CANDELILLA/PETROLEUM WAX MIXTURES FOR TREATING SOILS FOR WATER HARVESTING [1/] [2/]

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Abstract

A vegetable wax (candelilla), alone or in combination with petroleum waxes, was evaluated for treating soils for water harvesting. Samples were alternately weathered in a freeze-thaw cycle chamber, tested for water repellency and structural stability against water erosion, then subjected to more weathering, etc., until sample failure occurred. Soils treated with candelilla/paraffin wax mixtures were much more resistant to laboratory freeze-thaw cycle weathering than those soils treated with either of the waxes alone. Weatherability was further improved, and wax requirement reduced by (1) prior stabilization of the soil with cellulose xanthate made from chemically pulped waste paper; (2) incorporating 2% of a commercial antistripping agent into the wax; and (3) substituting a residual type petroleum wax for the paraffin in the wax mixtures.

Introduction

Paraffin wax has become accepted as a water harvesting treatment (Fink et al, 1973, 1980). Wax treated catchments currently are being used to supply water for livestock and wildlife (Cooley et al, 1978), and for various runoff farming purposes (Cluff, 1978; Schreiber and Frasier, 1978; and Fink and Ehrler, 1981).

Paraffin wax, when melted into soil, creates a water-repellent, but porous soil surface which readily sheds rainfall. Runoff efficiencies (efficiency = runoff/rainfall) for this water harvesting treatment are high, normally ranging from 70 to 90 percent. The wax treatment should be applicable to most hot, arid, and semiarid areas of the world provided certain soil property and site requirements are met (Frasier et al, 1979; Fink et al, 1980).

Most of the arid and semiarid regions of the world are located in so-called "developing countries". These countries desperately need the water that water harvesting can supply; unfortunately, few of them have the capital needed to import such "nonessentials" as wax. Water harvesting for them is restricted to simple land shaping and smoothing treatments which usually have a low runoff efficiency. Equally as undesirable, they produce no runoff at all from most small and medium size storms. Such small storms can constitute a half, or more, of the total rainfall events and the total yearly precipitation. Highly efficient, low cost, water-harvesting treatments are desperately needed.

While most developing countries lack sufficient capital to purchase petroleum base waxes, many have ready sources of natural vegetable waxes from indigenous xerophilous plants. In fact, some countries are already harvesting and processing vegetable waxes for export. Surpluses often develop, driving wax prices down drastically. At times it might be economically justifiable to use vegetable waxes for water harvesting — in essence, to trade wax for water.

Will vegetable waxes work for water harvesting? Vegetable waxes differ structurally from paraffin waxes. The vegetable waxes are esters of long chain fatty acids and alcohols; thus they contain both hydrophobic and hydrophilic groups in the molecule. In contrast, paraffin waxes, are simple straight, or slightly branched, alkanes. They have no electronegative atoms, like oxygen or nitrogen, in the molecules. "Residual" petroleum waxes are more structurally complicated and more diverse than paraffin. They generally contain more branching, unsaturation, cyclic and polar groups, and oils. Since laboratory studies (Fink, 1977) and preliminary field tests indicate that these residual waxes can be used successfully to treat soils for water harvesting, it seems reasonable that the vegetable waxes also should work for this purpose. Possibly too, these vegetable waxes could serve as diluents to reduce the need for petroleum waxes. Both of these techniques for substituting locally produced natural waxes for imported petroleum waxes would reduce the capital requirement and lessen the outflow of currency.

The objective of this laboratory study was to evaluate the feasibility of using a vegetable wax (candelilla), alone or in combination with petroleum waxes, to create water-repellent soils for water harvesting. A soil stabilizer and an antistripping agent also were evaluated to increase the weatherability and longevity of the candelilla treatment, while simultaneously reducing both application rate and material cost.

Materials and Methods

Two soils were selected for the laboratory study: Tremant gravely, sandy loam from our water harvesting field location, near Mesa, Arizona; and Pachappa, a loam from Riverside, California.

One hundred fifty grams of air dried soil (less than 2 mm fraction) were placed into 9-cm diameter petri dishes, leveled, uniformly wetted and packed, and air dried (Fink, 1976).

In Phase I of the study, candelilla wax and refined paraffin (128-131 AMP) mixtures (100, 50, 25 and 0 percent candelilla) were melted together and brushed onto the compacted soil surfaces. Application rates were 0.5, 1.0, and 2.0 kg/m^2. The coatings were melted into the soil using heat lamps. The glass, soil edges were sealed with a paraffin-petroleum jelly mixture to prevent water wicking. Treatments were duplicated.

