in a section below. Nevertheless, clays are avoided by many growers of desert plants because of their cohesive properties and potential compactibility. Addition of organic material to the clay is beneficial and at least one grower of desert plants uses a mix rather high in these two materials. Clays are also avoided by growers when plants are shipped for any distance if high shipping rates apply; a container filled with clay weighs more than one filled with organic material and sand.

Some Desert and Non-desert Contrasts. Under desert conditions, bare-root or balled-and-burlapped material has proven successful in limited situations only, as noted below. In contrast, in the eastern United States, or where humid conditions prevail, it has proven economically feasible to grow nursery stock in fields and to sell such material either as bare-root winter-dormant plants or as field-dug balled-and-burlapped stock. A soil high in clay is preferred for growing the latter material because the cohesive nature of the clay inhibits breaking of the root-ball. Citrus trees are successfully balled-and-burlapped and transplanted in Arizona, but this is an exception. Also, some large tree species are field-grown in Arizona and boxed for transplanting successfully. Most of the nursery industry in desert areas, however, centers on growing plants in containers. Cacti and succulents are bare-rooted routinely; most desert trees and shrubs are not. Containers are definitely preferred by nurseries for growing most desert plants.

Aside from differences in cultural practices for desert and non-desert plants, soils have been found to behave differently in deserts than elsewhere. For example, under non-desert humid conditions, clays of agricultural soils generally aggregate nicely with silt and sand in a non-compacted condition with numerous air-spaces. Under desert conditions, or if worked when too wet, clays tend to compact. Under non-desert humid conditions, continued growth of sod on compacted "worn-out" agricultural soil will eventually return the soil to a condition where the clays will once again aggregate with the other soil particles to form air spaces which enable the observable fertility of the soil to return. Unfortunately, under desert conditions, such a transformation is more difficult without adding various soil amendments.

Peat-moss and Sand, the "U.C. Mix". It has become popular with growers over the years to obtain a good CEC value in a potting soil by using peat-moss and to obtain good drainage by using sand, most often in a ratio of one part of peat-moss to one part of sand. However, when clay does not constitute the basis of the CEC of the soil, the CEC fluctuates with the acid-base balance (pH) associated with the soil's organic material. A one-to-one peat-moss and sand mix adjusted to a favorable pH with lime has long been recommended as a mix for container plants by the University of California. This mix is customarily referred to as a "U.C. Mix" and there are many variations and modifications. Such a "soil-less mix" has no fertilizer value itself until the nutrients required by plants are added to it. Nevertheless, when this mix can be afforded, it serves extremely well and has been tested by time. Nutrient retention is good and when slow-release fertilizers are used it is excellent. Peat-moss is produced in areas remote from the world's deserts and shipping charges make it a relatively expensive commodity for desert use. It tends to be used by desert growers for high-value plants grown in small containers.

Fertilizer Availability and Cation Exchange Capacity (CEC). Nutrient ions are continuously being removed from the soil solution by plant roots. When fertilizer is added to the water given to a container plant, its nutrient ions are available to the plant for a brief time only. Solution dripping out of the container through the holes in the bottom flushes the nutrients with it and these leached nutrients are no longer available to the plant being cultivated. But nutrient ions with a positive charge (cations) such as calcium, magnesium, potassium, ammonium, manganese, zinc and copper, can become attached to soil particles having suitable negatively charged exchange sites. Such sites with negative charges are the basis of the observed cation exchange capacity (CEC) of the soil. When the plant is watered with a solution containing relatively fewer cations than are being held by the CEC-providing material of the soil, then some of the cations leave the soil particles and once again become part of the soil solution. They may then be taken up by the roots of the plant being cultivated or may be lost through the holes in the bottom of the container. Roots themselves are negatively charged and have relatively good CEC values.

