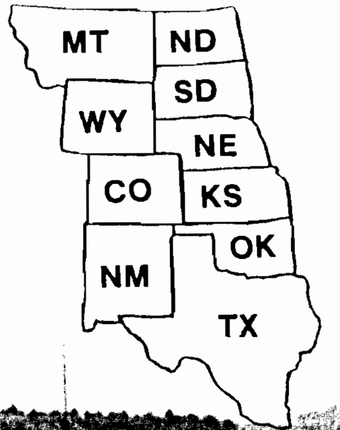

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Importance of Soil Characteristics on Herbicide Performance 1/

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Introduction

The labels of herbicides applied to soil (residual herbicides) contain information regarding application rates based on certain soil properties, usually pH, organic matter content (OM), and texture which are integral components of all soils. These are also the primary soil properties that influence the performance of soil-applied residual types of herbicides. The purpose of this paper is to explain the importance of these soil properties and how they effect herbicide performance.

Soil Description

A general knowledge of soil is needed in order to understand herbicide-soil property relationships. Soil is a complex everchanging dynamic system of a combination of many properties. All soils contain solid material and pore space, and the ratio is usually 1 to 1 in mineral soils. The solid portion consists of various percentages of sand, silt, clay, and organic matter. The pore space contains air and/or water and is sometimes called the soil solution.

The textural classification of a soil is obtained by laboratory analysis to determine the percentage of sand, silt, and clay present in the specific soil sample. This classification reveals to a large

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extent the amount of water that can be held in any given volume of soil. Generally, the higher the clay content the more water a given volume of soil will hold. Most soils in the Great Plains have been mapped and the textural classification of soils can be obtained from these maps which are available at District offices of the Soil Conservation Service within most counties in the Central Great Plains.

Organic matter is made up of plant and animal remains in various stages of decomposition and ranges from 0.5 to 4.0% in Central Great Plains soils. The residual fraction of organic matter (called humus) is found as a coating on clay particles. The amount of humus in the soils varies little from year to year and is that portion of the organic matter that influences herbicide rates.

Soil texture and organic matter contribute to the exchange capacity of the soil. The higher the organic matter and clay contents, the higher the exchange capacity. As the exchange capacity increases, more herbicide is usually needed to give effective weed control. The amount of clay in soil also influences herbicide performance, but the capacity of organic matter to attract (adsorb) and hold large numbers of a variety of chemical molecules (ions), including herbicides greatly exceeds that of clay. Consequently, organic matter is a major factor in determining herbicide use rates since adsorbed molecules are not free to move into the soil solution and, therefore, not available for uptake by plants, leaching, and microbial or chemical degradation.

Soil pH is the degree to which a soil is acidic or basic (alkaline) and is expressed as a number between 0 and 14. A soil that is neutral has the numerical value of 7. Soils having values less than 7 are acidic and soils having values greater than 7 are alkaline. The pH value reflects the relative number of hydrogen ions (H^+) to hydroxyl ions (OH^-) in the soil solution. This ratio is equal at pH 7. When more hydrogen ions are present than hydroxyl ions the soil solution is acidic. Conversely, when more hydroxyl ions are present than hydrogen ions the soil solution is alkaline. A change of one pH value reflects a tenfold change in the ratio of hydrogen to hydroxyl ions. Where pH values are high due to the presence of calcium the soils are classified calcareous.

Positively charged ions such as hydrogen (H^+) are attracted to and held by the negatively charged clay and organic matter particles in the soil. Thus, the higher the clay and organic matter contents of the soil, the greater the chance hydrogen or other positively charged ions (cations) will be adsorbed and held by these particles. These bonding or holding sites are also called exchange sites because a stronger ion such as calcium (Ca^{++}) can exchange or replace a weaker ion such as hydrogen on one of the bonding sites. This potential for exchange of ions or cations on the bonding sites is referred to as cation exchange capacity (CEC). Cation exchange capacity is shown on most soil test reports. The more exchange sites the soil has the greater the CEC.

Herbicide Characteristics

Many herbicides are ionic in solution which means that when dissolved in water they either act as an acid (give off H^+) or a base (attract H^+) depending on the pH of the soil solution. Several herbicides and their relative adsorption capacity to soil exchange sites are given in Table 1 (1). These herbicides establish an equilibrium between the soil solution and the bonding sites. The herbicide in the soil solution may be taken up by plants, which in turn will release herbicide from the bonding sites due to concentration changes in solution and the need to establish a new equilibrium. How tightly the herbicide is held to the bonding sites depends on the composition of the herbicide and the clay and organic matter contents of the soil.

