## GM Crops, Weed Resistance and Yield

*Additional evidence to the Inquiry into Innovation in EU Agriculture*
*House of Lords*
*EU Select Committee (Sub-Committee D Agriculture)*

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During oral evidence by Pete Riley (GM Freeze) and Emma Hockridge (Soil Association) the Committee requested further information on weed resistance in genetically modified herbicide tolerant crops (GMHT) crops and on the yields of GM crops.

This additional evidence seeks to cover the Committee's request.

### 1. Weed Resistance

Weed resistance is now a significant agronomic, economic, health and environmental issue in areas where GMHT crops (or Roundup Ready (RR) crops) with tolerance to Monsanto's Roundup have been grown over a numbers of years and where Roundup/glyphosate has been the only, or very dominant, means to control weeds. The situation is now so serious that some pro-GM crop commentators are urgently calling for action to prevent the loss of glyphosate as a herbicide in GMHT crops (Powles 2008).

The glyphosate resistance genes in weeds may have been present in weed genomes before RR crops were introduced or may have arisen from mutations since then. The heavy use of glyphosate has resulted in the weed biotypes with the resistance genes present being selected for, and the spread has been quite rapid in some species (see below and in video clip by Robert Nichols).

The evolution of glyphosate resistance in GMHT crops in the US and South America followed a brief honeymoon period when the technology proved to be very effective in controlling troublesome weeds. However it was often those same troublesome weeds that first developed resistance to glyphosate (Powles 2008). For instance:

- Palmer Amaranth (*Amaranthus palmeri*) in maize cotton and soybeans in the USA since 2005.
- Horseweed (*Conyza canadensis***)** in cotton, soybeans and maize since 2000 and in soybean in Brazil in 2005.
- Johnsongrass (*Sorghum halepense)* in soybeans Argentina (2005) and USA (2007).

Several of the most problematic weeds are also resistant to other herbicides' modes of action in addition to glyphosate. In addition glyphosate resistant volunteer plants cause additional problem in other RR crops, for instance RR maize in RR soya.

For background to the issue (including multiple resistant weeds) we recommend that the Committee refers to our 2010 briefing on the subject (See www.gmfreeze.org/uploads/resistance_full_Briefing_final.pdf).

Glyphosate resistance in weeds is not an event exclusive to GMHT crops, but there appears to be consensus amongst weed scientists that their development has been accelerated by the over-reliance of glyphosate in RR soybeans, cotton and maize and the use of zero tillage in these crops:

- *“Most of the documented cases of evolved GR [glyphosate resistant) weeds in the past 6 years have been in GR crops.” (*Duke and Powles 2008)
- “*Because glyphosate is the herbicide most often used in no-till and minimum-till systems, GR* [glyphoste resistant] *volunteer crop plants and glyphosate-resistant or tolerant weeds will jeopardize the sustainability of those systems.” (* Mallory-Smith& Zapoila 2008)

The situation in South America is following a similar pattern to that in the USA (Binimelis, et al, 2009).

Since GM Freeze published its 2010 briefing, the sense of the urgency of the need to develop strategies to prevent resistance to glyphosate developing has greatly increased amongst weed scientists. The following video clips are worth watching to get a sense of how seriously weed scientists, industry and the media are taking this issue in relation to RR cotton.

- Larry Steckel, University of Tennessee
  (See www.youtube.com/watch?v=2_iJhIGtOJM&feature=related)

- Robert Nicols, Cotton Incorporated
  (See www.youtube.com/watch?v=T2wTlzixSG8)

- GeorgiaFarmMonitor
  (See www.youtube.com/watch?v=ZUt_pp3NUUc&NR=1)

Monsanto are also taking the problem seriously as it represents a threat to their main sources of income: RR seeds and Roundup sales. They have embarked on major changes in weed management in RR crops, which still includes the use of glyphosate but also in-mixtures and combination with other herbicides, which is increasing herbicide usage on these crops. So instead of the promised decrease in pesticide use on GM crops, the arrival of resistant weeds has resulted in herbicide use increasing on RR crops. Analysis of USDA data (Benbrook 2001, 2005 & 2009) has found progressive increases:

- 39% rise for maize (1996-2005).
- Nearly 200% for cotton (1996-2007).
- Nearly 100% for soybean (1996-2006).

