SIMULATION OF HERBICIDE DEGRADATION UNDER SEMI-ARID CONDITIONS

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INTRODUCTION

A herbicide phytotoxicity is a function of time, concentration, and distribution in the environment. Initial concentration is determined by rate of application and soil absorption. Distribution is controlled by the uniformity of application and after application however, is a function of several chemical and environmental factors that are combined in the termrate of degradation. Most information on the rate of herbicide degradation in soil is from the word's temperate zones where agricultural practice and climate differ from what is common in semi-arid Morocco. Chivinge and Mpofu (1990) and Utulu et al. (1986) have reported on degradation of persistent herbicides in Zimbabwe and Nigeria, respectively. Their reports and data available from all temperate zone studies confirm that temperature and rainfall are important environmental determinants of rate of differences in adsorptive capacity and possibly in microbial activity.

Walker (1974) developed a computer model to simulate herbicide degradation in soil. The model combines the effects of soil temperature and soil

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moisture content (% field capacity) with data from field experiments to determine the rate of herbicide loss. Daily measurements of maximum temperature and rainfall are used to estimate fluctuations in surface soil moisture and temperature. A weakness of the model is that losses through processes other than enzymatic (microbial) and non-enzymatic (chamical) degradation are not accounted for. Therefore, susceptibility to leaching, volatility or photolability must be known and accounted for in other ways.

Models enable one to estimate the range of persistence and degradation pattern likely to be encountered in a dry versus wet year or with different times of application, to different sites. Models also enable accurate predictions concerning the probability of a given level of herbicide residue remaining in soil when a rotation crop is planted. Finally, models may eliminate the need to do extensive field and laboratory experiments over sevend years to obtain estimates of the agricultural and environmental risk of a given pesticide.

The purpose of this work was to provide information and to identify possible future research directions relative to the possibility of herbicide residues affecting rotational crops in Morocco's semi-arid areas.

METHODS AND MATERIALS

No field or laboratory experiments were conducted to evaluate soil degradation of herbicides in Morocco and derive the estimates reported herein. The estimates were derived from actual rainfall and temperature data recorded at Jemâa Shaim experiment station for the 1982-83, 1984-85, and 1986-87 cropping seasons and at Sidi El Aidy for the 1984-85 and 1986-87 cropping seasons. These sites were selected because they were the only ones in the semi-arid area with good weather data. Daily maximum and minimum temperatures, and daily rainfall were used for the simulation model. We acknowledge that if complete weather data for more sites had been available, predictions would have been more reliable and comparisons could have been made between years with different weather and between sites. For example, during the 1982-83 growing season, Jemâa Shaim received only 137 mm of precipitation whereas it received 359 and 266 in 19984-85 and 1986-87, respectively. No data were available for Sidi El Aidi in 1982-83 and in the other two years rainfall was 368 and 397mm, respectively. The limited weather data were not adequate to identify a difference in rate of degradation (expressed as days to reduce the applied amount by a definite percentage) between sites or between years with similar rainfall (ie. 1984-85 and 1986-87).

We assumed that herbicides would be applied to a typical soil for each site: a clay. Soils from the two sites were not different with pH 8 and organic matter averaging 1.6%. The Sidi El Aidi soil had a slightly higher clay content (55% versus 49%). Thus, for this simulation, soil type was not a major determinant of differences between sites or years.

Climatic data were incorporated into the model (Walker 1974 and Walker and Barnes 1981) and the model was run. Because degradation rates for specified herbicide in the soils at the sites were not available, the model was run with persistence categories.

The categories corresponded to the expected behavior of an herbicide with assumed half-life at 20°C and 100% soil field capacity of 40, 50, 60, or 70 days. Average constants, from other experimental work, were used to describe soil moisture and temperature dependance so that a 10° change in temperature or a two-fold change in soil moisture changed rate of degradation by a factor of 2.

Data were developed to show the percentage of the applied concentration (100%) remaining at 10 days intervals up to 360 days after application. These data were used to calculate the days required to degrade 10, 50, or 90% of the applied amount and the percentage of the applied amount that would remain on the following November Ist.