Herbicide Degradation

The soil pH, organic matter, and clay contents also influence herbicide breakdown by chemical and microbial processes. Organic matter is a major source of microorganisms. Consequently, herbicides are usually degraded faster as the organic matter content of the soil increases. Clay content contributes to herbicide breakdown by catalyzing chemical breakdown reactions. Soil pH effects herbicide degradation processes by influencing the number of H^+ ions in the soil solution, and by influencing the microbial life and population in the soil. Fungi predominate in acid soils and bacteria predominate in alkaline soils. Some herbicides are degraded better by fungi and some by bacteria, therefore microorganism differences can influence herbicide carryover.

Herbicide Performance

Herbicides applied at labeled rates to soils with uniform texture, organic matter content, and pH, and with normal climatic conditions provide weed control with little or no potential for carryover. This occurs because the herbicide-soil interaction will be consistent both in regard to herbicide bonding and degradation by chemical and microbial processes. However, as the degree that any one of the combined soil characteristics change within a field or climatic conditions deviate from normal, herbicide performance, degradation, and potential carryover will vary accordingly.

Herbicide Use Guidelines

Before herbicides are applied, a soils texture, pH, organic matter, and CEC should be known to determine a herbicides proper application rate to minimize potential herbicide carryover problems. The arbitrarily selected adsorption scale (Table 1) shows that herbicides with ratings between 3 and 8 have the most potential for carryover, because they are moderately bound and will be released with time and equilibrium changes in the soil. Conversely, herbicides with a 10 will be bound so tightly to the soil they are not released, and those with a one are for all practical purposes not bound to the soil at all. Atrazine is one of the most widely used herbicide in reduced and no-till conservation tillage systems and has a relatively high value which indicates a high potential for carryover. Because of this fact, guidelines have been developed for the use of atrazine (2). Relationships between various soil characteristics and probable winter wheat stand reduction due to the carryover of atrazine applied at 1.0 lb ai/ac 12 to 14 months prior to planting the wheat in areas receiving 14 to 16 inches of precipitation annually are shown in Figures 1, 2, and 3. These curves also show the atrazine user the probability of obtaining the stand reduction (values in parenthesis).

Examples of the use of the figures to determine the probable stand reduction are as follows: (I) a soil with 16 percent clay, pH of 7.8, CEC of 30 milliequivalent per 100 grams soil and OM of 0.8

percent has estimated stand reductions of 60 percent, 50 percent and 40 percent as depicted by the letter (A) in figures 1, 2, and 3, respectively; (II) a soil with 19 percent clay, pH of 6.8, CEC of 20 milliequivalent per 100 grams soil and OM of 3.7 percent, depicted by the letter (B), has no stand reduction indicated in any of the figures; and (III) a soil with 10 percent clay, pH of 8.3, CEC of 35 milliequivalent per 100 grams soil and an OM of 1.0 percent, depicted by the letter (C), has a stand reduction estimate of greater than 80 percent in all three figures. When differences in probable stand reduction are obtained between the three curves, the curve predicting the greatest stand reduction should be used. Organic matter is the most conservative of the three bases used for stand reduction. In this study yield reductions were not obtained until stand reductions exceeded 25 percent.

For each 0.1 lb/ac reduction in amount of atrazine active ingredient applied, wheat stand reduction decreases approximately 10 percent (2). The current atrazine label indicates the minimum use rate to be 0.5 lb ai/ac applied 12 to 14 months before wheat planting. Research results also indicate that atrazine should not be used in a winter wheat-fallow rotation when the clay content of the soil exceeds 30 percent, and average annual precipitation is 14 to 16 inches (figures 1 and 2). Where average annual precipitation exceeds 16 inches, and where stand reductions of 40 percent or less are expected, each 0.5 inch increase in precipitation would be expected to decrease the stand reduction by 10%. Where average annual precipitation is between 12 and 14 inches, atrazine should be used only where soil conditions show estimated stand reductions of less than

20 percent, and the rate of atrazine also should be decreased 0.125 lb ai-per-acre for each 0.5 inch decrease in precipitation. Where annual precipitation averages less than 12 inches, atrazine should not be used in a winter wheat-fallow rotation.

Summary

Soil organic matter, clay, and pH effect the activity of herbicides in the soil. Changing managment practices from a tillage system that mixes residue with soil to a reduced or no-till system can change soil pH and organic matter in the surface few inches of soil over a period of years. Such changes may require adjustments in herbicide use. Other factors influence herbicide performance but not to the extent that OM, CEC, clay, and pH do. A better understanding and knowledge of these factors should improve herbicide performance and reduce carryover risk.