Previous attempts to control resistant weeds by increasing the rate at which glyphosate has been applied have proved to be unsuccessful. Monsanto appears to have no intention of taking responsibility for the failure of their technology:

> *“Growers must be aware of and proactively manage for glyphosate-resistant weeds in planning their weed control program. When a weed is known to be resistant to glyphosate, then a resistant population of that weed is by definition no longer controlled with labelled (*sic*) rates of glyphosate. Roundup agricultural herbicide warranties will not cover the failure to control glyphosate-resistant weed populations.” (*Monsanto undated)

The company has published guidance on how to deal with the growing weed resistance problems in RR crops (Monsanto, 2010a) and has already started to develop prevention strategies based on the use of combinations of herbicides and timing of applications.

1. *The first method* is the use of tank mixtures of glyphosate and other herbicides (for instance 2.4 D is recommended for marestail (Monsanto 2008)) pre-sowing to "burn down" weeds.

2. *The second approach* is to produce GM seeds with several herbicide tolerant genes (gene stacking) by crossing GMHT varieties with different tolerant genes so different herbicides can be applied to the growing crop in rotation or in tank mixes to ensure that weeds which are resistant to glyphosate will be killed by other herbicides. For instance, Monsanto have recently announced an agreement with the German pesticide and biotechnology company BASF to develop crops stacked with glyphosate and dicamba tolerant genes (Monsanto 2010b).

3. *The third method* is to use herbicides that remain active in the soil (residual herbicides or residuals), which kill seedling weeds as soon as they germinate. Monsanto have secured co-operation with other companies to include their soil residuals in their "weed management platform". In October 2010, the FMC Corporation agreed to allow their "Authority" herbicides to be used with RR crops as part of Monsanto's offer to farmers struggling with resistant weeds (Monsanto 2010c). These residual soil acting herbicide are based on sulfentrazone in combination with other herbicides depending on the formation. Previous to this Monsanto also announced a link-up with the Valent Corporation's subsidiary the Sumitomo Chemical Co. Ltd to include flumioxazin based residual herbicides in the RR soya "platform" (Monsanto 2010d) in South America. On the same day Monsanto signed a similar agreement with the Makhteshim Agan Group (Monsanto 2010e) to use their herbicides. Earlier in 2010, Monsanto received approval to use an Acetochlor based formulation for early emergence weed control in cotton (Monsanto 2010f)

It is clear that the over use of Roundup on RR crops has come close to making glyphosate obsolete in many areas on the US and South America, and that only when it is used in combination with other products can it be effectively applied by growers. Thus the outcome is an increase of pesticide usage and the toxic burden on the environment from a cocktail of chemicals now needed to control weeds in RR crops. The herbicides being used with glyphosate, such as 2,4 D and dicamba, are old chemicals which were being phased out because of their toxicity and were supposed to be a thing of the past when RR crops came in.

Future options for chemical weed control are limited by the lack of new chemical herbicides in the pipeline. As Steckel points out (see video clip above) there has been no new herbicidal chemical introduced since the early 1990s, and there is no sign that a new chemical is anywhere near commercial production. Over-reliance on glufosinate ammonium (Liberty) by growing Liberty Link (LL) GM crops would also risk weed resistance developing and comes with concerns about mammalian toxicity (EFSA 2005).

There is also a growing body of evidence about the safety of glyphosate for human health, wildlife and the soil/plant health (PANAP 2009).

**Conclusion**

Weeds resistant to glyphosate are present in most major RR crops in the USA and South America to the extent that the easy weed control techniques which attracted farmers to adopt the technology are a thing of the past. Farmers are now faced with increasingly complex weed management strategies, increased costs and a supplier who appears to want to shirk responsibility if weed control fails due to resistant weeds being present in the crop. In some cases, such as Palmer amaranth in RR cotton, growers have had to resort to hiring labour to hand pull weeds at their own expense (see Steckel video clip). Far from making life simpler for farmers, the arrival of glyphosate resistant weeds in RR crops has led to the return of weed control methods more in keeping to the 1940s than the 21st century.

## 2. GM Yields

The actual yield of any crop is the product of its genetic make-up and how it responds to the environment in which it is growing, which can change very rapidly (for instance from drought conditions to water logging in a very short space of time). The current generation of GM crops mainly either have herbicide tolerance, insect resistance or combinations of both. These traits are primarily agronomic and are not targeted at increasing yield *per se*, but may do so indirectly when weed pressure or insect infestation reaches an economic threshold. It should be remembered that weeds and pests are also controlled using a variety of means in other cropping systems (both chemical and non-chemical approached are used), and that weed resistance to herbicides and insect pest resistance to GM insect toxins are on the increase.