Traditionally we classify the particles of the soil as mineral (sand, silt, clay) and organic (humus). These substances vary tremendously in cation exchange capacity. Of the three mineral particles, clays are finer particles than silts and silts are in turn finer in size than sands. But clays are not merely more finely divided than silts. Only the sands and silts are the simple weathered remains of gravels that were eroded from the rocks of the earth's crust. Clays are alteration products generated through crystallization of materials which had dissolved or worn away from rocks in the distant past. By virtue of their crystalline structure, clays possess an inherently large surface area, a negative charge and a good CEC value. Clays and humus both serve as nutrient storehouses of the soil because of their high CEC values and much less because of any nutrients which are contained in their own chemical structure.

Cation exchange acts as a buffer which eliminates rapid change of nutrient level in the soil solution. Loss of nutrient by leaching tends to decline with an increase in CEC value. Although fertility of the mix is improved with the addition of a material with a high CEC value, the nutrient is not provided by the high-CEC material itself; rather a fertilizer source external to such material is essential to act in conjunction with it. Addition of calcium and magnesium in the form of agricultural lime may be necessary when organic material provides the bulk of the CEC value of the soil mix if a large number of exchange sites in the humus become occupied by hydrogen or sodium ions after continued intermittent watering.

Slow-release Fertilizers for Incorporation into Soil. In recent years fertilizers have been encapsulated in tiny membrane-like plastic spheres which can be incorporated into soil mixes to slowly meter out nutrients to the soil solution with each watering. The result is similar to cation exchange but the process is very different. Such osmotically active coated fertilizers, named Osmocote by the manufacturer, have become very popular with commercial growers. They are available in several formulations and are intended to provide nutrients for periods of 3–4 months, 5–6 months, 8–9 months or 12–14 months. These slow release fertilizers have an action which seems further enhanced by presence of high CEC material in the soil mix.

Reasons for Using Organic Materials. Organic materials such as peat-moss, sawdust, compost, finally ground tree bark or animal manure can effectively be used as one ingredient in soil mixes for desert plants to serve three very important functions, 1) to increase fertility by providing the CEC that clay would have provided in a heavier mix, 2) to lighten the soil mix and improve its texture by making it loose, friable and well-draining, and 3) to physically retain moisture for a period of time short enough to inhibit growth of pathogenic organisms and long enough to minimize water-stress to the plant being cultivated. In addition, organic material such as manure, blood-meal, high-protein plant material or legume crops break down to provide natural fertilizer.

Although organic material, partly due to its spongy nature, has a tremendous surface area and a potentially high CEC value, the leaching action of continuous intermittent watering, when combined with the necessity of having a relatively fast-draining soil, can remove the mineral cations, particularly calcium and magnesium, replacing them with hydrogen ions. Such a soil becomes acid and its potential CEC value can not be realized with the lower pH. Organic material can also become loaded with (non-nutrient) sodium when this ion is abundant in the water supply. As opposed to the permanent negative electrical charge on clay particles (the charge that attracts and holds nutrient cations), the negative charge on particles of organic material, being pH-dependent, is reduced as the soil becomes acid. Routine use of either 1) water-soluble low-strength fertilizer injected into the watering system, or 2) slow-release fertilizer incorporated into the soil mix, can give good results, but probably never as good as when the pH of the soil is also kept critically adjusted with calcitic and dolomitic lime.

Breakdown of Organic Material. Organisms in soil break fresh organic material down into 1) some substances which can be used directly by plants and 2) other substances, chiefly wood lignins, waxes, fats and some protein compounds which are transformed by complex chemical processes to humus, a relatively stable colloidal material of the soil. It is this humus that provides abundant CEC sites and stabilizes the fertility of the soil mix. The less stable organic materials such as starches, sugars and water-soluble proteins are broken down in the soil to carbon dioxide, water and amino acids, all substances which can be beneficial to the plant being cultivated. In nature, plants without nitrogen-fixing root bacteria depend on ammonium ions from decomposition of the formerly mentioned amino acids for a source of nitrogen. Such ammonium ions behave like mineral cations and are held in reserve by clays and humus at exchange sites.

