Answers to Frequently Asked Questions on Herbicide Resistance Management

Muthukumar V. Bagavathiannan
Post-Doctoral Research Associate

Jason K. Norsworthy
Professor - Weed Science

Robert C. Scott
Professor - Weed Science

L. Thomas Barber
Associate Professor - Weed Science

Arkansas Is Our Campus

Visit our web site at:
https://www.uaex.uada.edu

Herbicide resistance is a growing threat to successful crop production in the Midsouth. Research in this area over the past decade has furthered our understanding of resistance development and helped identify effective measures for preventing/managing resistance. However, there exist several misconceptions on resistance development and management. The goal of this fact sheet is to clarify some key facts on herbicide resistance and answer some of the important questions on resistance management. Here we answer a list of frequently asked applied management questions through knowledge derived from model simulations, field research and field experience.

1. Why should I apply herbicides in rotation or in mixtures? Why can't I utilize the best herbicide for now and then move to the next when it fails?

First of all, there are no new herbicide chemistries to be released in the near future, and it is important that we preserve the utility of available herbicide options. The fact is that when herbicides are used in combination, they help protect each other and prevent the development of resistance to any single herbicide. As a result, the time taken for resistance development for the herbicide combination is much longer compared to the total time taken for losing all the herbicides when used individually. Moreover, if resistance is allowed to develop in a field, it subsequently increases the risk of resistance to the next herbicide through a sheer increase in the seedbank size (i.e., number of weed seeds in the soil). Thus, growers need to be proactive and ensure that resistance is prevented by applying herbicides in rotation or in mixtures.

Example: Many Arkansas rice growers have lost Propanil®, Facet® and Newpath® for barnyardgrass control within the past few decades. This situation happened because they used a single herbicide chemistry until resistance development and then moved to the next herbicide, causing a chain of herbicide loss.

Message: If these herbicides were used in combination from the start, all of them may still be effective and resistance might not have developed for any of these herbicides.

FIGURE 1. Severe infestation of herbicide-resistant barnyardgrass in rice.

2. When can I go back to using the herbicide chemistry that I just lost on a weed species?

Probably you won't be able to use it again, and this is what our field observations suggest. When resistant weeds are as equally fit as their susceptible counterparts, which is usually the case with most resistant biotypes, the resistance trait could be carried for generations. This means that resistance does not disappear from the soil seedbank, but rather waits to be seen again when that herbicide is used in the future. Thus, once a herbicide is lost due to resistance, it is perhaps lost forever on the weed species in question in a given production field.

FIGURE 2. A soybean production field with severe infestation of Palmer pigweed with resistance to Roundup® and to the ALS herbicides such as Staple® and Scepter®.

Example: A survey conducted in the Mississippi Delta region of eastern Arkansas revealed that >95% of the Palmer pigweed populations present in this region confer resistance to Staple® and Scepter® (both are ALS herbicides belonging to Group 2), even though they have not been widely used since the adoption of Roundup Ready® crops from the late 1990s.

Message: It is unlikely that we can go back to using Staple® or Scepter® for managing Palmer pigweed in most production fields in Arkansas. This herbicide chemistry is now lost for Palmer pigweed control. Therefore, it is critical that we preserve available herbicide options by preventing resistance.

3. How much diversity is sufficient in weed management programs?

It is always helpful to include as much diversity as possible, with the goal of maximizing weed control and minimizing weed escapes and seedbank replenishment. Field evidence suggests that a combination of three or more effective options used in rotation/mixture has been sustainable historically, but some other factors also need to be considered for better results (see question 6).

Example: Clearfield® rice production fields that receive Command® as a preemergence application and Ricestar HT® or Clincher® as a postemergence application in addition to the ALS herbicides (such as Newpath®, Regiment® and Beyond®) have greatly reduced weed escapes and consequently the odds of developing resistance. Field evidence shows that ALS-resistant barnyardgrass and sedges developed only in rice fields that relied solely on ALS herbicides.

Message: There should be sufficient management diversity so that the escapes for any single option used in the program are not allowed to build in numbers and enrich the seedbank.