RESULTS AND DISCUSSION

The effect of the 1982-83 season drought on the simulated rate of herbicide degradation at Jemâa Shaim was not as great as the 2.7 time difference in rainfall between 1982-83 and 1983-84 might to be suspected. A partial explanation for this is that there was some rain fall and the temperature was warm as it always in summer in semi-arid Morocco. Rainfall and temperature control the rate of herbicide degradation in soil but degradation proceeds even with very low soil moisture, if it is warm.

We did not observe any difference between the two sites included in this study so the data have been pooled for discussion.

In the Southern, semi-arid regions of Morocco farmers typically choose one of two cropping systems on the basis of annual rainfall. If annual rain is in the range of 200 to 300 mm and soils are shallow and not fertile most farmers grow continuous barley (**Hordeum vulgare L.**). If soil is slightly better, but not good, continuous wheat (**Triticum aestivum** L.) is normally grown. On good soils in the low rainfall areas, a wheat-fallow system is often practiced. When 350 to 450 mm of rain is expected farmers grow wheat followed by a food legume (primarily lentils **Lens culinaris** L.), maize (Zea Mays L.) or a weedy fallow.

Herbicide use in wheat or barley is not widespread, especially on the poor soils of the region. Some growth regulator herbicides, (phenoxy acid derivatives) may be used. With more rainfall (the 350 to 450 mm zone) and thus, confidence in the cropping system, farmers use more growth regulator herbicides in wheat. When used at rates appropriate for wheat or barley (0.5 to 1.25 kg/ha), worldwide experience has shown that there is no fear of residual injury to a hollowing crop.

Inappropriate to present specific herbicides that might be used in one or more of these croping sequences. However, when lentils (a crop very susceptible to herbicide injury) and maize (a crop in which several persistent herbicides may be used) are grown one should become wary of possible residue problems.

Because there are no degradation data for specific herbicides in Moroccan soils, the model was not employed to determine specific degradation rates nor is this paper intended to predict how a particular herbicide will behave in Morocco. However, the model showed that with the prevailing weather conditions, for the two driest years, the time to reach 10 to 50 % of applied herbicide remaining tended to be shorter when herbicides were applied on November 1 or February 1. While this may seem anomalous, it can be expained. In November, it is still warm with average daytime maximum temperature over 20° C and nighttime lows above 10° C. Soil is not at field capacity but it is moist because rain begins in November. December and January are cold months with average daytime highs in the high teens and nighttime lows of less than 5. In Februay daytime temperatures rise and soil is usually moist from residual rainfall. Because temperature and soil is usually moist from residual rainfall. Because temperature and soil moisture are the primary determinants of rate of herbicide degradation it is easy to understand why application in December or January degrade the first 10 to 50 % more slowly. Selected data sets are show in Table 1. Degradation for the wettest cropping season (1984-85) showed similar, short degradation times but no decrease in time after February application.

The more intersting analysis in terms of effect on a following crop is the estimate of the amount of herbicide remaining on the November it was chosen

Table I : **Days required to degrade 10 or 50 % of applied herbicide with a 40 or 70 day half-life.**

Application date	Rainfall between Nov. 1 and Oct 31	Time to degrade 10 or 50 % of the applied herbicide (days) 10		50	
		Assumed half-life			
		40	70	40	70
	(mm)	(days)			
Nov. 1, 1982	137	7	15	90	128
Dec. 1, 1982		17	31	93	143
Jan. 1, 1983		14	24	80	134
Feb. 1, 1983		11	19	69	134
Nov. 1, 1984	356	8	15	67	129
Dec. 1, 1984		7	15	78	149
Jan. 1, 1985		12	20	85	144
Feb. 1, 1985		14	23	87	142
Nov. 1, 1986	266	11	19	85	134
Dec. 1, 1984		12	23	76	125
Jan. 1, 1987		13	20	66	116
Feb. 1, 1987		8	14	66	109

