# EFFECTS OF A WETTING AGENT ON THE INFILTRATION CHARACTERISTICS OF A PONDEROSA PINE SOIL

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## ABSTRACT

An infiltration-wetting agent study, using the wetting agent "WATER-IN", was conducted in the ponderosa pine forest type of east central Arizona. An application rate of 10 gallons of wetting agent per acre was used on bare mineral soil and on ponderosa pine litter. The infiltration rate was measured by a modified North Fork infiltrometer. It was found that "WATER-IN" significantly increased water runoff when applied to litter, but, when applied to bare mineral soil, "WATER-IN" caused a significant increase in water infiltration. The wetting agent did not significantly affect antecedent moisture, soil particle distribution, litter water holding capacity, or litter bulk density. It is presently hypothesized that the increase in water infiltration on treated bare mineral soil is due to a decrease in the average bulk density of the surface inch of soil. The increase in runoff when litter is treated is probably due to an interaction, either physical, chemical, or both, between the humus layer and "WATER-IN", creating a hydrophobic condition where one did not exist before.

## INTRODUCTION

Water repellent or hydrophobic soils are found in many parts of the world--from Australia to the United States (Debano, 1969). These soils have wide-spread implications in watershed management, particularly on steep slopes where they reduce infiltration of rainwater and cause serious erosion problems. Severe water repellency can also alter soil moisture relationships and impair vegetation growth.

Evidence of water repellent soils in Arizona was disclosed by Zwolinski (1971) following a series of infiltration measurements on ponderosa pine soils near McNary. In that study a number of infiltration curves plotted from field data exhibited a prominent depression shortly after the start of water application. Although the cause of this temporary resistance of surface soils to wetting is not known, it is suspected that organic substances from plant materials may play an important role. Fires are also reported to accentuate hydrophobic soil conditions (Debano, 1966; Debano and Krammes, 1966). Heat from a fire is known to vaporize volatile oils and resins contained in surface litter and brush. These substances subsequently condense on soil particles to form a water repellent layer.

The study described in this paper was designed to investigate some of the effects of a wetting agent on the water infiltration rates of hydrophobic soils in the White Mountains of Arizona.

## WETTING AGENTS

Wetting agents (surfactants) have been used in southern California to reduce hydrophobic soil conditions following wildfire. By applying a wetting agent to several post-fire study areas in the San Dimas Experimental Forest, the Santa Ana and the San Gabriel Mountains, Krammes and Osborn (1969) were able to significantly reduce surface runoff and erosion.

Wetting agents used on water repellent soils are normally of the nonionic type, as opposed to the anionic and cationic types. Nonionic surface active agents are relatively unaffected by acids or alkalis and are less affected by strong electrolyte concentrations. The degree of solubilization, important to absorptive behavior, can be varied with more sensitivity using nonionic compounds (Black, 1969).

Several brand name wetting agents are available. Their addition to water results in a reduction of the water surface tension and a decrease in the water-soil contact angle. Soil water infiltration rates on water repellent soils are increased since the beneficial effect of lowering the water-soil contact angle normally overcomes the detrimental effect of decreasing the water surface tension.

The wetting agent "WATER-IN" was selected for this study because of its availability and relatively low cost compared to other commercially available surfactants. "WATER-IN" is a liquid wetting agent with a pH of 7 and a specific gravity of about 1.02 gm/cc at 21°C. Its chemical composition is alkyl polyethylene glycol ether, 95% by weight, and inert ingredients, 5% by weight. Treatment application was a rate of 10 gallons of active ingredient per acre.

## TREATMENTS AND RESULTS

The study was conducted on the Fort Apache Indian Reservation in east central Arizona, 5 1/2 miles east of McNary. Soils in this region are derived from a mixture of basalt slag and volcanic cinders under ponderosa pine vegetation. They are silt loam in texture and belong to the Sponseller series.

Four infiltration plots were installed on each of three field sites. Three of the plots were randomly selected for treatment while the fourth was designated as a control. Treatment 1, and later Treatment 2, was applied to each of the three treated plots on all sites. Treatments 3 and 4 were subsequently applied to Site 3 only. Infiltration rates were measured by a modified sprinkling-type North Fork infiltrometer.

