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# EFFECTS OF ORGANIC AND INORGANIC AMENDMENTS ON THE HYDRAULIC CONDUCTIVITY OF THREE SANDS USED FOR TURFGRASS SOILS*

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Good loam soils used for turf become impermeable under traffic due to their susceptibility to compaction and puddling. Sands have been proposed for turf soils (Lunt, 1956) since they remain permeable when compacted. When sands are used for turf soils, it is universal practice to add organic or inorganic amendments or both though the few experiments reported show little to commend the practice. Many sands are droughty, resilient, and are commonly thought to be sterile. Reasons given for adding amendments include improving water holding capacity, decreasing resiliency, increasing permeability and aeration and "buffering" the soil environment.

With wide differences in physical properties of amendments it is unlikely that all amendments would produce the same effect on a sand or that a given amendment would, produce the same effect on different sands. A particular amendment may beneficially increase water holding capacity of a coarse sand and detrimentally decrease permeability of a fine sand. For those familiar with amendments, the example may seem obvious, yet there is little published data to illustrate the range of differences between amendments or between rates of addition.

We have compared hydraulic conductivities of various compacted sand-amendment mixtures and results are given for three sands amended at 7 rates (0-60 volume %) with each of 10 amendments.

## METHODS AND MATERIALS

Particle size distributions of sands and amendments are given in Table 1. Particle sizes were determined for amendments by dry screening; for sands by wet sieving.

### SANDS

Sands are identified as 1, 2 and 3. All contain unweathered primary rock minerals in addition to quartz. Sands 1 and 3 are river sands, sand 2 is blown beach sand from dunes. They were selected for textural differences. Sand 1 is a fine-medium sand with 89% of its separates in the fine and medium fractions. Sand 2 is a medium-fine sand with 68.3% of separates in the medium sand fraction. Sand 3 is a coarse sand with a wider particle size distribution than sands 1 and 2.

### AMENDMENTS

Trade names are not used and amendments are referred to by code letters based on composition and/or processing.

### ORGANIC AMENDMENTS

Peat moss (PM) : the peat used was a screened, ground, and baled Canadian peat derived primarily from Sphagnum spp. and having a wide particle size distribution. Lignified sawdust (LS) : acidulated sawdust is heat reacted to produce a high lignin product. Fines are removed and residual acidity is partly neutralized by ammonification. Particle size distribution shows a coarse-medium textured material. Rice hulls (RH) : ground rice hulls are heated to destroy pests and lightly amoniated. They provide particles that are mostly in the coarse and medium sand range. Composted bark 1 (CB1) : pine, white fir and red fir barks are composted for an undetermined period to produce a material of wide particle size distribution. Composted bark 2 (CB2) : unspecified bark(s) (probably coniferous) are ammoniated and cornposited not less than 6 months to produce a material of wide particle size distribution.

### INORGANIC AMENDMENTS

Calcined clay-l (CC-l ) : montmorillonite clay is calcined at high temperatures to make porous, mechanically strong particles of mainly very coarse sand-fine gravel texture. Calcined clay-2 (CC-2) : an unspecified mineral is calcined to produce a porous, more or less spherical particle which falls mostly in the textural class of medium sand. Pumicite (P) : a pumice or perlite is industrially processed to produce a light-weight horticultural amendment. While particles were mainly in the very coarse sand range, they were fragile and tended to break down under compacting forces. Pumice (PUM) : this is a naturally occurring pumice with particles mainly of very coarse and coarse sand size. Vermiculite (V) : the material was an industrial chemical grade (No. 1) of expanded mineral. While the particle size consisted mainly of very coarse and coarse sand sizes, particles were readily deformed and compressed by compacting forces.

