# BRS Weed Risk Assessment

## Data Entry Form 4.0

Use the Weed Risk Assessment (WRA) Work Instructions to fill out the fields below. Be sure to read all of the text associated with each question *every time* you conduct a WRA.

## Basic information (8 questions)

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
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<tbody>
<tr>
<td>(1) WRA version number</td>
<td>4.0</td>
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<td>(2) WRA number</td>
<td>2015-315-001</td>
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<td>(3) GE or baseline</td>
<td>GE</td>
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<td>(4) Baseline WRA number</td>
<td>2014-273-001</td>
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<tr>
<td>(5) CBI</td>
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<td>(6) Applicant</td>
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<td>(7) Preparers</td>
<td>BRS</td>
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<td>(8) Reviewers</td>
<td>BRS</td>
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## Taxonomy and sexually compatible relatives (6 questions)

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
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<tbody>
<tr>
<td>(9) Common name</td>
<td>Corn (NRCS, 2015b)</td>
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<tr>
<td>(10) Scientific name</td>
<td><em>Zea mays</em> ssp. <em>mays</em> L. (ITIS, 2015)</td>
</tr>
<tr>
<td>(11) Other common names</td>
<td><strong>GE information:</strong> Optimum™ GAT™</td>
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<tr>
<td></td>
<td><strong>Baseline information:</strong> Maize, Indian corn (NCBI_Taxonomy Browser, 2015)</td>
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<tr>
<td>(12) Scientific name synonyms</td>
<td><strong>GE information:</strong> N/A</td>
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<td></td>
<td><strong>Baseline information:</strong></td>
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There are others but these synonyms show up in the literature more often.

(13) Taxonomic scope
This weed risk assessment covers only *Zea mays* ssp. *mays*. There are other subspecies of *Zea mays* but they will not be addressed here.

14) Sexually compatible relatives

**GE information:**

N/A

**Baseline information:**

*Teosinte* - Teosinte is the closest relative of corn; it hybridizes with corn and hybrids can be fully fertile (Wilkes, 1977; OGTR, 2008). Teosintes are generally not present in the U.S. other than in breeding and research programs and as occasional botanical garden specimens (Ilitis, 2003; EPA, 2010). Teosintes can be weedy in some regions or habitats (Mexico, Guatemala) (Ilitis, 2003; OGTR, 2008; EPA, 2010; USDA-NRCS, 2005). Despite the ease of crossing between subspecies, gene flow occurs at low frequency and all the subspecies still co-exist as genetically separate entities (Baltazar et al., 2005; Fukunaga et al., 2005). "The flow of genes has occurred in both directions" (Wilkes 1977; Doebley, 1990) "although a number of factors tend to favor gene flow from teosinte to maize rather than from maize to teosinte" (Baltazar et al., 2005). "There is also evidence of a restriction to crossability in some populations of *Z. mays* teosintes when teosinte is the female and maize the male parent and this has been linked to a teosinte gene or gene cluster known as *Teosinte crossing barrier*1 (*Tcb1*)" (Evans & Kermicle, 2001; Kermicle, 2006).

*Zea mays* L. ssp. *mexicana* (Schrader) Ilitis (English common name: Mexican annual teosinte)- Spontaneous hybridization occurs between corn and *Zea mays* ssp. *mexicana*, with hybrids exhibiting full fertility (Ellstrand *et al*., 2007; Fukunaga *et al*., 2005; Doebley, 2004). *Z. mays* ssp. *mexicana* grows primarily in central and northern Mexico, and is considered a troublesome weed of corn fields in central Mexico (Doebley, 2003; USDA NAL, 2012), and it may displace desirable vegetation if not properly managed (USDA-NRCS, 2005). Populations have been reported in FL, AL, and MD (USDA-NRCS, 2005; USDA-NRCS, 2014a), but local botanists have not documented any natural populations of *Zea mays* ssp. *mexicana* in Florida for over 30 years (EPA, 2010), and the AL and MD reports are over 30 years old.

- Florida: there are reports of pressed and thoroughly dried plant sample deposited in a herbarium (Atlas of Florida Vascular Plants, 2015).
- Alabama- last report was in 1965 in the *Castanea Index* - type of sample unknown
- Maryland- last report was in 1984 in the *Herbaceous plants of Maryland* type of sample unknown (Brown and Brown, 1984 as reported by USDA; NRCS, 2014a).

