BRAZILIAN SOYBEAN PEST MANAGEMENT AND THREATS TO ITS SUSTAINABILITY

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Introduction

Brazil is expected to harvest 198.65 million tons of grain in 2014/15 in an area of 57.08 million hectares and soybean stands out as the main crop sown. The cultivated soybean area has nearly tripled in the last 20 years, up from 11.6 million hectares in 1994/95 to 31.3 million hectares in 2014/15 (Conab, 2015). One of the main factors for the success of soybean crop in Brazil was the development of cultivars adapted to low latitudes (up to 0°) allowing for the expansion to the Cerrado region (Central Brazil), responsible for more than 50% of soybean production in 2014/15. The agricultural production in Brazil is focused on two regions; the South and the Center-West. The set of distinct geographic regions places the country in a unique situation concerning the management of pests, especially considering the absence of the seasonal break provided by winter in temperate regions. The intensive use of land, absence of crop rotation and increased use of chemical control as the only tool for pest control have threatened the sustainability of the soybean crop in recent years. This article gives a short overview of how the management of pests has changed with the expansion of the soybean crop.

Diseases

Soybean disease problems in Brazil vary amongst regions due to the large array of edaphoclimatic conditions. Breeding programs in Brazil have focused on incorporating disease resistance into their cultivars wherever possible and, as a result, several diseases are no longer an economic threat. For example, frogeye leaf spot (Cercospora sojina) was first identified in Brazil in 1971 and was considered a major disease. Nowadays, the disease is practically absent from the fields due to the incorporation of resistance gene Rcs3 from soybean cultivars Davis and Paraná. Stem canker, caused by Diaporthe phaseolorum var. meridionalis, detected in 1888/89, and bacterial pustule caused by Xanthomonas axonopodis pv. glycines have also been controlled by the introgression of resistance genes into cultivars (Almeida et al., 2005).

A disease that represents a breakthrough in the history of soybean in Brazil is soybean rust, caused by the fungus Phakopsora pachyrhizi, identified in Brazil in 2001. Soybean rust is the most aggressive disease of the crop and can cause yield losses of up to 80%. Its introduction had a large impact on soybean production and management practices. After its first detection, the fungus quickly spread to important soybean producing regions (Yorinori et al., 2005). Conditions in much of the country are conducive to year-round survival of the pathogen and disease outbreaks are frequent in years and regions with favourable rainfall distribution. Because of soybean rust, from 2006 the Brazilian states adopted a period of 60 to 90 days from July to September called the soybean-free period, during which the cultivation of soybean is restricted except under strictly controlled conditions. This measure was adopted to break the continuous cycle of the fungus and delay the beginning of the epidemic in the regular season. Early-planting with early-maturity cultivar has also been adopted to avoid the period with high amount of inoculum and weather conditions favorable for disease epidemics.

Digitaria insularis in soybean field.
Most commercial soybean cultivars are susceptible to soybean rust. To date, seven major resistance (R) genes have been reported (Rpp1 to Rpp6 and Rpp1b). In Brazil, commercial resistant cultivars harboring R genes have been available since 2009. However, the effectiveness of R genes is limited, as there are virulent isolates that are able to overcome each R-gene product. Therefore, the use of fungicides in conjunction with resistant cultivars is recommended.

The use of fungicides on soybean was intensified with *P. pachyrhizi* introduction. Despite the good control observed in the first years, the fungus started to show a decrease in sensitivity to Demethylation Inhibitors (DMIs) fungicides in Brazil from 2007 (Godoy, 2011). Since then, only premixes of DMIs and Quinone outside Inhibitors (QoIs) fungicides have been recommended to control the disease. Although QoIs fungicides have never been recommended alone, due to low efficacy against soybean rust, in 2013, a decrease in efficacy was also observed in this group of fungicides, compromising the control of the premixes at different levels. Products consisting of new broad-spectrum Succinate Dehydrogenase Inhibitors (SDHIs) fungicides mixed with QoIs were launched onto the market in 2013. The number of SDHI compounds is expected to increase rapidly in the next few years, and this may lead to strong selection pressure for resistance against this group of fungicides. These three groups (DMIs, QoI and SDHI) are responsible for mitigating yield losses due to soybean rust, but efficacy has been reduced each year due to the development of fungicide resistance. Costs to deal with rust in Brazil are estimated in US$2 billion per year, and basically encompass the cost of control with an average of 3 fungicide applications per soybean crop season.