### PREPARATION

All amendments were wetted by soaking in water for two or three weeks, drained, and stored wet until used. Mixes were made by hand-mixing moistened amendment with moistened sand until thoroughly blended. Zero, 10, 20, 30, 40, 50 and 60% unmixed bulk volume of amend-

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## TABLE 1.
### Particle size distribution of sands and amendments.

| Diameter mm | 2-12.7 | I-2 | 0.5-I | 0.25-0.5 | 0.1-0.25 | 0.05-0.1 | 0.05 |
|---|---|---|---|---|---|---|---|
| TEXTURAL CLASS | Fine Gravel | Very Coarse Sand | Coarse Sand | Medium Sand | Fine Sand | Very Fine Sand | Silt and Clay |
| SANDS | | | | % SEPARATE | | | |
| 1 | 0.0 | 0.4 | 1.8 | 38.6 | 50.3 | 2.9 | 6.0 |
| 2 | 0.0 | 0.3 | 2.3 | 68.3 | 24.6 | 0.9 | 3.6 |
| 3 | 19.9 | 14.2 | 33.4 | 18.2 | 7.2 | 1.8 | 5.3 |
| ORGANIC AMENDMENTS | | | | | | | |
| PM | 15.7 | 16.7 | 24.0 | 24.6 | 14.0 | 3.3 | 2.3 |
| IS | 12.6 | 28.2 | 33.6 | 22.0 | 3.0 | Tr. | Tr. |
| RH | 2.4 | 17.0 | 58.4 | 18.8 | 4.0 | Tr. | Tr. |
| CB-1 | 12.9 | 17.0 | 25.1 | 20.4 | 13.8 | 5.5 | 5.0 |
| CB-2 | 15.6 | 29.2 | 31.2 | 14.8 | 6.4 | 1.4 | 1.4 |
| INORGANIC AMENDMENTS | | | | | | | |
| cc-1 | 31.8x | 48.6 | 16.4 | 2.4 | Tr. | Tr. | Tr. |
| cc-2 | 0.3 | 0.4 | 4.2 | 94.0 | 0.5 | 0.2 | 0.2 |
| PUM | 0.0 | 65.2 | 29.9 | 4.3 | Tr. | Tr. | 0.4 |
| P | 1.6 | 49.4 | 30.4 | 9.0 | 3.6 | 1.0 | 4.6 |
| V | 10.0 | 60.6 | 24.0 | 3.3 | Tr. | Tr. | Tr. |

ment was mixed with sand. For example 10 bulk volumes of peat mixed with 90 bulk volumes of sand is named 10% peat though the mixture was less than 100 volumes.

The prepared mixes were packed by tamping into a polyvinyl-chloride cylinder fitted with a supporting screen on the bottom Cylinder dimensions were: length, 30-5 cm (12 in.) : inside diameter, 10.2 cm (4 in.); wall thickness, 0.64 cm (1⁄4 in.).

### COMPACTION

Compaction was given to simulate that which soil was estimated to receive within one foot of the cup of a golf green during 1-2 days of heavy play. The cylinder containing the mixture was submurged in water for at least 24 hours, then removed and allowed to drain until water ceased to drip from the bottom. Equilibrium occurred in less than 24 hours for all mixes. All mixes were compacted at a tension of 30.5 cm (12 in.). This equals the moisture content immediately after drainage of a soil 30.5 cm thick which is consistent with the tension after drainage of many artificial soils in use. This moisture level agrees with conditons usually found on golf greens.

Compaction was applied by the kneading action of a Soil Test Electra-hydraulic Kneading Compactor, Model CN-425A. The compacting foot has three curved sides of the same radius as the inside of the cylinder but has ca. 1/4 the area. The machine applied 40 1b./sq. in. (2.8 kg/cm2) to the compacting foot for a dwell time of 2 sec. The foot then withdrew, the cylinder rotated 1⁄4 turn and compaction was repeated until a total of 64 compaction strokes had been given, or 16 strokes per unit area. Following compaction, column length of mix varied due to differences in compactability of mixes.

### HYDRAULIC CONDUCTIVITY

The cylinder of campacted soil was submerged in water for not less than 24 hours and until saturation was achieved. Permeation was begun without permitting desaturation. With a head of 1 cm, percolation rate was measured. When it reached a constant, volume flux was divided by the overall gradient across the sample (range 1.03-1.04) to get the hydraulic conductivity, K, in cm/hr. Hydraulic conductivity in this report does not differ essentially from infiltration rate since the compacted surface was limiting.

Results for sands 1, 2 and 3 are illustrated in figs. 1, 2 and 3. For clarity results are broken into four sub-groups. Sub-figs. show results A for amendments, peat moss, lignified sawdust, and rice hulls; B for composted barks 1 and 2; C for calcined clays 1 and 2 and D for pumicites, pumice and vermiculite.

