Transpiration rates of Agropyron cristatum plants sprayed with 5% XEF were indistinguishable from controls after 24 hours (Figure 2). The pattern for photosynthesis was very similar. Because of the rapid decay of antitranspirant effectiveness of XEF on both Achillea millefolium and Agropyron cristatum, it seemed highly doubtful that this antitranspirant would be suitable for meeting the objectives of this project. Thus, no further trials with XEF on the herbaceous species were conducted.

Mobileaf (16.5%) reduced transpiration of A. cristatum plants 40-50% (Figure 3). The parallel slopes for the control and treated plants after 30 hours shows that most of the apparent decay of antitranspirant effectiveness is due to growth, i.e., the addition of new leaf surface. Note that control plants were adding biomass so rapidly that transpiration rates nearly doubled in four days. This rapid growth was typical of the four herbaceous plants studied, and emphasizes the necessity to correct antitranspirant data for the growth of controls in order to obtain an accurate picture of duration of effectiveness.

In Figure 4, the transpiration data are the same as those plotted in Figure 3, but the rates have been corrected for the growth of controls. The parallel reductions of transpiration and photosynthesis indicates that the antitranspirant film imposes a similar barrier to the diffusion of carbon dioxide and water vapor. It seems probable that the film is essentially impervious to both gases, and the magnitude of the reduction in rates is indicative of the extent of leaf surface coverage.

Initial reductions in transpiration and photosynthesis of A. cristatum treated with the Mobileaf/XEF mixture were greater than with Mobileaf alone (cf. Figures 4 and 5). However, effectiveness appeared to decay more rapidly with the Mobileaf/XEF mixture. Similar patterns were found in experiments on Elymus canadensis plants (Figures 6 and 7); but there was no doubt that effectiveness of the antitranspirant mixture decayed more rapidly than that of Mobileaf alone. After nine days, rates of the Mobileaf/XEF treated plants were indistinguishable from controls, whereas rates of Mobileaf treated plants were only ca. 60% of controls (Figure 6).

We repeated the experiments on Achillea millefolium, comparing the effects of the Mobileaf/XEF mixture to 16.5% Mobileaf. The results were essentially identical to those for A. cristatum and E. canadensis. The mixture resulted in a larger initial decrease in rates but effectiveness decayed more rapidly than with Mobileaf only. The short-term enhancement of effectiveness appeared to be more than offset by the long-term reduction of effectiveness.

Twelve days after treatment, transpiration and photosynthesis of A. millefolium plants treated with 16.5% Mobileaf were still significantly lower than controls (Table III). Average transpiration rate of treated plants was 51% that of controls, while net photosynthesis of treated plants was 62% of the control rates.

Table III. Transpiration and net photosynthesis of Achillea millefolium plants 12 days ater spraying with 16.5 Mobileaf or distilled water (controls).

Transpiration g H_2O/g dry weight leaf · hr		Photosynthesis mg CO_2/g dry weight leaf · hr	
Mobileaf	Controls		
7.7	3.5	53.8	31.8
7.3	4.4	43.1	31.2
6.6	3.6	48.1	27.7
$\bar{x}$ = 7.2	3.3	$\bar{x}$ = 48.3	28.8
	$\bar{x}$ = 3.7		$\bar{x}$ = 29.9

$t = 9.4$ with 5 d.f. $t = 6.5$ with 5 d.f.

$P < 0.001$ $P < 0.01$

Mobileaf (16.5%) and Wilt Pruf (16.5%) resulted in similar initial reductions of transpiration of *Melilotus officinalis*, but long-term effectiveness was significantly better with Mobileaf (Figure 8).

Figure 8 points out two difficulties encountered in our antitranspirant research methods. First, there are practical limits on the amounts of plant materials that can be enclosed in the cuvette without causing mutual shading of leaves or restricted air circulation. Initially, one must have enough plant material in the cuvette for accruate rate measurements after antitranspirant treatment. Because of rapid growth, the *M. officinalis* plants had practically outgrown the capacity of the gas exchange system in two weeks. From Figure 8, one can infer that the average leaf biomass of control plants had tripled in the 14-day experiment.

