To: Participants of the Herbicide-Resistant Ryegrass Working Group Meeting held at the University of Arkansas Lonoke Agricultural Research and Extension Center, September 17-18, 2009

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cc: Kater Hake, Mike Patterson, Stanley Culpepper, Bill Vencill, Mike Marshall, David Shaw, Dan Reynolds, Mike Chandler

Subject: Report of the Meeting

Participants:

Bob Scott	Ken Smith	Jeremy Ross	Larry Steckel
Joe Armstrong	Bob Nichols	Bill Williams	Nilda Burgos
Reiofeli Salas	Daniel Stephenson	Bob Montgomery	John Byrd
Dave Black	Alan Hopkins	John Braun	John Soteres
Tom Eubank	Vijay Nandula	Keith Driggs	Jason Bond
Jim Dickson			

Introduction

Italian ryegrass (*Lolium multiflorum*) is a winter annual used for over-seeding southern pastures to provide late winter and early spring grazing. Naturalized populations persist in certain pastures and are found along roadsides, railroad beds, and ditches. Ryegrass also invades agricultural fields. Observations suggest that ryegrass germinates from September through April, although the greater part of the population may germinate in November and February to early March. Fall establishing ryegrass may be well-tillered by spring and difficult to control in late-February – early March. Ryegrass is a serious weed in wheat (*Triticum aestivum*) and has developed resistance to several acetylCoA carboxylase (ACCase) and acetolactate synthase (ALS) herbicides. Since the 1970s, glyphosate has been used as a burn-down treatment to reduce the need for tillage before planting corn (*Zea mays*), cotton (*Gossypium hirsutum*), and soybean (*Glycine max*). Depending on latitude and late-winter/early-spring weather, burn-down treatments for corn, cotton, and soybean are typically applied from January to March, late February to mid-April, or late March to April, respectively. Ryegrass tends to occur more copiously and be more difficult to control on heavier soils. Ryegrass that emerges in the fall may be very large by spring, with larger plants often proving difficult to control by February. Control of ryegrass varies with stage of growth, amount of growth, herbicide, and rate. Most herbicide treatments require higher rates to achieve good control and overall are less reliable after ryegrass has reached two to three tillers.

For many years, large ryegrass plants have been observed to survive burn-down applications of glyphosate. In the early 2000s, a sufficient density of ryegrass plants in certain fields escaped treatments with glyphosate that Mississippi State University researchers evaluated collections made from two fields for possible resistance to glyphosate. In fact, some plants were found to be less sensitive to glyphosate than a reference population; however, since the level of resistance was low, less than four-fold, the researchers termed the populations tolerant (Nandula et al. 2007). In subsequent years, populations in Washington and Bolivar counties, Mississippi, were increasingly difficult to control. In 2009, there were numerous control failures in several Delta counties in Mississippi, south Arkansas, and northwest and northeast central Louisiana.

Purpose of the Meeting

The objectives of the meeting were:

1. Assess the current situation in the Mid-South with regard to the susceptibility of ryegrass to glyphosate
2. Determine if changes in herbicide recommendations for ryegrass should be made for the 2010 season
3. Identify research needs and opportunities

Official Weed Science Society of America (WSSA) Definitions

Herbicide resistance: "Herbicide resistance is the inherited ability of a plant to survive and reproduce following exposure to a dose of herbicide normally lethal to the wild type. In a plant, resistance may be naturally occurring or induced by such techniques as genetic engineering or selection of variants produced by tissue culture or mutagenesis."

Herbicide tolerance: "Herbicide tolerance is the inherent ability of a species to survive and reproduce after herbicide treatment. This implies that there was no selection or genetic manipulation to make the plant tolerant; it is naturally tolerant."

Source: *Weed Technology* Volume 12, Issue 4 (October-December) 1998. p.789.

