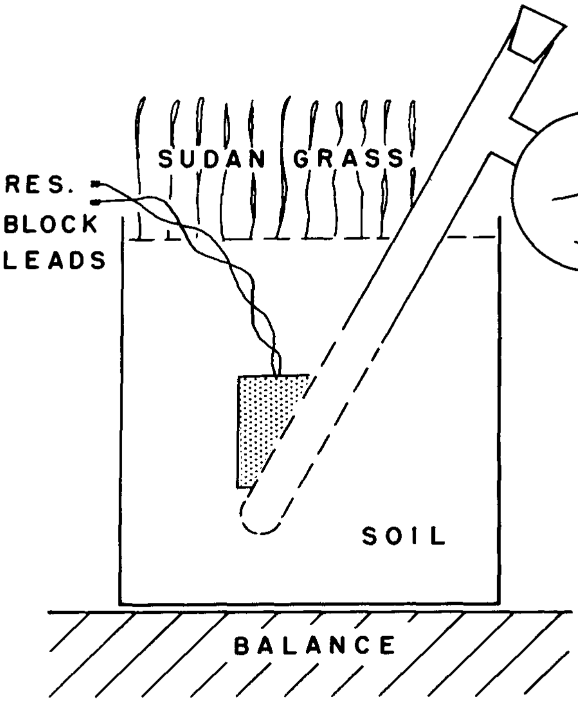
EVALUATING SOII

for improvemen



Schematic drawing of the soil-plant system for measuring soil water release properties.

All of the amendments tested lowered the bulk density and greatly improved the water flow rate through the soil mix, thereby reducing management problems. Wetting agents were found of value in management of soil mixes difficult to re-wet after being depleted of water. Water storage capacity of a soil mix was improved most by the addition of such water-absorbing materials as peat moss, redwood shavings, and vermiculite. Amendments that improved all soil properties, except water storage, included pumice and calcined clay. Only slight increases in water storage were obtained from use of larger wood chips, fir bark, or rice hulls.

Evaluations of various amendments to several soils by two different laboratory and greenhouse methods showed agreement in results but the laboratory method required much more equipment. The greenhouse method could easily be used by anyone interested in evaluating his own soil, and amendments. The only equipment needed is a balance and several small tensiometers. The greenhouse method also allows evaluation of the plant grown to extract the water, for its response to the treatment. The laboratory method offers the possibility of evaluating many more mixes over a shorter period of time, however.

J. E. WARNEKE · S. J. RICHARDS

AMENDMENTS ARE WIDELY USED today to change physical properties of soils so that they will be more suitable for plant growth. They range from chemicals such as gypsum, VAMA, and selected fertilizers to bulky materials such as porous minerals, organic peats, and wood shavings. The need for physical amendments is most evident in the ornamental nurseries where large volumes of soil mix are used daily. Also, large quantities of physical amendments are used in ornamental or recreational areas where substantial amounts of soil are moved for engineering and in new or altered soil areas—especially arid-zone soils with relatively low organic fractions, or weak soil structure.

Management

Any work aimed at amending soils to improve plant response should take into consideration the strong interaction existing between the physical properties of the soil involved and management practices. For example, a soil with a low infiltration rate can be productive (assuming all other factors to be within favorable bounds), if the irrigation application rate is reduced to correspond with the infiltration rate—and the duration of each irrigation is extended to resupply the depth of soil from which water is depleted by root action. More often than not, the use of an amendment can be justified if it results in less exacting management practices. For example, if an amendment increases the amount of water stored for plant use in the rooting depth, then intervals between irrigations may be extended, and irrigation management becomes more flexible.

The objective of this study was to update research reported 10 years ago on the interaction of various amendments and soils. The effects of amendments on soils for given physical properties were determined by laboratory procedures, and by short-duration greenhouse experiments.

Procedure

To determine physical properties relating to water and air transfer in the laboratory, tests were made on bulk soil samples prepared by standardized procedures. Fragmented soil samples were obtained from plow depth, taken to the laboratory, and screened through a 2-mm screen to remove stones and organic debris. When storage was necessary, the soil was air dried. At this point various soil samples were mixed with amendments.

Greenhouse subsamples of the soils and soil mixes were placed in number 10 cans as shown in schematic drawing. A tensiometer was installed at mid-depth, and sudangrass was planted in the soil. The grass was carried through several irrigation cycles to allow roots to develop and the soil to consolidate. When grass was approximately 6 inches in height, regular weighings of the entire system were made, and simultaneous readings of the tensiometer were taken. Water release values were calculated for each of the soils and soil mixes.

Two trials

The entire experiment was conducted in two separate trials. The first trial tested the effect of two physical amendments and one chemical amendment on five different soils. The soils, selected from different areas of California, were: Fallbrook sandy loam, Ramona sandy loam, and Delhi sand (not included in trial 1), Riverside County; San Emigdio sandy loam, Orange County; Oak Glen sandy loam, San Mateo County; and Panoche silty clay loam, Fresno County. The amendments were: redwood, in the form of shavings, from a commercial source; calcined clay, trade name "Turface," from Wyandotte Chemical Corporation; and VAMA, a chemical which forms water-stable soil aggregates. The aggregates formed by VAMA resist compaction, resulting in lower bulk densities and, therefore, higher water infiltration rates.