GM traits that would increase the intrinsic yields of crops, such as altering photosynthetic pathways or incorporation of nitrogen fixing into wheat, have been described as "high risk" by the Royal Society's Reaping the Benefits Report (Royal Society 2008). The genetic modifications required are far more complex than the single traits seen so far, and these changes may interfere with other biochemical pathways in addition to the target. They may be 30-40 years away if, indeed, they prove to be possible. It is worth noting that genetic traits showing great promise in the lab and therefore may have been patented may not transfer successfully into a commercial variety:

> *"It is necessary to point out the commercial reality that few, if any, of the patents and applications in these lists will ever produce a financial profit. The most common reasons for this lack of success are unexpected additional costs of development or failure of the underlying science during the transfer from laboratory to field scale."* (Dunwell 2010)

A review of the performance of GM crops in the US (Gurian-Sherman 2009) examined data on yields in the US concluded that GM traits have made a comparatively small contribution to corn yield increases since commercial growing commenced in the 1990s:

> *"Our review of available data on transgenic Bt corn, as well as on transgenic HT corn and soybeans, arrives at an estimated total yield benefit of about 3–4 percent for corn."*

And

> *"Corn yields over the past several decades have increased an average of about 1 percent per year – considerably greater than the increase that can be attributed specifically to GE. Corn yields have increased about 28 percent since Bt corn was first planted commercially (as determined by comparing the average yield for the five years preceding the introduction of Bt corn with the average yield over the past five years). But the 4 percent yield enhancement contributed by Bt varieties constitutes only about 14 percent of this overall corn yield increase, with 86 percent coming from other technologies or methods."*

One of the problems of assessing the impacts of GM traits on yields is that often the varieties under comparison have significantly different genomes. As Gurian-Sherman (2009) points out:

*"Ideally, the background genetics of the GE and non-GE varieties should be identical except for the presence or absence of the transgene. In practice, however, such complete genetic identity is not possible, though it can be approximated in so-called 'near-isogenic' (NI) varieties."*

Recent university-run crops trials of soybeans, maize and canola in North America demonstrate the point that the presence of GM traits for herbicide tolerance and insect resistance is no guarantee of higher yields and that external stresses on the plant have far greater impact on yield than the presence or absence of GM traits. Below we summarise three sets of university trial data for canola (University of Idaho), corn (Iowa) and soybeans (Michigan). In all these trials none of the varieties tested can be confirmed to be near isogenic.

**A. University of Idaho winter canola and deep furrow trials 2009**
(see www.cals.uidaho.edu/brassica/Variety-trial-info/Report%20WVT%2009.pdf)

These trials were conducted independently of the companies that supplied the seed for testing by the University of Idaho. The companies paid a fee to enter varieties in the trial, although these did not cover the full costs which were made up by the institutions that conducted them.

Nineteen *Brassica napus* canola or rapeseed cultivars and breeding lines plus three control cultivars ('Dwarf Essex' industrial rapeseed (*B. napus*), 'Bridger' industrial rapeseed (*B. napus*), and 'Salut' canola (*B. rapa*)) were planted in the fall of 2008 at eight locations. One third of the cultivars entered (7 in total) were Roundup Ready types, and these are designated with "RR" in their names.

Two trials were abandoned because dry conditions led to poor germination.

***Regional variety trials***
This trial was set up to access the performance of the winter canola varieties in the climate of the Pacific NW of the USA.

There were considerable differences in the mean yield achieved between the different trial sites ranging from 2337 lbs/acre to 4426 lbs/acre (an 89% increase between lowest and highest), clearly illustrating how the environmental difference between sites affected all the varieties tested. Yields of all the varieties tested ranged from a low of 1880 lbs/acre to a high of 4703 lbs/acre across all the trial sites.