- **Zea mays** L. ssp. *parviglumis* Iltis and Doebley - Spontaneous hybridization is rare but does occur between corn and *parviglumis* teosinte (Ellstrand et al., 2007). Hand pollination is the most successful method of hybridization and the progeny are viable no matter how the hybrid was developed (Ellstrand et al., 2007). This subspecies is found along the western escarpment of Mexico from Nayarit to Oaxaca (Doebley, 2003). The NRCS (2015a; 2015f) lists a population of *Zea mays* ssp. *parviglumis* in Miami-Dade county Florida based on a University of Florida Herbarium accession collected in 1975 (FLAS 2015).

- **Zea mays** L. ssp. *huehuetenangensis* (Iltis and Doebley) Doebley (English common name: Huehuetenango teosinte)- This teosinte is found in western Guatemala (Doebley, 2003). Cannot find any references regarding hybridization ability with *Zea mays* ssp. *mays*.

- **Zea luxurians** (Durieu and Ascherson) Bird (English common name: Guatemala or Florida teosinte)- According to NRCS (2015c). *Zea luxurians* was grown for forage in the southern U.S. over a century ago and sometimes is still used for forage in the southern United States, "but rarely hybridizes with maize" (Iltis, 2003). There are no other references except for Iltis (2003) to verify that *Zea luxurians* is still grown as forage in the U.S. This species is an annual native to southeastern Guatemala, Honduras and Nicaragua (Doebley, 2003).

- **Zea diploperennis** Iltis, Doebley and Guzman (English common name: diploperennial teosinte)- In 1980, a population of *Zea mays* "Colorado Klein" (*Zea mays* subsp. *mays* 'Colorado Klein'; Tropicos, 2015) was successfully crossed with *Zea diploperennis*. "Both species hybridize readily, and the F1 hybrid is not only fertile and vigorous but also preferably annual or biannual, except for 12% of the plants which are perennial" (Rosales & Molina, 1983). According to NRCS (2015d) *Zea diploperennis* is not found in the U.S. (Wilkes, 1977; EPA 2010). This species is found only in a small region of the Sierra de Manantlán in the southwestern part of the state of Jalisco, Mexico (Doebley, 2003).

- **Zea perennis** (Hitchcock) Reeves and Mangelsdorf (English common name: perennial teosinte)- Corn does produce non-fertile hybrids with the perennial *Zea perennis* under natural conditions. It has a narrow geographic distribution on the northern slopes of Volcán de Colima in the state of Jalisco at altitudes of 1500-2000 m (Doebley, 2003). (Iltis, 2003; OGTR, 2008). The NRCS (2015e) lists this species in Texas and Georgia. But the sample in Texas, "Zea perennis ‘Winning Streak'," is an ornamental plant. A map (NRCS, 2015e2.) of the location of the Texas samples is included in the reference list.

**Tripsacum** spp. - Outcrossing of maize with *Tripsacum* species is not known to occur in the wild. However, "although it is extremely difficult, it is possible to produce outcrossing between *Zea mays* and *Tripsacum* spp. " in non-natural situations (OECD, 2003). "These hybrids have a high degree of sterility and are genetically unstable" (Mangelsdorf, 1974 as cited in OECD, 2003).

- **Tripsacum dactyloides** (L.) L. var. *occidentale* Cutler & Anders.- This plant is distributed across the eastern half of the United States in the U.S. (USDA-NRCS, 2002). There are no reports of crosses with corn in the wild.

- **Tripsacum floridanum** Porter ex Vasey- This plant is found in Florida (USDA-NRCS, 2015g). There are no reports of crosses with corn in the wild.

- **Tripsacum lanceolatum** Rupr. ex Fourn.- This plant is found in Arizona and New Mexico (USDA-NRCS, 2015h). There are no reports of crosses with corn in the wild.
Zea mays (Corn) has been genetically modified with the \textit{gat}-gene that confers tolerance to glyphosate-containing herbicides.

\textbf{Intended phenotype:}

The subject of this WRA is the \textit{gat}-gene that confers tolerance to glyphosate-containing herbicides.

Glyphosate acetyltransferase (GAT) effectively detoxifies glyphosate by N-acetylation (Pioneer 2007). Like glyphosate, N-acetylglyphosate is stable and is not metabolized in plants, but it is not herbicidal (Castle \textit{et al.}, 2004). The \textit{gat4621} gene is based on the sequences of three \textit{gat} genes from the common soil bacterium \textit{Bacillus licheniformis}. \textit{B. licheniformis} is widespread in the environment; therefore, animals and humans are regularly exposed without adverse consequences to this organism and its components (US EPA 2001), such as the glyphosate acetyltransferase (GAT) protein. The GAT4621 protein is 75-78\% identical and 90-91\% similar at the amino acid level to each of the three native GAT enzymes from which it was derived (Pioneer 2007). In 98140 corn, the expression of the \textit{gat4621} gene is driven by the corn ubiquitin promoter (Pioneer 2007).