Research Updates

Managing Ryegrass in Wheat

Nilda Burgos, University of Arkansas

Accase resistance in ryegrass, especially resistance to diclofop (Hoelon®), has been widespread in AR, LA, and MO since 2008. Very high levels of resistance to Hoelon have been documented (up to 20x). Twenty percent of the diclofop-resistant samples were also resistant to ALS chemistry in 2008.

A ryegrass sample that escaped a glyphosate burn down treatment in 2007 was tested for resistance and determined to be three to four fold more tolerant to glyphosate than a

susceptible check population. Control was not achieved at rates as high as 1.45 lb. a.i./acre.

Joe Armstrong and Tom Peeper – Oklahoma State University
In Oklahoma, Italian ryegrass is most problematic in winter wheat production. While herbicide-resistant ryegrass has not been a concern, some producers have reported unsatisfactory control with herbicides that traditionally provided excellent control. To address this issue, 100 ryegrass samples with suspected resistance were collected from 23 counties during the summer of 2008 and screened for resistance to nine herbicides representing four modes of action. Italian ryegrass control estimates were categorized as: controlled (> 80% control), suppressed (50–79% control), or resistant (< 50% control). (These quantitative classes describe field efficacy and are not WSSA terms.) Results from this trial indicated that approximately 70% of the samples were not controlled with ALS-inhibiting herbicides, including chlorsulfuron + metsulfuron (Finesse®) applied pre-emergence, mesosulfuron (Osprey®), and pyroxsulam (PowerFlex®). None of the samples exhibited resistance to ACCase-inhibiting herbicides: diclofop (Hoelon), pinoxaden (Axial XL®), quizalofop (Assure II®), or clethodim (Select®); however, 21 of the samples were only suppressed by diclofop and three were only suppressed by pinoxaden. All ryegrass samples were successfully controlled with glyphosate and flufenacet + metribuzin (Axiom®). During the summer of 2009, 200 additional ryegrass samples with suspected resistance were collected and will be screened to further determine the type and level of herbicide-resistance present in Oklahoma. While Oklahoma does not have glyphosate-resistant ryegrass, at least 50% of the ryegrass samples tested were ALS resistant. Roundup Ready® canola (*Brassica napus*) acres will possibly increase to about 100,000 this year. Canola has been used as a rotational crop to manage ACCase and ALS resistance. Therefore, Oklahoma weed scientists are concerned about the possible development of glyphosate-resistant ryegrass.

Jim Swart – Texas AgriLife Research (presented by Bob Scott)
ALS resistance in ryegrass is a widespread problem in East Texas and the first priority is to continue developing strategies for controlling ALS resistant ryegrass. Sulfonylureas have been ineffective for years; now the diclofop is beginning to fail. Pinoxidan is still efficacious but it is also an ACCase. The flufenacet + metribuzin appears to offer some promise as a resistance management strategy. Based on grower observations, we are definitely seeing an increase in glyphosate tolerant ryegrass.

<u>Managing Ryegrass at Burn-down</u>

Jason Bond – Mississippi State University
A population of glyphosate-resistant Italian ryegrass was identified in field crops in Washington County, MS, in 2005 (Nandula et al. 2007). Initial studies to address management of glyphosate-resistant Italian ryegrass concentrated on post-emergence herbicide programs; however, the research focus has transitioned to using residual herbicides applied prior to glyphosate-resistant Italian ryegrass emergence.

Fall applications of paraquat (Gramoxone Inteon®) controlled seedling glyphosate-resistant Italian ryegrass. However, paraquat provides no residual control, so subsequent flushes after application jeopardizes the success of this treatment. Few effective spring management programs have been identified. Although sequential programs in the spring were better than single-pass applications, tank-mixtures of multiple herbicides were required as components of the sequential programs (Bond et al. 2008). Parquat (1 lb. a.i./acre) or glyphosate (0.77 lb. a.e./acre) plus clethodim (Select Max®) (0.047 or 0.07 lb. a.i./acre) followed by clethodim (0.07 lb./acre) and sequential applications of paraquat (1 followed by 1 lb. a.i./acre) were the best sequential spring programs for controlling glyphosate-resistant Italian ryegrass. All sequential programs were expensive and left a copious amount of Italian ryegrass residue on the soil surface at planting.