Secondly, in longer experiments differences in the growth rates of individual plants become a problem. Note in Figure 8 that the standard error of both treated and control plant means becomes greater with time. This differential growth, especially of controls, makes it difficult to evaluate long-term effectiveness because antitranspirant effects may be obscured by the large sample variance. The solution to this problem, of course, is a larger sample; but one is again practically limited to measuring about eight plants per day with one gas-exchange system.

Although in Figure 8 transpiration appears to be reduced in treated vs. control plants on day 14, there was no significant differences in absolute rates of transpiration or photosynthesis (Table IV).

Table IV. Transpiration and photosynthesis of *Melilotus officinalis* plants 14 days after spraying with 16.5% Mobileaf, 16.5% Wilt Pruf, or distilled water (controls).

Transpiration
g H_2O/g dry weight leaf · hr

Mobileaf	Wilt Pruf	Controls
8.9	10.8	11.7
9.3	11.0	10.7
7.4	9.5	7.8
7.9	8.2	7.9
$\bar{x}$ = 8.3	$\bar{x}$ = 9.9	$\bar{x}$ = 9.5

F = 1.2 with 9, 2 d.f.

P > 0.1 n.s.

Net Photosynthesis
mg CO_2/g dry weight leaf · hr

Mobileaf	Wilt Pruf	Controls
64.4	69.9	81.7
66.7	74.8	77.2
46.2	65.4	63.1
55.8	60.6	51.3
$\bar{x}$ = 58.3	$\bar{x}$ = 67.7	$\bar{x}$ = 68.3

F = 1.2 with 9, 2 d.f.

P > 0.1 n.s.

Conclusions and Recommendations: BLM Study

The results indicate that Mobileaf, Wilt Pruf, or similar antitranspirant formulations will effectively reduce transpiration of herbaceous species in the laboratory. Antitranspirant effectiveness, when corrected for growth of controls, appears to be satisfactory for 10-14 days after spraying. Obviously, because of rapid growth of new leaf area more frequent application would be necessary to achieve maximum water savings. This was found to be true for both dicotyledonous and monocotyledonous species.

The similarity of antitranspirant effects on all four species suggest that similar laboratory results could be expected with most herbaceous range or roadside species. It would be difficult, however, to achieve as thorough spray coverage in the field. Thus, the magnitude of transpiration reduction reported here probably indicates the maximum that can be achieved in the field.

An antitranspirant which would also function as a growth retardant, or a retardant/antitranspirant mixture, would be advantageous for meeting the BLM objectives. Several commercial growth retardants have been reported to have antitranspirant properties. We have obtained samples of two (Alar, a UNIROYAL product and Atrazine from CIBA-GEIGY Corporation) for laboratory trials singly and in combination with film-forming antitranspirants.

We would recommend the initiation of a small scale field study to attempt to quantify the magnitude of actual water savings along roadways by various antitranspirant treatments, including mowing. Using standard, inexpensive gravimetric soil moisture determination, it should be relatively easy to make quantiative estimates of the actual amount of water saved. Comparing soil moisture on clipped and unclipped roadside stands should indicate the maximum potential for water savings and provide a good baseline to which values from areas treated with chemical antitranspirants could be compared. The relatively homogeneous extensive stands or reseeded vegetation along intermountain roadways provide a unique outdoor laboratory for such experiments.

Phreatophyte Studies

Initial transpiration reductions in growth-chamber grown Tamarix plants treated with either XEF (5%) or Mobileaf (16.5%) were similar, but, as with the herbaceous species, XEF effectiveness was for more short-lived (Figure 9). Duration of antitranspirant effectiveness in Mobileaf-treated plants appeared to be better than that observed among the herbaceous species (compare Figures 3-8 with Figure 9). After six days, transpiration of the treated plants was still less than 55% of the original rates. Based on these results and discussions with co-workers at the University of California, Davis, Mobileaf was selected for use in the field studies at Bernardo, New Mexico.