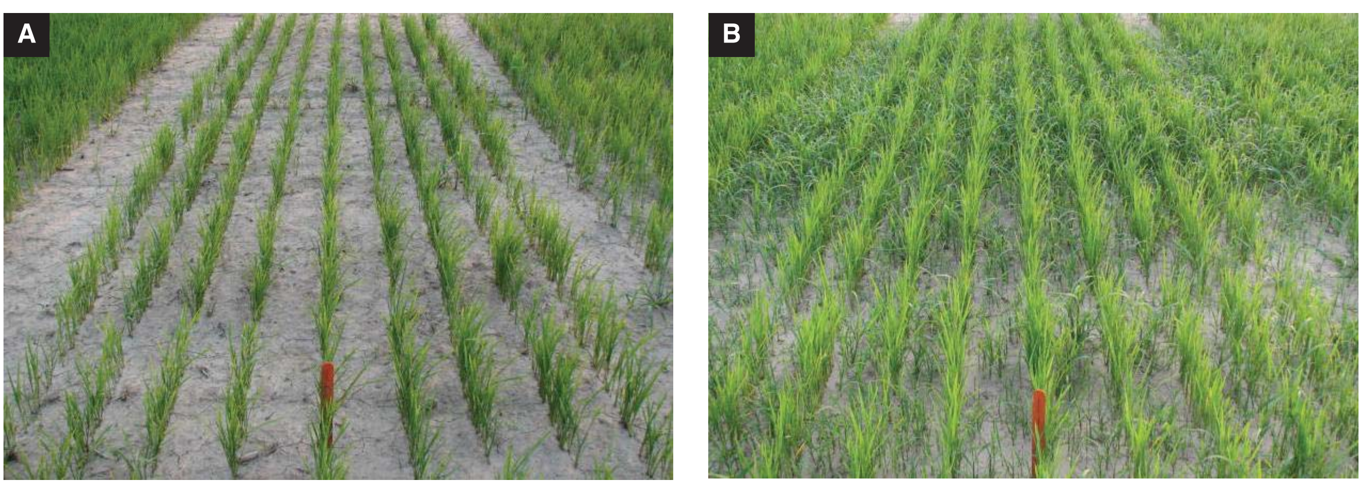


FIGURE 3. Effectiveness of weed control programs in Clearfield® rice (A) with and (B) without the inclusion of Clomazone® as preemergence application.

4. I can achieve acceptable levels of weed control using below the label rates. Why do the recommendations now insist on applications at full label rates?

The prime concern is that low-dose applications can favor the development of resistance through increased breakdown of the herbicide (i.e., metabolic resistance). This type of resistance usually requires the cumulative action of more than one gene which is less influential when acting alone (i.e., minor effect). Low-dose applications may allow for weed escapes that show some level of tolerance to the herbicide. When such escapes outcross, they can stack up minor resistance genes, eventually shifting toward resistance. Metabolic resistance is a bigger threat because it can show cross-resistance to a number of herbicide chemistries, even to herbicides that have never been used before.

FIGURE 4. Palmer pigweed escapes in a cotton field representing a low-dose scenario – outcrossing among these escapes may lead to a shift toward resistance.

Example: In Australia, researchers have found that low use rates favored resistance development in ryegrass through increased metabolic breakdown of the herbicide. It has also been speculated that resistance in some pigweed (particularly waterhemp) populations in the U.S. is caused in part by enhanced metabolic breakdown, possibly resulting from low use rates or due to conditions simulating low-dose scenarios (such as application at larger weed sizes, insufficient coverage, etc.).

Message: Recent knowledge reveals that resistance can develop through the above mechanism. In the past when lower than labeled rates were recommended, we did not face the extent of challenges we do today with herbicide resistance. At present, we cannot afford to lose any more herbicides to resistance.

5. Why should I integrate residual herbicides in my weed management program? When is the best timing to apply residual herbicides – in the front end or back end? What is the best use strategy for residual herbicides?