The testing, weathering sequence is outlined in Figure 1. The candelilla/paraffin treated samples were tested initially for water repellency using the 4-hr-hydration test, in which an approximately 3-cm diameter water drop must stand on the soil surface for 4 hours, and were tested for structural stability by brushing vigorously with a stiff bristled brush (Fink, 1976). One sample set was then weathered in a freeze-thaw chamber which cycled 7 to 9 times per day between +20 C and -20 C. An approximately 3-cm diameter water drop was centrally placed atop the samples to further accelerate structural breakdown. The other sample set was weathered in a 100% relative-humidity chamber at room temperature. A large (3-cm diameter) water-drop also was placed on these samples.

All samples were tested for erodibility after a day in the respective weathering chambers. Erodibility was evaluated with a dripolator (Fink, 1976) in which 1,000 water drops (5-mm-diameter) fell 2 m onto the center of the samples in 5 minutes. The degree of erosion was estimated as none (N), moderate (M) for pitting to 3 mm deep, severe (S) for pitting from 3 mm through the treated soil zone, and failure (F) for pitting to the bottom of the dish. Once the treated zone is breached using the dripolator, erosion through the untreated soil portion occurs almost instantaneously.

After each dripolator test, the samples were air dried and placed back in their respective weathering chambers. This process of weathering, followed by erosion testing was continued until a sample either failed or withstood 300 minutes under the dripolator (60 testing cycles and approximately 500 freeze-thaw cycles for the Phase I samples). Samples also were checked for cracking after each testing cycle.

In Phase II of the study, Tremant soil samples were prepared, as in Phase I, through the air drying stage. The air-dried samples were then stabilized using cellulose xanthate prepared from chemically pulped waste paper according to the method of Menefee and Hautala, 1978. The xanthate (0.4% by weight of paper solubilized in water) was sprayed onto the soil at 1.5 l/m^2, and was allowed to air dry and reconstitute into insoluble cellulose.

For Phase II, candelilla/Chevron unrefined wax 140 (140 slack wax) mixtures containing 2% by weight of the antistripping agent Trymeen 6639 from Emery Industries, Inc., were melted together and brushed onto the soil surfaces. The candelilla/140 slack wax mixtures (100, 90, 75, 50, 25, 10 and 0 percent candelilla) were applied to the soil at three rates: 0.25, 0.5, and 1.0 kg/m^2. Other preparation procedures were the same as in Phase I.

For initial water-repellency evaluation, the Phase II samples also were given the initial 4-hr-hydration test (Figure 1). For evaluation of initial structural stability, samples were subjected to 5 minutes under a water-jetting erosion apparatus, which jets a 1-mm diameter stream of water, at 34.5 kpa (5 PSI), 6 cm, onto the center of the treated soil surface. The jetting device was similar to that used by Morrison and Simmons, 1977, except that our petri dishes were set at a 15-degree angle to facilitate water drainage away from the impact point, rather than dropping the water vertically onto the samples. The nozzles were adjusted to deliver the water normal to and at the center of the soil surface. The erosive force of the water-jetting device was considerably greater than that of the dripolator used in Phase I. Degree of erosion in Phase II was expressed by N, M, S or F as in Phase I.

Weathering tests were imposed on the samples following these initial tests for water repellency and structural stability. After a day of freeze-thaw treatment, the samples were tested first for structural stability with the jetting device, followed by testing again for water repellency with the 4-hr-hydration test. Samples which passed these two tests were recycled into the freeze-thaw chamber. This process was repeated until a sample failed either test or lasted 200 minutes under the jetting device (39 weathering/testing loops). These samples also were checked daily for cracks.

Results and Discussion

Phase I: All but two samples passed the initial 4-hr-hydration test and the initial stiff brushing. The two failures were duplicates of the low rate (0.5 kg/m^2) of 100% candelilla wax on Tremant soil. Both samples adsorbed water and swelled during the initial 4-hr-hydration test, then cracked and lost structural stability during subsequent air drying. The loosened soil was easily removed by the brushing. These two samples were removed from further testing.