Sand 1 had the lowest conductivity (K= 2.4 cm/hr.) and conductivity was little affected by five of the amendments, but was appreciably reduced by vermiculite which gave a decrease with each addition. Rice hulls caused the greatest increase in conductivity (to 31.5 cm/hr. at 60%). Lignified sawdust increased conductivity steadily to 7 cm/hr., peat moss caused slight increases at 50 and 60%

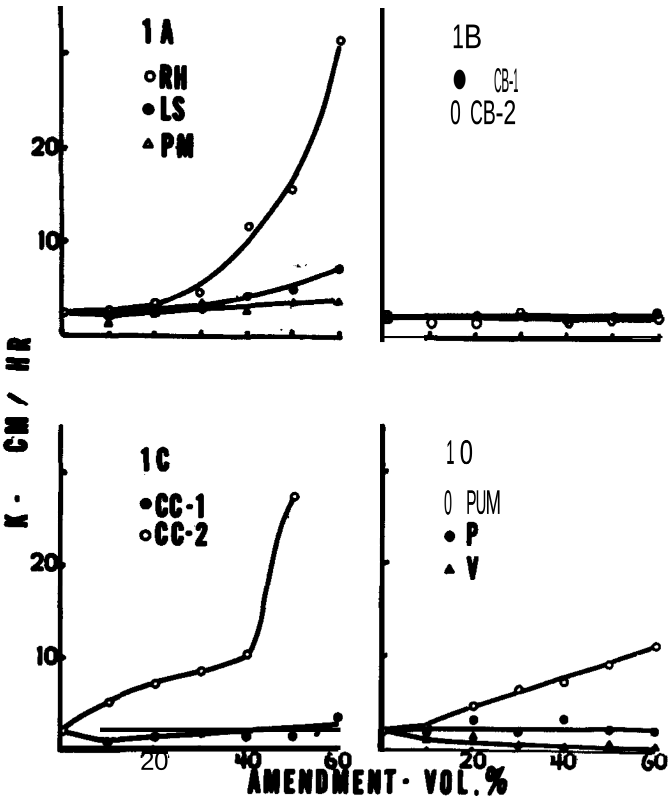


FIG. 1-Hydraulic conductivity of Sand 1 variously amended.

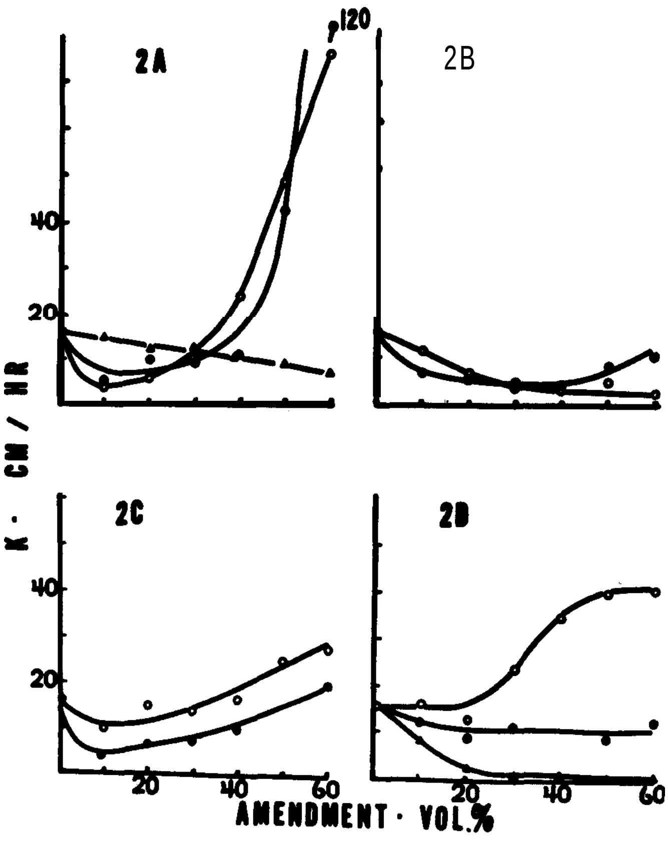


FIG. 2-Hydraulic conductivity of Sand 2 variously amended. Curves are arranged and keyed as in Fig. 1.