The \textit{gat}-gene inserted into the corn is based off of an artificially evolved glyphosate-resistance gene (Castle \textit{et al.}, 2004; Siehl \textit{et al.}, 2005; Siehl \textit{et al.} 2007), which inactivates glyphosate by attaching an acetyl molecule to it. A gene from the soil bacterium \textit{Bacillus licheniformis}, which encoded a weak glyphosate N-acetyltransferase (GAT), was selected through eleven iterations of gene shuffling to increase its activity by almost four orders of magnitude. Plants made resistant to glyphosate with this GAT transgene have been shown to be three orders of magnitude more resistant to glyphosate than non-transgenic lines (Green \textit{et al.} 2008 and Green \textit{et al.} 2009).

\textbf{Mechanism of Action:}

The \textit{gat4621} gene encodes a glyphosate N-acetyltransferase (GAT) enzyme derived from three \textit{Bacillus licheniformis} enzymes (Pioneer 2007). Siehl \textit{et al.} (2007) indicates that the lack of an essential cysteine in the GAT active site, suggests that the reaction proceeds via direct acetyl transfer from Acetyl coenzyme A (acetyl CoA) to the secondary amine of glyphosate.

The GAT4621 protein, which metabolizes the herbicide glyphosate, confers tolerance to glyphosate-containing herbicides by acetylating glyphosate and thereby rendering it non-phytotoxic which in turn gives resistance to the plant (CFIA 2009, USDA-APHIS 2009; Castle \textit{et al.}, 2004; Siehl \textit{et al.}, 2005). These GAT polypeptides transfer the acetyl group from acetyl CoA to the Nitrogen atom of glyphosate (Castle \textit{et al.} 2004, Castle \textit{et al.} 2008).

\textbf{Potential Unintended Phenotypes:}

USDA-APHIS requested additional information on the potential exposure levels of acetylated amino acids due
to the commercialization of 98140 corn, and additional information on the impact of potential increased
dietary exposure of N-acetylaspartate (NAA) to individuals with Canavan Disease (CD). Pioneer considered
whether increases in dietary exposure to NAA and NAG resulting from commercialization of 98140 corn would
have potential effects on individuals who may not express functional deacetylases, such as individuals with CD
or aminoacylase 1 deficiency. Individuals with CD do not express a functional aspartoacylase and are unable to
deacetylate NAA. Canavan Disease (CD) is caused by heritable mutations in the aspartoacylase gene (Zeng et
al., 2002; Hershfield et al., 2007). These mutations result either in the absence of, or expression of a non-
functional, aspartoacylase enzyme (Matalon and Michals-Matalon, 1999).

Pioneer (2007) responded by stating that, "Levels of two acetylated amino acids, NAA and N-acetylglutamate
(NAG), are slightly elevated in 98140 corn, although overall, levels of NAA and NAG remain low (together less
than 0.05% in grain on a dry weight basis and less than 0.5% of the total amino acids in grain). Commercialization
of 98140 corn may increase dietary exposure to NAA and NAG. NAA and NAG are common
constituents of the human diet present in eggs, chicken, turkey and beef. Acetylated amino acids are readily
metabolized and have a history of safe consumption by humans and animals; therefore, no safety issues are
expected to result from commercialization of 98140 corn."

Pioneer (2007, Appendix 7) examined the ability of the GAT4621 enzyme to acetylate free amino acids in vitro.
The GAT4621 enzyme had low but measurable activity on aspartate, glutamate, serine, threonine and glycine in
a substrate specificity end-point assay. Pioneer submitted an addendum of acetylated amino acids analysis to
the USDA (see Pioneer 2007 petition) and to the Food and Drug Administration (FDA 2008). Pioneer analyzed
the concentrations of N-acetylthreonine (NAThr), N-acetylserine (NASer) and N-acetylglycine (NAGly) in 98140
and control corn grain. Mean values for NAThr, NASer and NAGly were statistically higher than those of control
corn grain, although overall concentrations were very low (each less than 0.0003% on a mean dry weight basis)
(Pioneer addendum, 2007, Table A). The concentration range for NASer was within the statistical tolerance
interval for non-transgenic corn. Pioneer (2007, page 93) previously showed the mean concentrations of N-
acetylglutamate (NAGlu) and N-acetylaspartate (NAAsp) in corn grain.

Pioneer (2007) concluded that the concentrations of the five acetylated amino acids are higher in 98140 corn
grain than in near-isoline control corn grain. Since the GAT4621 enzyme has the ability to acetylate certain
amino acids with low catalytic efficiency, the observed results were not unexpected. Overall levels of NAAsp,
NAGlu, NAThr, NASer and NAGly in 98140 corn grain are very low (together less than 0.05% on a dry weight
basis) (FDA 2008).

