Site-Specific Management Guidelines

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SSMG-25

Weed Biology and Precision Farming

Summary

Weeds, and methods used to control weeds, can have negative economic and environmental impacts. With precision agriculture, growers can take advantage of the patchy nature of weeds by targeting management efforts only where they are needed instead of wasting expensive and potentially hazardous inputs where weeds are not present. Weeds are patchy because weed spread, survival, and reproduction are variable within a field and over time. Weed patches stay in about the same place from year to year, even though weed density within a patch may vary. This Guideline describes the biological basis for weed patchiness and discusses how human-aided dispersal and manipulation of field conditions contribute to the spread of weeds.

Introduction

For years, weed management inputs were applied uniformly to whole fields, like most other crop, soil, and pest management practices. However, growers have long recognized that weeds are not spread uniformly across fields, but are often quite patchy. Broadcasting herbicides uniformly across a field where target weeds are not uniformly distributed can waste resources and add to the social, environmental, and economic concerns about herbicide use. Precision farming offers a powerful set of tools for addressing these concerns and increasing the efficiency of weed management. Methods are being developed to scout and detect weeds so that control measures can be applied where and when they are needed. This technology should lead to lower herbicide costs, less risk of environmental damage, and greater social acceptance of farming methods. The objective of this guideline is to describe the biological basis for the spatial patterns in weed populations and likely responses of weeds to site-specific management.

Why Are Weeds Patchy?

Stand in a patch of weeds or at the edge of a field and it may look like the weeds are everywhere. But if you focus closely on just a small area, you will find that spaces between weeds are not uniform. Some weeds are clustered while others are separated and surrounded by open space. You are observing patchiness at a small scale. Now, if you fly over the field in an airplane, you will find that weeds have dense stands in some areas, sparse stands elsewhere, and virtually none in other areas. In this case, you are observing patchiness at a landscape scale. In fact, all weed infestations have a patchy (i.e. aggregated or clumped) distribution at one or more scales. Weeds are almost never distributed uniformly throughout a field, farm or watershed because of variable characteristics of weeds, the agents that allow weeds to move around, and the environmental conditions into which weeds are dispersed. Weed characteristics, dispersal agents, and site suitability are variable over time as well as space. While weed branching patterns may vary over a small scale, soil conditions may vary over a few acres, and dispersal agents such as animals might move in patterns over many fields. Therefore, when we consider how weeds, dispersal agents, and environmental conditions vary at different scales in time and space, it is easy to understand why weeds are not distributed uniformly throughout a field (**Figure 1**).

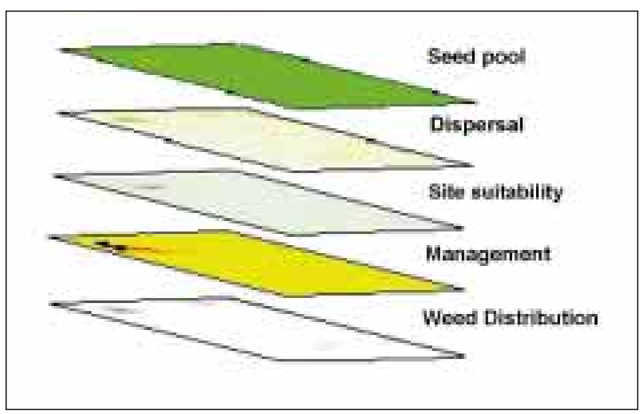

Figure 1. Weed patchiness is determined by many factors, including pattern of seed pools, dispersal, site suitability, and management acting overtime.

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Weed Characteristics

One reason weeds are patchy has to do with characteristics of reproductive units such as seeds, rootstocks, etc. Many fruits and seeds have adaptations for dispersal, such as wings or 'parachutes' that aid in wind dispersal, burs or tasty fruits that facilitate dispersal by animals, and buoyant tissues that allow for movement by water. Weeds that grow tall and release seeds from a height above a corn crop increase the potential for movement by wind, whereas those that creep and vine along the soil surface ensure that propagules are spread from the parent plant. Rootstocks and rhizomes, though not specifically adapted for natural dispersal, can often tolerate uprooting and regrow from adventitious buds after being dragged through the soil by field equipment. Not all reproductive units are dispersed the same distance from the parent plant. The height and timing of release, along with prevailing weather conditions, result in dispersal at various distances and directions. In spite of adaptations for dispersal, most seeds fall close to the parent plant, and relatively small proportions are carried significant distances. As a result, freshly produced seeds tend to be aggregated near the parent plant.

