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EC08-708 Precision Agriculture : Weed Targeting Herbicide Management

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Weed Targeting Herbicide Management

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RESOURCES

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Most producers use herbicides to manage weed infestations. Generally, herbicides are applied at a uniform rate to the entire field. However, a uniform application may not be appropriate for all areas of a field. As precision agriculture technologies have developed, site-specific management of most agricultural inputs, including herbicides, has become feasible. Differentiated application of herbicides is an effective way to minimize herbicide costs, maximize weed control and prevent unnecessary environmental waste. This circular provides basic guidance on site-specific weed management.

Spatial Distribution of Weeds

Typical agricultural fields may be infested by up to 20 weed species, of which three or four are dominant in terms of number of plants and land area covered. The distribution of weed species across a field is "patchy" in nature. Some areas will be densely populated by weeds, while others will have few or no weeds. Densely populated patches often occur along field edges, but may be found anywhere in the field where the environment and management have favored the establishment and survival of weeds. Many times patches are elongated in the direction of equipment operations. The composition of weed species varies across a field, and different patches may be dominated by different species. In addition to weed density varying spatially in a field, it also may vary temporally and can be strongly influenced by weather or crop rotation. For example, weeds that are a major problem in summer annual crops like corn or sugarbeet may not even emerge when a winter annual crop like wheat is grown.

Weeds exploit space not taken by the crop (inter-row areas) and not disturbed by control methods such as tillage or herbicides. Weeds vary in their response to different environmental cues and conditions that favor growth of one weed species over another. A few studies have correlated landscape features and management factors to the presence of weed patches. These characteristics include topography (or elevation), soil pH, soil organic carbon (OC), fertility (nitrogen and phosphorous), soil texture, field history, and herbicide use patterns. For example, topography, soil texture, and organic carbon can have a significant effect on available moisture, which affects the ability of weeds to germinate or later to grow rapidly. Soil pH, texture, organic carbon, and moisture can influence the availability or persistence of herbicides in the soil. Weeds may survive a sub-lethal dose in areas where too much of the herbicide is bound to soil particles. Repeated use of a single herbicide may lead to herbicide resistance in one species, allowing it to become the dominant weed species in the field.

The spatial distribution of patches is generally stable across years, although this depends somewhat on the species present and management practices. Spatial stability is due in part to the persistence of a soil seed bank. As long as there is viable weed seed in the soil, the patch will continue to be weedy. Most patches expand slowly, particularly in no-till fields. This is because most weed seeds shatter or fall to the ground around the mother plant shortly after maturing, limiting the spread of the patch unless the seed is dispersed by

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wind, like dandelion or marestail, or by runoff carrying the weed seed from higher to lower elevations. Annual operations such as tillage and harvesting may spread patches up to 60 feet. When a weed species occurs uniformly across a field, it is generally due to poor management or contaminated crop seed.

Patches with high weed densities are more stable across years than patches with low weed densities. High weed densities generally indicate more weed seed in the soil seed bank. In addition, control measures such as tillage or herbicide application are less likely to control all of the plants in a high-density patch than in a low-density patch. When more individuals survive, more seed is produced to replenish the soil seed bank. In studies where herbicide was only applied to patches where weed populations exceeded the economic threshold, untreated regions did not develop high weed populations. Although it is possible that allowing one uncontrolled weed to produce seed may lead to a patch in the future, these studies indicate that is unlikely.

Principles of Site-Specific Weed Management

Automated site-specific herbicide application for weed control has been the focus of many recent agronomic and engineering studies because it has the potential of reducing the amount of applied chemical, thereby increasing farmer profitability and improving water quality. Site-specific herbicide application technology treats the field as a set of small management zones, where specific amounts and types of herbicide can be applied to treat the weeds present. If no weeds are present, or if the weed density is below the economic threshold for treatment (minimum weed presence that would justify the cost of treatment), no herbicide is applied. Knowledge of the weed species present is important in order to select the most efficient herbicide. Weeds can be controlled either in real-time (tactical approach), where certain weeds have been detected, or by using a predetermined field map which identifies the species and location of weeds (strategic approach). The strategic approach requires a separate operation, but gives the grower a better estimate of the amount and type of chemical needed for a specific weed problem.

