5-1968

Evaluation of the Effects of Reduced Transpiration Upon Soil Moisture Retention in an Aspen Stand Throughout the Growing Season in Northern Utah

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Recommended Citation

Zan, Michael, "Evaluation of the Effects of Reduced Transpiration Upon Soil Moisture Retention in an Aspen Stand Throughout the Growing Season in Northern Utah" (1968). *All Graduate Theses and Dissertations, Spring 1920 to Summer 2023*. 3245.
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EVALUATION OF THE EFFECTS OF REDUCED TRANSPIRATION UPON SOIL MOISTURE RETENTION IN AN ASPEN STAND THROUGHOUT THE GROWING SEASON IN NORTHERN UTAH

by

Michael Zan

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Forest Science

UTAH STATE UNIVERSITY
Logan, Utah

1968

ACKNOWLEDGMENTS

In 1966 and 1967 a study was conducted to determine the effects of chemical treatments applied to aspen foliage, with particular emphasis on the effects on transpiration and soil moisture depletion. The study was under the direction of Professor John D. Schultz and Dr. George E. Hart, both of the Department of Forest Science, and Dr. George B. Coltharp of the Department of Range Science. I would like to thank these gentlemen for their guidance while I worked on this project.

Also, I would like to extend my appreciation to Dr. Donald V. Sisson of the Department of Applied Statistics for his critical review of the thesis. Dr. Sisson, together with Dr. Hart and Professor Schultz as Chairman, served on my Graduate Committee.

Finally I would like to pay regards to the United States Department of the Interior, Office of Water Resources Research, which provided the funds for this study as authorized under the Water Resources Research Act of 1964, Public Law 88-379.

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ABSTRACT

Evaluation of the Effects of Reduced Transpiration Upon
Soil Moisture Retention in an Aspen Stand Throughout
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by

Michael Zan, Master of Science

Utah State University, 1968

Major Professor: John D. Schultz
Department: Forest Science

The direct effects of chemically-induced reduced transpiration on soil moisture were studied in a sub-watershed of the greater Logan River drainage.

No statistically significant differences occurred among the total amounts of water transpired by the treated and control units.

The seasonal low points of soil moisture, in September, showed no significant differences in final moisture retention for the two years studied, either for the control or the treated portions of the study site.

The 1967 season showed a lag in soil moisture depletion compared to the 1966 season. Although a later spring in 1967 may have aided in the explanation of this lag, there was good reason to believe that the antitranspirant treatment incurred a significant delay in water use.

There was evidence that more effective application of chemicals might have given more positive results.

(57 pages)

INTRODUCTION

As the seemingly never-ending search for additional water supplies continues, scientists are becoming more aware of the possible advantages to be gained by manipulating the hydrologic cycle at the point where precipitation enters the soil. It is at this point that the bulk of precipitation is lost back to the atmosphere either by direct evaporation from the surface soil or by transpirational losses through native vegetation.

Although surface evaporative losses should not be underestimated, the greatest percentage of evaporative losses occurs through the stomata of leaves. This is explained by the fact that the roots of trees and other vegetation have a greater reservoir from which to draw water than does solar radiation acting directly as an evaporative force only in the surface few inches of soil profile.

What punctuates the evident waste of water by plants is that, in many instances, more water is used than is actually needed for survival. When this is so, it is reasonable to assert that any way which can be found to reduce transpiration should result in an increase in soil moisture and, ultimately, a corresponding increase in streamflow.

Quaking aspen (_Populus_ _tremuloides_ Michx.) covers thousands of acres of western watersheds. This species abounds in zones of generally higher precipitation, and it is recognized as being of great importance in the water budget of its environment. Thus it is evident that, through manipulation of the transpiration process, aspen lands offer a potentially rich source of previously untapped water supplies. Herein lies the theme of this thesis.

OBJECTIVES

The main objective of this study is to determine whether, and by how much, the transpirational use of water by aspen can be reduced by treating the trees with foliar chemicals. Any reduction in water usage should be reflected in increases in soil moisture on plots which have been defoliated or sprayed with an antitranspirant.

REVIEW OF LITERATURE

Prior to reviewing the work that has been conducted on transpiration control, it is desirable to discuss the chemicals involved in this study.

I emphasize that the chemicals which we ultimately used simply reflect the fact that they are the best choices available considering several factors. First, the chemicals must be effective for reducing transpiration. They must be relatively harmless to living organisms, including the plants sprayed (except for the foliage). They should be economical in acquisition and application.

The two chemicals chosen here may not be ideal, but probably no ideal chemical is available to achieve the prescribed effects. We feel that the ones chosen represent the best available for our purposes.

Mechanism of Chemical Action

2,4,5-trichlorophenoxyacetic acid

Absorption and translocation. The amount of herbicide absorbed and translocated by the leaves depends on several variables. One of the most important is season of application. Dalrymple and Basler (1963) found a seasonal variation in absorption and translocation of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) while experimenting with blackjack oak. They found that both were high during the early spring but decreased sharply during May and June to a minimum early in July. Translocation decreased more than did absorption. Both increased somewhat from July through September. This finding was substantiated later by Badiei, Basler, and Santelmann (1966), again with blackjack oak. They found that 50 percent of 2,4,5-T labeled with C^{14} was absorbed in May and June. Absorption fell off to 35 percent in September. Translocation was found to be highest in June. Sixty percent of that absorbed was translocated. Translocation was greater in leaves of mature plants than in those of young regrowth.

Mechanism in inhibiting transpiration. The basic action of 2,4,5-T on metabolic processes in plant tissues is still unknown although several modes of action have been postulated. It is generally accepted that the herbicide is involved in some metabolic process (Morton, 1966). Bruinsma (1965) has made an attempt to associate the metabolic process with the chlorophyll content of plants. He states that, in woody plants, 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-T delay what he calls "senescence" in those parts of the leaf where drops of spray fall in contact. The spray is not translocated throughout the entire leaf. Instead, Bruinsma believes, the treated part of the leaf stays green and photosynthetically active at the expense of untreated parts which age and die at accelerated paces. Evidently these treated areas act as wells which draw nitrogen compounds and carbon from surrounding areas and metabolize them at an increased rate.

Concentration of application. The amount of concentration applied depends on the effect the user hopes to achieve. The usual effect desired is death of the vegetation. Hyatt (1966) states that sagebrush is controlled by applications of two pounds per acre of butyl-ester 2,4-D, an herbicide very similar to 2,4,5-T, plus one and two-thirds gallons of diesel oil per acre. The Weed Society of America (1967) states that adequate brush control is achieved with 2,4,5-T applied at concentrations of from one-quarter to eight pounds per acre.

For our purposes, specific reports are not available considering the use of herbicides where the intent is to defoliate without killing vegetation. However, Barring (1965) notes that 2,4,5-T damages Scotch pine considerably less than does 2,4-D upon direct spraying of seedlings. This is true if spraying is performed before spring growth begins. Ives and Nairn (1966) found that 50 percent mortality of tamarack occurred two years after the trees were sprayed with concentrations strong enough to defoliate completely. Lesser concentrations resulted in no mortality after four years.

Decomposition rate. The rate of chemical decomposition after herbicides reach the soil is of particular importance. This may be a critical consideration, because any accumulation of these chemicals might cause an unwanted change in the soil microflora and microfauna or it might result in contamination of ground waters which ultimately replenish our streams.

Woodford, Holly, and McCready (1958) agree that herbicides usually disappear by decomposition after they are incorporated into the soil. Norris (1966) investigated the degradation of 2,4-D and 2,4,5-T in litter collected from a red alder stand in western Oregon. He found that, after 300 hours, more than 85 percent of 2,4-D applied was accounted for by the liberation of radioactive carbon dioxide. In the same period of time only about 23 percent of the 2,4,5-T was accounted for by carbon dioxide evolution. After 690 hours 53 percent of the 2,4,5-T was accounted for. Norris stated that the slower rate may be accounted for by a slower adaptation by the soil microorganisms to the use of 2,4,5-T. The Weed Society of America (1967) states simply that the microbial breakdown of 2,4,5-T moves more slowly than for 2,4-D because of the addition of an extra chlorine atom to the molecular structure. Follow-up studies by Norris have not been published yet.

