The limitations of technical assistance as a solution to glyphosate-tolerant weeds in Northern Paraná state, Brazil

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Abstract:

Dominant approaches to preventing herbicide-tolerant weed focus on individual outreach and technical assistance to encourage farmers to adopt best management practices. The case study of soybean producers in Northern Paraná state, Brazil, suggests that this approach has not been adequate, as many producers fail to implement preventative practices despite having access to information and technical assistance. We identify key assumptions of the technical assistance approach to resistance prevention and evaluate their validity within this case study, focusing on farmer interactions with herbicide vendors and technical assistants from agricultural cooperatives. We conducted questionnaires with 54 soybean producers in Northern Paraná to gain an understanding of their principal sources of technical assistance, the type of technical advice they receive, how they decide whether to implement this advice, and the practices that they end up implementing. Due to limitations in the sampling size and available recruitment techniques, we do not present our results as quantitative, statistically significant conclusions. Rather, this survey represents a preliminary overview of technical assistance in Northern Paraná, opening the door for future research. We found that cooperative technical assistants do not always recommend non-chemical, integrated pest control practices, and that producers face external barriers to implementing preventative practices including the close proximity of herbicide vendors.

Keywords: Glyphosate-resistant weeds. Technical assistance. Agricultural cooperatives.

Limitações da assistência técnica como solução às plantas daninhas resistentes ao glifosato na região norte do Paraná

Resumo:

Os enfoques dominantes para prevenir a resistência das plantas daninhas aos herbicidas concentram-se na divulgação individual e na assistência técnica para encorajar os agricultores a adotarem as melhores práticas de manejo. Um estudo de caso de produtores de soja no norte do Paraná sugere que essa abordagem não está sendo adequada, já que muitos produtores não implementam práticas preventivas, apesar de terem acesso à informação e assistência técnica. Identificamos as principais premissas da abordagem da assistência técnica para a prevenção de resistência e avaliamos sua validade neste estudo de caso, concentrando-nos nas interações dos agricultores com os fornecedores de herbicidas e os assistentes técnicos de cooperativas agrícolas. Realizamos questionários com 54 produtores de soja no norte do Paraná para entender as principais fontes de assistência técnica, o tipo de assessoria técnica que recebem, como eles decidem se implementam esse aconselhamento e as práticas que terminam implementando. Devido a limitações no tamanho da amostra e técnicas de recrutamento disponíveis, não apresentamos nossos resultados como conclusões quantitativas e estatisticamente significativas. Em vez disso, esta pesquisa representa uma visão preliminar da assistência técnica no norte do Paraná, abrindo as portas para futuras

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pesquisas. Constatamos que os assistentes técnicos das cooperativas nem sempre recomendam práticas de controle de pragas integradas, não-químicas, e que os produtores enfrentam barreiras externas para a implementação de práticas preventivas, incluindo a proximidade dos vendedores de herbicidas.

Palavras-Chave: Plantas daninhas resistentes ao glifosato. Assistência técnica. Cooperativas agrícolas.

1. Introduction:

In a recent review in *Science,* Gould, et al. (2018) propose an urgent new paradigm for weed management. The authors argue that our current system of chemical control will soon become ineffective against rising populations of herbicide-tolerant weeds unless we address the social, economic, and biological complexities that hinder actions to prevent resistance. In addition to proposing research into non-chemical control methods, the authors call for a reexamination of current sociopolitical solutions to herbicide resistance, including an assessment of the effectiveness of technical assistance in promoting preventative weed management practices (GOULD; BROWN; KUZMA, 2018). Largely responsible for this rise in tolerance in the past twenty years is the ubiquity of herbicide-resistant transgenic crops, particularly glyphosate-resistant (GR) soy and corn. While weeds have evolved resistance to a variety of chemicals, GR cropping systems are particularly prone to herbicide-tolerant weeds because the ease of application discourages producers from rotating pest-control practices. In fact, 90 percent of infested areas and economic losses due to herbicide-tolerant weeds are a result of GR weeds in GR cropping systems (HEAP; DUKE, 2017).

