EFFECT OF ENVIRONMENTAL CONDITIONS ON WEED/HERBICIDE INTERACTIONS

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Introduction

Environmental conditions, notably soil moisture, temperature, radiation, and, relative humidity, affect plant growth. Further, the environment affects herbicide properties whether soil-applied or applied postemergence to plants. The interaction of the herbicidal properties and the plant growth characteristics results in the plant response. Generally, the plant growth characteristics are the most important component influencing herbicide activity.

This paper will discuss the effect of environmental conditions on plants, herbicides, and the ability of several herbicide additives to improve plant response to herbicides applied postemergence.

Discussion

Soil-Applied Herbicides

The effectiveness of soil-applied herbicides depends on a number of factors including environmental conditions, soil type, and germination/dormancy characteristics of the weed seed. Rainfall has a major influence on herbicide degradation, the placement of the soil-applied herbicide, the relative availability of the herbicide to germinating weed seeds, and the position of the germinating weed seed relative to the herbicide. It is important to recognize that the herbicide and the weed seed/seedling must be in contact at a critical period during the development of the weed. Generally, if the weed has already germinated and emerged before the herbicide is available for uptake by the seedling, the effectiveness of the herbicide is reduced.

Herbicide degradation

Herbicides are degraded by a number of mechanisms which are in turn affected by environmental conditions. Herbicides can be characterized as those degraded microbially, chemically, or a combination of these mechanisms. Environmental conditions such as soil temperature, air temperature, soil moisture, relative humidity, and solar radiation influence the speed and effectiveness of the degradative mechanism. Environmental conditions that are not favorable for plant growth often slow herbicide degradation.

Environmental factors that have the greatest influence on herbicide degradation are soil moisture and soil temperature. Soils that are extremely dry or cool demonstrate poor herbicide degradation. Chemical degradation is enhanced by high soil temperatures presuming that favorable soil moisture conditions exist. Microbial degradation would not be favored under conditions of extremely high soil temperatures. Generally, soil microorganism growth is favored when soil temperature ranges from approximately 60° F to 85° F.

Another important consideration of microbial herbicide degradation is the temporal aspect of soil moisture. Generally the first 6 to 8 weeks after herbicide application is most critical for the degradation of soil-applied herbicides. Rainfall that occurs later in the growing season may not have the same relative impact on microbial populations and thus will not be as efficient with regards to herbicide degradation.

Chemical herbicide degradation responds somewhat differently to soil moisture and soil temperature than microbial degradation. Different herbicides respond differently to these environmental conditions. Soil moisture conditions, while important for most herbicides degraded chemically, do not seem to be as critical for the timely degradation of sulfonyl urea herbicides. Herbicides such as atrazine must have favorable soil moisture conditions for chemical degradation to proceed.

Soil type has a major effect on herbicide degradation by influencing herbicide availability to degradative processes. Soil texture, pH, and organic matter are characteristics that influence herbicide behavior in soils. Generally, soil pH affects the degradation of 2 herbicide families: the triazine herbicides and the sulfonyl urea herbicides.

Higher soil pH slows the degradation of these herbicides. Other herbicide families are not affected by soil pH within the range that is agronomically acceptable. Texture and organic matter content influence the ability of the herbicide to bind on the soil; when soil texture is fine and when organic matter content is high, the number of herbicide binding sites increases. It is also important to recognize that herbicide rate of application reflects soil characteristics; while coarse textured soils have fewer binding sites and thus herbicides may demonstrate shorter residual properties, coarser soils generally have less microbial populations. If the herbicide rate exceeds that which is normally needed for effective weed control, herbicide degradation is slowed and carryover is possible. Similarly, if soil moisture is limiting, given the number of herbicide binding sites in finer textured soils, herbicide degradation is slowed and carryover is possible.

Herbicide placement

Soil-applied herbicides must be placed in the zone of weed seed germination to be most effective. Herbicide placement must also reflect the physical and chemical properties of the herbicide. Herbicides that are subject to photodegradation or volatilization must be incorporated to protect the herbicide from these processes. Given that most weed seeds germinate in the top 1/2 to 1 inch of soil, and that most implements that are used to incorporate herbicides can not provide uniform vertical and horizontal distribution when operated shallow, much of the herbicide is placed below the germinating seed. If herbicides are applied to the soil surface, rain must move the herbicide in to the zone of germination. Thus timing between the last seed bed preparation, planting, herbicide application, weed seed germination, and rainfall is critical.

