FIELD OBSERVATIONS FROM ROUNDUP-READY SOYBEANS

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Introduction

The unprecedented popularity of the use of the "roundup-ready" (RR) system for soybean production begs the question: is there any persuasive reason not to adopt this practice? If national trends are any indication, the answer appears to be: no, for now. Surveys conducted in 2000-1 (Chen et al., 2001) reported that farmers listed the three most important reasons for adopting the genetically modified organism (GMO) technology as: better weed control, reduced herbicide use, and reduced labor demand. Any one of these reasons might be compelling by itself, but the combination seems too good to be true. Currently the major criticisms of the RR system are: there is potentially weak market support due general consumer sentiment against GMO crops and further farmer dependence on Agrochemical behemoths is not the way to improve farming. While both of these criticisms are potentially valid, they are beyond the scope of what an agriculturalist can address. What we can address are the likely biological consequences of the RR system. The short story is that farmers *like* the technology and they feel that they can justify its use; what can researchers do to help use it in the best possible way?

Agricultural researchers have approached understanding and improving the RR system from two different perspectives: (1) short-term tactical decision-making, and (2) farm-scale strategic planning. Examples of the former are the noted time-of-day effect on glyphosate efficacy due to diurnal changes in the positions of leaves in some species. An example of the latter is the construction of "resistance management" strategies. In this paper, I will report on the results of a survey (Curran, 2002) of weed extension specialists across the US concerning RR management advice and current observations of the effect of the RR system on weed community composition. I will then supplement this information with observations from an on-going study we are conducting on the interrelationship between weed communities and the RR soybean cropping system across the state of Wisconsin.

Materials and Methods

The survey participants were solicited via email listserver (weednet@iastate.edu). Participation was voluntary and hence results may be biased. The survey questions and a summary of responses are provided in the "results" section of this paper. Wisconsin field survey data on weed communities was collected from over 70 farms run by 32 producers in 6 counties (Walworth, Fondulac, Dane, Adams, Grant, and Tempealeau). Fields were visited at least two times: once for field margin scouting in June 2002, and another time for seed collection in October 2002. In the case of margin scouting, workers circumnavigated each field, marking the first occurrence of a given species within each type of boundary. The boundary-types were based on an evaluation of the type of habitat that extended out from that border (e.g., forest, road or field). Seed collection trips involved walking into fields collecting a sample from each species with sufficient seed production. The seed collection trips were not formal censuses of the weed population and they almost certainly would miss small or prostrate weeds that did not occur over the scouting path. It is likely that the impressions of both farmers and extension specialists are formed by a similar sort of qualitative survey rather than strict adherence to the sort of blind randomization necessary to draw formal statistically valid conclusions.

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Results

The first survey question was: (1) What glyphosate resistant crops are grown in your area and what is the percentage market share of the crops acreage? On the basis of the 25 respondents, RR soybean composed anywhere from 50 to 90% of soybean acres, RR cotton was 50 to 75% of cotton acreage, RR canola was 25 to 80% and RR corn was 5 to 30%. Idaho noted that RR sugar beet was to be planted in 2003.

The survey then asked: (2) Have you seen any changes in weed flora or composition as a result of RR? If yes, explain and answer subquestions a-c. (a) List shifts in weed flora due to glyphosate based systems, (b) list glyphosate-tolerant weeds and (c) list glyphosate resistant weeds.

Table 1. Answer to question (2a). Observed changes in weed flora associated with increased RR usage. The table is divided into four sections, the top section being perennial plants, second tier is biennials, third is summer annuals and the last is winter annuals. A series of plus marks indicate that at least five states noted the weed or weed-type.