Literature Cited

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Table 1. Relative adsorption of some common herbicides used in reduced and no-till conservation tillage systems (1).

Common neme	Trade name	Adsorptivity*
Dicamba	Banvel	1
2,4-D	--	2
Chlorsulfuron	Glean	3
Metribuzin	Sencor/Lexone	4
Metolachlor	Dual	4
Alachor	Lasso	4
Terbutryn	Igran	5
Cyanazine	Bladex	5
Atrazine	AAtrex	7
Glyphosate	Roundup	10
Paraquat	Paraquat plus/Gramorane	10

*Numerical rating of 1 to 10, least to greatest adsorptivity, respectively.

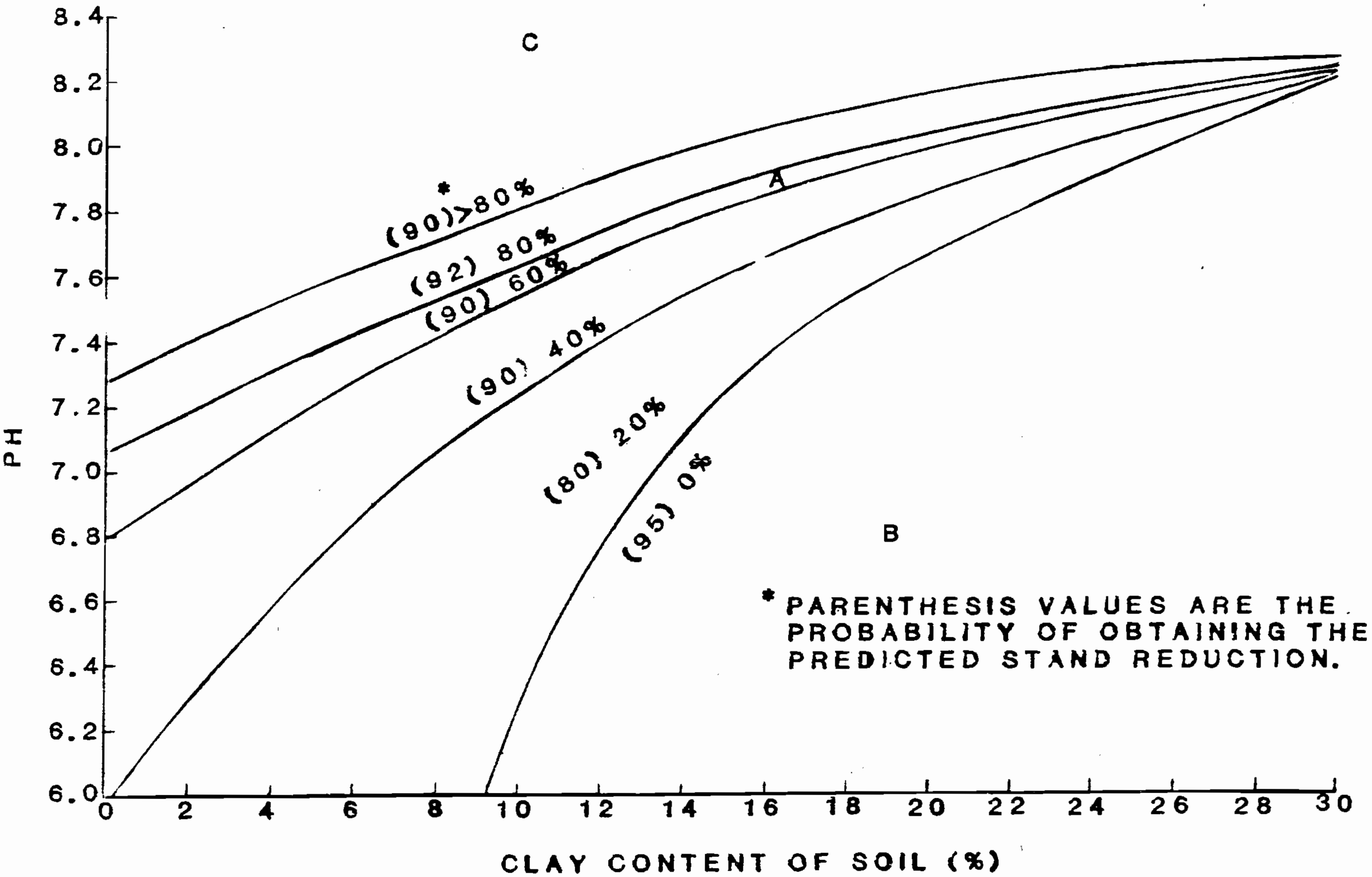

FIGURE 1. WINTER WHEAT STAND REDUCTION PREDICTION DUE TO THE CARRYOVER OF 1 LB. AI ATRAZINE PER ACRE IN A WINTER WHEAT-FALLOW ROTATION AS RELATED TO PH AND CLAY CONTENT OF THE SOIL IN AN AREA RECEIVING 14 TO 16 INCHES OF PRECIPITATION ANNUALLY.