When fresh organic material containing large amounts of carbohydrate and little protein are added to a soil mix, decomposition by microorganisms requires a source of nitrogen. If extra nitrogen is not added with such organic material, nitrogen can be "robbed" from other ingredients of the soil mix and from the nutrients of the soil solution intended for use by the plant under cultivation, thus greatly reducing the actual fertility of the mix. When animal manures are used, abundant nutrients are present which can be utilized not only by the plant being cultivated but by microbial agents of decomposition as well. Organic colloidal material is also present in manure to provide a good CEC value. Exploitation of local sources of manure becomes profitable to the desert grower as the cost of energy makes commercial fertilizer more expensive to produce and to transport.

Sand and Silt. Sand and silt, being finely worn rock fragments, continue to break down and release to the soil solution the chemicals they are composed of. Any of these chemicals which happen to be plant nutrients can be taken up by plant roots in a straightforward manner and utilized. The process of decomposition of sand and silt is very slow, however, and can not be depended on to support plant life with any degree of vigor. Sands, particularly, are often little more than silica. Silica provides no plant nutrients. Sands and silts also happen to have very poor CEC values. For these reasons, sands and silts are considered relatively inert ingredients of soil mixes, sands being more inert than silts. Sand is very popular with growers because it gives bulk to a soil mix and provides excellent drainage.

Non-soil Rock Materials, Vermiculite and Perlite. Aside from using sand, silt, clay and humus, the important soil components, growers have found that local non-soil rock materials such as granite, pumice, and scoria can beneficially be added to the soil mix, as can manufactured vermiculite and perite. Crushed granite is usually actually a decomposing partially saprolytic rock that is further broken down by crushing and sold for use as a top-dressing for yards with desert landscaping. It can also be used as an ingredient in soil mixes. Growers have discovered that it has not yet released its nutrients to the extent of a sand that has been well worn and reduced to silica.

Pumice is a volcanic glassy lava generally of rhyolitic (acid lava) composition. It formed during violent pyroclastic activity, is shot through with air spaces, is sponge-like, but hard and light. It can be used as a soil amendment to increase soil aeration. Being a volcanic glass, it is more or less inert and is devoid of much CEC value. Scoria, usually of basaltic (basic lava) composition, is also a naturally occurring volcanic material. Scoria, like pumice, is very light. It is sometimes referred to as volcanic cinder or lavic cinder. It is used more or less like pumice.

Vermiculite, as sold, is a clay mineral that has been greatly expanded through intense heat treatment. It combines characteristics of a clay with an extremely light weight. It has excellent CEC characteristics and holds water well. It tends to break down and lose its light fluffy character after much use. Aside from its horticultural value, vermiculite is utilized in the building industry as a poured insulation for both walls and the space between roof and ceiling because of its many air spaces. When vermiculite is used horticulturally, these air spaces fill with water. The material is often used as a substrate for germinating seeds because it retains moisture for a long period of time. When used alone it is poorly aerated when wet and is therefore often combined with perlite.

Perlite is a hydrated rhyolite which pops into an artificial pumice when water molecules are driven from its chemical structure by heating to an extremely high temperature. As processed, it is usually much lighter than pumice, has a greater aerating capacity, but floats to the surface of the soil because of its extremely light nature. It is much less easily crushed down than is vermiculite, but more readily so than pumice or scoria. Unlike vermiculite, perlite has little or no CEC value and is used exclusively to lighten up and aerate the soil mix. It is also used commercially outside of horticulture as a building insulation. Unlike the situation in vermiculite, the air spaces of perlite do not fill readily with water. For several years, the commercial source of perlite for processing by factories around the country has been the perlitic rhyolitic flank of Picketpost Mountain adjacent to the Boyce Thompson Southwestern Arboretum.