The remaining samples were split into two groups with one set going into the freeze-thaw chamber and the other into the hydration chamber, to begin the testing sequences as outlined in Figure 1. We determined that a water-repellent treated soil should withstand a minimum of about 100 minutes under the dripolator. This would represent about 150 freeze-thaw cycles for that weathering mode, which would be equivalent to about 10 years of such weathering even in the worst freeze-thaw cycle areas of the southwest, provided that one considers only those disruptive cycles where standing water is apt to be present. Dry soil is not damaged by freeze-thaw cycling. Samples which survived the full 300 minutes beneath the dripolator were extremely resistant to both water erosion and the weathering mode imposed, thus should be excellent soil treatments for water harvesting.

In general, weatherability improved with increasing wax application rate (Table 1). This is reasonable in that the wax served both as the water repellent and the soil stabilizer. Theoretically, at least, it takes only a monolayer of wax to mask the hydrophilic properties of soil. Attaining soil stability, however, is more difficult. Wax forms only the very weak van der Waals forces for both adhesive and cohesive bonding. Water, which adsorbs strongly to most soil surfaces, can easily strip away a thin wax layer. Also, the erosive force of water drops can readily break the wax/soil or wax/wax bonds. Applying multi-layers of wax helps to waterproof the soil surfaces from water-film penetration and adds structural strength against mechanical disruption.

Candelilla wax alone does not adequately treat Tremant soil, regardless whether the weathering is by freeze-thaw cycling or by simple continuous hydration (Table 1). Pachappa soil, on the other hand, can be adequately treated with candelilla, provided at least 1.0 kg/m^2 is applied.

Also, paraffin wax itself is not a good soil treatment if freeze-thaw cycling occurs. If hydration is the major weathering element, then paraffin should provide an adequate treatment on Pachappa, but not on Tremant soil. We know, however, from field testing that the paraffin water-harvesting treatment on Tremant type soil will last 8 or more years before needing retreatment (Fink et al, 1980). On this basis it appears that our laboratory requirements for recommended and acceptable treatments are stringent indeed.

Candelilla/paraffin wax mixtures were more resistent to weathering than was either wax alone (Table 1). On Pachappa soil an adequate treatment could be attained using only 0.5 kg/m^2 of either of the two mixtures tested, regardless of the weathering mode imposed. On Tremant soil the 50/50 mixture was acceptable (92 min) at the low 0.5 kg/m^2 rate, provided hydration was the primary weathering mode. Increasing the rate to 1.0 kg/m^2 (either mixture) provided added insurance. If freeze-thaw cycling was a factor with Tremant type soil one would need to apply at least 1.0 kg/m^2 of the 25/75 candelilla/ paraffin mixture.

Previous studies (Fink, 1976; 1977) have shown that other water-repellent chemical mixtures applied to soils weather better than when the components are used individually. For example, a paraffin treated Tremant soil withstood only four freeze-thaw cycles, and a dust suppressant oil treatment withstood over 250 cycles; but a treatment of 45% dust suppressant oil in paraffin withstood over 650 freeze-thaw cycles. Also, the paraffin in the mixture improved the resistance of the dust suppressant oil to degradation by ultraviolet radiation.

Several things are clearly evident from Table 1: (1) treated Pachappa soil withstood considerably more weathering than the Tremant soil; (2) freeze-thaw cycling was more destructive than simple hydration weathering; (3) weatherability improved with increased wax application rate; (4) mixtures of candelilla and paraffin waxes were more weather resistant than either wax alone; (5) Tremant soil was much more subject to cracking than Pachappa.

Phase II: All the samples passed the initial 4-hr-hydration and water jetting erosion tests, and then were subjected to the freeze-thaw weathering, water jetting, and 4-hr-hydration evaluation sequence (Figure 1). Results are expressed either as minutes under the jetting device for samples which failed in less than 200 minutes, or as degree of erosion for samples which survived the full 200 minutes of water jetting (Table 2).

As in Phase I, the 100% candelilla wax soil treatment quickly failed under freeze-thaw cycle weathering. This rapid failure occurred in spite of the soil-prestabilization treatment and the addition of 2% 6639 antistrip to the wax. However, adding only 10% of the 140 slack wax to the candelilla improved freeze-thaw weatherability 10 times, and brought it to acceptable levels (i.e., samples survived at least 100 minutes under the water jet). Even the low 0.25 kg/m^2 wax rate treatment survived 150 minutes.

Adding only 25% of 140 slack wax to candelilla increased weatherability to the maximum of the test (200 minutes under the jetting). Further increases in the proportion of slack wax brought no additional improvement in weathering resistance as judged by this test.