Postemergence herbicide applications should be made before the weeds can cause economic yield loss. UNL Weed Scientist Stevan Knezevic has identified this as the critical period of weed control. This period depends on the crop, weed species, environmental conditions, and the size and density of both the crop and weed.

Applying Precision Agriculture to Weed Management

Precision agriculture can enhance uniform herbicide application by minimizing the number of overlaps and skips and eliminating applications to non-crop areas such as waterways, wetlands, and odd-shaped boundaries. Adopting satellite-based auto-guidance (also called auto-steer) technology and using automatic boom section control can substantially reduce herbicide misapplications without requiring the operator to turn boom sections on or off. Auto-guidance allows more accurate control of the distance between two adjacent passes, significantly reducing steering-caused skips and overlaps, and does not require conventional markers. The automatic boom control shuts off individual sections of the sprayer when they are over areas that have already been treated, for example, previous pass, headland, or non-crop areas of the field. The automatic boom controller also can be programmed to spray areas that are not infested by weeds.

Site-specific herbicide management may be implemented through both soil-applied and postemergence herbicide treatments. The rate of soil-applied herbicides (preplant or preemergence) may vary according to the spatial variation of soil texture and organic matter content. Soil texture and organic matter are relatively constant across time, so once the field is mapped for these traits, the same map can be used each year. When historic weed maps are available, it is also possible to make preemergence herbicide applications only to infested areas, thereby reducing herbicide costs and protecting the environment from potential chemical contamination.

On the other hand, site-specific postemergence applications can be more dynamic than preemergence applications and will vary in response to the weeds currently growing in the field. Historical data on weed distribution can aid decision-making, but it is beneficial to provide the controller with real-time or recent evidence of the current spatial variability of weeds.

It is simple to make site-specific postemergence burndown herbicide applications to winter or summer fallow fields using current technologies such as CropCircle®, WeedSeeker®, GreenSeeker®, or N-Sensor®[1]). These close proximity optical sensors use near-infrared light reflectance measurements to distinguish green vegetation from bare soil and crop residue. These data can then be used to turn the sprayer on only when weeds or volunteer crops are present. Herbicide cost savings are realized from not spraying areas that lack weeds.

Unfortunately, the optical reflectance characteristics of crops and many weed species are similar. The optical sensors cited here cannot be used to accurately assess spatial weed distribution after the crop is emerged. Instead, weed scouting, remote sensing (including low-altitude airborne imagery) and machine vision techniques have been used to recognize spatial weed patterns after crop emergence. Because many remote sensing and machine vision systems are not commercially practical to develop in-season weed maps, weed scouting remains the most reliable way to acquire spatial data on weed distribution. An experienced scout or operator is able to map weed infestations by species and then select herbicides to best control the weeds present.

[1]Sensors manufactured by Holland Scientific, Inc. (Lincoln, Nebraska), NTech Industries, Inc. (Ukiah, California), and Yara North America Inc. (Tampa, Florida).

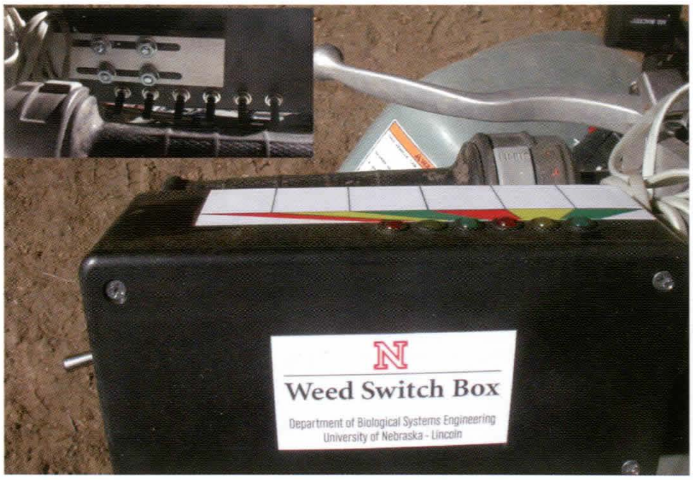

Figure 1. Weed Switch Box mounted to the handle bar of an ATV.