Dispersal Agents

Natural dispersal agents carry seeds from the parent, but not necessarily in a uniform way. Many animals that move seeds (birds, rodents, ants) tend to cache the seeds, resulting in clumping. Dispersal by farm machinery, especially combines, also results in a patchy distribution. Movement of weed seeds from field edges, woods, roadsides, waste areas, and fallow fields is unlikely to be uniform, but more likely resembles a slowly creeping front or scattered focal points from which patches are likely to spread.

Site Suitability

Reproductive units are dispersed to sites that may vary greatly in their suitability for weed growth, survival, and further spread. The suitability of a given site is determined by many factors, including inherent soil characteristics (slope, aspect, soil type, drainage, cation exchange capacity [CEC], pH, etc) as well as past and current soil and crop management. Thus, the interaction of non-uniform dispersal into a non-uniform environment results in the observed patchy weed distribution. Site-specific management is unlikely to result in more uniform weed populations but should help manage existing populations more efficiently.

If weeds were reliably associated with specific landscape features or soil characteristics, it would be possible to use soil maps as a guide to mapping populations. For example, large-seeded broadleaf weeds have been associated with areas in fields that are of relatively low elevation and high in organic matter, whereas annual grasses have been associated with well drained higher elevations. Different soil pH levels are thought to favor certain weeds, and other weeds are known to accumulate high levels of certain nutrients. But because soil pH affects nutrient availability, microbial activity, and herbicide availability, the relationship among soil pH, weeds, and landscape position is not well understood. Plants that are successful weeds are able to grow and reproduce under a wide range of soil conditions, so it is unlikely that the variation in soil nutrient or pH levels found in most good quality farm fields would correspond well to the spatial distribution of weeds. Therefore, based on present knowledge, soil characterization maps are not reliable indicators of weed presence or abundance.

Stability of Patches

A patch where weed density and location are consistent over time is considered to be stable. Several studies have shown that the location and size of weed patches tend to be stable over time, even though weed density within a patch may vary from year to year. Patches tend to expand following seasons of high weed seed production and to contract following seasons of low seed production. Patch stability is probably due to large, persistent seed pools, soil drainage patterns, and suitable local environmental conditions that favor certain weed species. Because stable patches are potential locations of serious crop loss as well as sources of spread to other sites, patch centers, which have highest densities, should be the focus of control efforts. The finding that patches are relatively stable over time is important because it means that the high cost of scouting can be amortized over several years. It also means that maps remain useful not only for targeting management efforts, but also for evaluation of progress in reducing weed populations over time.

Patch Size, Shape, and Edges

Often, it is difficult to identify the edges of a patch because they are usually not distinct, straight lines. One patch seems to run into another. Perennial weeds in no-till systems generally have the clearest boundaries. Natural and human-aided dispersal of seeds and rhizomes or rootstocks often results in diffuse edges around high-density patch centers. For example, in a conventionally tilled field, the shape of a hemp dogbane patch was influenced by the direction of tillage (**Figure 2**).

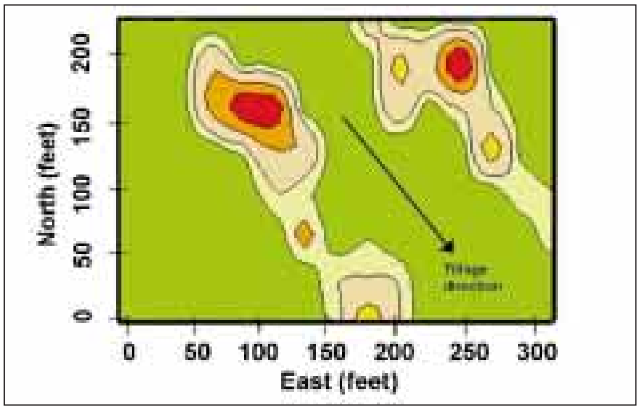
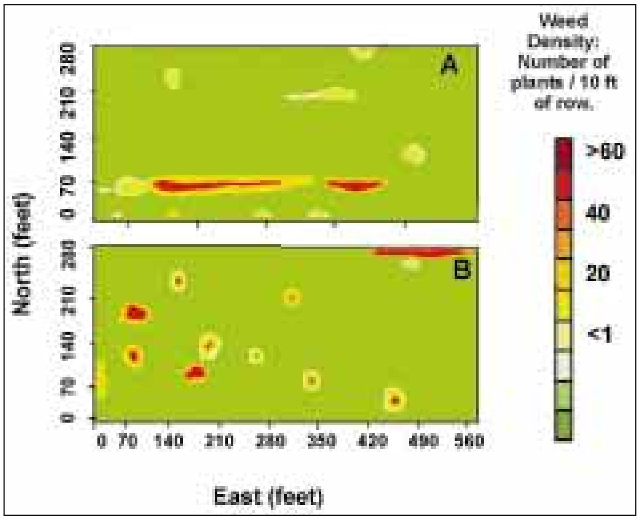