The cracking problem decreased as the proportion of slack wax increased (Table 2). Most treatments with the 100% and 90% candelilla mixtures cracked early in the weathering/testing sequence. Several of the 75% candelilla mixtures also cracked, but none cracked before 100 minutes of jetting. Cracking on wax-treated operational catchments has been suggested as a causal factor in reduction of runoff efficiency (Frasier et al, 1979), but there is no confirming evidence.

Conclusion

These laboratory findings suggest that candelilla wax can be used for treating soil for water harvesting, provided that the wax is mixed with at least 10 to 25 percent of petroleum base wax. Soil samples treated with as little as 0.25 kg/m^2 of such mixtures successfully withstood the laboratory weathering imposed on them, only when the soil had been first stabilized with a cellulose xanthate solution and when an antistripping agent was added to the wax mixture. Evaluation of other natural plant and animal lipids for water harvesting is warranted, as are field evaluations to assure the applicability of these laboratory findings to operational systems.

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Endnotes

1/ Contribution from the Science and Education Administration, U. S. Department of Agriculture.

2/ Trade names and company names are included for the benefit of the reader and do not imply any endorsement or preferential treatment of the product listed by the U. S. Department of Agriculture.

Table 1. Sample survival time (or degree of erosion after 300 minutes) with the dripolator, of two soils treated with candelilla/paraffin wax blends (Ca/Pa), and subjected to weathering by either freeze-thaw cycling or continuous hydration. 1/

		Weathering Mode					
		Freeze/Thaw			Hydration		
		Wax Application Rate (kg/m^2)					
Soil	Ca/Pa	0.5	1.0	2.0	0.5	1.0	2.0
		min					
Pachappa	100/0	75*	M	M	10	S	S
	50/50	M	M	M*	M	N	N*
	25/75	M	M	N	N	N	N
	0/100	30	40	-	125	175	-
Tremant	100/0	0	9*	13*	0	10*	64*
	50/50	20	70	119*	92*	S*	S*
	25/75	53	94	139*	70*	262*	S*
	0/100	15	20*	50	15*	45*	-

1/ Results are expressed either as actual survival time (in minutes) beneath the dripolator for those samples which failed during the testing process, or else as the final degree of surface erosion (N = none; M = moderate (<3 mm); S = severe (>3 mm); for those samples which survived the full 300 minutes beneath the dripolator. Samples which survived more than 200 minutes beneath the dripolator are blocked within solid lines; those which survived 90 to 200 minutes are blocked within dashed lines.

* Soil sample cracked during evaluation.

Table 2. Sample survival time (or degree of erosion after 200 minutes) with the water-jetting device of prestabilized Tremant soil treated with candelilla/slack wax (Ca/140) blends containing 2% antistripping compound, and subjected to freeze-thaw cycle weathering. 1/

	Wax Application Rate (kg/m^2)		
Ca/140	0.25	0.5	1.0
	min		
100/0	15*	25*	16
90/10	150*	S*	173*
75/25	M*	S*	M*
50/50	N	M	N
25/75	N	M	S
10/90	N	M	N
0/100	S	M	N

1/ Results are expressed either as actual survival time (in minutes) beneath the water-jetting device for those samples which failed during the testing process, or else as the final degree of surface erosion (N = none; M = moderate (<3 mm); S = severe (>3 mm) for those samples which survived the full 200 minutes beneath the jetting device. Samples which survived the full 200 minutes are blocked within solid lines; those which survived 100 to 200 minutes are blocked within dashed lines.

* Soil sample cracked during evaluation.

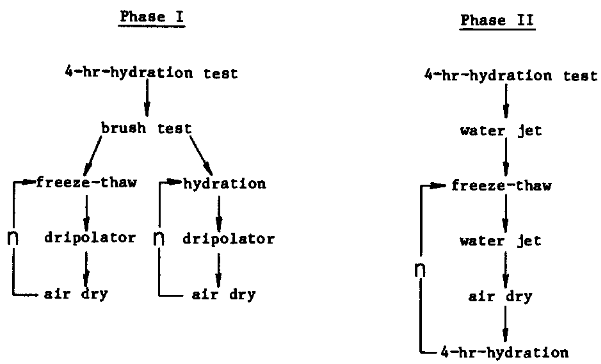

Figure 1. Testing/weathering sequence.