A Practical Approach to Weed Mapping

Many data logging tools connected to a Global Positioning System (GPS) receiver can be used to record geographic coordinates of weedy areas. When a crop scout moves across a field, he or she can manually (using software interface options) mark field spots where weed presence justifies application of a certain herbicide. A geographic information system (GIS) software package can then be used to convert recorded data into a map showing target areas of a field with weed infestations requiring herbicide application. Different herbicides can be prescribed to different patches as needed.

Unfortunately, most conventional tools are not easily operated when trying to record data while on the move. Various innovations (single button push, speech recognition, etc.) have been used to ease the work of a weed scout. At UNL, we built a Weed Switch Box that can be attached to the handle of an all-terrain vehicle (ATV). It contains six switches, each of which is assigned to a different weed species (*Figure 1*). As the scout moves across the field, he or she turns on the switches that correspond to the weed species present, and turns them off when targeted species are no longer seen. Normally, three or four weed species are mapped at a time, but extra switches allow marking field areas with either unusual species or other anomalies that may affect herbicide management. The Weed Switch Box is connected to a data logger, either directly or through a GPS receiver, and generates a digital code that records where switches are turned on and off.

The weed map shown in *Figure 2* was developed by mapping three species while travelling across the field following sprayer tracks spaced 30 feet apart. The herbicide application map was constructed using a 30-foot buffer around all data points marking weedy patches. After mapping, two herbicide treatments were applied to the field. On one pass, the herbicide was applied uniformly. On the alternate pass, the sprayer was turned on only for patches mapped as "weedy" (Figure 3).

Corn grain yield was mapped to see if yield was affected by the herbicide treatments. There was no significant difference in yield between passes where herbicide was applied uniformly and passes where herbicide was applied only to the weedy patches (Figure 4). This illustrates the potential to reduce herbicide costs by not spraying areas that are relatively weed free.

Figure 2. Results of weed mapping using the Weed Switch Box.

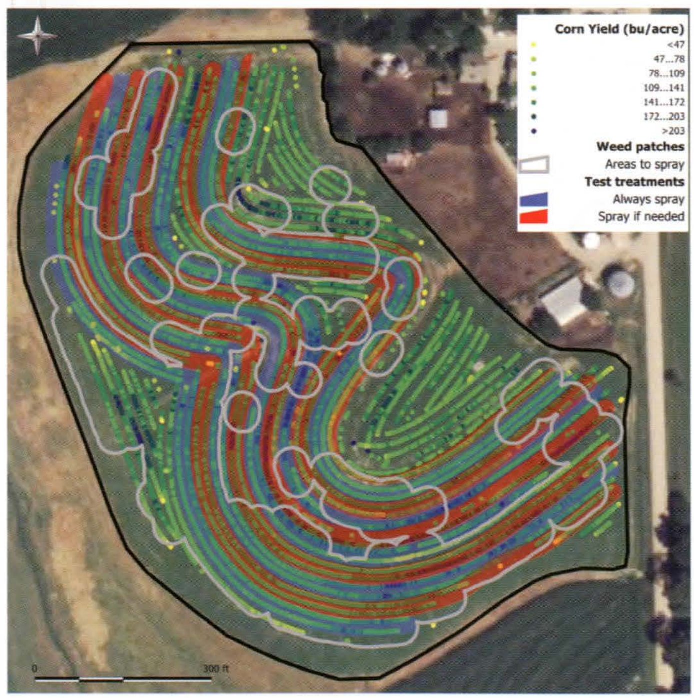

Figure 3. Split treatment of weeds.