Integration of soil residual herbicides is a valuable strategy in reducing the risks of resistance, because residual herbicides minimize weed escapes by providing extended activity. Sole reliance on POST herbicide programs is not sustainable because they increase the likelihood of weed escapes and there is no subsequent tool used to prevent seed production by escapes unless they were hand removed. In the

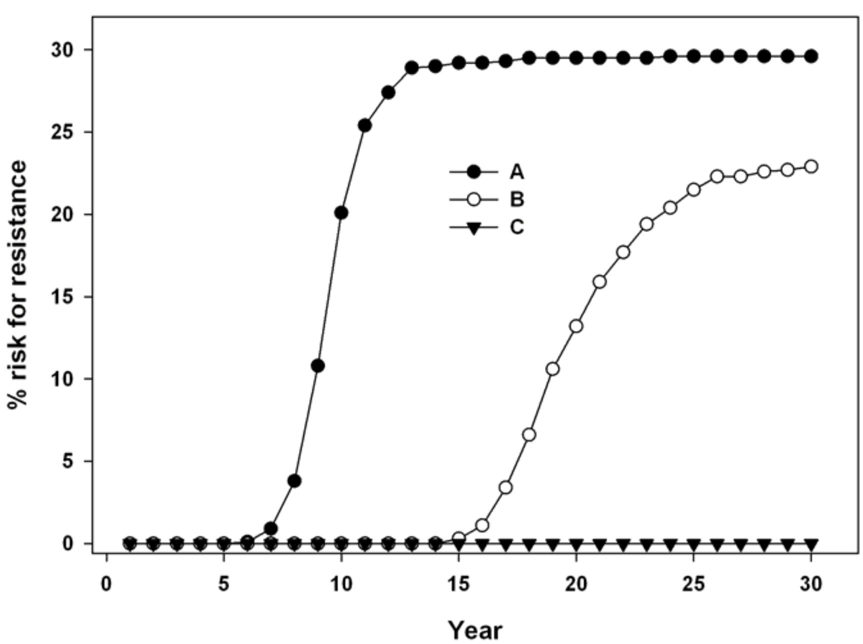


FIGURE 5. Differences in risks of barnyardgrass resistance to Roundup® under the inclusion of the following residual herbicide options in an otherwise Roundup®-only program in a continuous Roundup Ready® cotton: (A) Dual II Magnum®, Caparol®, MSMA® and Valor® applied at and after the first POST application, (B) Reflex® applied prior to planting and (C) Reflex® applied prior to planting followed by Cotoran® applied at planting.

absence of hand removing, even the use of diverse residual herbicides at the back end is not effective in preventing resistance. Applying residual herbicides early-on in the season (i.e., front end) is very effective because it minimizes the individuals that have high seed production potential. Moreover, the few escapes that exist in the field following early-season residual herbicides are controlled by POST herbicides. Overlaying residual herbicides is an effective strategy to keep the fields free of weed escapes throughout the growing season.

Example: Residual herbicides play an important role in the success of currently recommended best management programs for pigweed, which are very effective even in fields that have had a severe resistant pigweed problem.

Message: Few resistant weeds have developed after growers implemented programs consisting of residual herbicides, and it will most likely remain so. Residual herbicides are the backbones of herbicide-based weed management programs.

6. What are the factors to consider in improving the effectiveness of my herbicide programs?

Our model has highlighted three important considerations: (1) diversity, (2) application timing and (3) efficacy. Increasing management diversity through multiple herbicide chemistries is vital, yet there are additional factors to consider. Timing of herbicide applications is particularly important because it influences the likelihood for weed escapes. Diversified applications at peak weed emergence periods are particularly helpful (usually the period from planting to crop canopy formation). Further, the risk of resistance decreases with increase in herbicide efficacy. Although it is not feasible to increase the inherent efficacy of herbicide products, growers should aim at achieving the maximum possible efficacies by applying at the right weed sizes, using sound application techniques, and applying under ideal environmental conditions.

Example: Crop scouts and consultants suggested that weed escapes are common in many production fields due to application issues, particularly application at inappropriate weed sizes. For example, Liberty® and Flexstar® are highly effective in controlling Palmer pigweed only if applied before the plant reaches 4-6 inches tall.