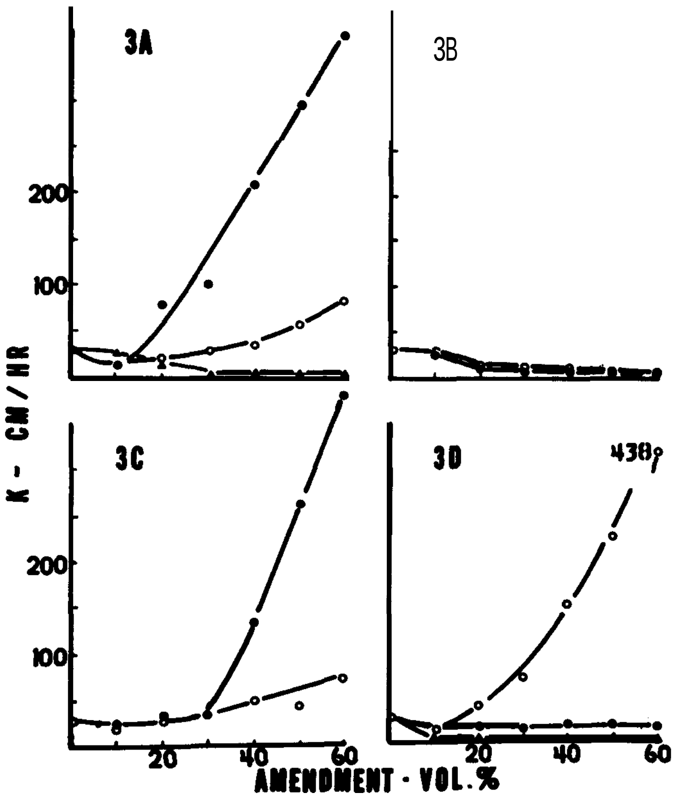


FIG. 3-Hydraulic conductivity of Sand 3 variously amended. Curves are arranged and keyed as in Fig 1.

additions. Calcined clay-l resulted in a slightly lower conductivity except at the 60% rate. Calcined clay-2 resulted in an increasing rate of conductivity. Pumice resulted in increased conductivity but pumicite did not.

Sand 2 had a hydraulic conductivity of 15 cm/hr. This was linearly decreased by additions of peat moss to 7 cm/hr. at 60%. Lignified sawdust and rice hulls responded alike. Additions of 10-30% decreased conductivity but with 50-60%, conductivity rose to high values. Increasing additions of the composted barks tended to decrease conductivity except that the trend was reversed by composted bark-l at 50-60%. Pumice again increased conductivity but only with additions of 30% or more.

Sand 3 had a hydraulic conductivity of 30 cm/hr. This was decreased by additions of five of the amendments (PM, CB1, CB2, P and V) . The remaining five caused increases but only at the higher rates. Three (lignified sawdust, calcined clay-l and pumice) increased conductivity to excessive levels when added above 40%.

Of the amendments, the two with unstable particles (P and V) resulted in decreased conductivity generally. The two composted barks with similar sources and similar particle sizes, behaved very similarly. Of interest are the calcined clays. These provided hard stable grains with different particle size ranges which when mixed with the sands produced new particle size distributions. With sand 1, calcined clay-2 resulted in a narrower particle size distribution and an increase in conductivity, while calcined clay-l resulted in a wider particle size distribution and decreased conductvity except at the 60% rate. With sand 3, both calcined clays-l and 2 widened the distribution at low rates and narrowed it at the higher rates. But calcined clay-l resulted in a narrow range of larger particles and conductivity was very much higher.