because it is the earliest time that a farmer, in this regions, is likely to plant the next crop. The primary point of this paper is not to show that a particular herbicide will injure a specific crop. It is to show that fairly high levels of herbicides with certain half-lives can be expected to remain in the year after they were used. The level remaining increases directly with assumed half-life, as expected (Table 2), it is plausible to argue that if a herbicide has a half life of 40 days the remaining residue is small and probably will not be detected by a succeeding crop. Therefore if herbicides such as the phenoxyacids (2,4-D, MCP), the acetamides (alchlor, metolachlor), carbamothioates = thiocarbamates (EPTC, butylate), or a triazine with short persistence (cyanazine) are used residual problems will be unlikely. An assumed half-life of 50 days give a similar answer and no residual problems should be expected when application is delayed in a very dry season such as 1982-83 (Table 2). However when half-lives of 60 or 70 days are assumed then it is likely that injury to following crops from residual herbicide can be expected (Table 2). Thus, when the persistent triazines (atrezine, simazine), the sulfonylureas (chlorsulfuron, metsulfuron), or one of the more persistent toluidines (pendimenthalin, trifluralin) is used residue problems should be excepted and minimized by application early in the cropping season when ever possible.

The simulation shows that residues above 15% of the amount applied can be expected with early application of herbicides with half-lives of 60 or 70 days in the wettest years. With late application or in a dry year, residues above 20 % of the amount applied are common and it is wise to expect some herbicide injury if a susceptible crop is planted.

The dry, warm climate of Morocco's semi-arid areas is not conducive to rapid degradation and residual problems are likely to occur as herbicide use expands. Studies to determine the specific rate of degradation of commonly used herbicides would be a wise agricultural research investment. These studies will lead to specific recommendations of herbicides to use by soil type and the possibility of residue problems after seasons with below normal, or above normal rainfall. Specific herbicide studies will identify potential problem herbicides and prevent some residue problems.

Table II : **Percent of herbicide remaining on November 1st following application .**

Application date	Percent of appleid hebicide remaining on the next November 1st with an assumed half- life of (days)			
	40	50	60	70
	(% remaining)			
Nov. 1, 1982	6.4	11.0	16.0	20.7
Dec. 1, 1982	8.5	14.0	19.0	24.5
Jan. 1, 1982	10.1	15.9	21.6	26.9
Feb. 1, 1983	12.3	18.8	23.9	30.2
Nov. 1, 1984	3.7	7.2	10.0	15.2
Dec. 1, 1984	5.5	9.8	14.4	19.0
Jan. 1, 1985	7.1	12.1	17.2	22.1
Feb. 1, 1985	9.5	15.2	20.8	26.1
Nov. 1, 1986	2.9	5.9	9.2	13.2
Dec. 1, 1986	3.9	7.4	11.4	15.5
Jan. 1, 1987	4.7	8.6	12.9	17.3
Feb. 1, 1987	6.1	10.7	15.5	20.2

RESUME

Un modèle mathématique a été utilisé avec le données climatiques des années 1982 à 1987 pour estimer la persistance des herbicides appliqués à différentes époques de l'année. Le modèle prédit la possibilité de rémanence des résidus des herbicides pouvant affecter des cultures dans une rotation en régions semi-arides du Maroc.

Mots clés : model / Persistance / Herbicides /Ramanence/Rotation /Maroc

ABSTRACT

A mathematical simulation model was used with real Moroccan climate data to estimate the persistence of herbicides applied at various times early in the cropping cycle. The model predicts that there is a possibility of herbicide residues affecting following crops in Morocco's semi-arid regions.

Key words : Model / Resistence / Herbicides / Residues / Rotation / Morocco

ملخص

استعمل نموذج رياضي بمعطيات المناخ المغربي لمدة مابين سنة 1992. 1987. وذلك من أجل تقريرالمدة الزمنية التي يمكث فيها المبيد في الأرض بعد استعماله في أوقات معينة خلال السنة.

هذا النموذج الرياضي أكد إمكانية وجود بقايا المبيدات بمقادير قد تؤثرعلى المزروعات الموجودة في الدورات الزراعية في المناطق الشبه الجافة في المغرب.

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