EFFECTS OF THE ENVIRONMENT ON FOLIAR APPLIED HERBICIDES

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Have you ever seen an herbicide used for its intended purpose and yet it failed to work, or it killed the plants that should have been left? I would guess that we all have at some time or other. This failure or excess may have been due to "the wrong target plants or wrong material," "the application" or it may have been "the effects of the environment."

This topic will include only the effects of environment on foliar applied herbicides. We know however that much of a foliar applied material eventually reaches the soil. This aspect of foliar applied herbicides will not be discussed.

The effects of the environment are subtle, variable, and usually not controlled. Knowledge of what the environment does, however, will mean that you can probably offset or avoid problems that may be caused by these variables. The environment does not determine overall plant/herbicide response, but it can substantially change the level of activity obtained. The principal factors that can concern use include:

1) moisture, both in the soil and the air
2) light
3) temperature
4) soil fertility

All the factors can influence herbicide activity either before spraying (preconditioning) or after spraying. The factors are also interacting, and frequently it may be difficult to determine which one is the more significant, in altering the activity of the herbicide. Each factor will be discussed separately, but it must be remembered that it may be modified by the other factions when considered in the overall picture.

Moisture - Both in soil and in the air. There are three aspects to moisture that must be considered in relation to the activity of foliar applied herbicides; these are relative humidity, soil moisture and rainfall.

Relative humidity is probably more important than the absolute amount of water in the atmosphere because relative humidity determines how fast a drop will dry on the surface of the plant and also determines the transpirational stress on the plant when associated with available soil moisture.

1/ Much of the material presented here was pulled together by Dr. Robert Norris for a previous University Extension handout.

Temperature alters relative humidity and thus cannot readily be divorced from a discussion on the effects of relative humidity.

Probably the main effect of relative humidity is in controlling the speed at which a spray drop dries on the leaf surface. There is good evidence that penetration slows down and may cease when the drop dries out. Low relative humidity causes the drop to dry out faster thus herbicide activity is usually less.

Glyphosate on johnsongrass was much more effective at 100% relative humidity than at 40% relative humidity. Dalapon uptake has also been shown to be greatly enhanced by high relative humidity.

Crop density can enter as a factor here. The relative humidity tends to be high in a dense crop stand and lower in a weak, open crop stand, and thus can alter herbicide activity. High relative humidity favors opening of the plant stomata, low relative humidity may lead to stomatal closure. Since herbicides such as 2,4-D and dalapon can be taken up through the open stomata and not through closed stomata relative humidity can alter their apparent activity.

Often relative humidity is coupled to soil moisture. Glyphosate activity on johnsongrass when measured at a constant relative humidity of 45% gave increased activity when soil moisture was at 20% compared to 12%.

Soil moisture - Plants grown with abundant soil moisture are more succulent than plants grown with low soil moisture. The succulent plants are typically much easier to control than those that have been stressed. Herbicides like glyphosate, paraquat, betanol, amitrole, dalapon and 2,4,5-T have all been shown to have less activity if the plants were growing in drier soil before or immediately following treatment. Labels of glyphosate and dalapon reflect this effect of soil moisture on control. To show the effect of different soil moisture levels Ahmadi et.al(1980) evaluated the effect of glyphosate on barnyardgrass at four moisture levels and two plant heights.

Herbicide	Rate kg/ha	Soil moisture %	Weight reduction(%) sprayed at 7.5 cm	15 cm
glyphosate	0.4	40	92	88
		30 (field capacity)	86	84
		20	80	7
		10	71	33

At field capacity control was excellent at either plant height but if soil moisture decreased control also decreased.

In California, Basagran when evaluated for sedge control is very moisture dependent, i.e. high soil moisture allows better control.

In another study on johnsongrass - Glyphosate gave much better control at 20% soil moisture (near field capacity) than at 12% (near permanent wilting point).

This type of response is at least in part probably due to the plant cuticle which becomes thicker under the stress conditions. Dry soil conditions following foliar applications can enhance activity of the herbicide also.

2,4-D injury to wheat was increased when the plants remained dry for 4 to 8 days after spraying. Increased injury has occurred to sugarbeets following Betanal application when irrigation was delayed for 10 days. As soil moisture varies during an irrigation cycle from essentially field capacity following irrigation to frequently not much above wilting point the timing of postemergence treatments in relation to soil moisture status may be much more critical than is generally considered. In brush and non-cropland areas, moisture level can be the important factor for uptake translocation and control.