As documented in this Weed Risk Assessment, evidence presented in the petition for nonregulated status to
the USDA, assessment by the FDA (2008) and in the literature shows that GE plants expressing the GAT proteins
do not exhibit new phenotypes other than herbicide resistance. Thus expression of the GAT protein that
inactivates glyphosate is unlikely to lead to a substantial change in flux through the pathway or cause
substantial changes in the levels of downstream products.

(18) GE genotype description

**GE Information:**

**gat-gene (Glyphosate Herbicide Tolerant) Maize Construct:**

The *gat* genes were isolated from three strains of *Bacillus licheniformis*, and the *gat4621* sequence was
generated by functional optimization of these genes using DNA shuffling to enhance the acetylation activity of
the GAT enzyme. This process of fragmentation and recombination followed by selection can be repeated using
those progeny with improved properties as parents for the next round of shuffling. In the case of the *gat4621*
gene, this process was repeated eleven times using a combination of multi-gene shuffling and the introduction
of genetic diversity via the polymerase chain reaction (PCR). The promoter for the *gat4621* coding region is the
promoter from the maize ubiquitin gene, including a 5’ untranslated region and an intron (Christensen et al., 1992). The terminator for the gat4621 gene is the 3’ terminator sequence from the proteinase inhibitor II gene of Solanum tuberosum (Keil et al., 1986; An et al., 1989).

**OECD Unique Identifier**
DP-Ø9814Ø-6

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**Plant context (7 questions)**

(19) **Plant history**

**GE information:**
Based on the GE gat gene, there is no change expected that would alter plant history. Corn growers have been applying glyphosate herbicides for many years and the GE version of the corn should not alter the history.

A list of events with the gene GAT can be found at: [http://www.isaaa.org/gmapprovaldatabase/](http://www.isaaa.org/gmapprovaldatabase/) the full list is with gene gat4621 (as of 07-2016) is at: [http://www.isaaa.org/gmapprovaldatabase/gene/default.asp?GeneID=43&Gene=gat4621](http://www.isaaa.org/gmapprovaldatabase/gene/default.asp?GeneID=43&Gene=gat4621)

**Baseline information:**

Zea mays ssp. mays is the only domesticated taxon in the genus Zea. There is no agreement about where exactly corn was domesticated and there are several proposals in this regard (see references in OECD, 2003). Matsuoka et al., (2002) concluded that "all maize arose from a single domestication in southern Mexico about 9,000 years ago." It is thought to have been first introduced and cultivated in the U.S. in what is now New Mexico and Arizona by 2100 BC (Merrill et al, 2009). In the U.S., corn is grown as an annual row crop. It is the most widely produced feed grain in the United States and is processed into a wide range of food, feed and industrial products including fuel ethanol (USDA, ERS, 2013b). All parts of the corn kernel and stalk are used. Stalks are made into paper and wallboard; husks are used as filling material; cobs are used for fuel, to make charcoal, and in the preparation of industrial solvents.

There are several types of corn grown in the U.S., with the major types including field corn, sweet corn, and popcorn. All can naturally outcross with each other (Iowa State, 2014). Field corn (also known as dent corn or simply, corn) occupies the majority of the corn acres in the United States, with 93.6 million acres planted in 2007. Of this, 42% went to animal feed, 22% to produce ethanol, 17% to export, 9% for domestic food uses, and 10% surplus (Iowa State, 2014). Sweet corn was grown on approximately 380,000 acres nationwide in 2007, with the crop used as corn on the cob or for processing as canned or frozen corn (Iowa State, 2014). Popcorn is grown on less than 1 percent of the harvested corn acres (Duffy & Calvert, 2010) and in 2012 shelled popcorn was grown on over 218 thousand acres (USDA-NASS Quick Statistics, 2015). Most corn produced in the U.S. today is genetically engineered (USDA-ERS, 2014b; USDA-NASS, 2014). In 2014, herbicide tolerant (HT) corn was grown on 89 percent of U.S. corn acreage and Bt corn was grown on 80 percent of U.S. corn acreage (USDA-ERS, 2014b). Accordingly, 76 percent of all U.S. corn acreage was planted to HT/Bt stacked corn (USDA-ERS, 2014b).

