Spatial Weed Distribution: Can It Be Used to Improve Weed Management

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Identifying the variability within a field and managing inputs to account for this variability is one of the underlying principles of precision agriculture. Although most agronomists recognize that weed populations within a field usually are highly variable, there has been relatively little effort to incorporate knowledge regarding weed populations into weed management plans. This paper will provide an introduction to the spatial characteristics of weed populations and how we might utilize this information to enhance weed management programs.

**Types of spatial distributions**

Three types of distributions have been used to characterize weed populations (Figure 1). In a regular arrangement each weed is spaced equidistant from another and weed density does not vary across the field. This type of arrangement rarely occurs except in poorly managed fields that have uniformly high weed densities (> 10 weeds per ft²). With a random distribution every site in the field has an equal chance of being occupied by a weed. Weed density varies across the field, and knowledge of weed density at one site in a field will provide no information concerning weed density at another location within the field. Weeds with wind-blown seed, such as marestail, could occur in a random arrangement, particularly if the seed source was at a considerable distance from the infested field. The final, and most common, arrangement of weeds is the patchy or aggregated distribution. In this situation, weed density varies widely across the field. The presence of a weed at one site increases the likelihood of a weed at a nearby site. Wind-blown seed would likely result in a patchy arrangement if the seed source was close to the field. In this situation, the weed density would be higher at a location near the seed source than at a site on the opposite side of the field.

![Figure 1. Types of weed spatial arrangements.](image-url)
Causes of Patchy Weed Arrangements

When a person observes a weed patch, one of the first questions asked is ‘why are there more weeds in that part of the field?’ Weed patches in a field may be the result of soil variability, introduction of seed from external sources or crop management practices. In some situations it is easy to determine the reason for the presence of the weeds, such as a sprayer skip or a pothole where the crop was drowned out early in the season. However, in many situations it is difficult to explain why weeds are present in one part of the field but not found elsewhere.

Differences in soil characteristics across a field may influence weed populations directly or indirectly. A direct affect would be a situation where a weed was better adapted to growing in a certain soil type than others, such as a high pH versus a low pH soil. Most annual weeds are classified as colonizers, a group of plants that quickly move into areas where the soil has been disturbed and previous vegetation eliminated. Under natural conditions, colonizers fill a void in the ecosystem and then are rapidly replaced by more persistent vegetation types, such as herbaceous perennials, shrubs and/or trees. Thus, the major requirement for annual weeds is bare soil, rather than a specific soil characteristic (texture, O.M., mineral balance, etc). The annual production of over 20 million acres of corn and soybeans in Iowa provides plenty of habitat for these colonizing species.

Occasionally it is stated that the presence of a weed is an indicator of a specific soil characteristic or nutrient imbalance (Table 1). In most cases these statements are an example of harmless folklore, but occasionally persons attempt to use this information to promote the use of a product to remedy a non-existent soil problem. Although soil characteristics may have subtle influences on weed populations, if the soil is a major driving force in weed distributions in a field then the soil probably is sufficiently out of balance that the weeds should not be the farmer’s major concern.


<table>
<thead>
<tr>
<th>Soil characteristic</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid</td>
<td>smartweed, scouring rush, hawkweed</td>
</tr>
<tr>
<td>Salty</td>
<td>shepherd’s purse, Russian thistle,</td>
</tr>
<tr>
<td>Lime stone</td>
<td>field pennycress, field peppergrass</td>
</tr>
<tr>
<td>High potassium</td>
<td>red clover, wormwood, marsh mallow</td>
</tr>
</tbody>
</table>

Although there has been considerable research looking at relationships between soil characteristics and weed populations, the majority of data indicate that most annual weeds are adapted to growing in any soil with characteristics favorable for crop growth. More recent studies investigating the spatial patterns of weeds in whole fields have identified some correlations between soil types and weed density that were not detected in earlier studies. Researchers at the University of Nebraska reported that velvetleaf and sunflower were more prevalent on soils with high organic matter and a low relative elevation, whereas annual grasses were more common on the upland, better-drained soils.
Soil factors may have a large affect on the occurrence of weeds through adverse impacts on crop growth. Suppression of the crop canopy increases the resources available to support weed growth, particularly light. Delaying crop development for a relatively short period early in the growing season (1-2 weeks) can provide weeds a competitive advantage over the crop for the remainder of the growing season. In most of Iowa, poor soil drainage would be the soil characteristic most likely to favor weeds, although high pH can be a problem in certain soil associations.

Crop production practices (tillage, herbicide application, harvesting) may have a major influence on the spatial arrangement of weeds in fields. These patches are often easy to identify since they are frequently oriented in the direction of machine operation. Weed patches can be created by: herbicide misapplication, introduction of a new species by farm machinery at a field entrance, gaps between passes of the planter or drill, and spread of weed seed by the combine. Herbicides place more selection pressure on weed populations than any other factor, and thus differences in herbicide activity across the field, whether due to variable soils or uneven application, can lead to aggregated weed populations. A study in central Iowa found that the soil characteristic most closely associated with annual weed populations was herbicide adsorptivity. As would be expected, weed densities generally were higher on soils that bound herbicides more tightly than on soils with less herbicide binding capacity.