The trial report says:

*"Work needs to continue to develop cultivars that are better adapted to direct seed systems and that have increased winter hardiness in the seedling stage to allow later planting during dry falls and in recrop situations.*

*"As in previous years these trials demonstrated that even with timely late summer rains, establishing winter canola can be difficult at some sites, especially in direct seed situations. In fact, both direct seed sites were abandoned this year because of poor emergence."*

***Performance of RR varieties***
Seven RR varieties from four companies were tested (four from Monsanto, one from DL Seeds, one from Crop Plan Genetics and one from Wilbur Ellis Co). The RR varieties

average yield was 3475 lbs/acre compared to the conventional varieties 3675 lbs/acre (5.7% higher).

The results show that only one of the RR varieties made it into the top ten varieties for yield (HyCLASS 154W RR from DL Seeds). The other RR varieties occupied positions 11, 15,16,18,19 and 20 out of a total of 22. The performance of the DL Seeds variety may be explained by the performance of the company's non-GM varieties, which finished first and second in the ranking, suggesting that their gene pool for canola is well adapted to this region of the USA.

***Deep furrow trial trials***

This trial was on a smaller scale than those for the 22 varieties. The purpose was to test the growing system to see if it led to earlier planted varieties establishing better and making better use of the available soil water. The average yield at the one site used was only 2594 lbs/acre compared to 3609 lbs/acre in the main trials. In this trial Monsanto's DKW.45-10 RR (GM) came out best, and a high non-GM performer from the main trial came last of five varieties (12.9% higher than the mean). The research team put forward the following in explanation for this reversal saying, *"DKW 45-10 is a moderately early cultivar, and this attribute might have given it an advantage*[in this trial at this site]."

They also suggested that, *"The relative branching ability of each variety could have had an effect on yield as well, since the trial utilized extremely wide row spacing."*

Thus the explanation from the researchers for the good performance of the RR variety was based on its traits for earliness and branching, neither of which are affected by the presence of the RR gene.

Incidentally DKW.45-10 RR performed much better in the main trail compared with the deep furrow trial - 2928 lbs/acre in the deep furrow trial against 3418 lbs/acre in the variety trial (>16.7%)).

These trial results illustrate that the presence of RR genes in canola do not guarantee a high yielding variety, and it is the background genetics of the variety that counts most. Generally the RR varieties performed worse than the conventional (>5.7%).

It is worth noting that the RR is promoted as the key breakthrough for zero tillage systems of cultivation whereas for winter canola in the Pacific North West of the US, the ability to germinate and survive when soil moisture is low seems as important as any other trait.

**B. 2010 Iowa corn performance test**

(see www.croptesting.iastate.edu/corn/reports/corn_2010_finalreport.pdf)

Every year Iowa State University carries out performance trials for corn varieties in a number of state districts and several locations in each district. The 2010 trials included the latest SmartStax GM maize varieties.

The result for each variety entered into the trials is compared to the average for the whole district. For the purposes of this analysis the yield as percentage of the district average is compared as well as average yields for particular varieties tested. Most of the varieties tested in the Iowa trials were GM hybrids with either single traits (herbicide tolerance or insect resistance) or stacked traits. Some varieties (about 23 out of 230 hybrids tested) were non-GM and contained neither insect resistant nor herbicide tolerant GM traits.

The 2010 performance test was therefore primarily a comparison of GM varieties. It is therefore not surprising that a GM variety was the best performer in each district, but as there was no information regarding the parents of the hybrids it is impossible to assess the significance of the GM traits compared to the background genetics in each variety.

SmartStax varieties were tested and were easily identifiable in the results from information provided in the report. This maize has eight GM traits in total – six for insect resistance and two for herbicide tolerance. The Iowa performance test included 11 varieties of SmartStax, produced by four companies, which were trialled at 22 sites across six districts. The 23 non-GM varieties tested were produced by 7 companies.

***SmartStax's performance 2010***
The overall performance of all the SmartStax varieties was poor compared with the other varieties trialled – on average Smartstax yielded 5.75% less than the district average (see table 1 below).