Economic Return

The economic benefit of site-specific herbicide management depends on the percentage of the field infested with weeds. If more than three-fourths of the field requires a herbicide application, it

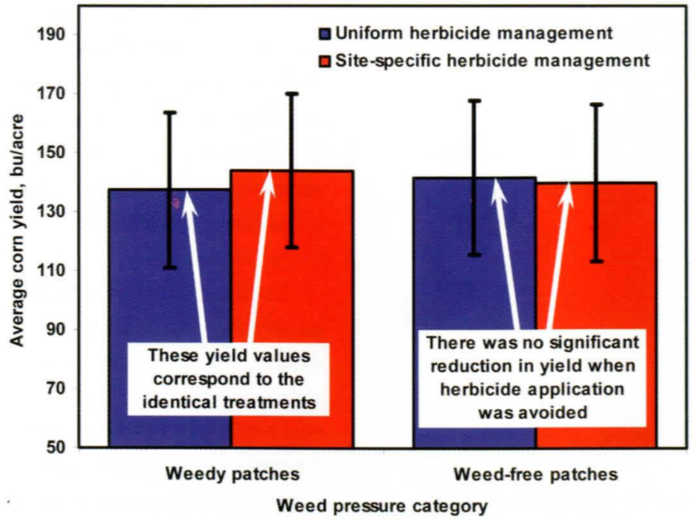

Figure 4. Field trial results (error bars indicate ±1 standard deviation).

is probably more economical to make a uniform application than a site-specific application because the cost of data collection to generate the weed map may equal the savings from reduced herbicide use. If less than three-fourths of the field requires a herbicide application, the cost of weed mapping and site-specific herbicide application may be less than a uniform application.

In the 17-acre field shown in Figures 2 and 3, only 45 percent of the area required a herbicide application. The remaining 55 percent (9.3 acres) could be left untreated. Assuming the applied herbicide cost is $20 an acre, the producer would save $11 an acre by treating only the weedy patches. Since it took the crop scout 1.5 hours to map the weeds in this field, and the cost of labor was $20 an hour, the cost of generating the map was $30, or $1.80 an acre. The difference between savings in herbicide costs ($11 an acre) and the expense of mapping the field ($1.80 an acre) is the savings to the farmer — in this scenario $9.20 an acre. Table 1 illustrates potential economic return as it changes with respect to the percentage of the field requiring a herbicide application and the cost of the herbicide treatment.

In many instances, costs of site-specific and blanket herbicide spraying are identical; however, an extra $1-$2 per acre can be assumed to cover additional custom applicator charges for applying herbicides only to delineated weed patches and/or the partial cost of data gathering equipment and processing software. Also, in some fields it may be reasonable to apply different herbicides to different patches, depending on the species present. If more than one product is applied, the overall economic return may be calculated according to:

$$\textbf{Economic return} = H_1 \cdot A_1 + H_2 \cdot A_2 + \ldots + H_n \cdot A_n - C$$

where $H_1, H_2, \ldots, H_n$ are the costs of herbicides

$A_1, A_2, \ldots, A_n$ are the percentages of field not requiring these herbicides

C is the cost of weed scouting and data processing (assuming $1.80 an acre)

However, if the herbicide cost is relatively low, environmental benefits of site-specific weed management may be more important than the economic return. In such a case, reduced environmental pollution becomes a driving adoption factor.

Evolving Technology

Essentially three kinds of technologies are currently in use or in engineering development for the detection, mapping, and control of weeds:

1) visual scouting assisted by electronic recording (as discussed earlier),
2) optical reflectance sensing systems, and
3) color and infrared machine vision with image analysis.

One of the main difficulties of visual scouting is that the detection of weeds in soybeans may become somewhat subjective due to the tediousness of the visual process. Optical sensing of weeds is best used in non-crop or ecofallow field areas because the green crop can be easily mistaken as green weeds. In this case, any vegetation can be immediately spot sprayed with herbicide under the assumption that it is a weed.