Decrease		Increase	
Grasses	Broadleaves	Grasses	Broadleaves
Johnsongrass - MO Perennial grasses +++	C. thistle WI, DE, PA Hemp dogbane - WI Sunflower - MO Horsenettle - DE		Dandelion - OH, MI Poison hemlock - OH Pokeweed - MI
			Burdock - MI Wild carrot - OH Evening primrose - NJ, DE
Foxtail spp - MO, PA	Cocklebur- MO Velvetleaf - WI	Barnyardgrass - CA Giant foxtail - MO Prairie cupgrass - KS Rattail fescue - WA Stinkgrass – CO Windmillgrass - KS Witchgrass - CO	Annual morningglory +++++ Black medic - PA Common Waterhemp - IL Copperleaf - IL, PA, MO Giant Ragweed - IL Horseweed - WA, MO Lambsquarters - MI, WI Nightshades IL, NJ, DE, ND Powell Amaranth - MI Prickly lettuce - WA Prickly sida - MO Russian thistle - WA Smartweeds - KS, PA, ND Texas croton - CO Velvetleaf – IA, MI Wild Buckw. - KS, PA, ND Wild pansy - NJ, DE
		Winter annuals +++++	Chickweed - MO Deadnettle - MO Henbit - MO Winter Annuals +++++

The responses to questions 2b and 2c; species suspected to be tolerant or resistant to the glyphosate, are shown below in Table 2.

Table 2. Species suspected of tolerance and/or resistance to glyphosate.

Tolerant	*Resistant*
Burcucumber - PA	Common waterhemp (suspected MO)
Copperleaf - MO	Horseweed - NJ,DE,MO,OH,IN,TN,MD
Dandelion – MO, PA, WI, OH	Lolium spp. Orchards/roadsides - CA
Eastern Black Nightshade – PA, ND	Volunteer RR corn – KS, PA
Field bindweed - ND	Volunteer RR soybean - MO
Field horsetail - WI	
Horsenettle - PA	
Horseweed – ND, MO, MI, MO	
Lambsquarters – IL, ND	
Morningglorys (3 spp) – MO, DE, NE	
Mugwort - PA	
Palmer Amaranth - MS	
Pokeweed PA - OH	
Prickly sida - MO	
Ragweeds (2 spp) - MO	
Rattail fescue - WA	
Smartweeds – MO, WI, PA	
Sweet clover - NE	
Velvetleaf - MO	
Waterhemp – IL, MO	
White cockle - WI	
Wild 4 o'clock - PA	
Wild buckwheat – NE, PA, ND, WI	
Yellow nutsedge - WI	

Lastly, with question 3, the survey collated the advice offered to the public by weed control experts across the country for preserving the ease of use of the RR cropping system for weed control purposes. Primarily the advice deigned to deal with delaying or preventing increases of difficult-to-control weed populations.

- Promote "resistance management strategies" – including crop rotation, herbicide rotation and mechanical removal of escapes (cultivation or hand weeding).
- Use of "sequential application": follow a compound with soil residual activity with a glyphosate application, or tank mix the two. (multiple modes of action)
- Rotate herbicide modes of action.
- Include a non-RR crop in the rotation
- Do not use sequential glyphosate applications in no-till soybean
- Use glyphosate in soybean and a different mode of action in corn.

It was also noted that many farmers seemed to be more concerned with ALS or triazine resistance problems and that it was hard to get across the importance of a problem *before* the impact was felt.

Our study of the RR soybean fields of Wisconsin produced the following frequencies of occurrence of various weeds along the margins of fields (Table 3), where frequency is the percentage of field sampled in which the weed was found. The species are also ranked in terms of frequency, where lower numbered ranks are increasingly common.

Table 3. Frequency and relative rank of weed species occurring along the margins of Wisconsin soybean fields using the RR system (N=72).