**Stability of Weed Patches**

The cost of obtaining spatial data has hindered many aspects of precision agriculture, and weeds pose a particular problem due to their dynamic nature. Soil characteristics remain relatively stable over time, thus a map of soil characteristics can be used for several years before resampling is required. Since weed distribution across a field can change rapidly, a weed map may only provide accurate information for one or two growing seasons. Although a few recent studies have investigated whether weed patches remain in the same part of a field from year to year, our understanding of this characteristic of weed populations is limited.

Perennial weed patches tend to be more stable than annual weed patches. Most perennial weeds found in agronomic crops spread primarily by vegetative structures (rootstocks, rhizomes, stolons) rather than by seed. Examples of creeping perennials include quackgrass, hemp dogbane, common milkweed and Canada thistle. Since most herbicides used in corn and soybeans are marginally effective on perennials, these weeds tend to be present at the same spot within fields from year to year. Patch expansion of perennials is relatively slow since they are dependent upon new growth of the vegetative reproduction structures. In an undisturbed habitat over a four-year period, a single common milkweed seedling produced a patch consisting of 56 stalks and covered 100 ft². The expansion rate of the patch edge for milkweed in this study was less than 1.5 ft per year. The spread of perennials is often aided by tillage, resulting in patches oriented in the direction of implement operation.

Although annual weed populations are normally aggregated, the patches tend to be less stable than perennial patches. Research has shown that the location of annual weed patches within a field remains relatively stable from year to year, but patch size can vary widely. The large capacity for seed production by many annual species is a major contributor to the patchy nature of weed populations. Although the weed seed bank fluctuates rapidly in response to seed inputs...
and seed losses, seed dormancy maintains a source of new infestations for several years. The potential for weed seed movement allows annuals to spread more rapidly than perennials. Weed species with seeds that remain on the plant until crop harvest may be spread rapidly across a field by the combine, whereas species with seeds that shatter prior to harvest will move less rapidly.

Weed management practices generally are targeted at annual species, thus effectiveness of control tactics is a main factor influencing the distribution of annuals in a field. Soil factors that affect herbicide activity (adsorption, persistence) have been shown to influence distribution of weeds. Herbicide activity is also influenced by weed density, with weeds more likely to escape control in areas with high populations. This factor contributes to the stability of patches, since weeds that escape control produce seed that increases the seed bank. The following year those areas with a large seed bank are likely to have high weed densities, and thus weeds are more likely to escape control in these areas again. Patch size will shrink in years with weather conditions favorable for herbicide activity, whereas conditions that reduce herbicide performance will allow the patch to expand.

Implications of Weed Distributions on Weed Management

One of the goals of precision agriculture is to make better management decisions through an increased understanding of the variability within a field. Although our understanding of factors that drive weed infestations has greatly improved in recent years, the potential for using this information to enhance weed management programs is still unclear.

Although economic thresholds have not been widely used to guide weed management decisions in corn and soybean, efforts continue to improve these tools so that they will be more widely accepted. Most economic thresholds are based on the assumption that weeds are uniformly distributed across the field, whereas this rarely occurs in the field. Failure to account for the distribution of weeds across the field reduces the accuracy of the yield loss predictions upon which economic thresholds are based. If a patchy weed infestation increased the expected yield loss compared to a uniform infestation, threshold models would recommend leaving a weed infestation that might result in yield losses exceeding the cost of control.

Weeds reduce crop yields primarily by competing with the crop for limited resources (light, water, nutrients, etc.). An isolated weed competes only with crop plants that occur within a certain distance. For example, common cocklebur was found to reduce the yield of all soybean plants within 20 inches of its stem. If two cocklebur plants occur within 20 inches of each other, they compete for resources among themselves (intraspecific competition) as well as with adjacent soybean plants (interspecific competition). Since the competition between the two cocklebur plants reduces their growth, the combined impact of the two weeds on adjacent crop plants is less than if the weeds are outside of each other’s area of influence. Thus, the same number of weeds in a field cause less yield loss when they occur in a patchy distribution than if they are spread uniformly across the field (Figure 2). Intraspecific competition among weeds in dense patches results in conservative estimates of yield losses when predictions are based on average weed densities, reducing the likelihood that the true yield loss from a weed competition will be underestimated.
Knowledge of the distribution of weeds across the field creates an opportunity for site-specific weed management. One potential way to utilize this information is through variable-rate herbicide application (VRA). The premise of VRA is that the optimum herbicide rate varies across the field and that the optimum rate for a specific area can be predicted based on information known about the field. Some of the factors that influence herbicide performance include soil characteristics (primarily soil-applied herbicides), weed populations and environmental conditions. The potential for economic benefits with VRA varies on the relative importance of these three factors.