Rainfall, as a moisture factor, following soon after treatment can wash foliar herbicides off the leaves and cause loss of activity. As little as 1/10" of rain one hour after application of 2,4-D caused a 50% loss of activity on several crops and almost complete loss of activity in brush. Herbicides differ in their susceptibility to washing off by rain, in terms of quantity of rain needed how soon after spraying it falls, and even formulation of herbicide used.

Paraquat, for example, is much less susceptible to rainfall than glyphosate or the phenoxy herbicides. I have observed where paraquat controlled grasses when 1/2" rain fell within 20 min. from spraying. Some people have said application in a light rain did not adversely affect control.

Bentazon when compared on a sensitive weed (velvetleaf) at 0.75 #/A did not show a great response (decrease in control) to time of rainfall, however, a less sensitive weed cocklebur appeared to need 24 hr. from application to rain for excellent control. (Doran and Anderson, 1975).

Rain following applications of different formulations of 2,4-D make a drastic difference. The 2,4-D acid form when dissolved in oil killed kidney beans if rain occurred within 15 minutes after application. At least 24 hours of lead time was needed when the ammonium salt was used.

In a study by Behren and Elakkad (1981) using two formulations of 2,4-D for the control of lambsquarter, the alkanolamine salt of 2,4-D needed up to 4 hours time without rain whereas the butoxyethanol ester of 2,4-D was effective at 0.5 hour. The effect of adding 0.3% v/v surfactant gave vertially no effect on control when added to the ester but did increase control with the salt at short rainfall intervals. Again looking at different weed (plant) species would also react differently. A more resistant species would need more time without rain.

Rates of the herbicide can be increased in some instances to offset the rainfall effect.

Bovey and Diaz-colon (1969) found that by increasing 2,4-D rates from 0.25 kg/ha to 1 kg/ha an 80% injury evaluation can be changed time-wise from 4 hours to 24 hours.

Increased paraquat rates also reduced susceptibility of rainfall wash-off time.

Again labels such as glyphosate indicate time to rainfall affects, i.e. (2 hours may need retreatment - 6 hours reduced effectiveness).

Traces of rain, or dew, however, can increase activity of some herbicides by rewetting previously dried drops and allow for further penetration to occur. Once again the same factor, although in differing quantity, can cause opposite effects.

Light - Higher light intensity before treating generally increases the resistance of plants to herbicides, conversely plants grown in shady conditions may be much more susceptible.

Under low-light conditions leaf area is usually greater, leaves are thinner, and have less cuticle and wax development; all these factors lead to increased herbicide wetting and uptake.

Changes in light at or immediately following application can have pronounced effects on herbicide activity. Stomata are typically open in the light and closed at night. Compounds such as 2,4-D and dalapon have been shown to be able to penetrate through open stomata when surfactants are added; when the stomata were closed penetration was reduced or stopped and activity was less.

Some herbicides need light to bring about their toxic action. Paraquat and Betanal are good examples, their activity is essentially stopped in the dark, is slow in low light, and very rapid in high light. This partly explains why these herbicides, and many others too, act much slower in the winter than they do in the summer.

Time of day at spraying can drastically alter the activity of some foliar herbicides. It was shown in the early 1960's that MCPA was severely toxic to peas when sprayed in the afternoon, but was essentially non-injurious when sprayed in the early morning. On a dry weight basis spraying at 9:00 a.m. caused no reduction in growth. Spraying at 4:00 p.m. caused a 50% reduction in growth. This effect was attributed to the greater translocation of the herbicide with the photosynthetic products in the afternoon than in the morning. Work by Robert Norris has shown that there is a time of day effect on Betanal and Betanex, but the response is exactly opposite that for the MCPA effect on pease. Application of Betanal or Betanex at 9:00 a.m. causes severe injury to sugarbeets (~30% stand loss) yet treatments made at 6:00 p.m. causes only light injury

(<3% stand loss). He attributed these effects to both light and temperature changes during the day in relation to the uptake and the photosynthetic inhibitory action of the herbicides. The lesson to be learned from this is that the reaction of the individual herbicide must be known, because if a prediction on the action of Betanal from the MCPA experience had been made it would have been 100% wrong.