Crop breeders, agrochemical companies, and other actors involved in the development of transgenic technologies and their associated herbicides frame resistant weeds as a problem to be addressed on the farm level, arguing for improved technical assistance to encourage farmers to adopt integrated management strategies (BAIN et al., 2017). While individual educational outreach is important for disseminating information about best management practices, experts are increasingly concluding that technical assistance isn't enough to address the "wicked problem" of herbicide resistance (BECKIE, 2011; BOREL, 2018; ERVIN; JUSSAUME, 2014; SHAW et al., 2018). Instead, social scientists have proposed that resistance must also be addressed on community and systemic levels, emphasizing the importance adapting rules to local conditions, implementing tailored systems of accountability, and assuring broad participation through collective-choice mechanisms (JUSSAUME; ERVIN, 2016; SHAW et al., 2018).

In Brazil, the idea of participatory agricultural extension has been present in the literature for decades, from the mid-century pedagogical texts of Paulo Freire (FREIRE, 1969) to then modern technical assistance manual of the public research institution EMATER (LOPES, 2016). In practice, however, this type of educational outreach is challenging, especially as Brazil's agricultural sector

becomes increasingly industrialized and producers rely more heavily on technology and inputs developed far from the farm. The region surrounding Londrina in Northern Paraná is a hub for this agricultural industry (ROLIM; SERRA, 2009). Most producers in the region farm relatively small areas, cultivating soybeans in the summer and corn or wheat in the winter. Many of these producers are supported by agricultural cooperatives, which represent one of the most important economic institutions in Paraná, accounting for 18 percent of the Paraná's gross domestic product and 56 percent of its agricultural production in 2015 (EMATER, 2016). Cooperative extension agents as well as private agrochemical vendors are farmers' most proximate sources of technical assistance for a variety of agricultural challenges including weed control. It is within this technical assistance ecosystem that farmers face significant challenges managing horsetail ("buva"; *Conyaza bonariensis, C. canadensis*) resistant to glyphosate and clorimuron, and sourgrass ("capim-amargoso", *Digitaria insularis*) resistant to glyphosate. An analysis of the relationships between farmers, cooperative extension agents, and herbicide vendors can therefore shed light on the dynamics that promote or hinder effective resistance mitigation education.

While education seems like a straightforward path to preventing herbicide-resistant weeds – a technical assistant teaches a practice to a farmer, the farmer implements the practice, then the practice prevents resistance – the efficacy of this solution depends on a series of unstated assumptions. For example, the technical assistant must possess sufficient knowledge of the resistance prevention practice; the farmer must be open to learning about the practice; there must be an opportunity for the assistant to impart his/her knowledge on the producer; and the farmer must not face any internal or external barriers that prevent him/her from implementing that practice. The goal of this study is to groundtruth some of these assumptions to identify social and economic barriers to the prevention of herbicide-resistant weeds in Northern Paraná. In this paper, we present the results from the first half of this study, which relies on qualitative surveys to provide an overview of the weeds farmers face, farmers' primary sources of technical assistance, the types of practices these sources recommend, and how they decide whether to implement this advice. The second half of this study is ongoing and relies on interviews with farmers and technical assistants to understand these questions in greater depth.

2. Methodology

We conducted surveys with 54 soybean farmers who belong to at least one of three prominent agricultural cooperatives in the Londrina area. Surveys took place in May, June, July, and September 2018 on producers' farms or at cooperative outposts (cooperative administrative offices where producers frequent to purchase inputs, conduct business, and socialize). Producers were approached by a researcher or cooperative staff members and asked if they would like to respond to a questionnaire. Participants were then given the option to fill out the six-page questionnaire themselves in the presence of the researcher, or have it read to them and filled out by a researcher. The surveys took between 15 and 30 minutes and respondents were not compensated for their participation. This study was approved by the Research Ethics Committee of the State University of Londrina (CEP 86.057-970, CAAE 82692518.2.0000.5231).

Due to limitations in the sampling size and available recruitment techniques, we did not intend to obtain quantitative, statistically significant results from this questionnaire. Instead, the purpose of this survey was to identify trends to be investigated through future quantitative and qualitative studies, and to provide additional context for the currently ongoing second stage of this study. As such, we summarized the means, medians, and general trends of the surveys, but did not subject the responses to rigorous statistical analysis. The following results are an overview of these trends, followed by a discussion of their implications for the present study and future research.