Because spring applications proved to be ineffective and/or uneconomical, residual herbicides became the focus of research with glyphosate-resistant ryegrass in 2007 and 2008. One study evaluated glyphosate-resistant ryegrass control with fall-applied residual herbicides. Treatments included surface applications of clomazone (Command®), pendimentalin (Prowl H2O®), metatolachlor (Dual Magnum®), flumioxazin (Valor®), and pyroxasulfone (KIH-485) and incorporated applications of pendimenthalin and trifuralin (Treflan®). Fall applications of clomazone (0.75 lb. a.i./acre), metolachlor (1.6 lb. a.i./acre), and pyroxasulfone (0.147 lb. a.i./acre) provided at least 92% control of glyphosate-resistant Italian ryegrass in May of the following year. In contrast, control with surface-applied pendimethalin and flumioxazin was 34 and 68%, respectively, at the same evaluation.

Glyphosate-resistant ryegrass represents a serious threat to agricultural systems in the Mid-South, especially if it continues to spread. The presence of glyphosate-resistant ryegrass will jeopardize the use of traditional glyphosate-based burn down programs. Programs targeting glyphosate-resistant ryegrass should be based on fall-applied residual herbicides. Fall applications of metolachlor, clomazone, or pyroxasulfone provide excellent residual control that holds until the following spring.

Bill Williams – Louisiana State University
Difficulties with ryegrass control have occurred in Louisiana. The first cases of partial control were observed in 2006 and 2007. Field experience indicated that at least one population was “considerably-tolerant” to glyphosate. Paraquat is used at heading for suppression in the most tolerant fields. ACCase and ALS resistant ryegrass has not been found in Louisiana. Most of the glyphosate issues have been located in the Northwest, Northeast and Central parishes.

Larry Steckel – University of Tennessee
Ryegrass is a problem for corn planting, but not much of a concern for other crops. The common practice is to use a two-pass program now with paraquat followed by (fb) glyphosate, or two applications of glyphosate. Diclofop resistance is present and at least one field very likely has ALS resistance.

Missouri – Position Vacant; Complaints have come to AR and TN
AR and TN specialists believe the situation is similar to TN. There is diclofop resistance and some ALS resistance. There have been reports of burn-down failures with glyphosate.

Monitoring Glyphosate-Resistance in Ryegrass

Vijay Nandula – Mississippi State University
Two Italian ryegrass populations from Mississippi, Tribbett and Fratesi, were suspected to be resistant to glyphosate. GR_{50} (herbicide dose required to cause a 50% reduction in plant growth) values for the Tribbett, Fratesi, and Elizabeth (a susceptible check) populations were 0.66, 0.66, and 0.22 kg/ha, respectively, indicating that the Tribbett and Fratesi populations were threefold more resistant to glyphosate compared with the Elizabeth population. Laboratory experiments were conducted to characterize the mechanism of glyphosate resistance in these populations. Results indicated that resistance to glyphosate in the Tribbett population is partly due to reduced absorption and translocation of glyphosate and in the Fratesi population partly due to reduced translocation of glyphosate. Germination of Tribbett and Elizabeth populations of Italian ryegrass was highest at 13ºC and decreased when temperature increased to 20 or 27ºC under both light and dark conditions. Seedling emergence was highest from seed placed on the soil surface. Seedling emergence was less than 7% from seed planted at a 0.5 cm depth and no seedlings emerged from seed planted below 2.5 cm for both populations. One hundred populations of Italian ryegrass across the Mississippi Delta, representing 17 counties where burn-down failures occurred in 2009 have been collected and are currently being tested for glyphosate resistance to determine the geographical distribution of glyphosate-resistant Italian ryegrass in the MS Delta.