(20) **Plant biology and ecology**

**GE information:**
Data collected and documented in this WRA demonstrates that the expression of glyphosate-herbicide tolerance (gat-gene) results in no change in the basic plant biology and ecology of corn.
Baseline information:

*Zea mays* is a robust monoecious annual plant (Cornell, 2006; OECD, 2003) in the Poaceae (grass) family (ITIS, 2015). Under natural conditions, corn reproduces only by seed (CERA, 2002; OECD, 2003) and requires human assistance (as discussed in question B01) to disperse its seeds for propagation and survival (OECD, 2003). Corn "is the most efficient plant for capturing the energy of the sun and converting it into food, it has a great plasticity adapting to extreme and different conditions of humidity, sunlight, altitude, and temperature" (OECD, 2003).

"The flowering stage in corn, which involves pollen shed and silking, is the most critical period in the development of a corn plant from the standpoint of grain yield determination" (Ohio State Extension, 1995). "Pollen shed usually begins two to three days prior to silk emergence and continues for five to eight days with peak shed on the third day" (Ohio State Extension, 1995). Normally, about 95% of the ovules in an ear are cross-pollinated and 5% are self-pollinated (Poehlman, 1995; Ohio State Extension, 1995), although plants are completely self-compatible (CERA, 2002). Pollen grains can survive for only 18-24 hours under favorable conditions (Ohio State Extension, 1995).

The critical soil moisture for seed germination to occur is 30% (Copeland, 1975 as referenced by Johnson, 2013). The temperature for seed germination is a minimum of 46°F with the optimum temperature 86°F (Isleib, 2012). Planting should not occur before soil temperatures are near 50° F (Johnson, 2013). At 50° F corn will take approximately 25 days to emerge; at 55-60° F corn will take 10-14 days to emerge; at 65-70° F corn only takes five to eight days to emerge (Meyer, 2011). "The energy storage structures of the seed remain below ground when the seed germinates" (Johnson, 2013).

"Corn prefers full sun and fertile, well drained soil for maximum yield" (Drost, 2010; Wright, n.d.) "with a pH from 5-8, (but 5.5-7 is optimal)" (CABI, 2012) and "with "regular watering, so maintain soils near field capacity" (Drost, 2010). Corn is a heavy feeder - particularly of nitrogen - and may require several applications of fertilizer for best yields (Cornell, 2006).

There are many weeds of corn in the U.S. Over the last 10 years, the most common and/or troublesome were lambsquarters, waterhemp/pigweeds, Palmer amaranth, morninglory species, giant and common ragweed, foxtail species, panicum species, Johnsongrass, Kochia, velvet leaf, and common cocklebur (Dow Agrosciences 2009, Van Wychen 2016). The most common insect pests attacking the corn are: A) Lepidoptera - European corn borer, southwestern corn borer, black cutworm, fall armyworm, lesser cornstalk borer, sugarcane borer, western bean cutworm, and corn earworm; B) Coleoptera – the *Diabrotica* complex (Western, Northern, and Southern corn rootworms), wireworms, and white grubs (Dicke and Guthrie, 1988; Eichenseer *et al*., 2008; Jordan *et al*., 2012; Kullik *et al*., 2011). Common diseases include Stewart's bacterial wilt, Corn smut, Southern corn leaf blight, Grey leaf spot, Crazy top disease, Maize Streak Virus (MSV), and Maize Dwarf Mosaic Virus (MDMV) (Guantai *et al*., 2010).

(21) Agronomic practices

**GE information:**

Based on the gat-gene, there is no change expected that would alter the agronomic practices used in corn cultivation.

Maize Event 98140 corn (Pioneer 2007) has been field tested at up to 15 locations in 2006, in the major corn-growing regions of the continental United States as well as in Hawaii and Puerto Rico. Analysis of agronomic and ecological data showed no biologically meaningful differences between Event 98140 corn and control corn lines.
Baseline information:
Corn is grown from seed. Agronomic practices used for production of corn include methods of tillage, agronomic inputs (fertilizers, pesticides, and herbicides), irrigation and crop rotation. The goal at planting time is to establish the highest population per acre that can be supported with normal rainfall without excessive lodging, barren plants, or pollination problems" (Nafziger, 2014). Nitrogen and phosphorus fertilizer are usually added to the soil and weed and insect control are commonly used (CIFA, 2014; Olson and Sander, 1988). When actively growing, corn obtains 90 percent of the water it uses from the top 3 feet of the soil profile (Rhoads & Yonts, 1991). “Corn producers must supplement rainfall with irrigation to meet crop water needs (Farahani & Smith, 2014). "Supplemental irrigation minimizes crop water stress due to inadequate and/or untimely rainfall during the season" (Farahani & Smith, 2014). Corn is planted in relatively wide rows, and the resulting penetration of light allows weed germination over a longer period of time, so corn is negatively impacted by early season weed competition. To obtain the best corn yields, growers manage weeds with pre-plant or pre-emergent herbicide applications. In addition, several types of tillage are used in corn fields (University of Wisconsin, 2012): "1) Conservation tillage (e.g. no-till, ridge-till, mulch till, zone-till, strip-till), which leaves 30% or more crop residue in the field. 2) Reduced till, which leaves 15 - 30% crop residue in the field. 3) Conventional-till (e.g. mold-board plowing), which leaves less than 15% residue but leads to soil erosion and greater labor and fuel costs" (CIFA, 2014). Organic production practices are increasing, from 130,672 corn acres planted in 2005 to 234,470 corn acres in 2011 (USDA-ERS, 2013a).