Precipitation and application. The final effects of a sprayed application of 2,4,5-T may, in the end, depend on whether enough of it is absorbed before a rain storm removes it from the leaf surfaces. Currier and Dybing (1959) state that rain is one of the important influences on penetration and movement. They found that if precipitation occurred soon after spraying of apple leaves much of the spray was removed and penetration was subsequently reduced. Dalrymple and Basler (1963) said that 80 percent of applied 2,4,5-T was absorbed by blackjack oak after 36 hours. From this it seems that a prolonged dry period following application is not necessary; the few days following application are the crucial period.

Weaver, Minarik, and Boyd (1946), using an aqueous solution of 2,4-D in a greenhouse experiment, found that plant responses were not decreased if artificial precipitation followed application by no less than six hours. The same test conducted outdoors showed that a lapse of 24 hours was required or there was a reduced effectiveness of the herbicide. All artificial rains applied were much heavier than natural rainfall.

The Weed Society of America (1967) states that esters of 2,4,5-T are relatively resistant to the washing action of rain.

Phenylmercuric acetate

Mechanism in inhibiting transpiration. It is generally accepted that phenylmercuric acetate (PMA) acts to reduce transpiration by its action upon the stomata of leaves. Waggoner and Zelitch (1965) state that inhibitors are grouped into one of two categories: (1) those inhibitors which interfere with metabolic reactions which increase the turgor of guard cells, and (2) those which alter the permeability of the cell membrane. They state that PMA falls into the second category. It is suspected that the PMA reacts with the sulfhydryl groups in the guard cell membrane and thus alters the permeability of the cell walls. This presumably prevents water from entering the guard cells with its resultant increase in turgor needed to open the stomata.

Concentration of application. Once again the concentration of chemical depends on the desired effects on the vegetation. Even with antitranspirants an overdosage has been found to kill vegetation. Waggoner and Zelitch (1965) state that, in the past, little attention was given to stomatal closure following chemical treatment probably because of the toxicity of chemicals involved. They note that M. M. Ventura was the first to observe closing of stomata in leaves of *Strizolobium* which were treated with weak solutions of several chemicals. A subsequent reduction in transpiration was observed.

Testing 10^{-5}, 10^{-4}, 10^{-3}, 10^{-2} molar solutions with eight antitranspirants, Slatyer and Bierhuizen (1964) found a reduction of transpiration with increased concentrations; but they also observed a corresponding increase in toxic effects. Davenport (1966) found that a 10^{-3} M solution of PMA reduced transpiration 30 percent in some grasses but proved somewhat toxic. He found that a 10^{-4} solution had no toxic effect but reduced transpiration only 7 percent. The critical maximum reduction of transpiration without toxic effects thus seems to lie between these two concentrations for grasses.

Zelitch (1967) showed that PMA succeeds in reducing stomatal opening to the same degree that it takes most other chemicals used in much stronger concentrations. This is true for concentrations which cause no toxic effects. Waggoner and Zelitch (1965) had shown earlier that 50 percent closure of stomata in tobacco leaves was achieved when a 10^{-5} M solution of PMA was used.

At high concentrations Granger (1966) found that PMA may harm apple leaves more than certain petroleum oils do.

Effects on growth. An important consideration in selecting an antitranspirant may be its effects on carbon dioxide assimilation and growth. PMA is found to be desirable from the standpoint of reducing transpiration without offering side effects of significant growth reduction. In the study conducted by Slatyer and Bierhuizen (1964) it was found that of the eight antitranspirants tested, only PMA reduced growth to a lesser degree than it did transpiration. Shimshi found, with tobacco (1963a) and with corn (1963b), that stomatal closure by PMA significantly reduced transpiration but reduced photosynthesis and growth considerably less.

In studies involving several inhibitors, Zelitch (1961) found the lower rate of carbon dioxide intake clearly did not reduce carbon assimilation in photosynthesis, even at high light intensities. Waggoner (1967) found that the shoots of jack pine trees sprayed with PMA had no fewer needles or less weight than had shoots of untreated trees after the second year of spraying.

Duration of effect. PMA is definitely one of the better inhibitors when lasting effects are considered. Zelitch and Waggoner (1962) and Waggoner and Zelitch (1965) found that the stomata of tobacco and maize leaves were still closed 14 days after being treated with a dilution as weak as 10^{-4} M. Slatyer and Bierhuizen (1964) found that a 10^{-4} M solution of PMA still produced significant reduction in transpiration from cotton leaves 12 days later. Zelitch (1967) found that cotton stomata were still closed 25 days after a 10^{-4} M solution of PMA was applied. Such findings were further supported by Shimshi (1963a) who used sunflowers grown outdoors and tobacco grown indoors.

Water Usage by Trees

Although it has been mentioned that vegetation utilizes vast quantities of water in the transpiration process, a realization of the absolute quantities involved commands attention. Such a revelation is what warrants an approach in conserving water by vegetative treatments.

Waggoner and Zelitch (1965) state that 71 percent of the precipitation in the United States is lost to evapotranspiration. This may be from pastures and meadows, cultivated fields, open water bodies, and forests. The bulk of this is lost through stomata no larger than 15 to 35 microns on their longest axis.

Kittredge (1938) estimated annual losses from various forest regions to range from 4 to 10 inches for desert shrub to 30 to 40 inches for southern pines and river bottom hardwoods. Aspen likely falls in the 10- to 20-inch region of lodgepole-grass-ponderosa pine. Kramer (1952) gives similar water-use figures. Brown and Thompson (1965), comparing aspen, spruce, and grassland uses of water in western Colorado, found that aspen was the most profuse user. It transpired over 19 inches annually compared with about 15 inches for spruce and 9 inches for grasses. Though the authors gave reason to believe spruce is as extravagant a user as aspen, it is the magnitude of these figures that warrants recognition.

Quantitative Effects of Antitranspirants

Little work has been done where 2,4,5-T was purposely used to inhibit transpiration. Most uses of 2,4,5-T have been for control of brush and trees by killing them. All studies hereafter mentioned will, therefore, focus on uses of antitranspirants, notably by PMA, in reducing transpiration.

Lab and greenhouse studies

Most studies with antitranspirants have been carried out in the confines of greenhouses or on small plots. Projection of the results of these studies to natural field situations must be viewed with caution.

Davenport (1966) found PMA to be quite effective in reducing transpiration of grasses. Under different moisture regimes he found varying effects. Transpiration was reduced 30 percent when a $10^{-3.2}$ M concentration was used on plants in a wet soil, and transpiration was reduced significantly by 20 percent even in a dry soil regime. Studies by Shimshi (1963a, 1963b) with corn and tobacco showed significant reduction in transpiration.

By far, the most earnestly conducted research with antitranspirants has been done by Israel Zelitch and Paul E. Waggoner of the Connecticut Agricultural Experiment Station. Waggoner, Monteith, and Szeicz (1964) found a reduction of transpiration by barley of 13 to 30 percent when alkenylsuccinic acid was used. Waggoner (1967), Zelitch (1967), Waggoner and Zelitch (1965), and Zelitch and Waggoner (1962) all showed antitranspirants, and particularly PMA, to be effective in reducing transpiration. Most of their experiments involved the use of tobacco.

It should be emphasized that all experiments were carried out with the expressed purpose of reducing transpiration while, at the same time, striving not to harm the vegetation with heavy concentrations.

Field studies

Few field studies have been conducted wherein the purpose was to achieve greater water availability by applying chemicals to reduce transpiration. Two attempts need to be mentioned.

Waggoner and Hewlett (1967) carried out the most ambitious effort so far conducted to increase water yield by the use of anti-transpirants. Two small watersheds of approximately 70 acres each at the Coweeta Hydrologic Laboratory in western North Carolina were studied. The watersheds were densely covered with a variety of hardwood tree species, mainly oaks and hickory.

The method chosen to determine the effect of treatment was to measure any increase in streamflow which might be yielded from the treated watershed. The second watershed was used as a control and a regression equation based on 15 years of precipitation and runoff data was calculated for the two watersheds. Thus, by observing the runoff of the control watershed, the predicted runoff of the treated watershed could be determined. Any runoff excess over the predicted amount would be considered due to treatment.

Only 30 of the 70 acres of the test watershed were treated, and from previous work it was calculated that reducing water loss on this 30 acres by 1.6 inches would result in a 12 percent reduction of transpiration for that area. This would be detected as a significant increase in streamflow.