Another consideration is that repeated wet/dry cycles will increase the amount of herbicide strongly adsorbed to plant residue and soil colloids. When herbicides are strongly bound on residue or soil, more rain is required to release the herbicide from the binding sight thus increasing the availability for weed control or degradative processes. Herbicide formulations have been developed that will lessen, although not eliminate, this adsorption effect on weed control.

Weed seed germination/dormancy

Weed seeds must be viable and lack dormancy in order to germinate. Dormancy can be lost in a number of ways: after-ripening, temperature, and light are generally considered most important. Once a weed seed is capable of germination, specific environmental conditions must be met for the weed seed to initiate germination. Notably, there must be appropriate seed/soil contact, oxygen, light, moisture, temperature, nutrients, and absence of catastrophic events if the weed seed is to develop. The placement of the weed seed in the soil strata is critical for successful emergence of the weed seedling. However, most weeds have some adaptability relative to soil depth. During conditions of poor moisture availability, weed seeds will germinate from deeper in the soil than during periods of relative good moisture availability. Further, weed seeds can generally imbibe sufficient moisture to germinate even when soil moisture availability may limit herbicide performance.

Postemergence Herbicides

The effectiveness of postemergence herbicides depends on foliar absorption and translocation of the herbicide. The primary barrier to absorption is the leaf cuticle. The cuticle is nonliving, often multilayered, lipoidal, and heterogeneous in chemical composition. It is composed of wax embedded within, and extruding from the surface of a spongy framework of cutin. The cuticle is composed of two layers, the inner layer of cutin and the outer layer of epicuticular wax. The chemical composition, structure, and amount of epicuticular wax deposited are affected by the environment in which the plant develops at the time of epicuticular wax deposition.

Epicuticular wax

The epicuticular wax is more important than all other cuticle components influencing the interactions between a herbicide and the plant. Increases in the amount of epicuticular wax on the leaves are likely to reduce the penetration of herbicides. Changes in the chemistry also affect penetration; generally surfaces rich in nonpolar groups ($-CH_3$) are difficult to wet while those rich in polar groups ($-OH$ and $-COOH$) are more easily wetted. However, the detrimental effect of the epicuticular wax can be overcome by the use of herbicide additives. The chemical characteristics of the herbicide additive are important in determining the efficacy of the herbicide.

Research at Iowa State University has investigated the importance of changes in the cuticle on herbicide efficacy. The responses of velvetleaf (Abutilon theophrasti Medic.) and giant foxtail (Setaria faberi Herrm.) to environmental conditions were observed. Specifically, the amount of epicuticular wax deposited in response to different temperatures and soil moisture conditions was determined.

Further, the uptake of bentazon (Basagran) in velvetleaf and fluazifop-P (Fusilade 2000) in giant foxtail was measured.

Effect of environmental conditions on epicuticular wax deposition

The response of velvetleaf and giant foxtail to different temperatures and soil moisture conditions is reported in table 1. The temperature regimes were designated low (15/20 C, night/day) and high (22/32 C, night/day) while soil moisture treatments consisted of field capacity and drought (-5 to -10 bars). The observations were conducted in the growth chamber. Giant foxtail and velvetleaf responded in a similar manner to the environmental parameters.

The low temperature regime resulted in greater amounts of epicuticular wax the high temperature regime. Giant foxtail grown under the low temperature regime had 39% more epicuticular wax than plants grown under the high temperature regime. Similarly, low temperature velvetleaf had 71% more wax than the high temperature plants. Differences between the temperature regimes were statistically significant for both weed species.

The soil moisture treatments also caused a statistically significant response in the weed species. The drought treatment resulted in more epicuticular wax deposition than the field capacity treatment. Velvetleaf grown under -5 to -10 bars had 80% more epicuticular wax than plants with sufficient soil moisture while giant foxtail had a 31% increase in epicuticular wax for the same comparison. The difference between species is not understood.

It should be noted that these environmental conditions also influenced the chemical composition of the epicuticular wax. However, this discussion will not be included, given the scope of the paper.

Effect of environmental conditions on herbicide uptake

The same environmental conditions were used to evaluate the uptake of bentazon and fluazifop-P in velvetleaf and giant foxtail, respectively. The herbicide additives used in these studies included crop oil concentrate (83% phytobland paraffinic oil plus 17% surfactants), 28% N liquid nitrogen solution (urea plus ammonium nitrate [NH_4NO_3]), and an untreated control. The herbicides were radiolabelled with ^{14}C in order to allow the measurement of herbicide movement in the plants.