(22) Management practices

GE information:
Based on the gat-gene, there is no change expected that would affect the ability to control volunteer corn in typical rotation crops (e.g., soybean). Therefore, no change to Management practices.

Data provided in the petitions indicated no differences in weediness potential as measured by differences in seed germination, dormancy, plant emergence, plant height, ear height, stalk lodging, timing of pollen shed or silking, pollen viability and morphology, and yield (Pioneer 2007).

Furthermore, data provided in the Pioneer petition (2007), indicated no differences in altered seed dormancy, over-wintering capacity, or other characteristics that would alter the prevalence of volunteer maize in subsequent growing seasons.

Following-season maize volunteers with the gat gene would not be expected to present any unusual weed management challenges and can be dealt with in a similar manner using alternative herbicides to glyphosate (Pioneer 2007; USDA-APHIS 2009). GAT-expression only affects the ability of the plant to survive if treated with glyphosate. It has been suggested that volunteer offspring of herbicide-resistant crops are more difficult to control than non-resistant volunteers (Stahl et al., 2013).

However, volunteers are easily controlled through manual or use of appropriate herbicides (Pioneer 2007). Furthermore, glyphosate resistant corn growing as a volunteer in rotation crops (soybean, cotton, sorghum, small grains), can be controlled by the use of other herbicides and other practices such as tillage. Pre-plant tillage or in-crop cultivation is very effective in managing volunteer maize in subsequent crops.

Baseline information:
The presence of corn in soybean fields following the corn crop from the previous year is a common occurrence (Purdue, 2011; University of Minnesota, 2013; Hartzler, 2012, Andersen et al., 1982 and Beckett and Stoller, 1988). It can occur in the field as isolated plants or as clumps that grow from grain that germinates on ears that
have been left on the field. Volunteer corn may reduce yields, cause harvest problems, reduce soybean seed
quality, and decrease the overall aesthetics of the field (Purdue, 2011; University of Minnesota, 2013). For
example, researchers at the University of Minnesota found that clumps of 7-10 volunteer corn plants in
soybean fields resulted in average yield losses of 31% to 83% depending on the density of clumps (0.4 to 1.6
clumps/meter) (Andersen et al., 1982). Researchers at the University of Illinois reported that a density of
10,760 clumps of ten volunteer corn per hectare reduced soybean yield by >50%, while yield was reduced by
20%-30% when clumps were at half that density, depending on environmental conditions. Clumps were more
competitive than individual volunteers (Beckett and Stoller, 1988). Similar findings are reported in more recent
studies using modern, often genetically engineered, corn varieties. For example, researchers at South Dakota
State University found that populations of volunteer corn ranging from 800 to 13,000 plants per acre resulted
in yield losses of 0 to 54% in soybean and 0 to 13% in corn. Nebraska researchers also found that volunteer
clumps were more competitive than individual plants. In soybean, 3,500 clumps of corn per acre reduced yield
40% while the same population of individual plants reduced yield 10% (University of Minnesota, 2013).

"Measures are often taken to either eliminate the plants with the hoe or use of herbicides to kill the plants in
soybean fields, but the plants that remain and produce seed usually do not persist during the following years"
(OECD, 2003). "Tillage provides immediate results and require more time relative to using burndown
herbicides" (Martin, 2012). There are many reasons not to use tillage such as increased erosion and the
possibility that by any remaining seed may germinate (Martin, 2012). The most common method of controlling
volunteer corn is chemical application. Some of the chemicals (grass herbicides) used for volunteer corn control
are the post-emergence herbicides glyphosate, glufosinate-ammonium, quizalofop, fluazifop-P, fluazifop +
fenoxaprop, and clethodim and sethoxydim (University of Nebraska, 2015). Most pre-emergence grass
herbicides used in soybean will only partially control volunteer corn (Young & Hart, 1997). "Grass herbicides
can't be used in-crop in a hybrid corn field for control of volunteer corn" (University of Nebraska, 2015).