An 0.1 M solution of glyceryl half-ester of decenylsuccinic acid (GIOSA) was applied to the treatment area by helicopter on June 9, 1964, a clear day with a faint wind.

In evaluating their results, Waggoner and Hewlett found that application of the calibrated regression to streamflow revealed no increase in flow when compared with actual after-treatment flow. They concluded that although streamflow may have increased, the increase was too small to be detected by hydrologic analysis. They also postulated that ultraviolet radiation may have destroyed the chemical.

Most likely, however, they were unable to close a sufficient number of stomata by spraying from above. Indeed, upon examination of the leaves, they found that even with the flutter of the helicopter so close to the treetops, few drops of spray struck the undersides of leaves where the bulk of stomata are found. Shorter but still sunlit trees were hardly touched by the GIOSA solution.

Waggoner and Bravdo (1967) carried out another less extensive experiment in which they attained more positive results. In a 25-year-old red pine plantation in Connecticut they sought to detect any increase in soil moisture after treatment with PMA. A neutron-scattering device was employed for taking soil moisture measurements.

Sixteen rows of access tubes, 6 tubes to a row, were laid out in the plantation. The 16 rows were divided into 8 adjacent pairs, and one row of each pair was selected for treatment. Tubes extended to depths of 183 cm (about 72 inches) and 318 cm (about 125 inches). The large number of replications was expected to give reliable averages for the surface 183 cm of soil moisture for both treated and untreated plots.

A treatment of 300 ppm PMA and 0.1 percent Triton B1956 was applied on more than 500 trees from the ground by a hydraulic sprayer jet. This was on June 2, 1966. Measurements were made with the neutron probe once each month from June through October following treatment.

At the end of the season an analysis of variance revealed no significant difference in soil moisture change either in the top 183 cm or the soil below. However, an observation of weighted sums of savings throughout the study period showed a 28 mm (1.06 inches) savings. A savings of this amount is significant in the hydrologic cycle even though it represented only 5 percent reduction in transpiration.

METHODS OF PROCEDURE

Location and Description of Study Plots

The site chosen for this study was a relatively dense stand of quaking aspen in the Twin Creek drainage, a sub-watershed of the greater Logan River drainage in Cache County of northern Utah. It is approximately 20 highway miles northeast of Logan, Utah, and about 2.5 miles from paved highway U.S. 89 on a dirt U.S. Forest Service road. The site is at an elevation of approximately 7800 feet. It has a south-facing aspect on a slope of approximately 25 percent.

Soils and geology

The soils of this area are generally deep and well-developed. A well-defined organic layer lies over a rich, generally loamy, topsoil. Drainage is good. About 20 percent of the soil volume is occupied by rocks which range in size from pebbles to boulders. The advanced development of this soil profile is illustrated by textural analysis of several samples taken from the top 30 inches of profile (Table 1).

Geologically speaking, this region was most probably covered during at least one of two glacial ages evident here from Pleistocene time. Young (1939) states that this is evident because of the U-shaped cross section of Twin Creek in its upper two miles, over which the glacier apparently crept. This contrasts with the

Table 1. Textural analysis of random soil samples taken from the study site

	Texture		
Depth	Sample no. 1	Sample no. 2	Sample no. 3
0-6	Loam	Silt loam	Loam
6-12	Silt loam	Silty clay loam	Clay loam
12-18	Clay loam	Clay loam	Clay loam
18-24	Clay loam	Sandy loam	Clay loam
24-30	Clay loam	Clay loam	Clay loam

V-shaped lower mile which the glacier did not cover. He also notes that several irregular deposits of moraine material and small kettle holes are found throughout the upper drainage. Young also states that on the upper north side of the canyon a lateral moraine commences at about 8000 feet elevation and extends down-canyon for about one mile. This is in the vicinity of, if not actually including, our study site. Such a geologic history would surely explain the preponderance of various sized rocks in the soil.

Climate

The study area is in a zone of generally cool summer nights and warm days. Winters are moderately severe and snow usually covers the ground from late November to May. The snow commonly reaches depths of over four feet. Mean annual precipitation is about 30 inches, much of which falls as snow. Summers are typically dry with occasional convective thunderstorms. Temperature extremes and precipitation data in the area during the months of study are shown in Table 2. The lowest the temperature ever reaches during the year is about -5 degrees F and the highest is in the high 80's. Besides temperature and precipitation information, data collected during the study included that for solar radiation, relative humidity, and wind velocity and direction.

Table 2. Temperature and precipitation data for the Twin Creek area during period of study

	Temperature (F)							
	Average maximum		Average minimum		Mean monthly		Precipitation (inches)	
Month	1966	1967	1966	1967	1966	1967	1966	1967
June	72	65	50	47	61	56	.94	3.54
July	80	76	60	52	70	64	.48	.63
August	76	82	52	52	64	67	.64	.12
September	71	73	48	50	60	62	1.96	.32
October	65	66	29	31	47	48	1.05	2.05
Total							5.07	6.66

Vegetation

As has been mentioned, the study site is situated in the midst of a rather dense stand of quaking aspen (Populus tremuloides Michx.). The stand is pure aspen and the tallest trees are about 60 feet tall. Bracken fern (Pteridium aquilinum (L.) Kuhn, var. pubescens Underw.) is found throughout the understory. The fern grows to heights of over three feet. Small amounts of larkspur (Delphinium occidentale

S. Wats) and some grasses are found in the openings.

Layout of Plots

Plot design

The entire study area is a rectangular tract 250 x 300 feet (Figure 1). Three adjacent treatment areas have been laid out in this tract and each has dimensions of 100 x 250 feet. Since aspen trees are often connected by suckers, the three treatment units have been separated from one another by use of a tractor trencher. Within each treatment area are three sample plots and each of these has four subsample units. The four subunits are arranged in a ten-foot square pattern. Soil moisture measurements were taken from access tubes installed at each subunit location.

Installation of access tubes

Installation of access tubes for the neutron probe proved to be a difficult task. We found, as did Koshi (1966), that hand-held drilling equipment was not satisfactory for drilling in rocky soil. Koshi found that a rigid-guide drilling system called the Minuteman proved to be the most satisfactory. On our site we installed the tubes with the use of a track-mounted power drill which was found to maneuver remarkably well on steep and wooded sites.

Application of Chemicals

The plots were sprayed by helicopter on June 28, 1967. Spraying commenced at about 8:00 A.M. and was completed within an hour. Skies were overcast and there was no noticeable wind.

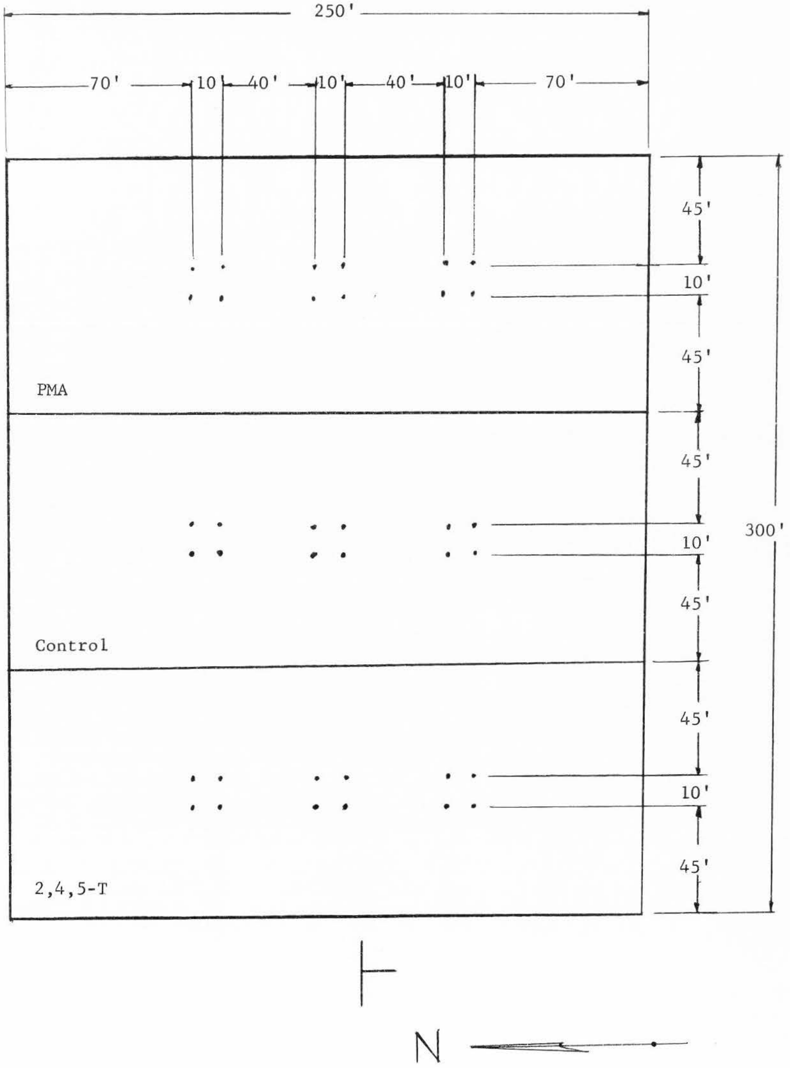

Figure 1. Layout of the plots.