Bentazon uptake by velvetleaf in response to different temperature regimes and several herbicide additives is illustrated in figure 1. The amount of bentazon found in velvetleaf was similar for the control treatments (no herbicide additive) regardless of the growth temperature. 28% N liquid nitrogen solution enhanced uptake for the low temperature regime while bentazon uptake was better for crop oil concentrate treatment in the high temperature regime. Significant differences were observed for the amount of bentazon uptake with the best herbicide additive treatment and respective temperature regime. However, the most bentazon uptake was measured where the greatest amount of epicuticular wax was deposited. Further, the consistency of herbicide additive response was lacking; crop oil concentrate was superior for one temperature regime while 28% N liquid nitrogen solution was best for the other temperature. Thus, it is suggested that differences other than total amount of epicuticular wax are influencing the uptake of bentazon and the efficiency of the herbicide additive. These differences are likely due to the chemical composition of the epicuticular wax as influenced by the temperature regimes.

The effect of soil moisture and herbicide additives on bentazon uptake by velvetleaf is illustrated in figure 2. No significant differences were found between the control herbicide additive treatments, regardless of oil moisture condition. Generally, more bentazon uptake was measured when the soil moisture was at field capacity. This represents a lower stress condition for the plant and plants grown under these conditions deposit less epicuticular wax than plants grown under drought conditions. There were no differences observed for the herbicide additives if plants were grown with soil moisture at field capacity.

When plants were grown under drought conditions, significant differences were observed for the herbicide additives. Less bentazon was taken up by plants when COC was the herbicide additive when compared with 28% N. Again, it is likely that the chemical differences of the epicuticular wax have influenced the herbicide uptake. The chemical properties of the herbicide additives, relative to the epicuticular wax, interact with the herbicide and the epicuticular wax thus resulting in herbicide uptake by the plant.

Giant foxtail responded in a different manner to velvetleaf, when evaluating the uptake of fluazifop-P in response to environmental conditions and herbicide additives. A consistent response to herbicide additives was noted. While changes in the chemical characteristics of the epicuticular wax were observed (data not reported), the crop oil concentrate herbicide additive consistently improved the uptake of 14C- fluazifop-P. It should be noted that the mechanism of action for fluazifop-P differs from bentazon. Bentazon is a contact herbicide and does not translocate in the plant. Fluazifop-P translocates in the plant and moves out of the treated leaf.

The uptake of ^{14}C-fluazifop-P in response to growth temperature regime was greater for the low temperature regime even though the amount of epicuticular wax deposited on giant foxtail leaf surfaces was greater than the amount for the high temperature regime (figure 3). The chemical composition of the epicuticular wax may have accounted for these differences. All herbicide additives improved uptake when compared to the control treatment. Crop oil concentrate consistently improved the uptake of fluazifop-P when compared to 28% N liquid nitrogen solution. A different trend was observed for the soil moisture factor (figure 4). Fluazifop-P uptake was better for all herbicide additive treatments for the soil moisture condition that resulted in less epicuticular wax deposition. Crop oil concentrate was the most effective additive for fluazifop-P activity. Differences between crop oil concentrate and 28% N liquid nitrogen solution were greater for the drought treatment.

The effect of environmental conditions in velvetleaf and giant foxtail can be observed in the amount of epicuticular wax deposited on the leaf surfaces and in the uptake of herbicides. The type of herbicide additive affects the relative uptake of the herbicide in these plants. However, bentazon and fluazifop-P uptake respond differently, depending on the environmental condition and herbicide additive.

Bentazon uptake was improved with the use of 28% N liquid nitrogen solution when the environmental condition resulted in a greater amount of epicuticular wax deposition in velvetleaf. There was likely an affect of the chemical composition of the epicuticular wax. Bentazon is a contact herbicide and 28% N liquid nitrogen solution could likely interact chemically with epicuticular wax.

However, the uptake of fluazifop-P was improved with the use of crop oil concentrate, regardless of the environmental condition, amount of epicuticular wax, and chemical composition of the wax. Fluazifop-P is a translocated herbicide and the effect of the crop oil concentrate could be simply a physical interaction of the wax thus improving the uptake of fluazifop-P.

Conclusions

Environmental conditions dramatically affect how plants grow and how herbicides interact with weeds. Environmental conditions affect the placement and availability of soil-applied herbicides and the also the rate of degradation. Environmental conditions influence the frequency, quantity, and location of weed seed germination. Environmental conditions that are not favorable for plant growth are not generally favorable for herbicide activity whether applied to the soil or postemergence. Different environmental conditions result in different amounts and chemical compositions of epicuticular wax. Generally, conditions that stress the plant result in types and amounts of epicuticular wax that inhibit the uptake of herbicides applied postemergence. The proper selection of a herbicide additive can improve the uptake of herbicides, overcoming these environmental barriers.