Curves from figs. 1-3 have been generalized into the 6 curves of fig. 4. Table 2 lists the type of curve produced

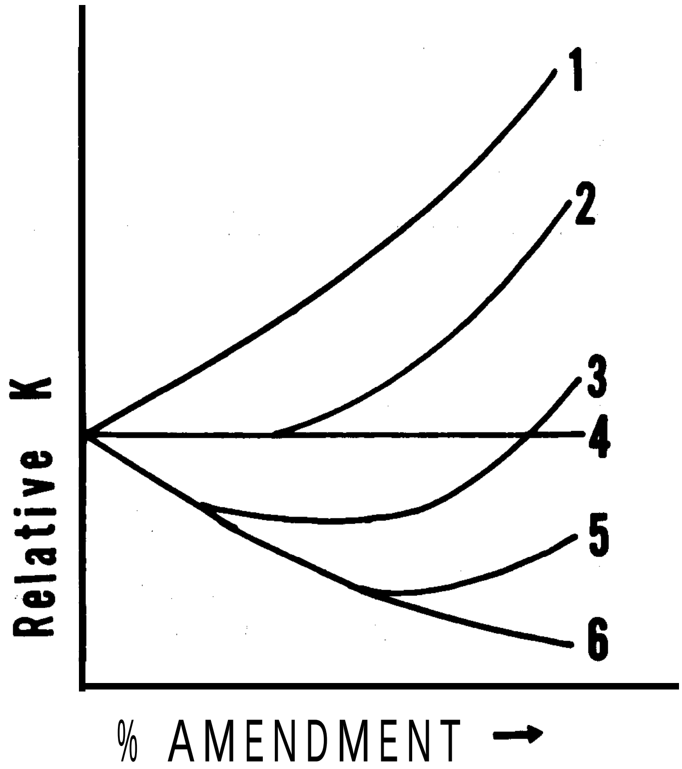


**FIG. 4-Effect of amendments on hydraulic conductivity of sand showing six generalized response curves. K values are relative to the sand under study.**

by each amendment in each sand . From the classification of amendments, we see there is no single kind of response produced by the same amendmnt in all three sands except for vermiculite.

DISCUSSION

The results reported show different amendments causing widely different effects on hydraulic conductivity in sands. If particle packing following amendment mixing, results in an increase of larger pores, one would expect increased hydraulic conductivity. Conversely, if the percentage of small pores is increased one would anticipate reduced conductivity.

In sands or other systems of rigid, solid particles pore geometry determines permeability and is related to particle size distribution. In systems made of a mixture of rigid and deformable particles, hydraulic conductivity is sensitive to stress history (compaction) and thus it is difficult to predict effects of mixtures on permeability since the pore geometry is more complex than in simpler systems mixed from non-deformable particles.

As an example, additions of pumice, which had a narrow particle size distribution of a strong particle, increased hydraulic conductivity in all three sands whereas addition of pumice having a weak particle that shattered into fine grains under compacting forces, decreased conductivity in these sands. Among the organic amendments lignified sawdust had a particle size distributon very similar to composted bark-2. Processes used to make lignified sawdust resulted in a particle of high integrity. In all sands lignified sawdust at higher rates increased hydraulic conductivity whereas composted bark-2 did not increase conductivity in any sand at any rate. The long recognized collapse of vermiculite under compaction results in platelets which are effective in blocking large pores. This is illustrated by the data; every rate of amendment with vermiculite in every sand resulted in decreased hydraulic conductivity. Peat moss is an organic material which similarly produces platelets and similarly decreased hydraulic conductivity except in Sand 1 where there were some small increases.

In practice adding amendments to sands used to build golf greens, athletic fields, etc., needs to be done on the basis of goals and of laboratory evaluations. Hydraulic conductivity is only one physical property used in evaluating a soil mix. Other properties such as available moisture, moisture release characteristics and air filled porosity also need consideration for a full evaluation. Goals may include increased water availability in coarse sands, increased or decreased hydraulic conductivity, increased air filled porosity, reduced resilience and others. In terms of fig. 4, if the goal were to increase hydraulic conduc-

**TABLE 2.**

**Classification of amendments based on response curve shown in Fig. 4.**

| Type of K-% amendment curve (Fig. 4) | Sand 1. | Sand 2. | Sand 3. |
|---|---|---|---|
| 1 | RH, IS, CC-2 | | |
| 2 | PM, PUM | PUM | CC-l, CC-2 |
| 3 | CC-1 | LS, RH, CC-l, CC-2 | LS, RH, PUM |
| 4 | CB-1, CB-2, P | | |
| 5 | | CB-1 | |
| 6 | V | V, P, PM, CB-2 | V, P, PM CB-1 CB-2 |

tivity an amendment would be selected that produced a type 1 curve with the sand used. If the sand had a high hydraulic conductivity and low available water one would look for a material that increased available water and had a type 3, 4, 5 or 6 curve. At the present state of knowledge, no approach to amending sands should omit laboratory evaluation of mixes.