Message: Insufficient diversity, improper application timing, and inadequate efficacy can lead to weed escapes and increase the risk of resistance.

FIGURE 6. Palmer pigweed seedlings with sizes larger than ideal for herbicide application.

7. Why should I integrate non-chemical strategies while my herbicide program is effective in controlling weeds?

Growers should always try to include non-chemical strategies in their weed management programs for two key reasons. First, non-chemical strategies augment chemical programs and reduce herbicide inputs, thereby minimizing the economic and environmental concerns associated with intensive herbicide use. Second, herbicide rotations may not be sufficient to prevent resistance development through metabolic resistance due to the action of several minor genes. Non-chemical strategies such as tillage, crop/trait rotation, increasing planting density, using competitive cultivars, and encouraging rapid canopy formation can be easily incorporated into the production system.

Example: As much as 90% of the ryegrass in the soil seedbank has been eliminated by simply allowing one or two flushes of ryegrass to emerge in the fall and controlling them using a tillage operation prior to planting wheat. Greater than 95% seedbank depletion has been accomplished by fallowing a ryegrass-infested field for one growing season and not allowing any ryegrass plant to go to seed.

Message: By integrating non-chemical strategies, we can reduce the likelihood of weed escapes for the herbicide options used. Thus, non-chemical strategies will extend the utility of herbicide options rather than replacing them.

8. Resistance management recommendations include crop rotation as a valuable strategy. Will I really be in better shape if I practice crop rotation?

In the context of herbicide resistance management, crop rotation provides little benefit if

FIGURE 7. Differences in seed production potential of barnyardgrass between (A) wide-row and (B) drill-seeded soybean.

management diversity is limited in the rotational crops. The key is that the crop(s) used in rotation should allow for diversified management options with opportunities for multiple herbicide chemistries and non-chemical strategies.

Example: The benefits of growing Roundup Ready® cotton in rotation with Roundup Ready® corn are not any greater compared to rotating Roundup Ready® cotton with Liberty Link® cotton. Weed control in corn is usually terminated after early-POST applications, and late-emerging pigweeds can set seed prior to corn harvest. In fact, growing Roundup Ready® cotton in rotation with Liberty Link cotton® would be much better if more diversified programs are used in the rotation.

Message: An effective crop rotation will be determined based on the opportunities for elimination of weed escapes in the rotational crops through the availability of additional management options.

9. What would be the best weed threshold to aim for in my weed management program?

It is critical to recognize that the thresholds should be based on seed production rather than number of individuals that escape control, meaning that a low threshold should be preferred for weeds with high seed production potential. The aim should be to reduce weed seed production as much as possible using diverse options. A "Zero Tolerance Threshold" has been recently promoted for Palmer pigweed with a goal to eliminate escapes that are easily noticed in the crop.

Example: A single Palmer pigweed plant has been proven to have the ability to produce over 1 million seed. Allowing this one plant to go to seed could replenish the soil seedbank for three to five years. In certain counties in eastern Arkansas (notably Clay and Crittenden counties), growers got together and determined that they are not going to let any Palmer

FIGURE 8. Comparison of the risks of barnyardgrass resistance to Roundup® when Roundup Ready® cotton is rotated (A) with Roundup Ready corn® or (B) with Liberty Link® cotton. In this case, a more diverse herbicide program was used in Liberty Link cotton® compared to Roundup Ready® corn.