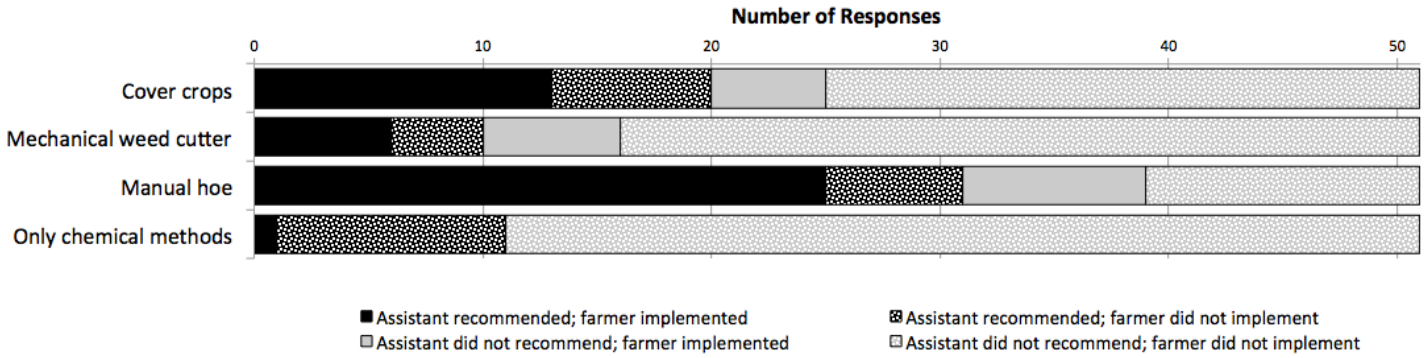
3. Results

To better understand producers' experiences with managing resistance, our survey contained questions about the severity of four herbicide-resistant weeds and the practices that producers implement to prevent the evolution of resistance. Our results suggest that glyphosate tolerance is the principal form of resistance that producers face: of the 54 producers surveyed, 98% (n=53) reported the presence of glyphosate-resistant sourgrass; 87% (n=47) reported glyphosate-resistant horsetail; 55% (n=30) reported clorimuron-resistant horsetail; 48% (n=26) reported glyphosate x clorimuron-resistant horsetail. Despite (or perhaps due to) the high prevalence of resistant weeds, 98% (n=53) of respondents reported that they implement practices to prevent the evolution of resistance: 83% (n=45) practice herbicide rotation; 63% (n=34) remove weeds manually with a hoe; 54% (n=29) practice crop rotation; and 35% (n=19) use cover cropping. Of these 53 producers, 6% (n=3) have

implemented preventative practices for less than one year; 28% (n=15) for 2-3 years; 40% (n=21) for 4-10 years; and 26% (n=14) for more than 10 years.

In addition to establishing basic information about weed management practices, these surveys also aimed to characterize the technical assistance that farmers receive from various sources, especially cooperatives and herbicide vendors. When asked about their primary sources of technical assistance, 96% (n=52) of farmers reported that they receive technical assistance from the cooperative; 39% (n=21) from input suppliers ("revendas"); and 9% (n=5) from other sources. 51 participants responded to questions about the nature of the technical assistance that they receive from the cooperative. 100% (n=51) responded that the cooperative technical assistant recommended applying at least one herbicide to control weeds: 94% (n=48) responded that s/he recommended glyphosate; 65% (n=33) responded that s/he recommended clorimuron. 78% (n=40) of respondents reported that the cooperative technical assistant recommended at least one non-chemical weed control practice: 61% (n=31) said that s/he recommended removing weeds manually with a hoe; 39% (n=20) said that s/he recommended cover crops; 20% (n=10) said that s/he recommended using a mechanized weed cutter; and 20% (n=10) said that s/he recommended using a plow. We also compared the non-chemical weed control recommendations that farmers received from technical assistants with the non-chemical practices that they implement to prevent the evolution of resistance (Figure 1).

Figure 1 – Practices recommended by technical assistant vs. Practices implemented by farmer

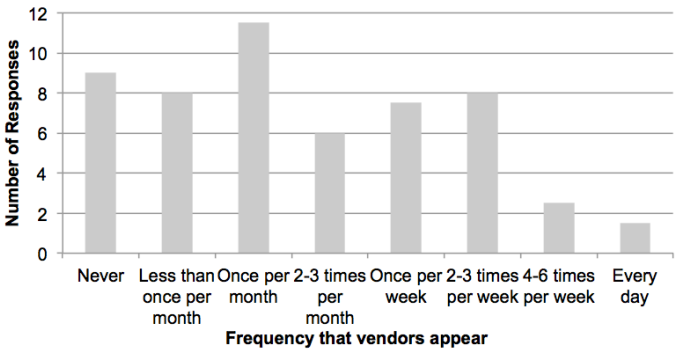


Source: Mittelberg & Moraes (2018).

