on their needs. It might be necessary for growers to have 5 or more watering classifications, as we do, if they are planning to grow a wide range of plant materials.

Large plants, such as Wheeler's dwarf pittosporum, develop canopies which act like umbrellas and make it almost impossible to get water into the container with overhead irrigation. The color of the containers, amount of exposure to sunlight and spacing of the containers also affect the amount of water required. It is possible to alter temperatures by occasional overhead watering during the heat of the day, thus taking advantage of its evaporative cooling effect.

In conclusion, there are many factors and variables that must be considered in soil/air/water relationships. The key is learning to manage these variables to the grower's advantage.

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SOIL ADDITIVES FOR IMPROVEMENT OF WATER RELATIONSHIPS

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Abstract. Soil drainage influences soil color; state of oxidation of iron, manganese, nitrogen, sulfur, and other elements; soil acidity; type and activity of microorganisms, production of certain toxic substances; and soil temperature. Poor drainage of many soils has encouraged consideration of several additives for the improvement of water relationships. Gypsum ($CaSO_4 \cdot 2H_2O$) has been found to be an excellent material for use in maintaining soils in good structural condition and for reclaiming structure in soils where poor structural conditions exist.

Soil Additives: Need. Soil additives come in many different sizes, shapes and forms. For the container grower, vermiculite, perlite, humus, sand, gravel, pine bark, etc. are very much a part of his mix. For many, one or a combination of the above may constitute the entire medium. But what about field grown stock? The above additives will quickly become too expensive for large acreage application.

Under field conditions, soil additives are usually needed to correct soil drainage problems. Soil drainage may be a cause or an effect of chemical, physical and biological properties of soils (3,13).

Precipitation varies considerably from place to place, but the total volume is no guide to the actual amount entering the soil. This is determined by intensity of precipitation, vegetative cover, infiltration, permeability, and slope or relief. Of these factors, infiltration, permeability, and slope or relief are inherent with the soil. If, for example, soil parent material is uniform on a slope, it is possible to find a sequence of soil sites with progressively deteriorating drainage conditions (3,7,8).

Infiltration and permeability may be a function of clay type, percentage of clay, and the percentage and type of cations absorbed on the clay colloids. A soil which contains absorbed sodium, generally in excess of 10% - 20% of the total cations, will have poor structure. Martin, et al. (11) suggest that sodium may be responsible for poor structure when it is present even in very low amounts. The detrimental effect of sodium is due to its high dispersing effect on soil colloids. Some detrimental effects of dispersion include: swelling, reduction in pore space, and increase hydration leading to reduced water infiltration and imbalanced nutrition of plants and soil micro-flora (12).

Soil color is one of the most obvious and easily determined soil properties. It has little direct influence on the functions of the soil, yet one may frequently estimate the degree of natural drainage from this characteristic. The state of oxidation of iron compounds, which is related to soil drainage, largely determines soil color in soils with low organic matter content. Red colors indicate good drainage and are usually due to oxidized and dehydrated iron oxides.

Yellow colors of soils are generally dominant when iron oxides become hydrated. However, if organic matter content is present in sufficient quantity to subdue red or yellow colors, soils with a brownish cast may result.

Gray colors usually occur in soils that are permanently water saturated unless artificially drained. Under these conditions iron is in the ferrous form.

Now that the effects of soil drainage have been established, are additives available that will improve soil water relationships? Many "soil conditioners" are on the market. Some work to a limited degree and some fail to produce any effect.

Gypsum as a Soil Additive. Gypsum is a mineral found in abundant quantities in the earth's crust. Chemically, gypsum

($CaSO_4 \cdot 2H_2O$) is calcium sulfate combined with two molecules of water. It occurs as a sedimentary rock, interbedded in most places with shale, limestone, or dolomite. It is soft and crystalline, with color varying from white to shades of pink, gray, yellow, or brown (3,12).

Gypsum can play a significant role as a clay soil conditioner. In this role, gypsum is used to flocculate the clay colloids. The effectiveness of gypsum is greatest when soil pH is optimum for plant growth.

Arizona Extension Service Bulletin 200 (1), states of gypsum, "this soil corrective is used as a major corrective for poor structural conditions in soils regardless of whether alkali or other causes are responsible. It aggregates or builds the fine soil particles into crumbs. In brief, gypsum is an excellent material both for maintaining soils in good structural condition and for reclaiming structure in soils where poor structural conditions exist."

The cation-exchange capacity (expressed in meq/100g) (7) is known to vary according to clay type, percent clay, and percent organic matter of the soil. Since flocculation is electrokinetic in nature, structural improvement of a soil is greatly influenced by the nature and proportions of cations in the soil.

When gypsum is applied to a soil containing a high concentration of sodium ions, the monovalent sodium ions are replaced by the divalent calcium ions. This results in a considerable reduction in dispersion and swelling due to flocculation of the soil colloids. The flocculation action of gypsum is the first step toward the formation of aggregates and good soil structure. Floccules are stable only as long as either the flocculating agent is present or the floccules are transformed into stable aggregates (2,3,12).

Several factors influence aggregate stability. There is the temporary mechanical binding action of microorganisms, fungi with their mycelia being especially effective. Intermediate products of microbial synthesis and decay, such as microbially produced gums and certain polysaccharides are important as cementing agents. However, most of the long term aggregate stability is by the cementing action of the more resistant stable humus components. Inorganic soil colloids, notably iron oxides, also contribute toward the formation of stable aggregates (2,11).

Marshall (10) states, "gypsum does not need the presence, or absence, of organic material; and, in the correct concentration, will form water-stable crumbs of between 1 mm and 4 mm in diameter, depending on the clay content of the soil. The higher the clay content, the larger the crumbs. In use, however, it must be mixed with the top 2-3 inches of soil and not just scattered on the surface."

CONCLUSION

We have seen that gypsum is effective in the improvement of physico-chemical conditions of soils. However, gypsum will be of little or no value if there is a hard, thick impermeable clay pan, silt layer, or massive rock layer at an appreciable depth below the surface layer causing the poor drainage condition. In such cases, the favorable effect of gypsum may be evidenced where the hard pan or rock layer has been broken mechanically prior to the application of gypsum. Examination of the soil profile characteristics provides the basis for determining the use of gypsum on a particular soil.

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