Jim Dickson – University of Arkansas
In spring burn-down trials, 88 oz./acre of glyphosate was needed to achieve 90% control of ryegrass. The same control could be reached with glyphosate at 22 oz./acre + 16 oz. of clethodim (Select Max). Jim also reported that the AR survey for resistant ryegrass was complete with over 300 samples from multiple counties collected. Samples will be tested for glyphosate, ALS and ACCase resistance. Twenty-five samples are from burn down failures with glyphosate, and are highly suspect to have increased tolerance to glyphosate. AR will also be screening samples from 25 commercial sources.

2010 Recommendations for Areas with Suspected Glyphosate-Resistant Ryegrass

Consensus recommendations for suspected, glyphosate-resistant ryegrass
- Early (up to 2-3 tiller or <4″)
  - Clethodim (Select Max @ 16 oz./acre)
  - Paraquat (Gramoxone Inteon @ minimum 32 oz./acre, good coverage)
  - Glyphosate + clethodim
  - Soil erosion programs need consideration before a residual is considered.

    - Fall residuals – metolachlor, trifluralin, or pendimethalin incorporated

– Late (> 3 tiller)
    - Paraquat (Gramoxone Inteon @ 48-64 oz./acre) + (diuron, metribuzin, atrazine)
    - Glyphosate 32 oz./acre + 16 oz. clethodim (Select Max)
– Salvage (TN)
    - Glyphosate 22 oz./acre fb paraquat 40 oz./acre + a photosystem II herbicide at 14-21 days after the first treatment

Research Opportunities

Research Opportunities (Field)
- ALS wheat chemistry, spring timings/warmer temperatures
- ALS and ALS combinations with Valor, or with other herbicides
- Interactions of herbicides in tank-mixtures
  clethodim + glyphosate, or + dicamba or + 2,4-D
- Effects of interactions of ryegrass growth stage with environment and application volumes and techniques on control
- Utility of KIH 485, Axiom, Boundary®, Envoke®, Resolve®, Command, Distinct®
- Fall residual timings
- Effect of fall burn-down on soil loss vs. that with tillage
- Weed control with tillage vs. that with herbicides

Research Opportunities (Greenhouse/Lab.)
- Growth stage by environment
- Ryegrass growth stage scale
- Ryegrass control by growth stage with glyphosate
- Surveys, levels of resistance – MS, AR, OK, LA
- Biology of ryegrass, longevity of seed bank, temporal emergence
- Antagonism, with broadleaf herbicides for horseweed treatments

Summary

Ryegrass has long been a serious weed in winter wheat. Many populations of ryegrass are resistant to ACCase and ALS herbicides principally because these modes of herbicide action have commonly been used to control ryegrass in winter wheat. With the expansion of the use of stale seed bed planting and conservation tillage, ryegrass has proven to be an increasingly difficult-to-manage weed with pre-plant (burn-down) herbicide treatments. Control with glyphosate in the spring is often problematic because treatments are made to populations that have emerged from the fall through early spring, and some plants are well-tillered, vigorously-growing, and difficult to cover and penetrate with applications made in 5-7 gal./acre, often by air. In recent years, a decrease in susceptibility of ryegrass to glyphosate has been suspected in west-central Mississippi, southern Arkansas and certain parishes in Louisiana. In 2009, many field

failures with glyphosate on ryegrass occurred in Mississippi, and a few in other areas in Arkansas and Louisiana.

Where difficulties with glyphosate have been experienced, two-pass programs will be prudent if large ryegrass (3 or more tillers) is found. Proposed recommendations are two applications of paraquat, or glyphosate + the full rate of clethodim, with the possibility of adding 2,4-D for glyphosate-resistant horseweed (*Conyza canendensis*). An alternative tactic would be fall application of trifluralin or pendamethalin with incorporation, or metolachlor, clomazone, flumioxazin. Paraquat + diuron may be recommended for fields that will be seeded to rice until the crop tolerance of metholachlor is confirmed.

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