By random selection, the most westerly treatment area, containing plots 1, 2, and 3, was sprayed with an aqueous solution of 2,4,5-T ester of between one and two pounds acid equivalent per acre. The middle area, consisting of plots 4, 5, and 6, was chosen as the control and received no spray treatment. The third treatment area, plots 7, 8, and 9, received 240 gallons of a 10^{-3} M solution of phenylmercuric acetate (PMA). No subsequent spraying was done in any of the plots.

Field Measurements

Soil moisture measurements were taken throughout the pretreatment growing season of 1966 at regular weekly intervals. Measurements were taken initially in May and continued through September. Thereafter, three- to four-week intervals separated measurements through November.

In the treatment year of 1967, due to an unusually wet and cold spring, measurements did not begin until June and then were taken at two-week intervals throughout the growing season. Periodic readings have been taken through the 1967-68 winter-spring seasons.

Measurements were taken with a Troxler neutron-scattering soil moisture probe with a 100-mc Americium-Beryllium source. Schultz (1967) discusses the advantages of this probe with respect to safety and precision.

Readings were taken at one-foot intervals in each access tube. All of the tubes penetrated at least six feet into the soil profile and many extended as deep as ten feet.

Analysis of Data

Since the concentration of aspen roots is generally greatest in the upper six feet of the soil, it is this surface six feet that is of most importance in detecting any increase in soil moisture due to reduced transpiration. Therefore, the top six-foot soil moisture totals became the immediate "raw" data we sought to analyze.

An analysis of variance of post-treatment soil moisture usage was conducted to determine significance in water usage, if any, among the treatment areas. Furthermore, soil moisture data for the three test areas were listed in tables and plotted as figures for comparing pretreatment with treated soil moisture content.

RESULTS AND DISCUSSION

When the total seasonal soil moisture depletion data were obtained in the fall of 1967, the first goal pursued was to determine if a statistical analysis would reveal a significant difference in water loss among the treatment areas. Use of an analysis of variance presented a special problem. Clarification follows.

Because of the nature of the design of the plots and the ultimate spraying procedure, we essentially worked with one replication per treatment. If one looks at Figure 1 this explanation becomes more clear. The chemical applications were assigned randomly to entire strips, each of which was, in essence, one replication. Such a situation cannot be analyzed in a normal analysis of variance. An acceptable situation for such an analysis would have occurred if we were to have randomly assigned a treatment (or control) to each of the three major units within each of the three strips. From a statistical viewpoint we would have satisfactorily ascribed three unbiased replications to each treatment and the control.

The acceptable statistical procedure for obtaining three replications was, therefore, recognized and desired; but from a practical standpoint it was difficult to attain. The difficulty arose with respect to the physical application of the chemicals. Because of the relative smallness of the study tract, it was plainly difficult for a helicopter to treat entirely and cleanly such small units without fear of an overlapping of one treatment onto adjacent units. An entire strip was treated with one chemical and this minimized the dangers of treatments overlapping. The analysis of variance, with the three replications "chosen" from the same strip, was performed with the realization that it was biased because there were no true replications.

The analysis (Table 3) suggested that a significant difference in soil moisture change among the three areas was unlikely. This should not be disheartening, however, since a small savings of soil moisture, although significant from the hydrologic viewpoint, may not have been detected. Another way to view the data is called for.

Table 3. Analysis of variance of soil moisture depletion following treatment

Source of variation	Degrees of freedom	Mean squares	F test value
Total	35	2.6313	
Treatments	2	6.5337	1.6794[a]
Experimental error	6	3.8904	
Sample error	27	2.0624	

[a] Not significant at the .95 level.

Data representing the amount of soil moisture retention at different dates throughout the growing season are presented for both the pretreatment and treatment seasons in Table 4 and Figures 2, 3, and 4. An immediately apparent comparison of the data for both years

Table 4. Soil moisture status throughout the growing seasons of 1966 and 1967, Twin Creek aspen site[a]

Dates measurements were taken	Mean water content in top six feet of soil[b]					
	1966			1967		
	2,4,5-T	Control (inches)	PMA	2,4,5-T	Control (inches)	PMA
May 3-6	26.59	24.65	23.35	--[c]	--[c]	--[c]
May 17-18	26.98	24.99	23.86	--[c]	--[c]	--[c]
May 24-25	27.02[d]	25.11[d]	24.27[d]	--[c]	--[c]	--[c]
May 31-June 5	26.17	24.36	23.30	24.70	22.83	21.88
June 14-15	25.17	23.12	21.92	--[c]	--[c]	--[c]
June 21-24	24.21	22.27	21.47	26.57[d]	24.68[d]	23.18[d]
June 28-30	23.14	20.49	19.52	25.82	23.82	22.74
July 12-13	21.61	19.29	18.27	24.15	21.97	21.06
July 25-27	19.97	17.33	15.98	22.45	19.77	19.09
August 4-5	19.21	16.65	15.13	--[c]	--[c]	--[c]
August 8-9	--[c]	--[c]	--[c]	20.22	17.35	16.65
August 22-24	17.11	14.34	12.31	18.68	15.60	14.12
Sept. 5-7	16.17	13.15[e]	11.07[e]	17.34	14.00	12.37
Sept. 20-21	16.50	13.96	11.93	16.02[e]	13.09[e]	11.30[e]
Sept. 28-30	16.01[e]	13.34	11.24	--[c]	--[c]	--[c]
Oct. 17-24	15.70[f]	13.31	11.18	16.75	13.38	12.11
Oct. 31-Nov. 2	--[c]	--[c]	--[c]	17.03	14.09	12.49
Nov. 15-18	17.96	16.34	13.45	--[c]	--[c]	--[c]
Seasonal water depletion[g]	11.01	11.96	13.20	10.55	11.59	11.88

[a] See Figures 2, 3, and 4 for the graphs of these data.

[b] These values are the means of the values taken from the twelve access tubes on each treatment area.

[c] Dash means data are missing for this date. Data were not collected.

[d] Highest observed soil moisture total for the soil profile.

[e] Lowest observed soil moisture total for the soil profile.

[f] Although this is the lowest observed value for the 2,4,5-T site, this soil water content exists after the natural autumn defoliation of the aspen trees. Therefore the September 28-30 value is used, as this date more closely coincides with termination of the growing season.

[g] Difference between the highest total and the lowest total soil moisture observed.