Water consumption measured on Bernardo evapotranspirometers 4, 5, and 6 for the period with the exception of tanks 5 and 6 on 16 June, day to day variations among values for the three tanks tend to be parallel, indicating that the vegetation on the three tanks responded similarly to changing environmental conditions and that the measuring system recorded those responses. These data suggest that the integrity of the evapotranspirometers is good, but the water consumption data also raise some serious questions. Presumably, if all other factors were equal, the evapotranspirometers would respond identically to changing environmental conditions. This obviously is not the case. For example, the decrease in water consumption on 17 June was due to afternoon cloudiness and high humidity on 16 June. But, the magnitude of the decrease on 17 June and following increase on 18 June was very different, especially comparing tanks 5 and 6. In addition, the percent of the total water consumed in 24 hours which was consumed during the night was usually higher on tank 6 than on 5 or 4 (Table V). There is no apparent reason for this difference, but it does indicate that there may be significant differences in the performance of the evapotranspirometers.

Table V. Comparison of "day" vs. "night" water consumption on evapotranspirometers 4, 5, and 6

		Gallons of Water Consumed		
Evapotranspirometer	Date	"Day" 08:30-18:30	"Night" 18:30-80:30	% "Night"
	June 14-15	93	30	24
	15-16	96	44	32
4	16-17	79	31	25
	17-18	75	41	35
	18-19	87	57	39
	June 14-15	128	53	29
	15-16	137	69	34
5	16-17	97	40	29
	17-18	104	44	30
	18-19	107	66	38
	June 14-15	130	71	35
	15-16	116	77	40
6	16-17	109	60	36
	17-18	125	77	38
	18-19	129	100	44

The arrows in Figure 10 indicate the time of application of anti-transpirant. Tank 4 was sprayed with 10% Mobileaf between 9:00 and 10:00 AM on 16 June. The decrease in water consumption immediately following spraying was probably due to afternoon cloudiness and high relative humidity. The data for the following days show a pattern very similar to that of the control tank (Number 6). No effect of the anti-transpirant application was apparent in the evapotranspirometer data.

Tank 5 was sprayed with 15% Mobileaf on 18 June. Again, no reduction in transpiration (water consumption) of the same order of magnitude expected from the laboratory results was found. The data suggest the possibility of some antitranspirant effect from 20-24 June. During the early part of the period, consumption on Tanks 5 and 6 were very similar. The large drop on Number 5 on the 17th was probably not due to spraying and it is not known. Whether the antitranspirant treatment was a factor in maintaining the lower rate of consumption on tank Number 5. If one assumes that the difference between the consumptions of Tanks 5 and 6 for for the period 20-24 June was entirely due to the antitranspirant, one could infer a maximum reduction in consumption of about a 30%. It seems doubtful that the difference was entirely due to the antitranspirant. The best interpretation is that the resulting water savings was probably something less than 30%.

Transpiration rates of individual branches after spraying, measured with the gas exchange system, are shown in Figure 11. None of the five sprayed branches showed a transpiration reduction of the same order of magnitude as was observed in the laboratory; initial reductions ranged from near zero to about 30 percent. Water consumption rates of sprayed branches were consistently lower than those of controls for six days after spraying, leaving little doubt that there was some antitranspirant effect. Absolute transpiration and photosynthetic rates on 24 June were significantly lower among treated than among control plants (Table VI).

Table VI. Comparison of transpiration and net photosynthetic rates of sprayed vs. control *Tamarix* branches 6 days after spraying at the Bernardo evapotranspirometer site.

Transpiration ($g\ H_2O$/g dry weight leaves · hr)		Photosynthesis ($mg\ CO_2$/g dry weight leaves · hr)	
Sprayed	Control	Sprayed	Control
2.7	4.5	10.7	15.0
2.5	3.4	10.1	13.8
2.7	3.5	11.6	13.2
2.3	3.5	9.8	14.1
2.4	$\bar{x}$ = 3.5	10.7	$\bar{x}$ = 14.0
$\bar{x}$ = 2.5		$\bar{x}$ = 10.6	

t = 2.48 with 7 d.f.
$P < 0.05$

t = 7.17 with 7 d.f.
$P < 0.001$

It should be noted that 2 of the control branches were on the sprayed tank (branches 5-6 and 5-11 in Figure 11). These were covered during spraying. The data for these branches is similar to the control branches in Tank 6.

It is encouraging that there was no large discrepancy between the evapotranspirometer results and the gas exchange results. Both suggest a transpiration reduction of somewhat less than 30%, and the gas exchange measurements indicate clearly that despite considerable "environmental noise" such a reduction can be detected in the field with an adequate sample size.