Temperature - Changing response in relation to effect of temperature is probably the single most important aspect of the environment when considering activity of foliar herbicides. Temperature influences virtually all growth and development processes in the plant, and can thus alter the activity of an herbicide anywhere between uptake and the final metabolic action.

Plants grown at higher temperatures are typically much "tougher" than plants grown at moderate temperatures and are consequently much more difficult to kill with foliar applied herbicides. Changes in temperature at and directly following spraying a foliar herbicide can dramatically alter the activity of the herbicide. Increased temperature typically results in increased activity and more rapid kill. Glyphosate activity on johnsongrass has been shown to be greater at 35°C (95°F) > 29°C (84°) > 24°C (77°F). Some herbicides cannot be used selectively in crops in hot weather due to this increase in activity: dinoseb in peas or seedling alfalfa can cause severe crop injury if the temperatures are exceeding about 70°F. Ammonium thiosulfate burns grass and dichondra turf over 85°F. 2,4-D, bromoxynil, Betanal and many others show decreased selectivity at high temperatures.

2,4-D has been shown to penetrate through isolated cuticle five times greater at temperature of 87°F than at 60°F indicating that increased uptake at higher temperatures is a major reason for the increased activity. 2,4,5-T penetrates and moves into the roots of several tree species more rapidly when applied at 75°F than when applied at 55°F. Neidermyer et.al.-working on barban (Carbyne) found if night temperature decreased from 18-10°C (1 night) wild oats were more sensitive. Three nights at 10°C however gave wheat injury from barban. If daytime air temperature increased following treatment there was reduced wheat injury.

It should be remembered that these effects of temperature may be considerably modified by changes in relative humidity and light intensity which may also be changing at the same time. Trying to isolate which environmental variable is responsible for an altered response is frequently very difficult due to the complex interactions that occur between the herbicide, the plant, and the environment.

Soil fertility - Although there is not a great deal of knowledge on effects of nutrient status it is generally thought that higher fertility levels lead to greater activity of foliar applied herbicides.

High nitrogen has been implicated in higher activity of 2,4-D on soybeans and Betanal on sugarbeets in greenhouse experiments. These interactions have not been proven in the field.

Other environmental factors that are frequently overlooked but have a profound affect on application include:

- High carbonate-bicarbonate in water reduces the available copper for weed uptake because of percipitation.
- The acidity (pH) of water. Both applications in acidified water and application into low pH water.
- Soil pH
- Age and stage of growth of weeds.
- Where some foliar herbicides have soil activity as well the amount of organic matter and clay content of soils.

to name a few.

This discussion on the effects of the environment does not include all of the possible changes that have been reported by researchers. I have attempted to relate some general principles where they seem to be valid, and to give some examples where they are appropriate.

Actual responses of individual herbicides in actual use situations vary so greatly that no attempt has been made to try to cover all these situations.

The following table will summarize (generally) some of the recorded effects of the environment on foliar applied herbicides.

Activity of herbicides as influenced by environmental factors

Herbicide	Relative Humidity	Light	Temperature
2,4-D	High = >	High = ><	Low = >
bromoxynil	High = >	High = >	Low = >
dalapon	High = >	High = >	High = >
triazines	High = ><	High = >	High = >
glyphosate	High = >	High = >	Low = slowed
paraquat	High =	High = >	High = >

< = reduced or slowed activity
> = increased activity

Although many generalizations can be made regarding overall reasons for changes in relative activity of foliar applied herbicides, in most cases the individual plant/herbicide interaction may vary greatly from the general pattern.

Audus in a "State of the Art" statement said "For best results, most susceptible species should be treated during a period of active growth and high humibity. Conditions favoring the growth of one species may not be the same for another. For most plants of temperate regions, a temperature approaching 30°C (86°F), a light intensity near the saturation point for the particular species, a relative humidity approaching 100% and ample soil moisture will lead to increased phytotoxicity."

If there is one "take home message" in relation to the modification of herbicide activity by the environment it would be that prediction of herbicide activity on one plant species may not be valid based on experience gained with a different herbicide or another plant species. We should be aware of possible changes that can occur from the environmental changes and use them, however, whenever possible to our advantage for weed control and crop safety.

References

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