Figure 2. Two hemp dogbane weed patches showing high density foci and tapering edges elongated in the direction of tillage operations.

While there is very little scientific information available about how fast patches expand or the significance of patch shape, careful in-field observation of weed patches may tell us much. For instance, a long, narrow patch suggests insufficient spray overlap or a bad nozzle (**Figure 3A**), and random patches of annual weeds may result from weed seed deposited by the combine (**Figure 3B**).



Figures 3. Weed maps with very different distribution patterns. Figure 3A demonstrates a linear weed patch due to sprayer malfunction; Figure 3B demonstrates random clumps from seeds deposited during last year's harvest.

Because most seeds fall close to their source, natural primary dispersal is generally not an important means of patch expansion. **Figure 4** shows how the shape of a velvetleaf patch is distorted in the direction of crop rows by movement of seeds via combines and other equipment. These observations suggest that growers need to think about ways their farming practices are contributing to the spread of weeds within and among fields. Efforts to stop weed spread will be less expensive in the short and long terms than trying to control weeds after patches become established.

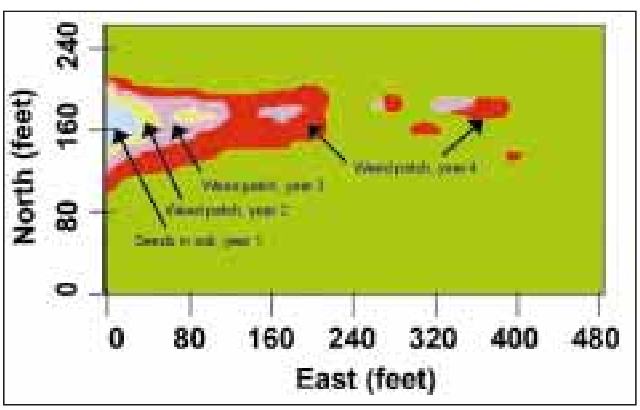


Figure 4. Expanding velvetleaf population from small seed pool at the edge in year 1 to several patches in year 4.

Within-Patch Dynamics

The changing density of weeds within a patch over time is determined by the balance of additions and losses of individual plants, seeds, buds, etc. Increases in the density of plants or shoots come from seeds (or perennial buds) produced within or moved to the patch, whereas losses occur by mortality (due to natural causes or control practices) or movement out of the patch. The density of weeds within a patch is not uniform. There may be one or more points of high density and decreasing density toward the patch edge, as seen in **Figure 2**. The most intense weed-crop competition occurs in areas of high weed density. Patch expansion and dispersal to form new patches occur at the patch edge where weed-to-weed competition is less intense. Therefore, to manage weed patches we need to: (i) reduce weed density where competition is limiting crop production; and (ii) contain reproductive units to limit spread and initiation of new patches.

Just because a field has a low weed density does not mean that site-specific management is not appropriate. In fact, weeds tend to be more clumped when the density is low. Therefore, a field with low weed density could benefit more from site-specific management because a larger proportion of the field would not require a herbicide application than a field with high weed density. No weed management practice will control all weeds. Over time, uncontrolled species will develop into patches. A realistic starting point for site-specific management may be to focus on these patches of hard to control weeds.