Black bands indicate the number of respondents that said that the technical assistant recommended that practice; gray bands indicate that technical assistants did not recommend that practice. These black and gray bands are further subdivided to denote whether farmers implemented that practice: solid bands indicate that the practice was implemented while speckled bands indicate that the practice was not implemented.

In addition to investigating the nature of the technical advice that farmers receive from the cooperative, we also sought to understand the nature of farmer interactions with door-to-door herbicide vendors. We asked farmers how often vendors come to their property attempting to sell herbicides before and during the planting season, presenting eight options ranging from "never" to "every day." Figure 2 represents the average frequency that vendors appear on farmers' properties before and during the planting season. 39% (n=21) of respondents reported that vendors come more often during the planting season than before; 13% (n=7) reported that they come more often before; and 48% (n=26) reported that they come with the same frequency in these two periods. 51% of respondents (n=27) had purchased a product from these herbicide vendors in the past five years.

Figure 2 – Frequency that vendors appear on farmers' properties selling herbicides (average of before and during the planting season)



Source: Mittelberg & Moraes (2018)

Finally, we asked producers to reflect on their thought process as they decide whether or not to implement the advice they receive from herbicide vendors and other sources of technical assistance. Producers indicated the extent to which six factors (cost, prior experience, trust in source of technical assistance, consultations with neighbors, consultations with relatives, consultations with other sources of technical assistance) affected their decision whether or not to pursue the advice of a technical assistant. Potential responses were "0 = did not affect their decision," "1 = slightly influenced their decision," or "2 = greatly influenced their decision." 53 respondents reflected on how they decide whether to follow the advice of their primary source of technical assistance excluding vendors (for 50 of these respondents, the cooperative was the primary source of non-vendor technical assistance). On average, the most important factor in farmers' decision-making processes for whether to follow the advice of non-vendor sources of technical assistance was his/her trust in the technical assistant followed by cost and their prior experience with the practice. For comparison, 26 producers ranked the importance of these factors in deciding whether to purchase a product from door-to-door herbicide vendors. In this case, the most important factor in farmers' decision-making

processes was previous experience with the product, followed by cost and trust in the source of technical assistance. These results are summarized in Table 1.

Table 1 – Average responses to: How important was the given factor in your decision on whether or not to follow the practice recommended by the source of technical assistance?

	Non-Vendor Technical Assistant (n=53)	Herbicide vendor (n=26)
Cost of implementation	1.15 ± 0.77	1.00 ± 0.88
Prior experience with practice	1.11 ± 0.70	1.40 ± 0.74
Trust in source of technical assistance	1.45 ± 0.75	0.93 ± 0.83
Consultations with neighbors	0.60 ± 0.82	0.33 ± 0.55
Consultations with relatives	0.35 ± 0.68	0.20 ± 0.62
Consultations with additional sources of technical assistance	0.89 ± 0.78	0.60 ± 0.81

Source: Mittelberg & Moraes (2018).

Respondents ranked each factor as ""0 = did not affect their decision," "1 = slightly influenced their decision," or "2 = greatly influenced their decision" when deciding whether to follow the advice of non-vendor technical assistant (n=53) or purchase an herbicide from a door-to-door vendor (n=26).

4. Discussion

Nearly all survey respondents reported implementing practices to prevent the evolution of resistant weeds, yet farmers in Northern Paraná still face severe populations of GR horsetail and sourgrass. This contradiction suggests that the current practices that farmers implement are not sufficient for mitigating resistance. Studies in the United States have found that producers become concerned with preventing resistance only as they experience the costs of managing already resistant weeds (GREEN; OWEN, 2011). Our survey results support this tendency – GR horsetail and sourgrass first appeared in Brazil in 2005 and 2008, respectively, meaning that more than 3 in 4 survey respondents first adopted preventative practices only after the rise of these weeds (ADEGAS et al., 2017). It should also be noted that many preventative practices (e.g. cover cropping, herbicide rotation, manual weed removal) are also common strategies for controlling existing weeds. Thus, although our survey question asked about preventative practices, it is impossible to discern the extent to which farmers' actions are actually preventative rather than reactionary.