(23) Current U.S. geographic distribution

GE information:
The gat gene (glyphosate -herbicide tolerance gene ) in corn varieties is unlikely to alter the potential
geographic distribution of corn to novel areas where corn could not previously be cultivated.

The introduced gene only confers tolerance to glyphosate-containing herbicides (Castle et al., 2004; Siehl et al.,
2005; Siehl et al. 2007).

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Baseline information:
Corn is grown throughout the contiguous United States (see map attached). Most areas have a wide
distribution of corn. The only areas where corn is grown sparsely are shorelines, mountain chains, alpine areas
(growing in the biogeographic zone including the elevated slopes above timberline) and deserts. Hawaii and
Puerto Rico both report some corn production in 2012.

Six states are responsible for more than 60% of corn planted and harvested in 2014 (Illinois, Indiana, Iowa,
Minnesota, Nebraska and South Dakota) with 55 million acres out of the 90.5 million acres planted/harvested
in the United States (USDA-NASS Quick Statistics, 2014; see attached table below).

There have been no reports of corn being naturalized, weedy or invasive in the United States. Corn cannot exist
outside of cultivation and cannot exist as a wild plant in its present form (OGTR, 2008; Gibson et al., 2002;
(24) Plant hardiness and precipitation zones

Plant hardiness zones (Temperature range)

1 (-60 to -50 F)
   Presence no  Certainty Very high
   
   **GE information:**
   Cultivation only.

2 (-50 to -40 F)
   Presence no  Certainty Very high
   Cultivation only

3 (-40 to -30 F)
   Presence no  Certainty Very high
   
   **GE information:**
   Cultivation only.

4 (-30 to -20 F)
   Presence no  Certainty Very high
   
   **GE information:**
   Cultivation only.

5 (-20 to -10 F)
   Presence no  Certainty Very high
   
   **GE information:**
   Cultivation only.
Baseline information:
Cultivation only

6 (-10 to 0 F)
   Presence  no  Certainty  Very high

GE information:
Cultivation only.

------

Baseline information:
Cultivation only

7 (0 to 10 F)
   Presence  no  Certainty  Very high

GE information:
Cultivation only.

------

Baseline information:
Cultivation only

8 (10 to 20 F)
   Presence  no  Certainty  Very high

GE information:
Cultivation only.

------

Baseline information:
Cultivation only

9 (20 to 30 F)
   Presence  no  Certainty  Very high

GE information:
Cultivation only.

------

Baseline information:
Cultivation only

10 (30 to 40 F)
   Presence  no  Certainty  Very high

GE information:
Cultivation only.

------
Baseline information:
Cultivation only

11 (40 to 50 F)
  Presence no  Certainty Very high

GE information:
Cultivation only.

-----

Baseline information:
Cultivation only

12 (50 to 60 F)
  Presence no  Certainty Very high

GE information:
Cultivation only.

-----

Baseline information:
Cultivation only

13 (60 to 70 F)
  Presence no  Certainty Very high

GE information:
Cultivation only.

-----

Baseline information:
Cultivation only

Precipitation zones (Precipitation range)

1 (0 to 10 inches)
  Presence no  Certainty Very high

GE information:
Cultivation only.

-----

Baseline information:
Cultivation only

2 (10 to 20 inches)
  Presence no  Certainty Very high

GE information:
Cultivation only.
Baseline information:
Cultivation only

3 (20 to 30 inches)
  Presence   no  Certainty Very high

GE information:
Cultivation only.

-----

Baseline information:
Cultivation only

4 (30 to 40 inches)
  Presence   no  Certainty Very high

GE information:
Cultivation only.

-----

Baseline information:
Cultivation only

5 (40 to 50 inches)
  Presence   no  Certainty Very high

GE information:
Cultivation only.

-----

Baseline information:
Cultivation only

6 (50 to 60 inches)
  Presence   no  Certainty Very high

GE information:
Cultivation only.

-----

Baseline information:
Cultivation only

7 (60 to 70 inches)
  Presence   no  Certainty Very high

GE information:
Cultivation only.

-----

Baseline information:
Baseline information:
Cultivation only

8 (70 to 80 inches)
  Presence  no  Certainty  Very high

GE information:
Cultivation only.

9 (80 to 90 inches)
  Presence  no  Certainty  Very high

GE information:
Cultivation only.

10 (90 to 100 inches)
  Presence  no  Certainty  Very high

GE information:
Cultivation only.

11 (100+ inches)
  Presence  no  Certainty  Very high

GE information:
Cultivation only.