AMENDMENTS

of soil physical properties

The physical amendments were incorporated into the soil at the rate of 30% amendment to 70% soil on a volume basis. Also, a 50:50 mixture of redwood and calcined clay was incorporated at two rates: 30% and 60% amendment.

Based on the results of the first trial, the second trial was set up to test a wide range of both organic and inorganic physical amendments on three selected soils: Fallbrook, San Emigdio, and Delhi. All of the amendments were incorporated in the soil at a ratio of 1:2 with the resultant mix being one-third amendment by volume. Organic materials included: peat moss, redwood shavings, lignified redwood "Loamite," fir bark wood chips "Forest Humus," "Oak Leaf Mulch," and rice hulls. Inorganic materials and their approximate particle sizes were: perlite, "Perl-lome," (<1/8"); pumice (1/16 to 1/8"), pumice (1/8 to 5/16"), volcanic tuft, "Volcanite," (<1/8"), vermiculite (>1/8"), calcined clay, both "Turface" and "Terra-green" (1/16 to 1/8").

A wetting agent, CS 555, was added to the water in the initial irrigation of separate samples of mixes containing peat moss, redwood shavings, fir bark, and rice hulls. The object was to test the effect of the wetting agent on the property of water release following an irrigation. At the time of irrigation, indicated by a tensiometer reading of greater than 50 cb, one surface inch of water was added to each container of mix. After excess water had drained from the holes in the bottom, each container was weighed to determine the amount of water retained.

Analysis

The densities from the greenhouse samples were calculated after the sudangrass had extracted water for several cycles, and consolidation of the soil mix had stopped. By adjusting the moisture content of the time of compaction, values of bulk density from the laboratory samples were closely related to the soil mix bulk density in the greenhouse containers. VAMA (.0003 gm/gm) reduced the density of all five soils, which would make them easier to manage. Trial 1 results showed that the addition of 30% by volume of redwood shavings, calcined clay, or a 50:50 combination of the two amendments resulted in an average decrease in bulk density for the five soils of 25%, 18%, and 21%, respectively. The addition of a 60% combination of redwood shavings and calcined clay reduced bulk density 42% and nullified the effect of the soil type. This effect also was observed in earlier work, so the addition of 60% amendment was not used in Trial 2. A ratio of 1:2 was used because it would show treatment differences for both soil and amendment.

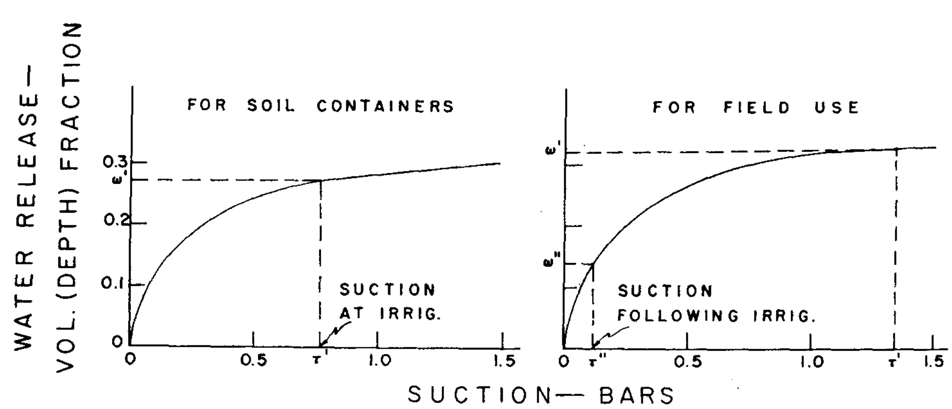
In Trial 2 the reduction in bulk density caused by the addition of one-third amendment by volume averaged 19% for inorganic materials and 25% for organic materials. The large-sized pumice (1/8–5/16") gave somewhat higher densities than small-sized pumice—which resulted in lower water conductivity and less water stored. Both sources of calcined clay, "Terra-green" and "Turface," gave the same results. The rice hulls, with fewer fine particles than other organic materials, produced results between the average for organic and inorganic materials.

If the water flow rate through the laboratory-compacted core is less than 2 cm/hr, it can be predicted that the soil will be difficult to manage. To supply ample water for plants in containers with such soil, water would have to be standing on the surface almost continually, which would promote aeration, salinity, and disease. Four of the five soils in Trial 1 fell into this category with rates less than 2 cm/hr. The most significant benefit derived from adding the chemical amendment VAMA, was improvement in the water flow rate (bringing all soils above 2 cm/hr). In both trials, the addition of the physical amendments resulted in a dramatic increase in hydraulic conductivity.