Fungicide resistance has become an important issue for other foliar diseases such as target spot (*Corynespora cassicola*) and anthracnose (*Colletotrichum truncatum*). Due to fungicide resistance problems in the field, old multi-site fungicides such as mancozeb, have recently been introduced into the soybean market to increase the efficacy of control and reduce the risk of resistance.

Other diseases that represent a threat to productivity occur, but are restricted to certain regions due to their need for specific conditions for infection and survival. For example, Sclerotinia stem rot (*Sclerotinia sclerotiorum*), important in central and southern Brazil at altitudes above 700m with moderate air temperatures and frequent rain events during the flowering stage; Rhizoctonia foliar blight (*Rhizoctonia solani AG1*) in northern regions of Brazil where warm, wet weather conditions prevail; Phytophthora root rot (*Phytophthora sojae*) and brown stem rot (*Cadophora gregata*) in southern regions (both controlled mainly by the use of genetically resistant cultivars); and charcoal rot (*Macrophomina phaseolina*), a serious problem in southwestern, southern and northern Brazil where environmental stresses occur during the growing season (Almeida et al., 2005).

**Insects**

In the early 70s, the use of insecticides on soybeans in Brazil was widespread, with about six applications per crop season. Growers used to spray toxic and broad-spectrum products such as DDT and monocrotophos, amongst others. In 1975, Embrapa Soybean and other institutions such as EMATER-PR, the Agronomic Institute of Paraná-IAPAR, and some universities began pioneering work on Integrated Pest Management in soybean (Soybean-IPM) in the country, mainly to encourage the rational use of insecticides. IPM was based on the premise that cultivated plants can tolerate certain levels of injury without economically significant yield reductions; and insecticides should be used only as a complementary method, since natural biological control must be responsible for keeping pests under control when the crop environment is close to a natural balance (Higley & Peterson, 1996). The appropriate time to initiate the control measure to prevent the pest population from reaching the economic injury level, therefore causing damage, is termed the Economic Threshold (ET) (Pedigo et...
The economic threshold was established in the 70s for the major soybean pests that are defoliating caterpillars, and seed sucking stink bugs. After the adoption of IPM for soybean in Brazil in the mid-80s, the use of pesticides was reduced to approximately two applications per season.

Over the last 40 years, soybean yield has doubled, rising from an average yield of less than 1500 kg ha⁻¹ in the 1970s to more than 3000 kg ha⁻¹ today. This yield increase, along with higher soybean prices and the lower cost of many insecticides, has fostered the abandonment of IPM and led to excessive use of insecticides once again. Consequently, insecticide applications again reached an average of four to six or even more sprays per crop cycle, impairing the efficiency of all existing biological control agents for soybeans (Carno et al., 2010). The arrival and spread of the fungus P. pachyrhizi also had an impact on the use of Soybean-IPM; the schedule-based fungicide application for soybean rust had undesirable side-effects. Some of the most effective fungicides against P. pachyrhizi are also harmful to entomopathogenic fungi such as Nomuraea rileyi and others (Sosa-Gomez, 2012). In addition to beneficial fungi that can be affected by fungicides, predators and parasitoids might also be harmed by such sprays.

Moreover, in an attempt to make control practices quicker and simpler, soybean growers are mixing insecticides with fungicides or even with herbicides and applying earlier in the crop season in a single operation. This practice has been generally adopted by soybean growers in Brazil in an attempt to optimize the agricultural operation, even without performing pest sampling and, therefore, without taking the ET into consideration.