After several days of gas exchange measurements in the field it became obvious that the *Tamarix* plants were behaving quite differently than laboratory reared ones. Some appeared to have high transpiration and low photosynthesis rates, while in others the opposite was observed. This suggested a difference in stomatal resistance among plants. Water vapor diffusing from a leaf encounters two major resistances, a stomatal resistance (r_s) which is dependent upon stomatal pore size, and a boundary layer resistance (r_b) which is dependent upon wind or turbulence at the leaf surface (here we will ignore cuticular resistance). Carbon dioxide diffusing into the leaf encounters r_b and r_s and a third resistance at the mesophyll (r_m) which is a resistance to trnasport from the mesophyll surface to the site of carboxylation at the chloroplast. Since the resistances are in series, an increase in r_s (decrease in stomatal aperture) is expected to reduce transpiration proportionately more than photosynthesis. Thus, different ratios of photosynthesis to transpiration, which we shall refer to as water use efficiency, indicate different stomatal resistance.

Water use efficiency values for all the individual branch measurements made at Bernardo show a definite increase in the afternoon, indicating partial stomatal closure (Figure 12). Thus, it is apparent that the *Tamarix* plants, growing with a constant water supply, are closing their stomata and reducing transpiration during the afternoon of a typical June day. Such closure could be in response to one or a combination of three factors: (1) plant water stress, (2) high ambient temperatures, and (3) low relative humidity. During the field study, afternoon air temperatures were usually between 32 and 37°C, with relative humidity varying between 10 and 15%.

In an attempt to assess the magnitude of the afternoon depression of transpiration, steady-state measurements of transpiration and photosynthesis at 30°C were made on three *Tamarix* branches during the morning or early afternoon and were then repeated during the latter part of the same day. Afternoon transpiration reductions ranged from 17 to 43% (Table VII) and corresponding increases in water use efficiency were observed.

Table VII. Transpiration, photosynthesis, and water use efficiency of three *Tamarix* branches at different times of day, 23 June 1975, Bernardo, New Mexico

Plant	Time	Net Photosynthesis (mg CO_2/g dry wt · hr)	Transpiration (g H_2O/g dry wt · hr)	Water Use Efficiency Net Photosynthesis / Transpiration x 10^{-3}
6-3	10:00AM	15.4	3.8	0.41
	2:30PM	14.0	3.2	0.44
6-4	11:35AM	13.9	3.3	0.43
	3:15PM	11.5	1.8	0.62
6-5	12:45PM	11.2	2.6	0.44
	4:15PM	11.0	1.7	0.65

Conclusions and Recommendations: Phreatophyte Studies

Laboratory transpiration reductions and antitranspirant persistance with Mobileaf on *Tamarix* appeared very satisfactory. Reuctions obtained in the field were not as large as in laboratory tests, but it was possible to show an antitranspirant effect with the gas exchange studies. Six days after antitranspirant application transpiration of sprayed branches averaged 70% of that of controls.

It is possible that the difference between laboratory and field effects is due to a lack of uniformity and thoroughness of spray coverage. It is very difficult to achieve as thorough of coverage in the field even with a hand-held sprayer. Under the high temperatures and low humidities encountered, some of the spray droplets may have evaporated before touching plant material. Coverage appeared to be enhanced by using a slower engine speed resulting in larger droplets during the final spraying. A study of application techniques to determine the best droplet size is needed. It it also possible that coverage would be enhanced it spraying could be completed at night or during the very early morning hours when evaporative demand are lower.

More information on the physiological ecology of _Tamarix_ is sorely needed. Studies should be initiated to determine the cause and mechanisms involved in the afternoon depression of the transpiration. If the mechanisms were understood, it might be possible to take advantage of the natural processes to reduce water consumption. Information on diurnal cycles in gas exchange rates is needed to facilitate the interpretation of data collected after antitranspirant application.

Field studies should be initiated to compare water consumption by various phreatophyte species. It was found in this study that salt cedars do not transpire at a potential rate all day. It should be ascertained if this is generally true of phreatophytes. At present, two evapotranspirometers at Bernardo are planted with Russian Olive. Water consumption on those tanks is double that of the _Tamarix_ tanks. This suggests that it might be advantageous to have _Tamarix_ present rather than another phreatophyte.