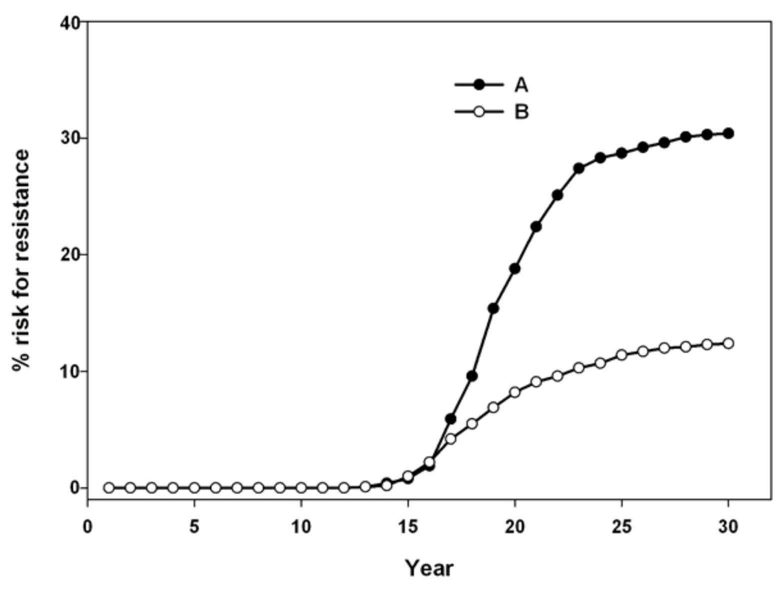


FIGURE 9. The consequence of allowing Palmer amaranth escapes to go to seed. The size of a resistant patch in (A) year 1 and (B) year 2.

pigweed plant go to seed in that region, even if that means hand removing Palmer pigweed escapes later in the season.

Message: The above strategy has been very effective in eliminating resistant Palmer pigweed and preventing further spread. Growers in all regions can benefit by implementing such cooperative efforts.

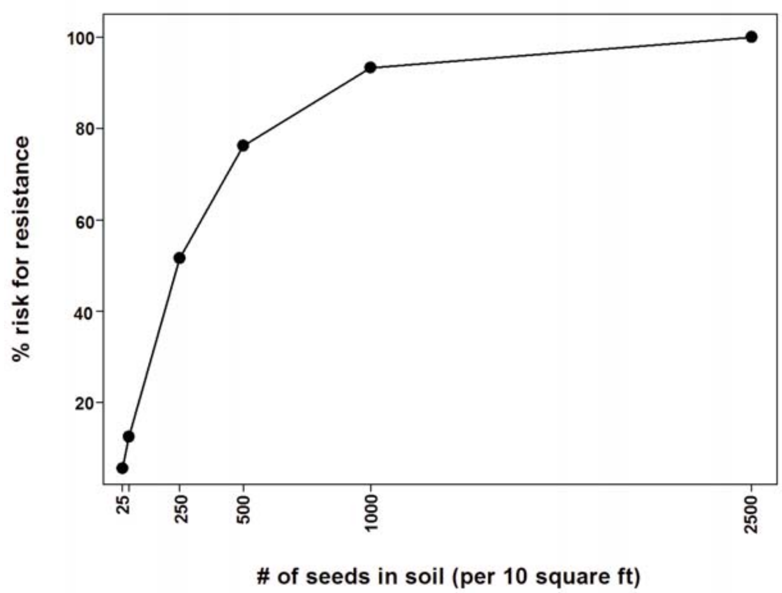
10. Why is there a strong emphasis on weed seedbank management for preventing herbicide resistance?

The simulation models have clearly demonstrated that resistance risk decreases with every increase in weed seed loss. Typically, seedbank management starts with preventing in-crop weed escapes and continues through managing weeds that come up after harvest.

Example: Research into our Zero Tolerance plots has indicated that Palmer pigweed populations show significant signs of seedbank depletion in around three years if no weeds are allowed to set seed. As a result, further risks for resistance are greatly minimized in these plots.

Message: Weed management programs should aim at reducing weed seedbank size.

FIGURE 10. The influence of seedbank size on the risk of ALS resistance in barnyardgrass when nothing but ALS herbicides are used in Clearfield® rice.



DR. MUTHUKUMAR V. BAGAVATHIANNAN, post-doctoral research associate, and **DR. JASON K. NORSWORTHY**, professor - weed science, are with the Crop, Soil and Environmental Sciences Department at the University of Arkansas, Fayetteville. **DR. ROBERT C. SCOTT**, professor - weed science, and **DR. L. THOMAS BARBER**, associate professor - weed science, are with the University of Arkansas Division of Agriculture and are located in Lonoke.

FSA2172-PD-11-13N