SUMMARY OF DISCUSSION

Effects on the hydraulic conductivity of stable particles of known particle size distribution added to sand may be anticipated in a general qualitative way. When particles are deformed or broken by compacting forces, results of additions on conductivity cannot be anticipated. Often, notable effects of additions are seen only when additions exceed ca. 40% by volume. Where amendments are needed to change physical characteristics of a sand, amounts and kinds of amendments should be selected on the basis of laboratory tests.

ACKNOWLEDGMENT

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REFERENCE

Lunt, O. R., 1956. A method of minimizing compaction in putting greens. S. Calif. Turfg. Cult. 6( 3) :1.

# CONTROL OF BILLBUGS ON TURF

***F. S. Morishita[1], W. Humphrey[2], L. C. Johnston[3], and R. N. Jefferson[1]***

The Hunting billbug, *Sphenophorus venatus vestitus* Chittenden, has been intercepted on *Zoysia* and Centipede grasses shipped in from Georgia and other southeastern states for many years. On July 30, 1968, a medium infestation was discovered on a golf course in Ontario, San Bernardino County, by Mr. Gene Harper, Deputy Agricultural Commissioner. The specimens were identified by the taxonomy departments of the California Bureau of Entomology and the U.S. National Museum.

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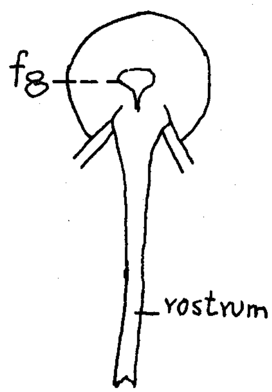
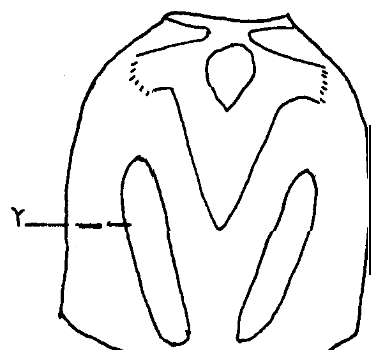
Front of head (Fig. A) with a frontal groove (fg) in the form of a rough arrowhead and with groove completely clothed with tan-colored scales: raised ridges (r) on top of prothorax (Fig. B) usually not joined to form a letter "M"------- Sphenophorus venatus vestitus

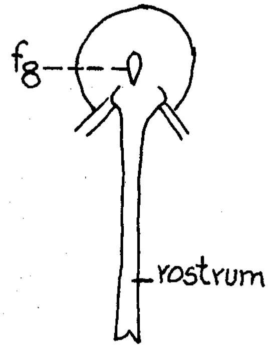



A. S. venatus Front of head.

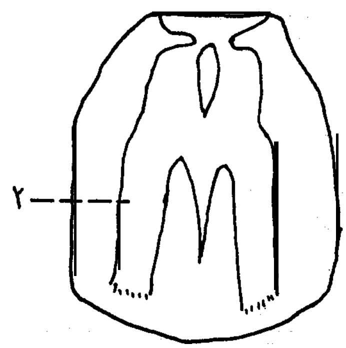



B. S. venatus. Top of prothorax.

Front of head (Fig. C) with a frontal groove (fg) oval-shaped and often pointed at the lower end, but not expanded laterally to form an arrowhead, and groove not clothed with scales: raised ridges (r) on top of prothorax (Fig. D) usually joined to form a letter "M" ----Sphenophorus phoeniciensis




C . S. phoeniciensis. Front of head.




D. S. phoeniciensis 'Top of prothorax.

Though it has been reported in the literature as being a pest of various types of grasses (Zoysia, centipede, Kikuyu and bermuda grasses), this insect has been found only on hybrid bermudagrasses in southern California. The damage caused in this area is hardly discernible unless the grasses are under some sort of stress.

The Hunting billbug is very similar to the Phoenix billbug, which has been established in southern California for many years and is the most prevalent one. The following diagram, prepared by F. L. Blanc and T. Freeman, will enable the field entomologist to make a tentative separation (with hand lens) and was taken from a communique from the California Department of Agriculture Bureau of Entomology dated November 29, 1968.