Practice and Specifics

Growers of desert plants have variously combined theory with trial and error and a good deal of personal ingenuity to develop soil mixes which perform satisfactorily under their special circumstances. It is certain that there is no one "correct" mix. Materials that prove economical in one area may not be so in another. Subtle conditions such as the pH and salt content of the water supply vary from one location to another. In addition, Canadian peat-moss, which is a major ingredient in one of the most popular soil mixes, has recently become very expensive in the Southwestern United States partly due to increasing shipping costs resulting from radically higher prices of gasoline. A number of growers who once used peat-moss have replaced it with other materials. To provide for an interchange of information on current practices and to create something of a mini-symposium on soil mixes for desert plants, several nurseries or institutions which grow desert plants commercially or for other purposes were invited to contribute information concerning mixes they are currently using.

Grigsby Cactus Gardens, Vista, California (Information courtesy of Dave Grigsby.) This leading specialty nursery concentrates on growing rare and unusual cacti and succulents for collectors, largely as a mail-order business but also for a walk-in trade during limited hours. A wholesale trade is also maintained. All sizes of plants from small seedlings to large specimens are marketed. Cacti and succulents require good drainage and good soil aeration, so pumice is added to the soil mix. The mix for flats and pots consists of 1/3 pumice, 1/3 humus and 1/3 sand. A Toyota pickup truck load of pumice, one of humus and one of sand are mixed together to make a batch. To this, 10–15 pounds of gypsum (hydrous calcium sulphate) are added. For delicate *Crassula* species and some *Haworthia* species such as *H. truncata*, a number 6 charcoal (3/16th inch to 1/4 inch in diameter) is added to the pumice-humus-sand mix in a ratio of one part charcoal to three parts ordinary mix. The soil mix for the growing beds consists of 1/2 decomposed granite and 1/2 horse manure. The growing beds retain their fertility for about three years. The horse manure could perhaps more accurately be described as used stable bedding and consists of about 1/2 wood shavings or chips. At one time in the past it was decided to have the soil mix custom-prepared by others and delivered to the nursery. Various batches seemed to differ somewhat in composition. In order to establish strict quality control and uniformity, mixing at the nursery itself was re-instituted.

Hines Wholesale Nurseries, Santa Ana, California (Information courtesy of George Fraser.) This large grower, a subsidiary of Weyerhaeuser Corporation, ships container plants by semi tractor-trailer to nurseries around the United States. Several desert plants are included in the trees and shrubs currently being grown and a number of others are adaptable to desert situations and are commonly grown in deserts. In addition, in recent years, a large cactus and succulent department has been developed. The soil mix for the cacti and succulents is made by combining a 34 cubic yard truck load of lavic cinder (scoria) with 30 cubic yards of composted bark. In the past peat-moss was used and 300 pounds (6 bags) of 18–6–12 Osmocote of 6-month duration were added to the batch. Favorable results are now obtained with the composted bark and with fertilization by watering. The regular field mix for other container plants, chiefly trees and shrubs, is made up in batches of 180 cubic yards each, consisting of 2/3 cedar sawdust and 1/3 fine nursery sand having a 4% content of silt and clay. To this are added 52 bags (80 lbs. each) of 38–0–0 Nitroform prefertilizer mix blended and bagged for Hines and consisting of calcium nitrate, potassium nitrate, single super phosphate, iron sulphate and manganese sulphate. The pH is adjusted by adding 11 bags (80 lbs. each) of dolomitic lime and 18 bags (50 lbs. each) of calcitic lime. The various bags are color-coded so that field hands speaking either English or Spanish can readily and accurately prepare the mix.