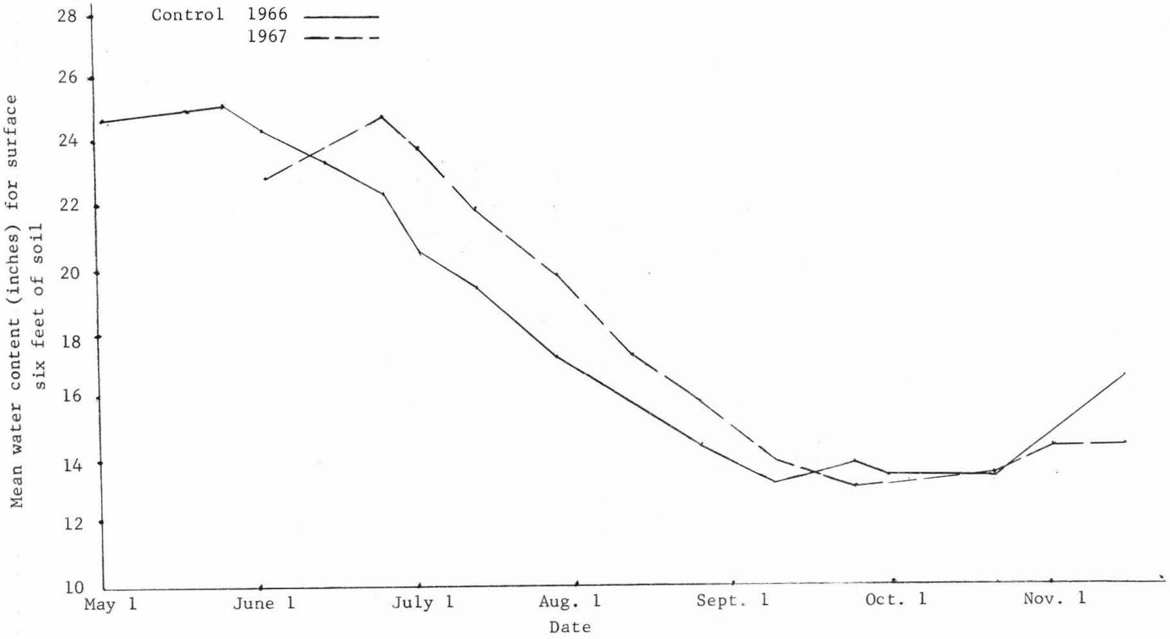

Figure 2. Mean soil moisture status throughout the growing seasons of 1966 and 1967, Twin Creek aspen site, control plots.

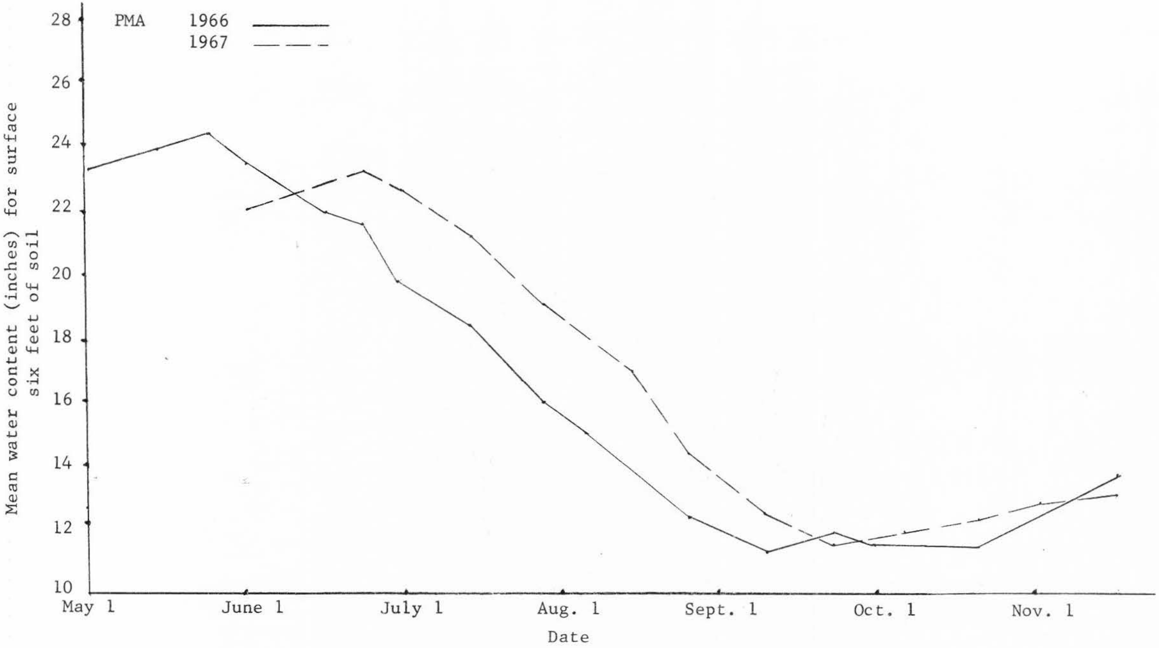

Figure 3. Mean soil moisture status throughout the growing seasons of 1966 and 1967, Twin Creek aspen site, PMA plots.

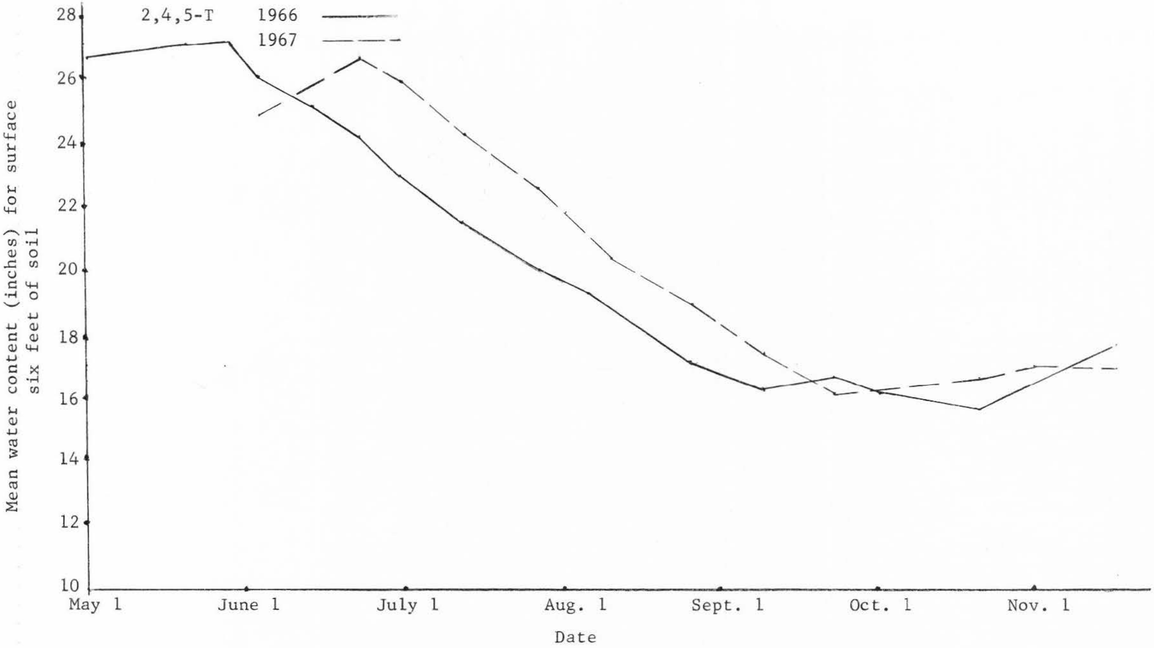

Figure 4. Mean soil moisture status throughout the growing seasons of 1966 and 1967, Twin Creek aspen site, 2,4,5-T plots.

can be made with respect to the time of peak soil moisture recharge. The peak soil moisture storage for 1966 is found to fall on May 24-25. In 1967, as close as could be ascertained, the peak fell on or a little before June 23-24. The six-foot totals for the two dates are similar for both years. Thus, the seasonal peak of soil moisture storage for the test year follows the peak storage for the pretreatment year by nearly one month on the calendar. This is easily explained. The spring of 1967 was an unusually prolonged one and the weather was cold and wet nearly up to the time of treatment. It is shown in Table 2 that the month of June, 1967, had 3.54 inches of precipitation compared with 0.94 inch for the same month of 1966. Furthermore, the mean monthly temperatures for June, 1966, and June, 1967, are 61 and 56 degrees Fahrenheit, respectively. Aspen leaves did not appear until three weeks later in 1967 than in 1966. Excessive rainfall prohibited the taking of initial soil moisture readings until late in the 1967 season.

The amount of soil moisture held in retention at the end of the growing season is of considerable hydrologic importance. If more water were retained in the soil at this time, it would take less to saturate the soil profile in the spring. Any subsequent snowmelt and precipitation would move away as surface runoff to streams. In short, an increased saving in soil moisture in the late summer may mean a corresponding increase in runoff the following spring. The soil moisture situation in late September, when the amount of water in the soil is at a minimum for the year, is shown in Table 4 and Figures 2, 3, and 4. As is evident, on all three areas, there are no significant differences in soil moisture retention from one year to the other. The differences involve only a few hundredths of an inch. It appears that the chemicals may have had no real effect in reducing soil moisture loss over the entire season (even though they may have temporarily delayed water use during a part of the season).