The field studies indicate that our knowledge of the physiology and ecology is insufficient for the interpretation of antitranspirant field trials. A better understanding of these should be of fundamental use in any future phreatophyte management program.

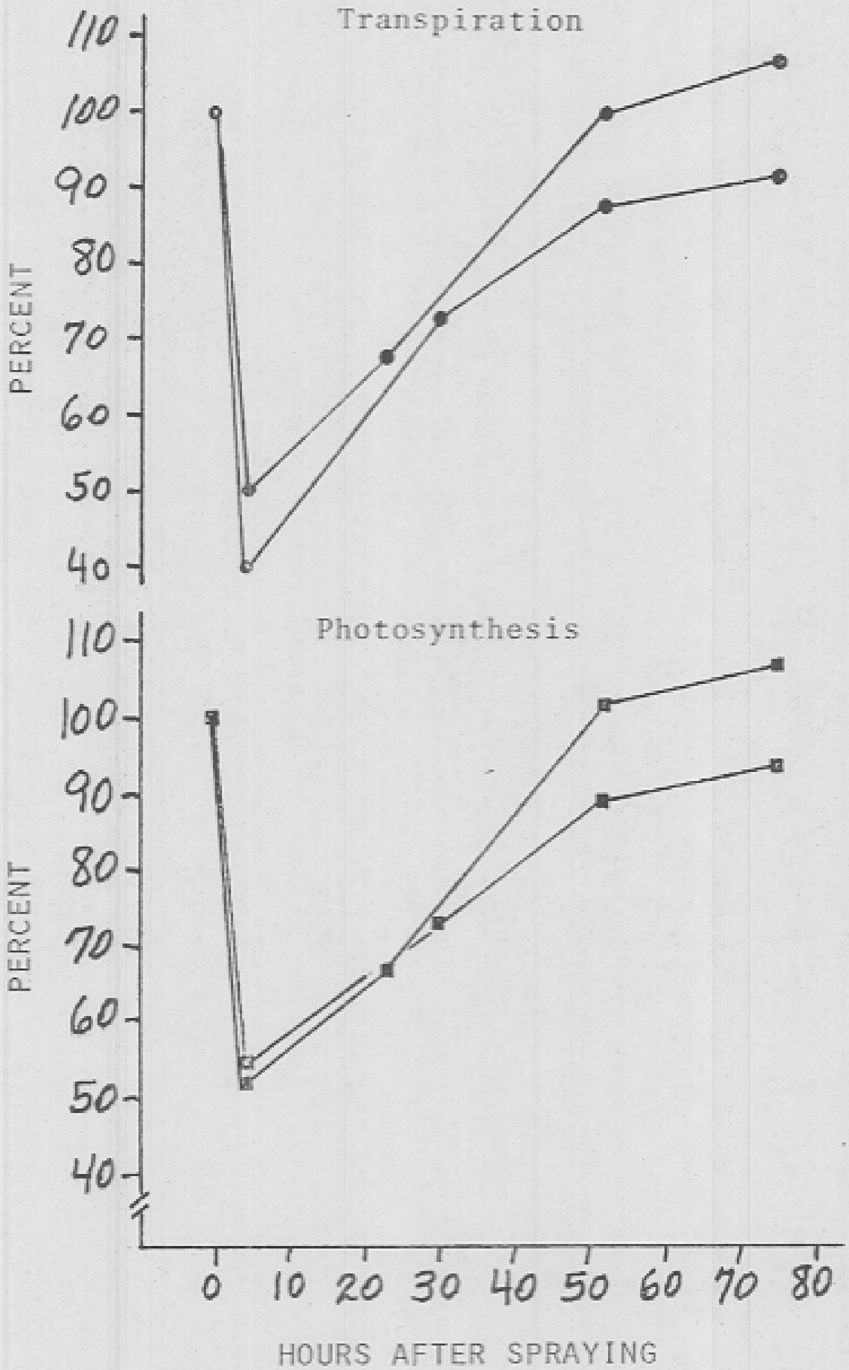

Figure 1. Transpiration and net photosynthesis of *Achillea millefolium* plants sprayed with a 5% solution of XEF-4-3561. Rates are expressed as percentages of the steady state rates just prior to spraying (time zero).