Northern Arizona University, Flagstaff (Information courtesy of William Lipke and Maxine Rusche.) Desert plants, mostly succulents, are grown in a University greenhouse, primarily for class use. The soil mix is prepared from 2/5 native soil, 2/5 vermiculite and 1/5 perlite. The native soil is of a silty alluvial type and includes clay. Osmocote of 12–14 months duration is incorporated into the top 1/2 inch of soil. Depending on the nature of the soil being used, the proportions in the mix may be varied by feel to produce a good loose soil that drains well. Whenever it is necessary to recycle the soil mix, fresh vermiculite is added to replace that which was crushed down in use.

Native Plants, Inc., Salt Lake City (Information courtesy of Steve Pendleton.) A wide variety of trees, shrubs and other plants native to many vegetational zones, including deserts, are grown for reclamation and other uses in the Western United States. It has been desirable to establish one economical mix for growing all of these plants from desert flora to high elevation conifers, shade trees, aspen and birch. One batch of mix consists of 56 cubic feet of material in the following ratio: coarse peat-moss, 24 cubic feet; vermiculite, 8 cubic feet; perlite, 8 cubic feet; composted bark, 16 cubic feet. An Osmocote fertilizer of 14–14–14 formulation and 5–6 month duration is added as well as fritted trace minerals. For some species the soil mix has been altered somewhat. For example, a few pounds of dolomitic lime are added to the mix when growing the desert Winter-fat *(Eurotia lanata)*.

Desert Botanical Garden of Arizona, Phoenix (Information courtesy of Victor Gass.) All types of desert plants are grown at this institution for display purposes and educational or research use. Generally soil mixes are specially modified for the material being grown according to experience. The basic mix for trees and shrubs in 1-gallon to 5-gallon size containers is 1/3 decomposed granite, 1/3 compost mix and 1/3 sand. The compost mix is custom made from horse manure and other organic material and delivered to the nursery. When transplanting liners to 1-gallon containers, up to a tablespoon of Osmocote is placed under the root system. The 12–14 month type is used for slow growing plants and the 5–6 month type for fast growing species. Pumice or perlite is used in the mix to replace half of the compost when growing cacti. Relatively more decomposed granite is used in the mix when growing *Agave* species. Seeds are germinated in a mixture of 50% vermiculite and 50% perlite to which nothing else is added. Liners are grown in a U.C. mix of 1/2 peat-moss and 1/2 sand to which Osmocote has been added. It should be emphasized that all soil mixes mentioned are stock mixes and that these are adjusted according to the needs of individual species.

Desert Tree Farm and Desert Tree Nursery, Phoenix (Information courtesy of Greg and John Augustine.) Desert Tree Farm is a wholesale grower of desert plants for the Arizona market. Desert Tree Nursery is a retail operation which markets a complete line of desert plants, including but not limited to those grown at Desert Tree Farm. The basic mix for these nurseries consists of 50–60% decomposed bark mulch, about 40% desert silt and 10% local commercial compost of horse manure and grass. To each 10 cubic yards of mix, 50 pounds of Sulfa Soil, a red powder consisting of 20% iron and 30% sulphur, is added. Soil for larger containers is prepared using less of the bark mulch to economize. For germinating mesquite, palo-verde or *Acacia farnesiana* directly in 1-gallon containers, a light mix is used to which 160 pounds of rough yellow granulated 18–18–0 Orchard Starter fertilizer is added to each 10 cubic yards of mix. Liners are grown in a U.C. mix of 1/2 peat-moss and 1/2 very coarse sand to which an 18–18–18 Osmocote fertilizer and a fungicide such as Captan or Coban have been added.

Mountain States Wholesale Nursery, Phoenix (Information courtesy of Ron Gass.) This nursery is probably the largest grower of desert trees and shrubs for the Arizona market and plants are also sent out-of-state. The general soil mix used at the Paradise Valley nursery (a location being phased out) has been 50% Paradise Valley clay silt and 50% organic mulch, usually of decomposed bark and sawdust. At the new location in west Phoenix the same proportions are used but the soil is a little more sandy. When transplanting liners to 1-gallon containers about a teaspoon of 18–6–12 Osmocote of 8–9 month duration is placed under the root system. Liners are grown in a U.C. mix of 50% peat-moss and 50% sand to which Osmocote has been added. Seeds are germinated in vermiculite or in a vermiculite and perlite mixture.