The impact of soil type on herbicide activity is well documented. Most herbicides bind to soil colloids, and the portion of the herbicide adsorbed to these colloids is not immediately available to control weeds. Rates of soil-applied herbicides are routinely adjusted according to the soil type present in the field. Traditionally the rate has been selected based on the ‘average’ soil type found in the field. However, with today’s technology it is possible to adjust rates ‘on the go’ according to soil variability across the field. Herbicide manufacturers have developed equations to calculate herbicide rates for a specific soil texture and organic matter. For example, the Dual II MAGNUM label recommends increasing the rate by 0.1 pt/A for every one percent increase in organic matter on a medium texture soil. Based on this information, in a typical Iowa field the Dual rate would vary by 15-30% due to changes in soil organic matter. While this may seem to be a significant rate change, it is relatively small based on the level of precision of herbicide application in field crops. The potential for economic benefits with VRA based on soil type decreases with responsiveness of herbicides to soil changes.

Herbicide performance generally tends to decline as weed density increases. Therefore, weed management might be made more efficient by adjusting herbicide rate according to changes in weed populations. The cost of gathering data needed to accurately map weed populations is a major problem at this time. In most situations, the traditional methods used to scout for crop pests do not allow development of weed maps with sufficient detail to base herbicide rate adjustments. Current research is investigating the potential for using remote sensing to map weed populations, therefore reducing the cost of gathering this information.

While the effect of soil type and weed population on herbicide performance is well documented, it also is known that environmental conditions strongly influence performance. Understanding
the relative contribution of these three factors is important in determining the potential benefits of VRA. In ISU studies in the late 1980’s, the rate of Dual needed for 80% control of woolly cupgrass ranged from less than 2 pts/A to more than 10 pts/A during 6 years of research. This research was conducted in the same field with uniformly high cupgrass populations, thus differences in environment were largely responsible for the wide range in Dual efficacy. If the environment has a greater influence on herbicide activity than either soil type or weed population, then there may be little, if any, economic benefit to VRA. Unfortunately there have been few studies investigating these interactions on a field-scale basis.

Another opportunity for site-specific weed management is the use of intermittent applications. Due to the patchy nature of weed populations, many fields may have large areas that are weed-free. Intermittent applications would allow a manager to only spray those areas of the field that are actually infested. Two approaches have been used to control sprayers for intermittent applications, historic spatial distribution maps or the use of real-time sensors to detect the presence of weeds as the sprayer moves across the field.

The use of historic maps for directing intermittent application is limited by the cost of obtaining accurate maps of weed distribution within fields. The potential for economic benefit from this approach increases as the percentage of the field that is weed-free increases. Researchers at the University of Nebraska intensively mapped weeds in a 10 acre section of a field. They found that 59, 40 and 34% of the sampling area was not infested by common sunflower, velvetleaf and foxtail, respectively. Although there were large areas of the field not infested by the individual species, when the maps for different species were overlaid there was very little weed-free area in the field. In this situation, there would be no benefit to intermittent application if the treatment being applied was a broad-spectrum treatment targeting all three species.

Smart-sprayers use sensors to detect the presence of weeds. The sensors are linked to the sprayer through a computer and turn the boom or nozzle on and off depending on whether weeds are present or not. Smart-sprayers have been marketed for use in fallow ground where they can distinguish between bare ground and plant foliage; however, sprayers that can distinguish between crops and weeds are still in the experimental stage. The obvious advantage to this technology is that it eliminates the need for detailed scouting and mapping of weed populations. A logical application for these sprayers would be for supplemental control tactics targeting weeds that escape primary control tactics. However, the low threshold level for weeds may limit the potential for this technology in corn and soybeans. There is a high probability that weeds growing under the crop canopy would not be detected by the sensor and therefore would escape control. These weeds may be the most competitive with the crop due to their close proximity to the crop row.

**Summary**

The aggregated nature of weed populations is well documented and our understanding of the factors leading to the development of weed patches is increasing. The objective for studying the structure of weed populations is to improve weed management systems. In the short term, knowledge about spatial variation in soils and weeds may provide benefits in the area of variable rate herbicide application. While the influence of soils and weed populations on herbicide performance has been known for a long time, the relative contribution of these factors compared
to the influence of environmental conditions is poorly understood. Additional research is required to determine whether the added cost of variable rate application based is warranted considering the large influence weather has on herbicide performance.

In the long run, the current research on spatial weed populations may provide a better understanding of the soil characteristics that favor development of weed patches. This information may lead to novel methods of soil manipulation to create an environment less favorable for weed species. While it is unlikely these tactics would be as effective as current herbicide technology, they could be employed to enhance the activity of other control strategies (herbicides, cultivation, etc.).