INTRODUCTION

This is the third article of a series on integrated weed management (IWM). Initial articles can be found as special alert editions 2020 at the following link: https://extension.umd.edu/annearundel-county/agriculture/vegetable-fruit-headline-news Certain weeds thrive in specific cropping systems because they are well adapted to the competition, planting dates, tillage patterns and other conditions associated with those systems. When a single crop species is grown in the same field over multiple years, this can result in the buildup of weeds that become adapted to that crop’s requirements. Deploying a complex crop rotation plan is a desirable method to “keep weeds off balance” and prevent them from becoming a severe problem. Crop rotation is recognized as an important integrated weed management (IWM) tool because some crops in rotation suppress weeds by outcompeting them for resources and/or possessing allelopathic properties that reduce their establishment. Further, cropping system diversification through the deployment of long rotations of dissimilar crop species can increase the range of stress and mortality factors inflicted upon weed communities. Research has shown that complex sometimes referred to as diverse crop rotations, significantly reduce weed density and biomass compared to simple rotation systems. Further, diversified crop rotations can reduce the occurrence of dominant weed species while increasing crop productivity. Despite these and other advantages, conventional cropping systems in temperate environments are characterized by large monoculture plantings and simple rotation schemes that consist of a restricted number of crops.

CROP ROTATION IMPORTANCE

The value of crop rotation as part of an IWM program cannot be overstated. For a long time, crop rotation was considered the foundation for maintaining healthy crops and bountiful yields. This concept was put on the back burner as dependency on agrichemicals increased. However, crop rotation is being revived and its value has gained renewed interest. Crop rotation should be a cornerstone of any pest management program whether targeting insects, weeds or pathogens.
The more complex the crop rotation scheme the better. Notwithstanding, diversity is typically neglected in favor of simple rotation systems. However, simple rotation schemes can amplify weed problems, especially if weeds within a field have similar lifecycles and growth requirements to crops frequently grown in the field. Weeds fortunate enough to inhabit fields with no crop rotation or simple rotation schemes will have little difficulty adapting to and thriving under these predictable conditions. Complex crop rotations are better for “keeping weeds off balance” by disrupting their lifecycle. This disruption prevents the composition of the weed community within a field from shifting to one that is more difficult to manage. Rotating crops means that different resources are utilized at dissimilar times during and between seasons. Moreover, complex rotation schemes ensure farmers grow crops with varying weed management practices, planting and harvest dates, tillage, residues, etc. (Figs. 1a, b). This makes field conditions erratic, unpredictable and subsequently inhospitable to weeds.

Under these circumstances, weeds will find it difficult to adjust to all the different situations being thrown at them over time. Consequently, this will restrict their adaptation to a field site. Nevertheless, it is imperative to note that a diverse crop rotation scheme will only be successful if it is practiced in coordination with other ever-changing weed management tactics. For example, certain weeds will proliferate under complex rotation schemes if the soil is tilled on a similar schedule each year. Thus, through long-term variations in crop species, husbandry practices and planting times, rotations create a changing environment that prevents the occurrences of dominant weed species. This is critical because over time, dominant weeds that are established in a field become more and more difficult to control and manage.