Educational outreach has been the dominant approach to preventing herbicide-resistant weeds in Paraná, with cooperative extension agents and herbicide vendors as the principal sources of information to producers. Our surveys indicate that herbicides are the most-recommended form of

weed control by the cooperative, with 94% of farmers reporting that technical assistants recommended glyphosate, compared to 49% who recommended any non-chemical weed control practice besides manual hoeing (which is largely a control, rather than preventative practice). While chemical pest control can play a role in an integrated weed prevention strategy, herbicides must be combined with non-chemical practices to most effectively mitigate resistance (GORDDARD; PANNELL; HERTZLER, 1995). Through informal conversations, technical assistants in Northern Paraná have suggested that they sometimes do not recommend non-chemical preventative practices because they know farmers will not implement them. Surveys conducted in the U.S. have shown that producers are more open to adopting chemical-based preventative practices such as herbicide rotation because they view physical and cultural practices as inconvenient and complex to implement (BECKIE, 2011). Through the ongoing second stage of this study, we are further investigating how technical assistants perceive farmers' willingness to adopt certain practices, and how this perception influences the type of recommendations they make.

Our survey results indicate that agrochemical vendors play a prominent role in the northern Paraná technical assistance ecosystem, presenting a potential challenge to enforcing an integrated weed management system. Farmers reported agricultural vendors as the second most common source for technical advice after the cooperative; 70% of producers report that vendors come to their property attempting to sell herbicides at least once per month, and 50% of producers have bought these vendors' products. When compared to how they receive technical assistance from the cooperative, farmers appear to purchase herbicides from vendors due to the cost of and their prior experience with the product, rather than their trust in the vendor (see Table 1). These interactions with herbicide vendors offer insight into the challenges of preventing resistance in a highly industrialized agricultural system. Multinational agrochemical companies resist regulation of their products and insist that solutions to resistance must be at the farm level. At the same time, their vendors have strict herbicide sales quotas, meaning one of farmers' most important sources of technical assistance have little incentive to recommend non-chemical preventative practices.

This study frames the cooperative and agrochemical vendor as separate sources of technical advice, yet this distinction has become blurred in recent years as cooperatives increasingly turn to selling inputs to remain economically competitive. For example, in 2016 the value of agricultural inputs sold by the largest agricultural cooperative in Brazil was roughly equal to the value of its

agricultural exports (COAMO, 2016). Input supply has become a key source of income for cooperatives, demanding an honest examination of whether cooperative technical assistants can offer impartial advice on chemical weed control – and whether producers can perceive it as so. In an empirical study of a prominent agricultural cooperative in Western Paraná, researchers found that as the size of agricultural cooperatives increases, the proportion of members who participate in the cooperative's social and educational activities decrease. The authors suggested that as a cooperative grows in size and economic output, farmers are more likely to become cooperative members for economic motives instead of for social benefits (BIALOSKORSKI NETO, 2007). This perception that the cooperative is an economic enterprise rather than a social institution as well provides the backdrop of the relationship that producers form with cooperative technical assistants. Given that community-enforced initiatives are the most effective strategy for inducing farmers to adopt resistance mitigation practices, one would expect producers to be more likely to uptake the advice of an institution that they view as an integral part of the social fabric of their community (ERVIN; JUSSAUME, 2014). As cooperatives grow in size and diminish in perceived social value, farmers will begin to view the technical assistance from private, non-cooperative institutions as a comparable substitute for that from the cooperative.

5. Conclusions

Most producers report implementing practices to prevent herbicide-resistant weeds, yet they still face significant populations of glyphosate-resistant horsetail and sourgrass, and clorimuron-resistant horsetail. This dichotomy suggests that the status quo approach to resistance prevention is not adequate, particularly in GR cropping systems. Our survey results suggest that cooperative technical assistants do not always recommend non-chemical, integrated pest control practices, and that producers face external barriers to implementing preventative practices including the close proximity of herbicide vendors. These findings challenge several key assumptions about the flow of information from extension agents to farmers, demanding a reexamination of current technical assistant methods as an adequate solution for herbicide-tolerant weeds.

This survey represents the first step in characterizing the relationship between farmers, technical assistants, and vendors, and provides an overview of resistance-management trends in Northern Paraná. Our survey was broad, but offers interesting leads for future research. Ongoing

interviews with technical assistants and producers aim to further reveal how trust dynamics between these two actors influence the types of preventative practices that are recommended and implemented. We also aim to understand how sales quotas by agricultural vendors and cooperatives influence the types of weed control practices they recommend. Future researchers could study the correlation between the types of weed control practices recommended to farmers, which practices they actually implement, and populations of herbicide-tolerant weeds on those properties. Such a study would help illuminate at which point the standard resistance-mitigation intervention breaks down.

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