**Table 1 SmartStax variety performance**

| **Company/Brand** | **Variety/entry** | **District** | **Relative maturity in days** | **Yield as % of district average** | **Yield in bushels/ acre** |
|---|---|---|---|---|---|
| Mycogen | 2P486 | NW | <104 | 95% | 166.3 |
| Mycogen | 2J597 | NW | 104-110 | 100% | 177.6 |
| Renk | RK764SSTX | NW | 104-110 | 91% | 160.7 |
| Cornelius | C53SSTX | NW | 104-110 | 91% | 160.5 |
| Epley | E2472SS | NW | 104-110 | 90% | 159.3 |
| Mycogen | 2P486 | NE | <104 | 98% | 170.3 |
| Renk | RK619SSTX | NE | <104 | 96% | 167.9 |
| Mycogen | 2K594 | NE | 104-110 | 102% | 186.8 |
| Mycogen | 2J597 | NE | 104-110 | 101% | 184.0 |
| Cornelius | C536SS | NE | 104-110 | 94% | 171.2 |
| Renk | RK764SSTX | NE | 104-110 | 90% | 164.1 |
| Epley | E2472SS | NE | 104-110 | 89% | 163.2 |
| Mycogen | 2D692 | Central West | 104-110 | 101% | 190.9 |
| Epley | E2472SS | Central West | 104-110 | 88% | 166.8 |
| Cornelius | C536SS | Central West | 104-110 | 88% | 166.3 |
| Mycogen | 2D692 | Central East | 104-110 | 99% | 180.6 |
| Epley | E2472SS | Central east | 104-110 | 93% | 168.7 |
| Renk | RK764SSTX | Central east | 104-110 | 92% | 168.3 |
| Cornelius | C536SS | Central east | 104-110 | 92% | 168.2 |
| Mycogen | 2D692 | SW | 109-112 | 97% | 183.5 |
| Epley | E2472SS | SW | 109-112 | 86% | 163.3 |
| Micogen | 2T784 | SW | >112 | 99% | 167.0 |
| Micogen | X21771 | SW | >112 | 94% | 158.7 |
| Micogen | X21771 | SE | >112 | 96% | 135.8 |
| **SmartStax average** | | | | **94.25%** | **168.7** |

The yield as a percentage of district average for non-GM varieties is shown in the table 2 (below). These performed far better than SmartStax and came out just 0.4% below the district mean on average. Overall GM varieties which were not SmartStax performed best across the trials.

The actual yields from SmartStax compared poorly with the non-GM varieties. The 24 trials of SmartStax average 168.7 bushels/acre, compared with 176.3 bushels/acre for the 46 trials of non-GM maize tested – 4.3% lower. The average yield from all varieties tested for each district ranged from 141.7 to 191.8 bushels/acre, which suggests that local factors, such as soil, disease/pest pressure and weather, played a big a part in how crops perform. The performance of individual varieties varied greatly between different districts. For example, Delkab's DKC61-69 (GM) varied between 156.4 bushels/acre in the SE district and 200.6 bushels/acre in the SW district – a 22% reduction. Mycogen's SmatStax variety 2D692 yielded 190.9 bushels/acre in Central west but only 180.6 bushels/acre in Central east district (down 5%). The performance trials do not attempt to explain these variations, but they clearly indicate that the prevailing environmental stresses and the impact they have on the plants is more important than the presence of GM traits. Again this illustrates that yield is the product of how the whole crop responds to differing external stresses such as low rainfall, high wind, fungal disease or insect pests.

**Table 2 Non-GM hybrids performance**

| **Company/Brand** | **Variety/entry** | **District** | **Relative maturity in days** | **Yield as % of district average** | **Yield in bushels/ acre** |
|---|---|---|---|---|---|
| Epley | E1311 | NW | <104 | 97% | 169.4 |
| Prairie | 2730 | NW | <104 | 96% | 166.3 |
| Prairie | 590 | NW | <104 | 94% | 163.4 |
| Cornelius | C462 | NW | 104-110 | 103% | 182.4 |
| Rainbow | X1079 | NW | 104-110 | 103% | 182.2 |
| Epley | E1471 | NW | 104-110 | 102% | 181.0 |
| Prairie | 4760 | NW | 104-110 | 101% | 178.4 |
| Prairie | 5879 | NW | 104-110 | 99% | 175.6 |
| Prairie | 3074 | NW | 104-110 | 96% | 169.9 |
| Titan Pro | 1059 | NW | 104-110 | 95% | 168.6 |
| Viking | 40-09N | NW | 104-110 | 94% | 165.8 |
| Epley | E1170 | NE | <104 | 104% | 182.1 |
| Viking | 60-01N | NE | <104 | 101% | 176.0 |
| Prairie | 579 | NE | <104 | 100% | 174.2 |
| Prairie | 2730 | NE | <104 | 97% | 169.1 |
| Epley | 1311 | NE | <104 | 95% | 165.7 |
| Epley | E1471 | NE | 104-110 | 103% | 187.7 |
| Titan Pro | 1098 | NE | 104-110 | 102% | 186.4 |
| Prairie | 5879 | NE | 104-110 | 101% | 183.9 |
| Cornelius | C462 | NE | 104-110 | 100% | 181.8 |
| Titan Pro | 1059 | NE | 104-110 | 99% | 180.3 |
| Prairie | 4368 | NE | 104-110 | 98% | 179.0 |
| Viking | 40-07N | NE | 104-110 | 97% | 177.4 |
| Cornelius | C591 | Central west | 104-110 | 110% | 209.0 |
| Prairie | 4760 | Central west | 104-110 | 107% | 202.4 |
| Rainbow | X1079 | Central west | 104-110 | 103% | 196.2 |
| Epley | E1471 | Central west | 104-110 | 98% | 186.2 |
| Prairie | 3074 | Central west | 104-110 | 93% | 175.9 |
| Titan Pro | 1059 | Central west | 104-110 | 91% | 173.7 |
| Titan Pro | 1149 | Central west | 109-114 | 107% | 194.3 |
| Prairie | 7820 | Central west | 109-114 | 105% | 191.0 |