Weed Species	**Rank**	**Frequency**
Common Ragweed	1	97.2
Lambsquarters	2	95.8
Ladysthumb Smartweed	3	89.6
Milkweed	4	89.6
Velvetleaf	5	88.9
Dandelion	6	86.6
Canada Thistle	7	84.0
Pigweed spp	8	80.9
Giant Foxtail	9	80.2
Barnyardgrass	10	76.6
Wild Buckwheat	11	75.3
Burdock	12	70.5
Quackgrass	13	70.3
Giant Ragweed	14	69.9
White Cockle	15	68.8
Horseweed	16	65.0
Prickly Lettuce	17	57.9
Large Crabgrass	18	57.8
Curly Dock	19	54.7
E. Black Nightshade	20	49.8
Yellow Nutsedge	21	44.3
Field Horsetail	22	42.5
Hemp Dogbane	23	40.7
Wild Carrot	24	36.9
Woolly Mullein	25	35.7
Hedge Bindweed	26	34.7
Yellow Foxtail	27	30.8
Woolly Cupgrass	28	30.5
Bull Thistle	29	29.7
Swamp Smartweed	30	27.6
Annual Sowthistle	31	23.2
Wild Proso Millet	32	21.0
Field Bindweed	33	17.6
Wirestem Muhly	34	17.4
Musk Thistle	35	15.3
Pennsylvania Smartweed	36	14.7
Wild Mustard	37	14.7
Jimsonweed	38	12.6
Horsenettle	39	11.5
Smooth Crabgrass	40	11.1
Green Foxtail	41	9.8
Perennial Sowthistle	42	7.9
Cocklebur	43	7.1
Shattercane	44	5.1
Field Sandbur	45	4.2
Foxtail Barley	46	1.4
Sunflower	47	1.4

Discussion

The use of RR traits in crops causes some immediate changes in the composition of the weed community at a site. Perennial weeds that are relatively more susceptible to a well-translocated herbicide, like glyphosate, will experience relatively more difficulties in RR systems. Conversely, winter annuals may have an easier time because of both the lack of residual activity of the product and the tendency to reduce or eliminate aggressive tillage when the perennial weed control is good.

There are several patterns that are quickly evident in Table 1. First, there were clearly many more observations of weeds that were increasing in frequency within the RR system than there were observations of decreasing populations. This undoubtedly reflects the fact that increases or occurrences are verified by actually *seeing* something, whereas absence is much harder to demonstrate. There is therefore a natural bias toward reporting events over non-events.

Another trend evident in Table 1 is that broadleaves appear disproportionately numerous. One possible explanation for this is the disproportionately large number of RR systems that have broadleaf crops. The initial weed community upon which the RR system was operating might have had a more diverse broadleaf constituency.

Many researchers participating in the survey listed weeds as “tolerant” of the RR system. Without digressing into the semantics of what distinguishes “tolerance” from “resistance”, tolerance can arise from many different sources; inherent physiological differences, differences in life-cycle timings, as well as the heritable quantitative genetic traits necessary for the RR system to select for “more tolerant” weeds. Additionally, RR systems have allow producers to shift from PRE to POST control measures, which we might suspect should cause changes in its own right. It is likely that any large changes in the nature of the weed control system as large as the move from conventional to RR soybean would produce a list of problem weeds as large or larger than Table 1.

Our research into Wisconsin weed communities points out that there are at least 19 weeds that commonly (>50% of the time) occur in close proximity to RR soybean fields. This is a strong indication that (a) the weeds are capable of growing in that particular environment, and (b) that the weeds are locally present. Even if the weed is not represented in the field seed bank, dispersal from margin plants or elsewhere is likely (after all there had to be some source of seed for the margin population). Of particular note are some of the most ubiquitous weeds: lambsquarters, smartweed, dandelion, velvetleaf and wild buckwheat are both very common adjacent to Wisconsin soybean fields and potential problems (Table 1).

So, have the observations presented here provided a case for *not* adopting the RR system? Clearly resistant weeds are possible and conventional wisdom designed to mitigate resistance problems (see the bulleted list at the bottom of the last page) would be advisable to follow. However, beyond advice that can be summarized with a single word, “moderation”, it appears that the roundup-ready soybean system is both robust and simple.

References

Chen, L., B.L. Barham, and F.H. Buttel. 2001. Update on the adoption and de-adoption of GMO crop varieties in Wisconsin. Wis. Farm Res. Summary, Progr. Agric. Technol. Studies #6. Madison, WI.

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