Modulus of rupture tests (showing strength or hardness of core when dried) are important in landscaping where the soil does dry and crust. In trial 1, the modulus of rupture was reduced 40% by adding 30% calcined clay and 50% by adding 30% redwood shavings, with similar results obtained in trial 2. The VAMA treatment reduced the modulus of rupture an average of 60% in both trials. The Delhi sand and mixes would not hold together when dried, because of their coarseness.

In Trial 2, a comparison was made of the amount of water retained by the four soil mixes (peat moss, redwood shavings, fir bark, and rice hulls) when treated with a wetting agent. The San Emigdio soil mixes indicated problems in wettability. After the addition of 1 surface inch—which was less than the amount needed to replenish the depleted water—the treated San Emigdio soil mix retained 85% and the untreated mix 71%. The Fallbrook and Delhi soil mixes retained nearly 100% of the surface inch under both treatments with and without the wetting agent. Possibly, there would have been larger differences in water re-

EXAMPLES OF WATER RELEASE CURVES FOR COMPUTING IRRIGATION WATER FOR SOIL CONTAINERS, AND FOR FIELD APPLICATION



tention if the mixes had been allowed to dry down in excess of 50 cb soil suction. Water release was calculated from successive weighings and corresponding tensiometer readings and plotted into curves as shown in the graph. The value of water release for 50 cb of soil suction was then extrapolated from the curve and expressed as a volume fraction. For a container 6 inches high, there would be approximately 5 inches of soil mix. To calculate the amount of water to apply, one of the following equations may be used: (1) Irrigation water volume = $\omega' \times$ soil volume; or (2) Irrigation water depth = $\omega' \times$ soil depth.

Average value

An average value of water release (ω') for the mixes of .20 would be multiplied by the 5 inches to obtain 1 surface inch of water required to replenish the water used during the drying cycle. In the first trial, the average value of water release (ω), for 0–50 cb soil suction, was .17 for soil, .18 for calcined clay, and .23 for redwood shavings, indicating the shavings have increased the water storage capacity. It is significant to note the steepness of the water release curve at low suction values. For soil mixes, which have relatively lower densities and correspondingly higher water conductivities than the soil, the curve is even steeper: 60–80% of the 0–50 cb water available was released to the plants by 10 cb. Therefore, it is important to begin irrigations before reaching 50 cb soil suction. The water stored in most mixes generally exceeds 1 surface inch (water release $>$ .20). If the soil mix is dried to a suction of 50 cb, it will require a double irrigation to replenish the water used. The improvement of water stored under low soil suction in the container is a disadvantage when the plant and mix are placed in contact with the soil.

Under field conditions an average soil suction of 5–10 cb exists after drainage has stopped. Therefore, most of the water stored in the mix would drain down through the profile, and water available to the plant would be $\omega' - \omega'' \times$ soil depth (graph). It is important to be aware of this condition when plants are set out so that frequent irrigations will be made until the roots are established in the surrounding soil.

J. E. Warneke is Staff Research Associate, Department of Soil Science; and S. J. Richards is Soil Physicist Emeritus, Department of Agricultural Engineering, University of California, Riverside.

IMPROVED *Pistacia* SEED GERMINATION

Scarification with sulphuric acid speeded up—and increased the percentage of* Pistacia *seeds germinating

J. C. CRANE · H. I. FORDE

THE PISTACHIO NUT TREE (*Pistacia vera*) is propagated by T-budding on seedling rootstocks of *P. atlantica* and *P. terebinthus*. These species are preferred over *P. vera* mainly because they are more resistant to nematodes. Other species of *Pistacia*, such as *P. chinensis* and *P. intergerrima*, have attracted attention from time to time as possible rootstocks for pistachio.

Rapid expansion

Rapid expansion of the pistachio industry in California has brought with it an unprecedented demand for seedling rootstocks. The research described here was undertaken in response to nurserymen and others experiencing difficulty in obtaining rapid germination of high percentages of *Pistacia* seeds, and who requested specific information concerning this aspect of pistachio culture.

The covering of a *Pistacia* seed presents a formidable barrier to growth of the embryo. The seed is surrounded by a bony, indehiscent (except *P. vera*) endocarp which is extremely hard and somewhat resistant to the passage of water. This structure, which is commonly termed "shell" in the pistachio, is known as the "pit" in fruits such as apricot and cherry. With prolonged exposure to moisture, the layer cementing the two halves of the shell softens, permitting their separation. This, in turn, permits the embryo to grow and develop. However, such exposure frequently brings about deterioration and rotting of the seed, which results in a disappointingly low germination percentage and seedling survival rate from a given lot of seed.

With many species, reducing the thickness of the hard seed coverings or otherwise modifying them by mechanical or acid scarification, has improved germination. However, preliminary testing of *Pistacia* seeds in a conventional abrasive scarifier produced disappointing results. Lining the scarifier with two different types of abrasive paper failed to appreciably reduce the thickness of the shells after several hours of operation.

In contrast, the use of sulfuric acid gave highly satisfactory results. Dry *Pistacia* seeds were placed in a glass