The machine vision approach is based on attempts to mimic and automate the human plant identification method. This process quickly leads one to appreciate the complexity of how people visually identify weed species based on botanical knowledge. Nevertheless, current machine vision prototypes can isolate single, fully exposed leaves in young weeds and determine the species based on taxonomic shape and leaf vein patterns and features. There have been attempts to use machine vision to separate broadleaf and grass-type shapes, but there are still some major limitations. Currently, low cost digital color cameras with high image resolution capability and automatic lighting adjustment can provide color images at a high rate. These color images are taken directly over the surface while moving the camera across a field. Images are then analyzed using special weed segmentation and feature analysis computer programs (Figure 5), which allow identification of crop and weed species. A sequence of such images can be

Table 1. Per acre savings from site-specific weed management.

Percent of area		Per acre cost of herbicides				
Weeded	Weed-free	$5.00	$10.00	$15.00	$20.00	$25.00
10%	90%	$2.70	$7.20	$11.70	$16.20	$20.70
25%	75%	$1.95	$5.70	$9.45	$13.20	$16.95
50%	50%	$0.70	$3.20	$5.70	$8.20	$10.70
75%	25%	$(0.55)	$0.70	$1.95	$3.20	$4.45
90%	10%	$(1.30)	$(0.80)	$(0.30)	$0.20	$0.70

Figure 5. Using machine vision to recognize different plant species grown in a field.

used to construct weeded area maps and implement site-specific herbicide management, as was illustrated earlier. For example, promising success of the "single leaf method" has been reported; however, this technology still needs considerable development and testing before it's ready for growers.

Practitioner Notes

From a practical point of view, large numbers of small — less than sprayer boom width — weed patches may add up to a small percentage of the field area, but still require application to most of the field. If prevention of weed seed production is the primary goal of the herbicide application, more of the field will likely need spraying than if controlling competition is the driving factor. This is particularly true with seed from species such as velvetleaf (*Abutilon theophrasti*) that has a long life in the soil, and common waterhemp (Amaranthus rudis) that produces many small seeds per plant.

It is essential to have a clear understanding of the goal of herbicide application when scouting weeds. The scout should be experienced in judging a weed stand as to its potential for damage, since this must be done quickly and many times across the field. Weed competition ratings are an excellent source for this information. As mentioned previously, it is only practical to prepare a herbicide map for two or three species of weeds (or groups of species) at a time because of the number of additional functions required (driving, navigating, etc.). With the Weed Switch Box shown in Figure 1, switches 4 through 6 have been used for noting species that are seen occasionally and not accounted for while making prescription maps.

In order to scout fields for a postemergence herbicide application, data processing must be done quickly, since time is a factor. With current technology, this is possible, but experience with the entire process is essential. Time is less of a constraint for controlling winter annuals when growing corn or soybean. The winter annual populations can be scouted in the spring, and an application map prepared well in advance of treatment. If weed growth is sufficient, remote sensing can be used to create winter annual weed maps, saving considerable time over in-season scouting. Henbit (Lamium amplexicaule) can be effectively detected with aerial photography since it has a low growth habit and occurs in dense patches.

Targeted weed control has benefits in addition to cost savings and reduced herbicide use. The scouting effort required often reveals needed equipment adjustments, stand problems that create opportunities for weed competition, and earlier detection of invading species. While more time is required for scouting, the time needed for herbicide application is reduced by avoiding equipment travel in areas that do not need additional weed control.

Summary

Site-specific herbicide application has been used by fewer farmers than other precision agriculture technologies, even though the potential benefits are large. Consultants and farmers interested in site-specific herbicide application will be most likely to succeed by starting with fields having large, weed-free areas. Regular scouting using a systematic approach such as with the UNL Weed Switch Box will allow the development of maps with weed management zones.

There are two important benefits to managing weeds by management zones. First, not applying herbicide to weed-free zones will reduce input costs without jeopardizing yield while avoiding unnecessary environmental pollution. Second, knowing "how many?" of "what?" is in a weed patch will allow more aggressive management to reduce the size and/or density of the patch. A uniform herbicide application across a field may be effective in low weed density areas or for controlling some species, but less effective on other species and high density areas. By targeting patches and not treating the entire field as an "average," managers may be able to justify the cost of higher use rates or more effective chemical mixtures to better control the weeds in the high density areas and reduce the weed pressure potential in the field.