GOOD ROTATION PLAN
Crop rotation requires a plan to stave off the establishment of problem weeds and prevent shifts to more difficult to control weeds. Knowledge of specific weeds in each field will allow for the creation of specialized rotation systems best suited to deal with weeds on a field-by-field basis. For example, if mid-summer germinating weeds are a constant issue, establishing a spring crop that gets well established and/or forms a dense closed canopy by early summer can break the cycle by preventing the establishment of weeds that would otherwise germinate during mid-summer. If perennial weeds become a problem, an option may be to plant a perennial cash crop or cover crop into the rotation that can be mowed or grazed regularly as part of an overall management plan. Rotating fields into perennial cover for multiple years can be especially effective in disrupting the life cycle of annual weeds. The most effective crop rotation schemes will be multifaceted and subsequently “force” producers to implement diverse husbandry and weed management practices that take into consideration the biology and ecology of weeds occupying a field. Further, rotations that increase variation in crop planting dates (crop lifecycles) are generally more crucial than those that enhance...
crop diversity. Rotation tips. The simple notion that the only requirement of a good crop rotation plan is that a different crop be planted in succeeding years or occasionally allowing a field to lay fallow for a year is misguided at best. Weeds will take advantage of these simple rotation plans. Some tips for formulating a successful and more complex rotation scheme are: 1) alternate crops with different types of vegetation such as rotating: (a) leafy crops [e.g., lettuce, cabbage, spinach], with (b) root crops [e.g., carrots, daikon], with (c) fruit crops [e.g., tomato, squash], with (d) tuber crops [e.g., potato], and with (e) bulb crops [e.g., onion, garlic]; 2) include monocots [e.g., corn, sorghum, oats] and dicots [e.g., tomato, summer squash] in the rotation, 3) rotate crops with different crop-cycle [e.g., winter cereals with summer crops, fall with spring crops], 4) alternate short- [spinach, cucumber] and long-season [tomato, okra] crops, 5) avoid succeeding crops of the same family [e.g., tomato, eggplant & pepper (Solanaceae) or watermelon, cantaloupe & cucumber (Cucurbitaceae)], 6) rotate poorly [e.g., onion, pepper, lettuce] with highly competitive [e.g., cabbage, potato] crops, and 7) avoid growing crops in fields with weeds known to be particularly problematic to that specific crop. The requirements of some weed species can be so similar to crops being grown, that management practices being utilized to cultivate the crop are more beneficial to weeds in the field. This can occur if weeds in a field are of the same family as the crop such as solanaceous weeds in a tomato field. In situations where a complex crop rotation plan is adopted (Fig. 2), fields should still be scouted and the situation assessed annually to determine if problem weed species are exploiting the rotation system and thriving in the field. If so, adjustments should be made to the rotation system and overall IWM plan to make it less hospitable to problem weeds.

![Fig. 2. Rotation system of vegetables with varying vegetation, cotyledon type, crop cycle, above and below ground competitiveness, and management practices.](image)

**Note:** All rotation plans must be assessed to assure no weeds are proliferating.

**Cover Crops and Rotation.**
Cover crops are generally not viewed as rotational crops but they are often part of a rotation system. There are various options with respect to species, cultivar and management tactics to include in a rotation system. The choice may be guided by which cover cropping services are most important, weed species in a particular field, requirements for their control and the subsequent cash crop following the cover crop.
Cover crops can be: i) used as a green manure and plowed under before planting the subsequent crop, ii) terminated and allowed to remain as a layer of dead mulch on the soil surface, iii) used as a dying mulch [allowed to die naturally during the cash crop lifecycle], iv) deployed as a living mulch or v) a combination of these tactics (Fig. 3). In the case of living mulches, the cover crop is not terminated and the subsequent cash crop is interplanted into a cover crop that lives the entire duration of the cash crop cycle. Though a living cover crop can suppress weed establishment better than the other cover cropping tactics, living mulches may behave similar as weeds by competing with the cash crop. Thus, caution must be considered when deploying this tactic. One can also take advantage of the fact that cover crops have differing lifecycles. For example, it is often recommended that winter cereals be included in a summer crop rotation scheme to suppress winter annual weeds and alternate crops of varying lifecycles. For those vegetable farmers that don’t market winter cereals, using a fall planted winter cover crop can influence weeds similarly. Further, some cover crops have the potential to suppress weeds via two mechanisms – competing for resources and releasing allelopathic compounds. Thus, rotation schemes incorporating different cover crop species or including cover crop mixtures may provide greater weed suppression as they exert different stresses on weeds and subsequently furthers the goal of “keeping weeds off balance”.