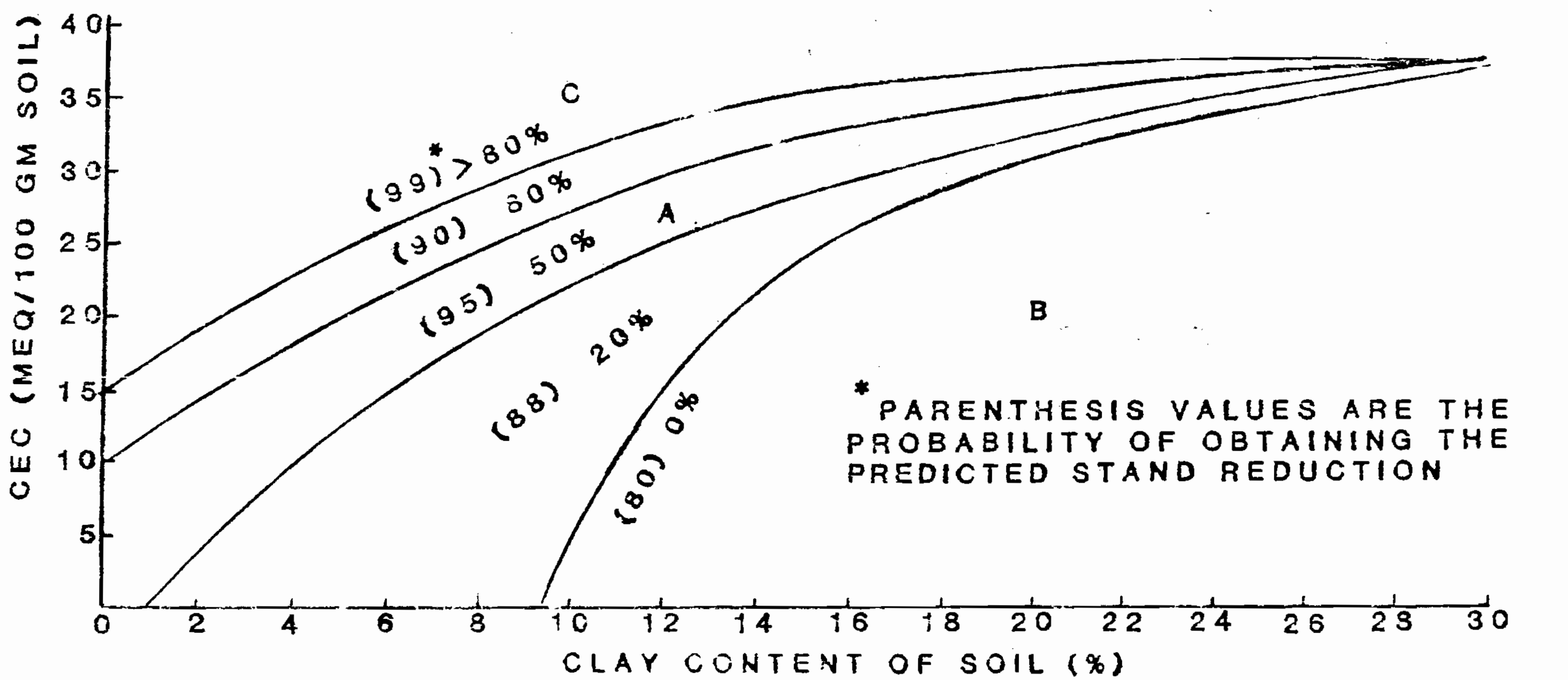

FIGURE 2. WINTER WHEAT STAND REDUCTION PREDICTION DUE TO THE CARRYOVER OF 1 LB. AI ATRAZINE PER ACRE IN A WINTER WHEAT-FALLOW ROTATION AS RELATED TO CATION EXCHANGE CAPACITY AND CLAY CONTENT OF THE SOIL IN AN AREA RECEIVING 14 TO 16 INCHES OF PRECIPITATION ANNUALLY.