| | | | | | |
|---|---|---|---|---|---|
| Rainbow | 3157 | Central west | 109-114 | 96% | 174.8 |
| Prairie | 5879 | Central east | 104-110 | 101% | 184.2 |
| Rainbow | X1079 | Central east | 104-110 | 99% | 179.7 |
| Prairie | 4368 | Central east | 104-110 | 98% | 179.2 |
| Titan Pro | 1059 | Central east | 104-110 | 98% | 177.8 |
| Prairie | 5820 | Central east | 104-110 | 96% | 174.4 |
| Prairie | 7820 | Central east | 109-114 | 106% | 202.4 |
| Master choice | MC-534 | Central east | 109-144 | 96% | 184.1 |
| Rainbow | 3157 | SW | >112 | 99% | 166.7 |
| Prairie | 7820 | SE | 109-112 | 110% | 176.1 |
| Cornelius | C591 | SE | 109-112 | 104% | 167.2 |
| Rainbow | X1079 | SE | 109-112 | 101% | 161.6 |
| Prairie | 8229 | SE | >112 | 100% | 141.4 |
| Titan Pro | 1149 | SE | >112 | 94% | 133.8 |
| Rainbow | 3157 | SE | >112 | 94% | 133.0 |
| **Non-GM average** | | | | **99.6%** | **176.3** |

The Iowa performance trials for maize show that SmartStax maize varieties did not yield as well as conventional or other GM varieties in the environments where they were tested. Whether this effect was due to yield drag (the impact of the GM traits on the physiology of the hybrid) or yield lag (the impact of background genetics of the parent plants which were genetically modified and crossed to produce the hybrids) is not known. Both may be playing a part. External factors had a noticeable impact on the performance of individual varieties.

Thus the insertion of GM traits in corn alone cannot guarantee higher yields. The performance of crops comes from how well they are adapted to local conditions – and that is a product of all the genes in the plants and their relationship with the prevailing environmental conditions, which vary from season to season and within seasons.

**C. Michigan State University soy trials 2010**
(see www.css.msu.edu/varietytrials/soybean/2010%20pdf/2010%20Performance%20Report-final.pdf)

**Table 3 2010 soybean trials summary**

| Region | Variety type | Mean yield bushels/acre | Max | Min | CV | LSD % (0.05) |
|---|---|---|---|---|---|---|
| Central | Conventional | 45.1 | 50.7 | 38.8 | 11.3 | 3.0 |
| Southern | Conventional | 51.3 | 57.3 | 39.1 | 10.9 | 3.3 |
| Central | RR (early) | 48.6 | 51.3 | 44.7 | 11.2 | 3.2 |
| Central | RR (late) | 49.3 | 53.4 | 44.7 | 10.1 | 2.9 |
| Southern | RR (early) | 57.8 | 62.8 | 53.6 | 9.9 | 3.3 |
| Southern | RR (late) | 57.6 | 61.9 | 54.4 | 10.2 | 3.4 |
| Central and Southern | LL | 53.3 | 58.6 | 49.6 | 9.4 | 2.4 |