The excessive use of insecticides encourages selection of insect strains resistant to the most commonly used chemicals. Brazilian soybean growers are already facing serious problems with stink bugs, Euschistus heros, for which insecticide resistance issues have been reported and nowadays almost all registered products are encountering this problem.

In an attempt to mitigate these problems, recent results have demonstrated that ETs currently recommended are appropriate for stink bugs and defoliators, regardless of soybean cultivar growth type, and should be abided by and used by growers to restore balance in the agroecosystem (Batistela et al., 2012, Bueno et al., 2015). It is true that the established ETs for soybean pests are for a limited number of species (key pests), and they only address the use of chemicals. There is little information regarding secondary pests and other control strategies in addition to insecticides. It is clear that much progress is still needed to improve ETs for pest management decisions. Nevertheless, using the current ETs provides a basis for reducing the use of chemicals in soybean without reducing yields and overall production, thereby improving soybean sustainability (Bueno et al., 2013).

Recent results from Soybean-IPM have been shown to be efficient in pest management. Bueno et al., (2011) reported that the inappropriate and excessive use of insecticides on soybeans does not result in higher productivity (Table 1). Therefore, the use of IPM still remains the best alternative for pest management in soybean fields.

Recently, consideration of IPM was revived with the introduction of a new pest in the Americas. In Brazil, Helicoverpa armigera was identified for the first time in February 2013, almost simultaneously and independently by taxonomists Dr. Alexandre Specht and Dr. Vitor Becker (Bueno et al., 2014). Damage estimates reached US$0.8 billion in the first crop season. The Brazilian government, throughout its institutions, established a task force to train most of the growers and consultants all over the country to identify and control the pest correctly. Therefore, if on the one hand, H. armigera brought some yield losses to Brazilian growers in its first years in the country, on the other hand, the presence of this pest brought back some old IPM concepts which had almost been forgotten by most growers. With the presence of H. armigera in Brazil, growers are learning that to address the insect problems and still maximize agricultural production, pest control programs must be guided by a proper IPM approach. Abiding by the economic threshold and the choice of selective pesticides to protect the beneficial arthropods are the clues to both: efficient pest control, and reduction of the use of chemicals in agriculture improving its sustainability.

### Table 1. Mean productivities of the soybean crops (kg/ha) obtained in five different counties of two soybean-producing Brazilian states [Goiás (GO) and Paraná (PR)] from experiments using different pest-management systems in the 2008/2009 and 2009/2010 growing seasons. Bueno et al., 2011.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2008/2009 growing season</th>
<th>2009/2010 growing season</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Castelândia, GO</td>
<td>Santa Helena de Goiás, GO</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>SE</td>
</tr>
<tr>
<td>IPM</td>
<td>3,180.40</td>
<td>185.43</td>
</tr>
<tr>
<td>BC</td>
<td>3,171.21</td>
<td>124.08</td>
</tr>
<tr>
<td>PUI</td>
<td>2,981.49</td>
<td>178.97</td>
</tr>
<tr>
<td>C</td>
<td>2,555.12</td>
<td>73.14</td>
</tr>
<tr>
<td>F</td>
<td>12.64</td>
<td>3.71</td>
</tr>
<tr>
<td>P</td>
<td>0.0014</td>
<td>0.0550</td>
</tr>
<tr>
<td>df</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>CV (%)</td>
<td>5.54</td>
<td>4.54</td>
</tr>
</tbody>
</table>

1IPM = integrated pest management; BC = biological control; PUI = prophylactic use of insecticides; C = control without pest treatment. Mean followed by the same letter in the column do not differ statistically from each other by the Tukey test (P > 0.05).
The 2015/2016 crop season will be the second after the release of transgenic soybean Bt (Cry 1Ac) into the Brazilian market. Transgenic soybean Bt will control the major caterpillar problems except Spodoptera spp which might also occur. It certainly will help pest management. However, the biggest risk of this technology is the selection of strains resistant to the Bt mode of action. This might happen very quickly if refuge areas are not properly adopted. However, refuge areas will only be efficient to preserve Bt technology if IPM is likewise properly adopted. Excessive use of insecticides on the refuge area will endanger the production of susceptible moths and therefore put Bt technology at risk. Hence, more than ever, IPM adoption is of paramount importance and might now have a second chance of succeeding since not only will it help to preserve soybean sustainability but also new tools of pest control such as Bt technology what will certainly bring a larger number of proponents of IPM into action.