Table 1. Effect of temperature and soil moisture on velvetleaf and giant foxtail epicuticular wax deposition

Environmental parameter		Plant species	
		Velvetleaf	Giant foxtail
	Treatment	(ECW in $\mu g\ cm^{-2}$)	
Temperature	15/20 C	9.22	15.48
	22/32 C	5.38	11.10
	LSD (0.05)	0.90	1.80
Soil moisture[a]	SMFC	5.21	11.52
	Drought	9.40	15.06
	LSD (0.05)	0.90	1.80

[a]SMFC - soil moisture at field capacity, drought - drought stress, soil moisture from -5 to -10 bars.

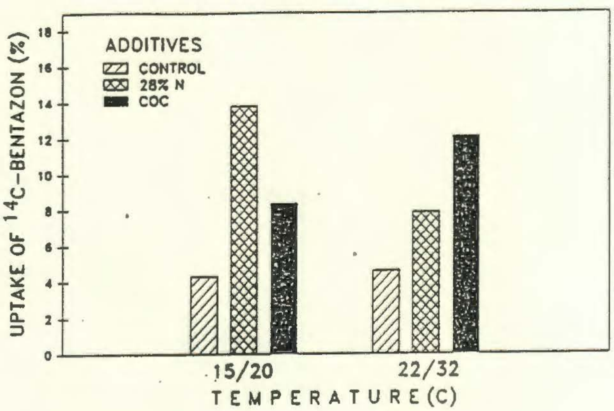

Figure 1. Effect of temperature and herbicide additives on ^{14}C-bentazon uptake by velvetleaf, LSD - 1.90

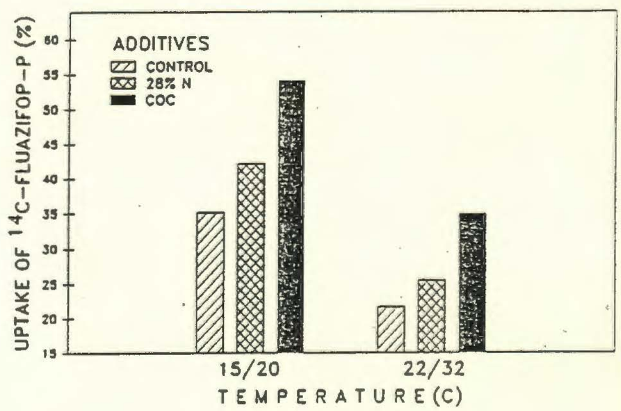

Figure 3. Effect of temperature and herbicide additives on ^{14}C-fluazifop-P uptake by giant foxtail, LSD - 4.7

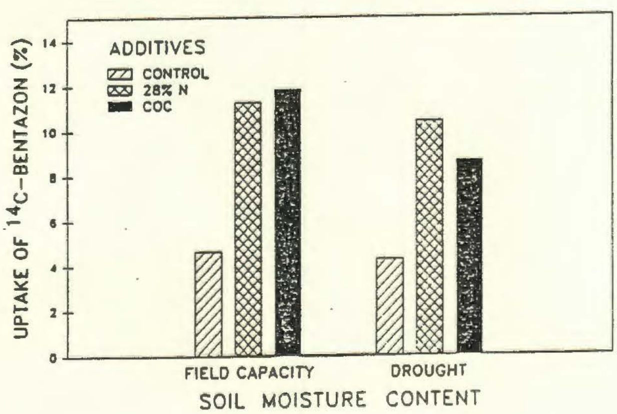

Figure 2. Effect of soil moisture and herbicide additives on ^{14}C-bentazon uptake by velvetleaf, LSD - 1.7

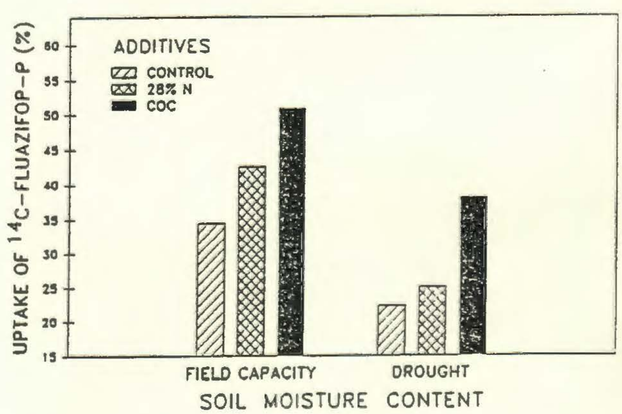

Figure 4. Effect of soil moisture and herbicide additives on ^{14}C-fluazifop-P uptake by giant foxtail, LDS - 4.3