Another point of interest is the two-year comparison of soil moisture retention for any given treatment area on any given calendar date throughout the growing season. One notes in Table 4 and in Figures 2, 3, and 4, that, on any given date, the site in 1967 showed a higher water retention than in 1966. This occurs right up to the end of the growing season in late September when water retention for the two years is the same. This delay occurs on any of the three study areas. Upon first glance it may seem that this is entirely due to the late spring of 1967. However, a closer look at the data may suggest otherwise. As we have found (Table 4), the total amounts of water depleted from each of the three sites were remarkably similar for 1966 and 1967 as were the amounts retained in the soil at the ends of the seasons. With this in mind it is reasonable to believe that for a given amount of seasonal depletion, the rate of depletion would depend on certain environmental factors. Among these would be surface evaporation, seasonal precipitation, leakage, and transpiration. In comparing the rates of depletion among different sites in a homogeneous environment, differences in rates due to surface evaporation, seasonal precipitation, and leakage are likely to be negligible. Our site can confidently be considered a homogeneous unit because precipitation occurs uniformly over the tract, surface evaporation losses occur uniformly over the tract, and leakage is assumed negligible. The soils of the three sites differ slightly in their water-holding capacities and therefore their water-depletion quantities. From this it is evident that for two sites in a given environment, the slight differences in rate of depletion are likely due to small differences in soil morphology. These differences in rate of depletion should be consistent under a variety of climatic conditions.

As an example, let us consider cumulative losses of soil moisture for a given environment. Cumulative percent soil moisture loss is the total percentage of total seasonal soil water depletion that has been extracted from the soil up to a specific date. Zero percent loss would be in late spring when the soil is saturated. One hundred percent cumulative loss occurs in the fall when soil moisture content is at a minimum. Now assume that for a given climatic situation 50 percent cumulative loss at Site 1 coincides with 47 percent cumulative loss at Site 2. Under the above argument, given a different climatic situation, when a 50 percent cumulative loss is attained at Site 1 we would again expect a 47 percent cumulative loss at Site 2. With this in mind we should now focus attention on Figures 5 and 6.

Figure 5 illustrates the cumulative soil moisture (percent) loss through the 1966 growing season. Curves for all three plots are presented. Dates are given to show the periods of depletion considered. Figure 6 illustrates the same situation for 1967. These curves are derived from the data in Table 4 and the

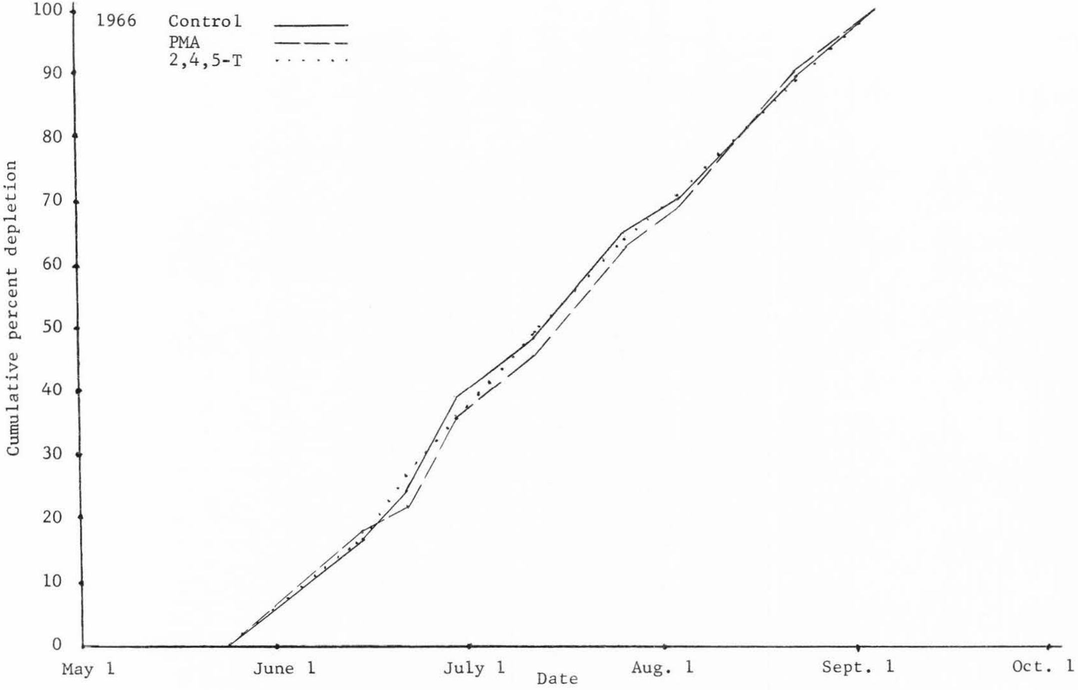

Figure 5. Cumulative percent soil moisture depletion, Twin Creek aspen site, 1966.

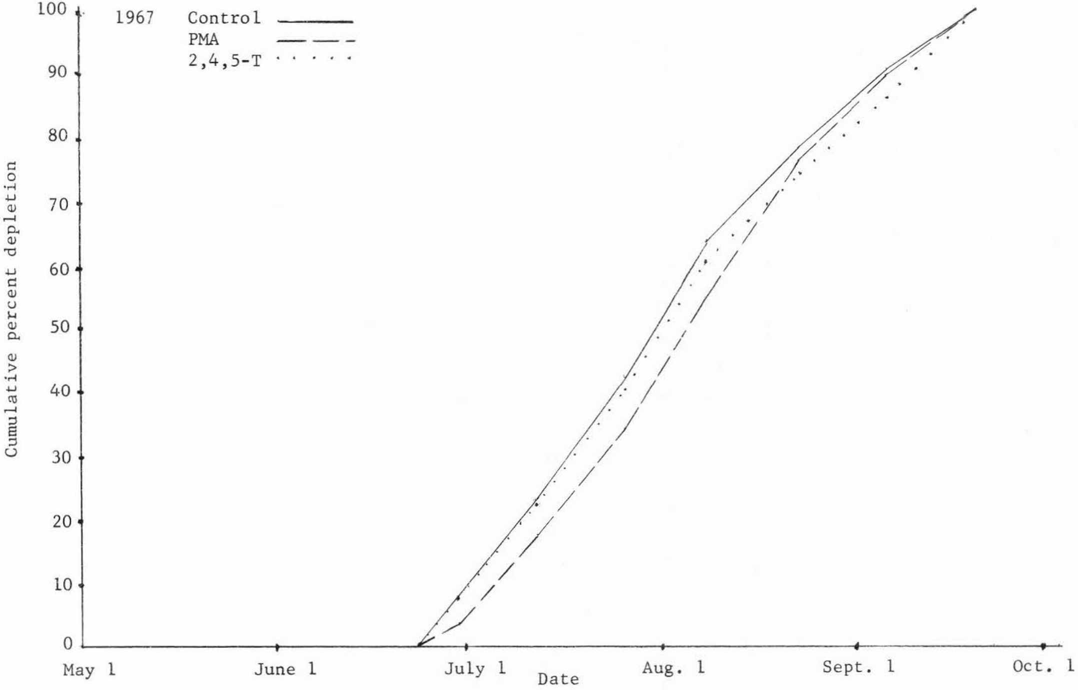

Figure 6. Cumulative percent soil moisture depletion, Twin Creek aspen site, 1967.

calculations are shown in Tables 5, 6, 7, 8, 9, and 10 in the Appendix. As is apparent, the 1966 growing season saw a soil water depletion between May 24 and September 7 (September 28 for the 2,4,5-T site) equivalent to the 1967 depletion between June 23 and September 20.