Treatment 1, consisting of an application of 100 ml of distilled water to the three treatment plots on each site, served as a calibration for subsequent infiltration determinations. Plots were undisturbed with litter and soil intact. The third and fourth infiltration runs on each plot showed consistent infiltration capacities. The mean infiltration rate for all sites with this treatment was 6.3 inches of water per hour.

The application of 100 ml of "WATER-IN" solution on each treatment plot on each site, in a manner similar to and under the same litter and soil conditions as Treatment 1, comprised Treatment 2. This treatment caused a significant increase in the amount of runoff from each treated plot. The mean infiltration rate following Treatment 2 over all three sites was 5.0 inches per hour.

Treatment 3 involved the removal of all litter from the three treatment plots on Site 3 and the spraying of 100 ml of distilled water on the exposed mineral soil within the treatment plots. This treatment resulted in a mean infiltration rate of 6.1 inches of water per hour. This value was not significantly different from the mean infiltration rate for the plots receiving Treatment 1 on Site 3.

Treatment 4 consisted of an application of 100 ml of "WATER-IN" solution in the same concentration as used for Treatment 2 to the bare soil of the three treatment plots on Site 3. This treatment increased the final infiltration rate to a mean of 8.1 inches per hour.

When comparing the mean infiltration rates following Treatments 1 and 3 on Site 3 (Figure 1), it appears that raindrop impact was negligible on bare mineral soil. Whether this was due to the small size of the water droplets, the failure of the droplets to reach terminal velocity, or an effect of the wetting agent is not clear.

The increase in the final infiltration rate caused by "WATER-IN" applied to bare soil on Site 3 (Treatment 4) appears to be related to a decrease in the soil bulk density for the surface one-inch of soil and possibly a reduction of the soil-water contact angle. How the bulk density is decreased is not known at this time.

There was no fungi mycelia growth to account for the reduction in infiltration rate with Treatment 2 on any of the three sites. Treatments 3 and 4 suggest that "WATER-IN" reacts upon the litter or is acted upon by the litter, probably in the H layer, creating a hydrophobic condition. Several possibilities exist on how these hydrophobic conditions can possibly be created.

First, a chemical reaction in the wettable litter may destroy the effectiveness of the wetting agent. Since the litter material was initially wettable, it is possible that the wetting agent was adsorbed on the litter in such a fashion that it made the litter water repellent. Chemically, the nonionic wetting agents have a hydrophilic (polar) group at one end and a hydrophobic (hydrocarbon) chain at the other. When added to a hydrophobic material, the hydrocarbon end of the wetting agent tends to be adsorbed onto the surface leaving the hydrophilic end in contact with water. Hence, good wetting properties are imparted to the water repellent substances. However, when the wetting agent is placed on a wettable surface, it is possible for the wettable end of the wetting agent to be adsorbed by the wettable surface leaving the hydrophobic end exposed to the water. This type of adsorption can leave a formerly wettable material water repellent.

Secondly, the dissolution of hydrophobic resins from the top litter layers may be redeposited in the H layer with its finer texture and more chemically active surfaces causing increased runoff. And, thirdly, a reduction by "WATER-IN" of the surface tension of the water passing through the litter may make it easier for the water to run off rather than infiltrate.

The interval between the start of rainfall application and the appearance of surface runoff is affected by the amount of surface litter. In general, the greater the amount of litter, the longer the period before runoff occurs. This is due to the water storage capacity of litter which must be satisfied before surface runoff can occur. Calculations using an average litter depth of 2.8 inches, a litter bulk density of 0.119 gm/cc and an average water holding capacity of 170% show that surface runoff is delayed until more than half an inch of rain has been absorbed by the litter. Therefore many rainstorms fail to wet the surface soil. It would be beneficial if a wetting agent could be found that could reduce the storage capacity of the litter without having a detrimental effect on the infiltration rate of the soil thus increasing substantially the amount of water entering the soil.