Arizona State University, Tempe (Information courtesy of Ralph Backhaus.) Desert plants are raised for teaching and research purposes. It is important that each batch of soil mix be exactly like each other batch so that results can be reproduced. For this reason no native soil is used. A U.C. mix of 1/2 Canadian peat-moss and 1/2 sand is used. Superphosphate, ammonium nitrate and iron sulphate are added and the pH is adjusted with calcium carbonate and dolomite. Osmocote of 8–9 month duration is used in an amount calculated to provide nitrogen in the quantity that blood meal would provide in a straight U.C. mix. Succulent plants are grown in a medium consisting of 1/2 sand and 1/2 U.C. mix. Seedlings are germinated in a mix consisting of 50% vermiculite and 50% perlite.

Boyce Thompson Southwestern Arboretum. During the last nine years considerable experimentation with various soil mixes, sometimes on a theoretical and sometimes on a trial and error basis, has occurred. For several years a mix of 1/3 soil, 1/3 organic material and 1/3 sand was used to which was added an Arboretum blend of commercial field fertilizers theoretically capable of providing nutrients in the right proportions. Until the perlite processing plant in Phoenix was closed about 1974, this material was generously added when growing cacti and succulents. After 1974 it was used more judiciously because of the price when ordered from California. The soil used in preparing the mix consisted of silt dug from the Queen Creek floodplain downstream from the Arboretum or of "topsoil" from a local construction company.

The organic material usually came from three sources for any one batch: 1) Arboretum compost of leaves, wood chips and waste organic material, 2) horse manure cleaned by the Arboretum from local corrals and 3) wood-shavings or sawdust from the sawmill at Globe. A goodly number of *Eucalyptus* leaves were always put into the compost and it was felt that these inhibited germination of weed seeds. When the compost pile was dismantled and no longer used, the weeds became a problem in the soil mix. Horse manure was used in reliance on published information that micro-organisms that multiply in this material destroy root-knot nematodes which are a serious problem with cultivation of cacti. About 1975, slow-release fertilizer replaced the other type (blended field fertilizers) and has been used ever since with very good results.

In recent years a dump-truck load at a time of commercial soil mix has been purchased for Arboretum use. Results have tended to vary with the batches obtained from the producers. Currently a prepared mix of soil and organic material obtained from a Phoenix nursery is being modified as follows for general purposes such as the Arboretum's retail nursery: 3/7 prepared mix, 2/7 sand and 2/7 perlite or pumice. To this, Osmocote of various formulations and durations is added depending on the type of plants being grown. For growing certain plants or because of personal preferences of staff, various modifications are freely made. Kent Newland has recently had a special soil mix prepared for the display cactus greenhouse beds, a mix which includes generous portions of sand and pumice.

Adams Nurseries, Tucson (Information courtesy of Joan C. Johnson.) Native trees and shrubs are a specialty of this nursery. The general mix for container plants consists of one part topsoil to two parts sand and two parts bark mulch. The emphasis is on keeping the mix loose and well-draining. Soluble fertilizer is injected into the watering system. Peat-moss is no longer used in the greenhouse for liners. A mixture of vermiculite and perlite is used for germinating purposes. An 18–6–12 Osmocote fertilizer of 3–4 month duration is used in the liner mix.