**Table 4 Soybean yield ranges**

| Region | Variety type | Range of mean yields between sites | % difference min and max | Max range of mean yields within one variety | % difference min and max |
|---|---|---|---|---|---|

| | | bushels/acre | | between sites bushels/acre | |
|---|---|---|---|---|---|
| Central | Conventional | 28.1-55.0 | 95.8% | 15.3-54.0 | 252.9% |
| Southern | Conventional | 42.2-72.0 | 70.6% | 24.4-52.3 | 114.3% |
| Central | RR(early) | 34.0-58.6 | 72.3% | 29.9-64.3 | 115.1% |
| Central | RR(late) | 31.5-59.8 | 89.8% | 24.4-59.4 | 143.4% |
| Southern | RR(early) | 48.0-80.6 | 67.9% | 41.3-83.0 | 101.0% |
| Southern | RR (late) | 46.3-83.9 | 80.9% | 42.9-93.8 | 118.6% |
| All | LL | 28.7-58.8 | 104.9% | 29.8-85.9 | 188.3% |

RR crops' weed control was with Roundup Ultra. In conventional and LL varieties weed control was with standard herbicides (with some minor variations the same for each plot). It is assumed that weed competition was not a major issue. One test centre (Saginaw) had a severe drought during the growing season, and hence all varieties performed badly in comparison to other sites. Ingram district also had low rainfall. St Joseph district plots received irrigation and temperatures were high throughout the trials creating pretty well optimum conditions for growing.

The data (Table 3) indicate that for central area RR varieties average yield is 8.5 % more than conventional. In the southern region the increase is around 12.5%. No information about the background genetics of the varieties tested is given, so it is impossible to say if this results from the GM trait and weed control or from the background genetics of each variety. However a clue may be available in that in GM LL variety trials the same herbicides as the conventional were used and not Liberty (glufosinate ammonium) (to which the GM trait provided tolerant). The mean for LL trials was 53.3 bushels/acre, compared to 45.1 and 51.3 bushels/acre for conventional (an increase of 10.5% taking a mean for the conventional varieties). At the site with the best conditions LL also outperformed the conventional (77.0 bushels/acre against 72.0 bushels/acre), RR (early and late) yielded more than both (80.0 and 83.9 respectively). The LL/conventional comparison hints that the background genetics in the latter may be inferior in the conditions prevailing and this could explain the yield differences. No information about the genetics the conventional varieties or when they were first bred was given. The RR varieties may also have superior genetics for the condition in Iowa, but unless information on parentage of the varieties is forthcoming no firm conclusion can be drawn.

Table 4 shows how yield varied hugely between sites for all types (GM or conventional) and within varieties. The differences are larger within individual varieties (GM or conventional) than they were between conventional and GM. This clearly illustrates how yield is strongly influenced by the prevailing conditions at each site (soil quality, temperature, rainfall, disease/pest presence etc) and how the whole genetic make-up responds to these external stimuli.

Without detailed knowledge of the background genetics and previous performance of parent varieties it is not possible to conclude whether the yield differences recorded are due to the respective weed control regimes facilitated by the RR trait or the underlying genetics of the varieties, all of which would have arisen from conventional breeding programmes. Genetic modification was only used to insert the RR and LL traits, which would only impact on yield if heavy weed competition was present in the trial plots for conventional but not GM. The trial report details weed control methods used in all plots and makes no reference to different levels of weed infestation that might have impacted on the results.

**The importance of the socio-economic and cultural influences on crop performance**

It cannot be assumed that GM seeds will automatically benefit all farmers equally, especially poorer farmers who have no access to other crop inputs, such as fertilisers, or rely on rain rather than irrigation for water. We strongly recommend that the Committee read a paper that examines the performance of Bt cotton and the claims that it is pro-poor (Glover 2009), which says:

> *"Those assumptions have involved the radical simplification of the complex agronomic and livelihood contexts into which GM crops have been inserted. They have thus undermined the usefulness and relevance of the information which has been presented to both farmers and policy makers."*

**Conclusion**

Yield of any crop in any year results from the interaction of its genome with the surrounding environment, which can change greatly during the growing season. The current GM crops, herbicide tolerant and insect resistant, are not designed to increase the intrinsic yield of the crop but to help prevent losses due to weed and pest pressure. Resistance can undermine the ability of GM crops to prevent losses and increase pesticide use and costs. Increased yields in GM crops cannot automatically be assumed to result from GM traits.

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