Adult billbugs and larvae have been collected throughout the year. From these observations, it appears as if there is continuous or overlapping generations. The size of the adults varied from small in the colder months to large in the summer months.

Chemical control of the Phoenix billbug was evaluated in Orange County in 1969. Table 1 shows the results of the test and all but two of the eight materials were effective. These materials were all in granular form and applied with a fertilizer applicator at ten pounds of active ingredient per acre. Counts were taken two months after application. To make the counts, a sod cutter was used to cut a strip the length of the plots, and two samples (15" square) from each strip were taken at random. These squares were beaten and screened for the insects.

A location with a fairly high population of the Hunting billbug was located in Los Angeles County in 1970. Seven materials were applied with Bean pump at 200 psi and a #8006 Spraying System nozzle. The amount of water used was 500 gallons per acre and the rate was five pounds of active ingredient per acre. Five of the seven materials applied gave satisfactory control (Table 2). Counts were taken as described above.

Tests indicate that granular formulations of insecticides can be used effectively as well as the sprays applied with a power sprayer. It is important to note that with spraying it is imperative to use an adequate amount of water with the insecticides. In the tests 500 gallons of finished spray per acre was used as any amount less than this would not have permitted the insecticides to be carried down to the zone where the larva were found. In the 1969 test the turf was watered heavily after the application of the granules.

From the results of the tests, it appears that these two insects have become tolerant to the chlorinated hydrocarbons. Also, reports that some of the materials used in these tests have not given adequate or satisfactory control may be due to the fact that the dosage was marginal or not enough water was used to place the materials where the larva were located. For maximum efficiency the thatch should be removed and the grass aerated before insecticides are applied.

**TABLE I.-Control of the Phoenix billbug on Tifdwarf bermudagrass, Orange County; treated June 10, 1969, at 10 lbs. of active ingredient per acre; counts made August 5, 1969.**

| Material[1] | Total number alive[2] | |
|---|---|---|
| | Larvae | Adults |
| Dasmit | 0 | 3 |
| Akton | 0 | 7 |
| Landrin | 0 | 3 |
| Dyfonate | 0 | 0 |
| Lannate | 68 | 4 |
| Luradan | 0 | 0 |
| Diazinon | 0 | 5 |
| Heptachlor | 74 | 7 |
| Control | 82 | 6 |

[1]Applied as granules

[2]2 replications, 2 samples per replicate

**TABLE 2.-Control of the Hunting billbug on Tifgreen bermudagrass, Los Angeles County; treated April 15, 1970, at 5 lbs. of actrve ingredient per acre; counts made June 24, 1970.**

| Material[1] | Total number alive[2] | |
|---|---|---|
| | Larvae | Adults |
| Diazinon | 0 | 2 |
| Dursban | 1 | 8 |
| Alston | 5 | 13 |
| Biothion | 11 | 22 |
| Sevin | 1 | 6 |
| NC6897 | 0 | 9 |
| Aldrin | 27 | 19 |
| Control | 18 | 46 |

[1]Applied as sprays

[2]3 replications, 2 samples per replicate

# COLORADO RIVER WATER-IT'S BETTER THAN YOU THINK

*by Roy L. Branson* [1]

From time to time articles are written about Colorado River water and often they are highly critical of its quality. As a result of these derogatory comments, Colorado River water has developed a reputation in some circles as being a highly saline water quite hazardous to use for irrigation. Let's examine the facts and I think you will conclude that this valuable water resource in Southern California has been unjustly slandered. One of tht best ways to get an accurate picture of the quality of Colorado River water is to look at the results of those who use it. Growers of a wide range of crops in Southern California depend on this source of water for their livelihood. Their experiences show that it can be used very successfully for irrigation of even the most salt-sensitive of plants. Examples of such plants are strawberries and avocados, both of which are much more sensitive to soil salinity than are turfgrasses. Even the most sensitive turfgrasses, Kentucky bluegrass and Highland bentgrass, can tolerate double the soil salinity that strawberries and avocados are able to withstand.