## SUMMARY

The application of "WATER-IN" at the rate of 10 gallons of active ingredient per acre to soil covered with ponderosa pine litter significantly increased surface runoff. However, an application of "WATER-IN" at the same rate to bare mineral soil significantly increased the infiltration capacity from an average of 6.2 inches per hour to 8.1 inches per hour. This same treatment significantly decreased the average bulk density of the surface inch of soil from 1.17 gm/cc to 1.05 gm/cc, resulting in an increased total soil porosity from 56.0% to 60.4%. No other changes in soil physical properties were detected.

Average soil pH of 5.8 was not affected by the "WATER-IN" treatments nor were antecedent soil moisture contents and soil particle distribution.

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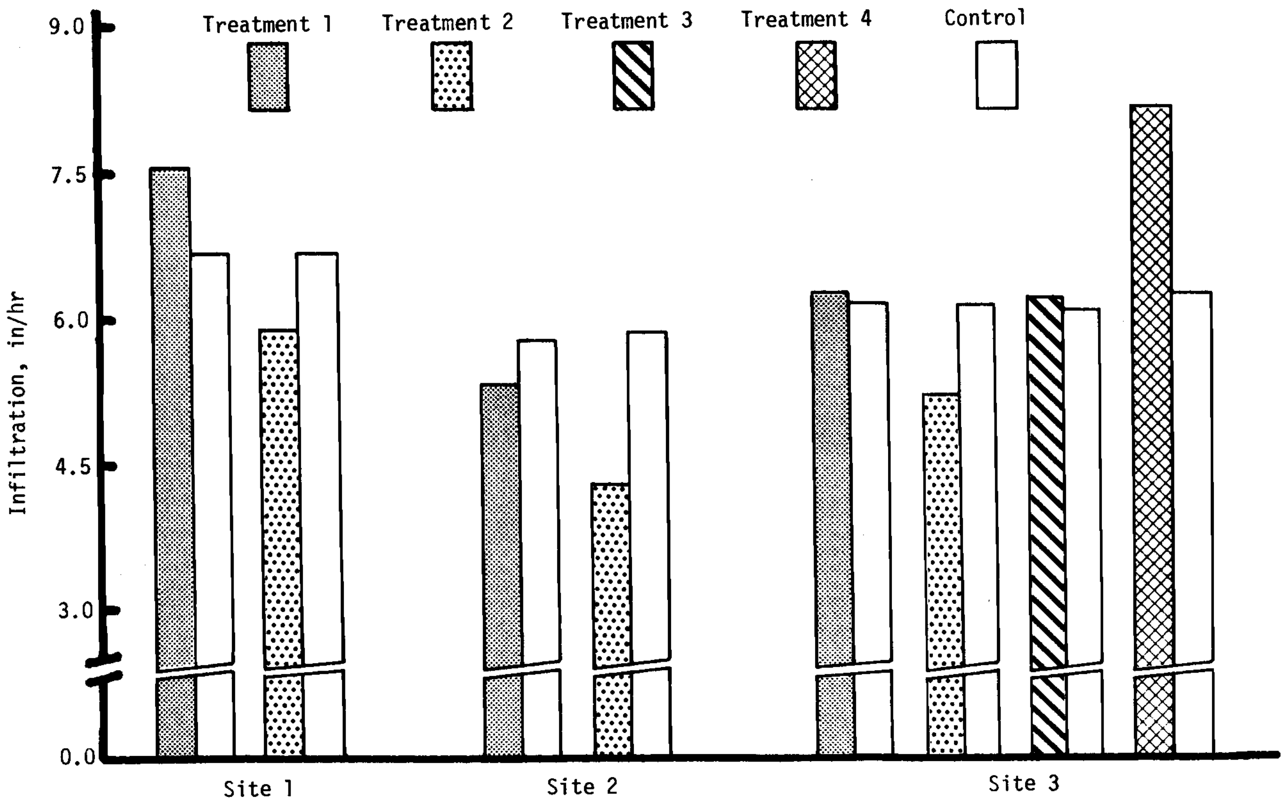


Figure 1. Mean final infiltration rates for treatment and control plots for three sites.

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