**Rotation and tillage.** The effectiveness of crop rotation may vary according to tillage practices. For example, a review of 54 studies across six continents that compared weed response due to simple and more diverse crop rotation schemes found that diverse rotation schemes reduced weed density 49% more compared to simple rotations. The study also exposed the fact that the impact of diverse crop rotation on weed density is stronger in no-tillage than tilled systems. Greater weed suppression in no-tillage compared to tilled systems occurred regardless of environmental conditions and herbicide programs that were administered in the field. The review also found that across all rotation schemes whether simple or diverse, mean weed density was lower in no-tillage compared to tilled systems. These findings not only highlight the value of diversifying crop rotation schemes but also supports the synergistic use of conservation tillage and crop rotation as components of IWM programs. However, one difficulty of deploying no-tillage and complex crop rotation concomitantly in specialty crops such as vegetables is not much research has been conducted in this area compared to agronomic crops. As such, there is not a lot of written recommendations to help farmers navigate this strategy. Further, certain specialty crops such as some small seeded vegetables or those that require a deeply worked, finely tilled seed bed don’t grow well under no-till conditions. Another important finding of the review was that variations in crop-planting dates were much more important than crop diversity in explaining greater weed suppression in complex than simple rotations. This suggest that when devising rotational schemes, in addition to ensuring that a diversity of crop species exist in the plan, farmers should consider how well their plan maximizes chronological differences among crop planting dates.
Rotation Influence on Weed Control Tactics
Different cropping systems tend to have dissimilar planting dates, growth requirements and competitive abilities. They also vary in strategies required to effectively manage weeds. As such, rotating different crop species will invariably cause tactics deployed to control weeds be rotated as well. Employing multiple weed suppression tactics supports the goal of “keeping weeds off balance” and better ensures that no one weed species proliferates from year to year. For example, including potato in rotation allows frequent, aggressive cultivation to kill emerged weeds. In contrast, including crops on raised beds under plastic within the rotation allows inter-row areas to be mowed, cultivated or spot sprayed while intra-row areas remain undisturbed during the crop’s growth cycle. Introducing a monocot such as sweet corn into the rotation allows for the use of selective herbicides that target broadleaf weeds, or including a dicot allows the use of selective herbicides that target grass weeds. Further, practicing crop rotation will help prevent the build-up of other pest complexes such as herbivorous arthropods as well as pathogenic nematodes and other infectious organisms. These added stresses can make crops less vigorous and consequently reduce their competitiveness with weeds. Another potential benefit of crop rotation is that it impels conventional producers to use different herbicides and mode of actions, which is important to help prevent the creation of herbicide resistant weeds. A model rotation plan will change many aspects of the cropping environment from year to year and accordingly diversify the number of tools used to suppress weeds, which supports IWM. Specifically, IWM encourages a holistic approach to managing weeds.

SUMMARY
Crop rotation should be the foundation of any pest management program. Cropping systems that provide a consistent environment from year to year will inevitably support the proliferation of some pest (insect, pathogen, weed) species that adapt to these conditions. Producers who establish a diverse crop rotation plan are forced to vary the timing of their operations, plant families being grown and pest management practices from year to year. The latter causes yearly changes in IWM tactics (i.e., mechanical, cultural, biological and chemical tools), which “keeps the weeds guessing” and off balance. This consequently reduces the opportunity for any weed species to escape control and proliferate. Financial support for the publication of this article is via USDA NIFA AFRI CARE and EIPM grant award numbers 2016-68008-25079 and 2017-70006-27171, respectively.

Vegetable & Fruit News
A timely publication for the commercial vegetable and fruit industry available electronically in 2020 from April through October on the following dates: April 16, May 14, June 11, July 9, August 13, September 10 and October 29 (Special Research & Meeting Edition).

Published by the University of Maryland Extension Focus Teams: 1) Agriculture and Food Systems; and 2) Environment and Natural Resources.

Submit Articles to:
Editor,
R. David Myers, Extension Educator
Agriculture and Natural Resources
97 Dairy Lane
Gambrills, MD 21054
410 222-3906
myersrd@umd.edu

Article submission deadlines for 2020 at 4:30 p.m. on: April 15, May 13, June 10, July 8, August 12, September 9 and October 28 (Special Research & Meeting Edition).

Note: Registered Trade Mark® Products, Manufacturers, or Companies mentioned within this newsletter are not to be considered as sole endorsements. The information has been provided for educational purposes only.

The University of Maryland Extension programs are open to any person and will not discriminate against anyone because of race, age, sex, color, sexual orientation, physical or mental disability, religion, ancestry, national origin, marital status, genetic information, political affiliation, and gender identity or expression.