From the previous contention we would expect the curves to follow their same shapes relative to each other. Comparing the PMA and control plots for the two years we can see that this is not the case. In 1966 the PMA curve follows the control curve more closely than in 1967. In 1966, we find that the greatest the PMA curve lagged behind the control was on August 4 when its cumulative loss was 3.5 percent less than for the control (see Tables 5 and 6 in Appendix). In 1967 we find that the PMA cumulative curve lagged behind the control by 8.2 percent on August 8 (see Tables 8 and 9 in Appendix). According to the previous argument they should be the same. However, it is evident that the maximum cumulative differences differ by 4.7 percent. What accounts for this 4.7 percent? As has been mentioned all the environmental factors are uniform for the entire tract--all that is except transpiration. It is probable that the PMA had a slight delaying effect on evapotranspirational losses. This slight effect may be significant from a hydrologic standpoint. What this means is that there is 4.7 percent more of the potential water loss still left in the soil than would be at this date had there been no treatment. If the total cumulative water loss is 11.00 inches, this represents a "surplus" of 0.48 inch more water in the profile than is normally expected.

What would this 0.48-inch delay mean? From a hydrologic standpoint it is important when measured against soil water percolation beyond the root zone. If the soil has not yet exhausted its content of gravitational water, an 0.48-inch delay in transpiration losses may enhance percolation quantitatively by that amount. This would later be reflected in increased streamflow. Of course the big question here is whether the soil still contains gravitational water. It is evident that the antitranspirant must act to delay transpiration and increase deep percolation when there is much water in the soil. This would be in the spring soon after foliation. This is one of the reasons why we sprayed our plots so early.

For our purposes it is difficult to discern whether the delay we caused with the PMA was of consequence to percolation. No analysis of soil pore space and soil water availability was made. The relative amounts of soil water depletion at the dates observed cast doubt on the possibility. The important immediate conclusion is that we most likely delayed transpiration on a cumulative basis by about one-half inch. Efforts to correlate the delay with the proper season must be pursued.

Similar comparisons with the 2,4,5-T unit fail to show any apparent delay.

At this point it is worthwhile to mention the observed effects of the chemical applications.

On the 2,4,5-T plots it was noted, several weeks after application, that the spray was not applied in sufficient concentration to defoliate all of the area sprayed. Most of the leaves in the upper canopy dried up and died, but personal observation showed that much of the lower crown was not affected. Furthermore, it appeared that the perimeter of the tract was not touched by the herbicide and thus these trees were left to carry on full transpiration.

Considering the PMA treatment, upon laboratory analysis it was found that the mean width of those aspen stomata contacted by the spray was 2.4 microns, compared with a mean width of 4.3 microns for normally-transpiring stomata. In the field, it appeared that the tract was sufficiently covered with spray. However, it is more difficult to observe over-all coverage effects of PMA compared with 2,4,5-T because the latter kills and dries, whereas leaves treated with PMA appear healthy. Whether enough of the underleaf surface was reached by the inhibitor or whether the reduction in stomatal aperture was sufficient to reduce transpiration is difficult to discern. Other studies have shown that such a reduction is achieved when similar foliar responses are observed.

It is evident that future treatment would call for heavier concentrations and, if possible, several applications of chemicals in order to ensure the desired effects of closed stomata.

A final point of interest concerns the precipitation patterns during the two years of study. Once again, reverting to Table 2, one can observe that the data show an opposite trend in seasonal precipitation patterns for the two years. In 1966, little precipitation occurred earlier in the year relative to the same period in 1967. As the 1966 season progressed, a general increase in precipitation was observed; whereas, during the 1967 season, a corresponding decrease occurred during the same period. It is interesting to speculate whether, without the rather wet season marking the late growing season in 1966, there might have been even less water in the soil than is shown in Table 4. Or, perhaps, the soil had already lost all of its available water to transpiration.

SUMMARY AND CONCLUSIONS

During the 1966 and 1967 growing seasons a study was conducted in a uniform stand of aspen on a mountain site in northern Utah. The objective of the study was to determine whether, upon treatment of sections of the study site, a reduction in transpirational uses of water by aspen could be induced with a subsequent increased savings in soil water.

The study site consisted of a rectangular tract of 250 x 300 feet dimensions. The tract was divided into three units, one of which was randomly picked as a control. One of the other units ultimately received an herbicidal treatment of 2,4,5-trichlorophenoxyacetic acid. The third area was picked to receive treatment of an antitranspirant, phenylmercuric acetate. Both chemicals have had wide use and their effectiveness has been demonstrated.

Soil moisture readings were made on all three study units for the pretreatment season, 1966, and before and following treatment on June 28, 1967. Measurements were made with a Troxler neutron soil moisture probe with an Americium-Beryllium source. Twelve replications--four in a 10-foot square at each of three locations--were accorded each of the three test sites. All access tubes penetrated the soil from six to ten feet.

The surface six feet of soil moisture readings were examined with respect to effects of the chemicals upon aspen use of water since aspen roots are mostly concentrated above this depth. An analysis of variance suggested no significant difference in water use among the three plots following treatment.

A closer look at six-foot soil moisture totals for the two years revealed an interesting occurrence. In the treatment year, 1967, the peak soil moisture retention occurred nearly a month later than for the year before. This was due to an unusually cold and wet late spring.

A look at the seasonal low point of soil moisture in September showed no significant difference in moisture retention for the two years, either for the treated or control portions of the study tract. This would serve to suggest that the chemical applications were inadequate to accomplish the primary objective of the study.

However, it was found that throughout the 1967 growing season the depletion of soil moisture for all three sites lagged behind the depletion for 1966. This occurred right up until late September when the differences in depletion for the two years disappeared. Although the late spring in 1967 aided in the explanation of the lag it is evident that the PMA treatment incurred a significant delay in water use.

An observation of the effectiveness of spraying suggests that for both the herbicide and antitranspirant an insufficient concentration was applied and/or spraying was ineffective in contacting a significant percentage of the leaf area.

LITERATURE CITED

Bandiei, Amir A., Eddie Basler, and Paul W. Santelmann. 1966. Aspects of movement of 2,4,5-T in blackjack oak. Weeds 14:302-305.

Barring, Ulf. 1965. Treatment of broadleaved trees with herbicides. Studia Forestalia Suecica 25:1-65. (English summary)

Brown, H. E., and J. R. Thompson. 1965. Summer water use by aspen, spruce, and grasslands in western Colorado. J. Forestry 63: 756-760.

Bruinsma, J. 1965. Effects of pesticidal treatments on the chlorophyll content of plant parts. Residue Reviews 10:13.

Currier, H. B., and C. D. Dybing. 1959. Foliar penetration of herbicides--review and present status. Weeds 7:195-213.

Dalrymple, A. V., and E. Basler. 1963. Seasonal variation in absorption and translocation of 2,4,5-trichlorophenoxyacetic acid and respiration rates in blackjack oak. Weeds 11:41-45.

Davenport, D. C. 1966. Effects of phenylmercuric acetate on transpiration and growth of small plots of grass. Nature 212: 801-802.

Granger, R. L., and L. J. Edgerton. 1966. Effects of two new petroleum spray oils and phenylmercuric acetate on stomata of apple leaves. Proc. Amer. Soc. Hort. Sci. 88:48-51.

Hyatt, S. Wesley. 1966. Sagebrush control, costs, results, and benefits to the rancher. J. Range Management 19:42-43.

Ives, W. G. H., and L. D. Nairn. 1966. Effects of defoliation on young upland tamarack in Manitoba. Forestry Chron. 42:137-142.

Kittredge, J. 1938. The magnitude and regional distribution of water losses influenced by vegetation. J. Forestry 36:775-778.

Koshi, P. T. 1966. Soil moisture measurement by neutron method in rocky wildland soils. Proc. Soil Sci. Soc. Amer. 30:282-284.

Kramer, P. J. 1952. Plant and soil water relations on the watershed. J. Forestry 50:92-95.

Morton, Howard L. 1966. Influence of temperature and humidity on foliar absorption, translocation, and metabolism of 2,4,5-T by mesquite seedlings. Weeds 14:136-141.

Norris, Logan A. 1966. Degradation of 2,4-D and 2,4,5-T in forest litter. J. Forestry 64:475-476.

Schultz, John D. 1967. Current status of soil-moisture measurement by the neutron method, pp. 791-796. In W. E. Sopper and H. W. Lull (Eds.). Forest Hydrology. Pergamon Press, Oxford, England. 813 pp.

Shimshi, Daniel. 1963a. Effect of chemical closure of stomata on transpiration in varied soil and atmospheric environments. Plant Physiology 38:709-712.

Shimshi, Daniel. 1963b. Effect of soil moisture and phenylmercuric acetate upon stomatal aperture, transpiration, and photosynthesis. Plant Physiology 38:713-721.