Citrus has a salt tolerance more like that of the sensitive turfgrasses. Is there great concern about the salinity hazard of Colorado River water for irrigation of citrus? Not really. Many orchards are irrigated with it without any bad effects. We should expect to get as good or better results when this source of water is used on turfgrass. The reason we might expect to get even better results on turfgrass is that many kinds of turfgrass grown in Southern California have a salt tolerance considerably greater than does citrus, almost 100% greater in the case of alta fescue, for example, and several hundred percent greater in the case of the bermudagrasses.

If Colorado River water is all this good, then why all the slanderous remarks to the contrary-remarks which are not consistent with grower experience? Most of these remarks can probably be traced to the USDA system in common use for classification of irrigation waters. This system tends to downgrade the quality of Colorado River water more than is justified based on experiences mentioned above. According to this system, Colorado River water is classified as follows:

"High salinity water. Cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected."

Recently the University of California Agricultural Extension Service modified the USDA system of water quality classification to bring it more in line with grower experience. The table below shows the modified system now in use by the Agricultural Extension Service.

According to the classification system of the Extension Service, Colorado River water, whose electrical conduc-

| (Millimhos) Salt in Water | Salinity Hazard |
|---|---|
| Below 0.75 | Low |
| 0.75 - 1.5 | Medium |
| 1.5 - 3.0 | High |
| Above 3.0 | Very High |

tivity is approximately 1 millimho (or about 700 parts per million), would fall at the lower end of the medium salinity category. Thus, the modfied classification system changes the salt hazard of Colorado River water from high to medium. This means that if Colorado River water is used with average management skill and on soils with reasonably good drainage, one can expect not to have a salinity problem in growing turfgrass of any variety-even the most salt sensitive. If a salinity problem does develop in using this water, it indicates that water management and/or soil conditions are not up to par and as a result insufficient water is moving through the soil past the root zone. To eliminate a problem of this nature, the cause of the inadequate leaching should be determined and corrected. First, look into the quantity of water used. If this appears to be normal, then check the following which can cause excessive runoff and thereby increase the possibility of salinity developing: thatch and compaction.

Despite good intentions, it may not always be possible to correct soil conditions which cause salt accumulation. Difficult soils or limited budgets may make it necessary to live with some salt build-up. Fortunately this can be done with turfgrasses far more easily than with many other types of plants. If the soil becomes too saline for one kind of turfgrass, others of higher salt tolerance may be planted. Turfgrasses are rather unique in the plant world in having such a wide range of salt tolerance thereby providing many choices for difficult situations.

Where salinity is marginal and cannot be eliminated, another helpful practice is more frequent irrigation. This keeps the soil solution less concentrated than it would be if irrigation were less frequent.

So far, this discussion of salts has dealt with the mixture of various kinds of salts normally present in irrigation water and soil, i.e. calcium, magnesium, sodium, chloride, sulfate, etc. In some irrigation waters the sodium needs to be considered separately for excess sodium can cause a special problem with soils. It causes the aggregates of fine particles to disintegrate. This clogs soil pores making it difficult for water and oxygen to get into the soil in sufficient amounts. Addition of gypsum is the common corrective treatment.

Natural Colorado River water has a very low sodium hazard. No sodium problem is likely to occur from use of this water because it contains, among its dissolved salts, an appreciable amount of gypsum. Some irrigation waters in California have a gypsum requirement to reduce the sodium hazard. Colorado River water on the other

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hand already contains the gypsum necessary for prevention of a sodium problem.

Some Colorado River water distributed in Southern California is softened at the facilities of the Metropolitan Water District, (MWD) . To make the water more suitable for domestic and industrial use, the softening treatment removes or reduces the dissolved substances which make water hard, causing the formation of boiler scale, deposits in pipes, soap curds, "tattletale gray," and the familiar "ring around the tub." The softening process removes some calcium and magnesium and substitutes sodium in their place. If carried to extreme (as occurs in home water softeners),. this, process can produce water with a high sodium hazard. Stringent controls in the MWD's softening operation prevent this from happening. Therefore, MWD-softened Colorado River water has a sodium hazard low enough to be satisfactory for irrigating turfgrasses without having to resort to any corrective treatment.

Concerning the future, all indications are that the salt content of Colorado River water will gradually increase. Eventually, it may become a high-salt-hazard water but presently it is not. Until it deserves a bad reputation, shouldn't we criticize it less and appreciate it more?

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