Perennial Patches

Perennial weeds generally rely on vegetative structures rather than seeds for spread and overwinter survival. As a result, individual shoots within a patch are often connected by rhizomes, stolons or rootstocks. Depending on the length and type of connections, this can result in linear, branched, or clumped distributions of shoots. Two strategies of growth in perennials have been described. Weeds such as johnsongrass and Canada thistle use the **guerrilla** approach, with widely spaced shoots that infiltrate but do not dominate surrounding vegetation. For Canada thistle and some other species, patch centers die off over time, while new rootstocks forming at the patch edge are less established and easier to control than those inside the patch. Weeds such as yellow nutsedge or wirestem muhly use the **phalanx** strategy, where a solid advancing front of shoots occupies and engulfs the invaded site. Managing encroachment from field edges is more difficult with guerrilla type perennials that send out shoots at seemingly erratic distances and directions. By comparison, phalanx type weeds, with plodding growth from the patch edge, are more easily kept out of fields by mowing. Transport of plant parts on tillage and other machinery is especially helpful to phalanx type weeds that have less ability to spread widely and rapidly than do guerrilla type weeds.

Relationships of Weed Patches to Crop Productivity

Because weeds compete with crops for light, water, and nutrients, weeds are a significant cause of variation in crop yield. Many growers using yield monitors the first time are startled to see how much yield is reduced as they drive their combine through a patch of weeds. Competition studies have shown that the yield reduction caused by weeds increases rapidly with increasing weed density. Therefore, yield losses are higher at the high-density areas in the center of patches than they are at the patch edge. Early emerging weeds are more competitive. They cause greater yield reductions and return more seeds to the soil than later emerging individuals. This means that attention must be given not only to where management efforts are needed, but also to when they are needed. Early emerging species must be monitored and targeted at an appropriate growth stage to prevent crop loss, whereas patches of later emerging species would be targeted afterward. Also, weed species vary greatly in their ability to reduce crop yields. One giant ragweed is about five times as competitive as one cocklebur, which is about 10 times as competitive as a single pigweed plant. Of course, the competitiveness of crops also varies with species, variety, row spacing, planting density, planting time, fertility, and other management variables. Therefore, herbicides are only one of many management approaches, including crop rotation, that can be used to decrease the size and density of weed patches.

Diagnosing Yield Maps

It may take several years of collecting and mapping yield data before patterns caused by weed patches can be detected reliably. Areas of the field where site conditions result in poor stands or inherent low productivity are likely spots for weed infestations. Such low-yield spots, which should be consistent and clearly delineated over time, are generally related to topography or other large-scale characteristics. Weeds may be dense in such areas, and increased weed management may not result in significant crop yield improvement unless the root cause of poor crop productivity can be remedied. It is conceivable that some low-yield areas should be converted to permanent sod rather than continual cropping, which only creates favorable conditions for annual weeds. Although weeds can compete with crops for light, water, and nutrients, if one of these factors...say water...is not limiting, then the overall effect of weeds will be less than if all are limiting. For instance, with corn, yield losses due to weeds are most severe in dry years because nutrients are typically supplied in abundance, and corn is taller and able to capture more light than most weeds. Therefore, if weeds infest areas of a field where water is abundant, yield maps may not show the expected yield losses. Generally, the presence of weeds will add to the yield losses caused by other yield limiting problems, such as drought, nematodes, and other pests.

One of the best ways to relate the pattern of yields to weed infestations is by mapping weeds when crops are harvested. Some growers have developed simple devices connected to the global positioning system (GPS) signal on their yield monitor to record weeds as they harvest. By simply pushing buttons on a signaling device when they enter and exit a weed patch, they can produce a map that can be matched to the yield map to determine if the pattern of weed patches is related to yield patterns. Yields mapped at field edges are generally less reliable than those in the middle of the field. Yet it is at the edge where weeds generally invade and where light penetration through the canopy to the weeds is most likely. Therefore, field edges should be scouted carefully and mapped independently of yield maps.

Weed Response to Site-Specific Management

One of the most consistent features of weeds is that they are not consistent. In other words, virtually every experience of effective management of a weed prepares the way for another weed or group of weeds to invade or increase in importance. Growers should always be looking ahead to anticipate the weeds that will increase because of their management practices even if they are site-specific. Therefore, after several years of successful mapping, monitoring, and management of weeds, shifts in species are likely to occur. Weeds that can disperse long distances might increase, such as guerrilla perennials. If on-the-go sensors are used to activate sprayers, weeds that resemble crops…those that fool the sensor…are likely to increase. This is one reason field mapping of weeds is so important: to determine where today’s problems are and to anticipate tomorrow’s weeds before they become problems.

Precision agriculture is a powerful technology with potentially important applications to weed management. However, growers should remember good agronomic practices, including preventing weed infestations, managing herbicides wisely to prevent resistance, and minimizing environmental impact associated with weed management. ■

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