Slatyer, R. O., and J. F. Bierhuizen. 1964. The effect of several foliar sprays on transpiration and water use efficiency of cotton plants. Agric. Meteor. 1:42-53.

Waggoner, P. E. 1967. Transpiration of trees, and chemicals that close stomata, pp. 483-489. In W. E. Sopper and H. W. Lull (Eds.). Forest Hydrology. Pergamon Press, Oxford, England. 813 pp.

Waggoner, P. E., and B. A. Bravdo. 1967. Stomata and the hydrologic cycle. Proc. Nat. Acad. Sci. 57:1096-1102.

Waggoner, P. E., and J. D. Hewlett. 1965. Test of a transpiration inhibitor on a forested watershed. Water Res. Rev. 1:391-396.

Waggoner, P. E., J. L. Monteith, and G. Szeicz. 1964. Decreasing transpiration of field plants by chemical closure of stomata. Nature 201:97-98.

Waggoner, P. E., and I. Zelitch. 1965. Transpiration and the stomata of leaves. Science 150:1413-1420.

Weaver, R. J. 1946. Influence of rainfall on the effectiveness of 2,4-dichlorophenoxyacetic acid sprayed for herbicidal purposes. Bot. Gaz. 107:540-544.

Weed Society of America. 1967. Herbicide Handbook. W. F. Humphrey Press Inc., Geneva, New York. 296 pp.

Woodford, E. K., K. Holly, and C. C. McCready. 1958. Herbicides. Annual Review of Plant Physiology 9:311-358.

Young, J. Llewellyn. 1939. Glaciation in the Logan quadrangle, Utah. Masters thesis, Utah State University, Logan, Utah. 79 pp.

Zelitch, I. 1961. Biochemical control of stomatal opening in leaves. Proc. Nat. Acad. Sci. 47:1423-1433.

Zelitch, I. 1967. Control of leaf stomata--their role in transpiration and photosynthesis. Amer. Scientist 55:472-486.

Zelitch, I., and P. E. Waggoner. 1962. Effect of chemical control of stomata on transpiration and photosynthesis. Proc. Nat. Acad. Sci. 48:1101-1108.

APPENDIX

Table 5. Soil water depletion data at various dates throughout the growing season for 1966--control plots

Dates	Absolute soil water depletion[a] (inches)	Cumulative absolute soil water depletion (inches)	Percent soil water depletion[b]	Cumulative percent soil water depletion[c]
May 24-25		0.00		0.0
	1.99		16.6	
June 14-15		1.99		16.6
	0.85		7.1	
June 21-24		2.84		23.7
	1.78		14.9	
June 28-30		4.62		38.6
	1.20		10.0	
July 12-13		5.82		48.6
	1.96		16.4	
July 25-27		7.78		65.0
	0.68		5.7	
August 4-5		8.46		70.7
	2.31		19.3	
August 22-24		10.77		90.0
	1.19		10.0	
September 5-7		11.96		100.0
Totals	11.96		100.0	

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[a] These figures are obtained from Table 4 by taking the differences in soil moisture between successive dates.

[b] These figures are the percent of total seasonal depletion that was lost at the various time intervals.

[c] See Figure 5 for the curve representing these data.

Table 6. Soil water depletion data at various dates throughout the growing season for 1966--PMA plots

Dates	Absolute soil water depletion[a] (inches)	Cumulative absolute soil water depletion (inches)	Percent soil water depletion[b]	Cumulative percent soil water depletion[c]
May 24-25		0.00		0.0
	2.35		17.8	
June 14-15		2.35		17.8
	0.45		3.4	
June 21-24		2.80		21.2
	1.95		14.8	
June 28-30		4.75		36.0
	1.25		9.5	
July 12-13		6.00		45.5
	2.29		17.3	
July 25-27		8.29		62.8
	0.85		6.4	
August 4-5		9.14		69.2
	2.82		21.4	
August 22-24		11.96		90.6
	1.24		9.4	
September 5-7		13.20		100.0
Totals	13.20		100.0	

[a] These figures are obtained from Table 4 by taking the differences in soil moisture between successive dates.

[b] These figures are the percent of total seasonal depletion that was lost at the various time intervals.

[c] See Figure 5 for the curve representing these data.

Table 7. Soil water depletion data at various dates throughout the growing season for 1966--2,4,5-T plots

Dates	Absolute soil water depletion[a] (inches)	Cumulative absolute soil water depletion (inches)	Percent soil water depletion[b]	Cumulative percent soil water depletion[c]
May 24-25		0.00		0.0
	1.85		16.8	
June 14-15		1.85		16.8
	0.96		8.7	
June 21-24		2.81		25.5
	1.07		9.7	
June 28-30		3.88		35.2
	1.53		13.9	
July 12-13		5.41		49.1
	1.64		14.9	
July 25-27		7.05		64.0
	0.76		6.9	
August 4-5		7.81		70.9
	2.10		19.1	
August 22-24		9.91		90.0
	0.94		8.5	
September 5-7		10.85		98.5
	-0.33		-3.0	
September 20-21		10.52		95.5
	0.49		4.5	
September 28-30		11.01		100.0
Totals	11.01		100.0	

[a] These figures are obtained from Table 4 by taking the differences in soil moisture between successive dates.

[b] These figures are the percent of total seasonal depletion that was lost at the various time intervals.

[c] See Figure 5 for the curve representing these data.

Table 8. Soil water depletion data at various dates throughout the growing season for 1967--control plots

Dates	Absolute soil water depletion[a] (inches)	Cumulative absolute soil water depletion (inches)	Percent soil water depletion[b]	Cumulative percent soil water depletion[c]
June 21-24		0.00		0.0
	0.86		7.4	
June 28-30		0.86		7.4
	1.85		16.0	
July 12-13		2.71		23.4
	2.20		19.0	
July 25-27		4.91		42.4
	2.42		20.8	
August 8-9		7.33		63.2
	1.75		15.1	
August 22-24		9.08		78.3
	1.60		13.8	
September 5-7		10.68		92.1
	0.91		7.9	
September 20-21		11.59		100.0
Totals	11.59		100.0	

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[a] These figures are obtained from Table 4 by taking the differences in soil moisture between successive dates.

[b] These figures are the percent of total seasonal depletion that was lost at the various time intervals.

[c] See Figure 6 for the curve representing these data.

Table 9. Soil water depletion data at various dates throughout the growing season for 1967--PMA plots

Dates	Absolute soil water depletion[a] (inches)	Cumulative absolute soil water depletion (inches)	Percent soil water depletion[b]	Cumulative percent soil water depletion[c]
June 21-24		0.00		0.0
	0.44		3.7	
June 28-30		0.44		3.7
	1.68		14.2	
July 12-13		2.12		17.9
	1.97		16.6	
July 25-27		4.09		34.5
	2.44		20.5	
August 8-9		6.53		55.0
	2.53		21.3	
August 22-24		9.06		76.3
	1.75		14.7	
September 5-7		10.81		91.0
	1.07		9.0	
September 20-21		11.88		100.0
Totals	11.88		100.0	

[a] These figures are obtained from Table 4 by taking the differences in soil moisture between successive dates.

[b] These figures are the percent of total seasonal depletion that was lost at the various time intervals.

[c] See Figure 6 for the curve representing these data.

Table 10. Soil water depletion data at various dates throughout the growing season for 1967--2,4,5-T plots

Dates	Absolute soil water depletion[a] (inches)	Cumulative absolute soil water depletion (inches)	Percent soil water depletion[b]	Cumulative percent soil water depletion[c]
June 21-24		0.00		0.0
	0.75		7.1	
June 28-30		0.75		7.1
	1.67		15.8	
July 12-13		2.42		22.9
	1.70		16.1	
July 25-27		4.12		39.0
	2.23		21.2	
August 8-9		6.35		60.2
	1.54		14.6	
August 22-24		7.89		74.8
	1.34		12.7	
September 5-7		9.23		87.5
	1.32		12.5	
September 20-21		10.55		100.0
Totals	10.55		100.0	

[a] These figures are obtained from Table 4 by taking the differences in soil moisture between successive dates.

[b] These figures are the percent of total seasonal depletion that was lost at the various time intervals.

[c] See Figure 6 for the curve representing these data.

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