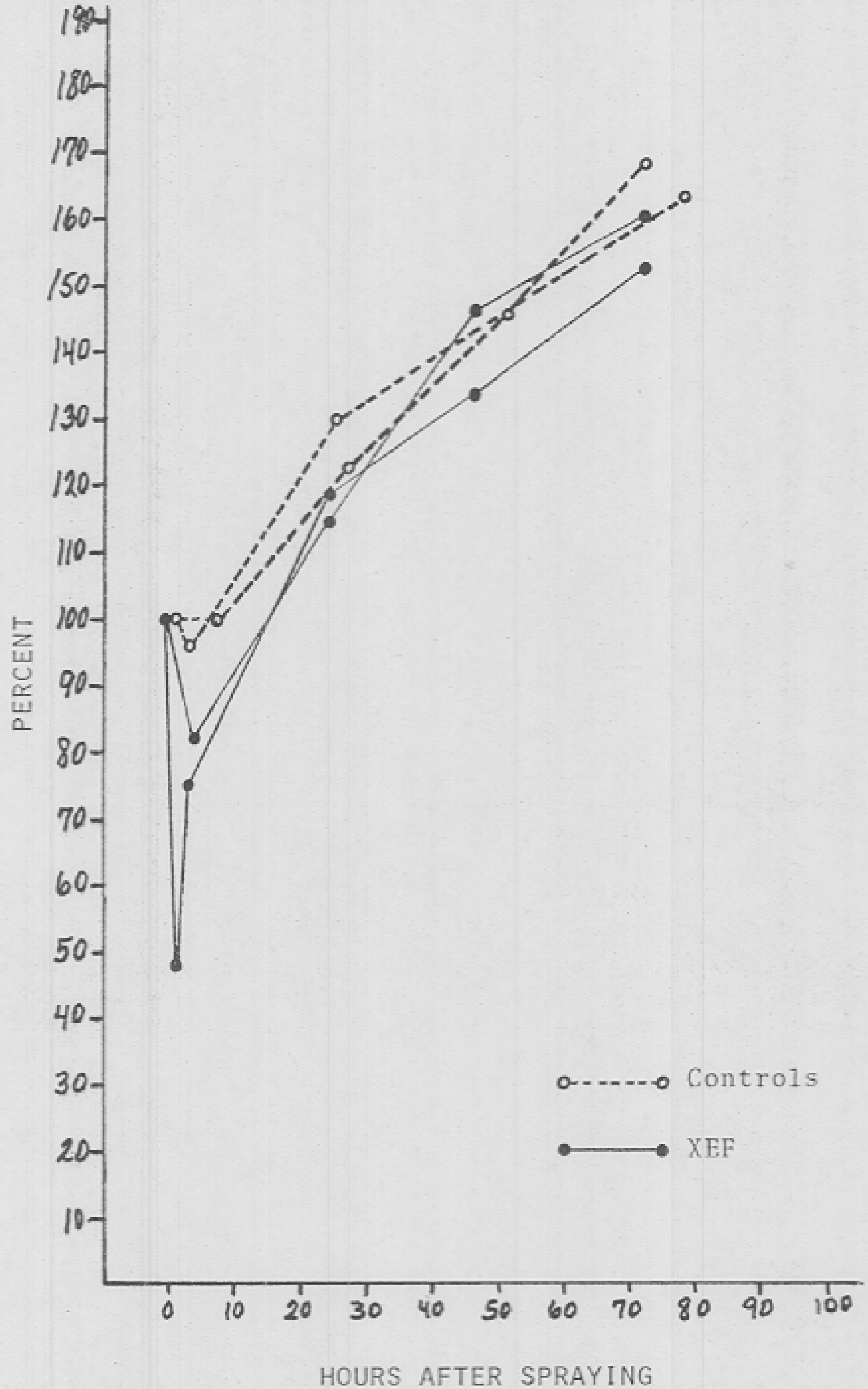

Figure 2. Transpiration of *Agropyron cristatum* plants sprayed with 5% XEF-4-3561, compared to control plants sprayed with distilled water. Rates are expressed as percentages of the rates just prior to spraying (time zero).