Weeds

When glyphosate-resistant GM soybean was officially launched into the Brazilian market in 2005, many farmers believed that the problems with weeds had definitely been solved. They had not considered the possibility of the selection of glyphosate resistant weeds. In the past, farmers had experience with weeds resistant to herbicides in conventional soybean. In 2006, history began to repeat itself with glyphosate. Cases of weed resistance to glyphosate indicate that even this product was not immune to the natural selection of resistant individuals. Resistant biotypes of Lolium multiflorum (Italian ryegrass), restricted to Brazil’s southern regions with cooler temperatures, Digitaria insularis (sourgrass) and three species of Conyza spp (horseweed): C. bonariensis, C. canadensis, and C. sumatrensis spread to southern and Central regions of Brazil and recently, a new case of Chloris elata was reported (Heap, 2015). Areas infested with resistant weeds are difficult to manage and incur a higher production costs. Despite the reality of the weed resistance problem in Brazil, prevention is still possible. In Central Brazil, due to weather conditions, management options are more restricted.

In the dissemination process of glyphosate resistant weeds four factors contributed to speed up the process in the southern regions. The farms are small and it is common to rent harvest machinery contaminated with resistant biotypes for use in areas free of the problem. Another factor is the wind. Conyza and Digitaria possess small seeds easily spread by wind. The third factor is the no-tillage system, since seeds of this species are well adapted to undisturbed conditions. The last factor is the absence of crop rotation and also herbicide rotation. Glyphosate has been used four or five times in the same area, in the same year. The dynamics of weeds in a tropical country such as Brazil are unique. Since the early 70s, when trifluralin was used incorporated to the soil, weed problems were hard to solve and it became worse with the selection of triluralin resistant species as Euphorbia heterophylla, Bidens subalternans, and Brachiaria plantaginea amongst others. In the 80s, ACCase and ALS-inhibiting herbicides were launched into the market and solved these problems. In the 90s and 2000s, due to the selection of resistant biotypes, the same species are back as biotypes resistant to herbicides that had worked previously (Gazziero et al., 1998; Vidal & Merotto Jr.1999).

In 2005, the rapid adoption of glyphosate-resistant soybean was due to easy management and high efficiency in weed control no longer practised in the conventional system. Chemical control is always the first option in weed control because it is fast and easily adopted. But it should be considered as a tool and not the only solution. The integration of chemical control with cultural control, using straw produced in the no-tillage system has improved Digitaria and Conyza control. If on one hand these species are well adapted to areas with no-tillage systems on the other they are adversely affected by soil with good straw cover mainly due to the low light incidence. Nowadays, new technologies for weed control in soybeans are being developed for use with glyphosate, which still is the standard weed killer. Old herbicide active ingredients used on conventional soybean in the past are returning to the market to improve weed control. But the problems will continue to increase at an accelerated rate if the farmer does not use the weed management principles which include integration of control methods, crop and herbicide rotation or a mixture of different mode of action herbicides (Gazziero, 2012).

Conclusion

The increasing use of new chemicals and GM soybean varieties resistant to pests and herbicides represents an important tool to be incorporated into crop pest management, which must be used as additional strategy to IPM, crop rotation, and resistant varieties. It is important to emphasize that the selection of pests resistant to pesticides is more rapid than the discovery of new solutions by the industry. If farmers do not become concerned with this situation, the sustainability of the soybean crop and the maintenance of current levels of productivity may be threatened in the near future.

References

Similar articles that appeared in *Outlooks on Pest Management* include –


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