Bach's Greenhouse Cactus Nursery, Tucson (Information courtesy of Dan Bach.) Cactus seedflats, clumpflats and specimen plants are grown in several large greenhouses, the first of which were converted from large chicken houses of a commercial egg farm. The nursery is a wholesale operation (with one retail showroom) where cacti grown by a large number of cactus nurseries in the United States actually first begin life. In the past the mix for flats consisted of 50% peat-moss and 50% sand, with an 18–6–12 Osmocote of 5–6 month duration. This has now been altered to 1/3 peat-moss, 1/3 perlite and 1/3 sand. The previous mix performed well but was modified because of problems in obtaining peat-moss at a cost-effective price. The nursery is well-known for specimen cacti grown in greenhouse beds. The mix for these beds consists of 50% chicken manure and 50% sand, roto-tilled and allowed to rot for six months. The beds retain their fertility for one or two crops (1-2 years) and nutrients are replenished by adding new ingredients to the top and roto-tilling into the previous material.

Arizona-Sonora Desert Museum, Tucson (Information courtesy of Mark Dimmitt.) This institution concentrates on display and educational or research use of plants, animals and minerals of the Sonoran Desert of northern Mexico and adjacent portions of the southwestern United States. Presently a U.C. mix of 50% peat-moss and 50% sand is being used. This is stretched by addition of recycled soil whenever the plant material being grown allows it. A mixture of 50% U.C. mix and 50% pumice or perlite is being tried for cacti and for some other plants that tend to rot away when drainage and aeration are not adequate. *Fouquieria* (Ocotillo) and *Bursera* (Elephant Tree) are grown in a mix of one or two parts silt, one part coarse sand and one part peat-moss. Experiments are planned to compare use of Osmocote and MagAmp fertilizers.

USDA Soil Conservation Service, Tucson Plant Materials Center (Information courtesy of Patrick Williams.) Desert shrubs and grasses are grown for conservation uses in the southwestern United States. Large-scale experiments are conducted under field conditions of a farm. When container-plants are grown, the soil mix consists of 1/3 loam from Pima County, 1/3 washed and screened river sand and 1/3 milled sphagnum moss. One pint of 8–9 month duration Osmocote is added to each cubic yard of soil mix. A mixture of 50% vermiculite and 50% perlite is used for germinating seeds.

University of Arizona, Tucson (Information courtesy of LeMoyne Hogan.) Many different desert plants, principally trees and shrubs, are grown at the Campbell Avenue Farm of the University by the Department of Plant Sciences. The soil mix currently being used consists of 1/4 sandy loam, 1/8 plaster sand, 1/8 composted pine bark, 1/4 perlite and 1/4 vermiculite. Various other mixes are used by professors and students for experimental purposes, for plants with special requirements or for germinating seeds or rooting cuttings.

New Mexico State University, Las Cruces (Information courtesy of Joe Corgan.) For growing cacti and succulents a mix of 40% sand for good drainage and to prevent root rot is used with 20% peat-moss to regulate water retention and availability and 40% soil. A crushed lava rock or scoria is used locally as a desert landscaping mulch and this material is also incorporated into the mix to replace half of the sand when certain species are grown. Perlite is avoided because of its characteristic of floating to the surface and vermiculite is avoided because it tends to compact and make for poor aeration. The plants are watered two or three times a year with a nitrogen fertilizer and no fertilizer is incorporated into the soil mix itself.

New York Botanical Garden, Bronx Park (Information courtesy of Julie Schaller.) Desert plants are displayed in a large glassed-in conservatory and are also grown in auxiliary greenhouse facilities. The beds in the conservatory are high in sand and very quick draining. The formulation is 6 parts sand, 3 parts topsoil and 1 part zoo manure, plus a light sprinkling of lime. Since the Garden is located next to the Bronx Zoo, a never ending supply of manure is available. Plants in containers, including a large number of cacti, are grown in a mixture of 1/3 Terra Green, a material similar to finely chipped fired clay pots, and 2/3 soil. Sand is not used in the mix because that which is available locally tends to compact when added to the soil which is used. To each wheelbarrow of the mix, half of a four-inch pot full of bone meal and two four-inch pots full of limestone are added. The pH is carefully adjusted, partly because of the local water.