Baseline information:
Cultivation only

(25) Potential U.S. geographic distribution

GE Information:
The *gat* gene (glyphosate-herbicide tolerance) in corn varieties will not alter the current U.S. geographic distribution of currently existing corn.

The introduced gene only confers tolerance to glyphosate-containing herbicides (Castle *et al.*, 2004; Siehl *et al.*, 2005; Siehl *et al.* 2007) and is only grown in cultivation.

----------------------------------
Baseline information:
There are no reports of naturalized or invasive corn in the literature. Volunteers are not considered weeds for the purpose of this risk assessment.

Twenty two references from Randall's 2012 book "Global Compendium of Weeds, 2nd edition", were located and reviewed (See attached chart below). Many references were charts with abbreviations that do not explain the status of *Zea mays* in their country but none called *Zea mays* a weed. The references either do not say that corn is naturalized or do not provide enough information to verify that *Zea mays* is naturalized in their country.

**Weed Risk Questions (25)**

**Weed risk - Biology (16 questions)**

<table>
<thead>
<tr>
<th>(B01) Current weed and invasive status</th>
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</thead>
<tbody>
<tr>
<td><strong>Baseline risk</strong></td>
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<tr>
<td>Negligible</td>
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<tr>
<td><strong>GE risk</strong></td>
</tr>
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<tr>
<td><strong>Baseline certainty</strong></td>
</tr>
<tr>
<td>Very high</td>
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<tr>
<td><strong>GE certainty</strong></td>
</tr>
<tr>
<td>Very high</td>
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</tbody>
</table>

**GE Information:**
The engineered trait in Maize Event 98140 is not known to alter the current weed and invasive status of corn. Thus, there can be no change in GE risk for this question.

-----------------------------

**Baseline information:**
Corn has been cultivated for over 100 years. The domestication of corn has made it totally dependent on human intervention for survival, and when a corn plant is found outside a cultivated field it can’t establish a self-sustaining population. Corn has become completely dependent of human intervention to grow and survive (Andersson & de Vicente, 2010; Doebley, 2004; OECD, 2003; OGTR, 2008; Owen, 2007). "Corn is unknown in the wild" and several traits selected during domestication are not only individually non-adaptive in the wild, but their total combination is lethal to survival in the wild” (Galinat 1988). In particular, corn seed is retained on the cob and thus corn needs human intervention to disseminate its seed (OECD, 2003; Owen, 2007). Corn can be found on roadsides and wastelands next to corn fields but is incapable of sustained reproduction outside of domestic cultivation (Gould, 1968, Muhlenbach, 1979). Although unharvested corn can overwinter and germinate the following year, and thus may volunteer in subsequent crops (Purdue, 2011; University of Minnesota, 2013; Hartzler, 2012), it cannot persist as a weed and volunteers are not considered weeds in this WRA. There is no indication that corn has great potential for ferality (Owen, 2007).

Twenty-two references from Randall's book, *Global Compendium of Weeds* (2012) were reviewed to determine whether *Zea mays* ssp. *mays* is actually a weed as proposed by Randall. The geography covered by these references include many countries in Europe, China, Taiwan, Australia, New Zealand and Ethiopia.

- Five sources said that *Zea mays* L. can escape from cultivation but some stated that corn cannot survive as an escape.
• New Zealand said it can escape right next to its cultivated parent plant.
• Nine sources called it an alien, casual, exotic or non-native plant. Insufficient information is provided within these references to determine if corn is an occasional escape. The information was presented in tables that just said "alien", "non-native", etc.
• The remaining seven references called it an agricultural crop or never mentioned Zea mays L. at all.
• There are 57 total references for Zea mays L. and four for Zea mays L. subsp. mays listed in Randall with 2 of the references being copies, for a total of 59 references. After an extensive search, the other 27 references could not locate to verify the reports.

A Negligible risk rating is supported by the evidence above: 1) corn has been cultivated for well over 100 years, 2) the domestication of corn has made it dependent on human intervention and 3) when a corn plant is found outside a cultivated field it cannot sustain itself or reproduce without human intervention.

(B01) Current weed and invasive status – Certainty documentation

GE information:
Based on the gat gene (glyphosate-herbicide tolerance gene) in corn varieties, there is no change expected that would alter the Very High certainty rating of the current weed and invasive status of corn.

There is no change in the GE certainty rating from the baseline certainty rating.

Baseline information:
Andersson & de Vicente, 2010- High reliability; High applicability
Doebley, 2004- High reliability; Very High applicability
Galinat 1988- High reliability; High applicability
Gibson et al, 2002- Moderate reliability; High applicability
Gould, 1968- Moderate reliability; Moderate applicability
Muhlenbach, 1979 – Very high reliability; Very High applicability
OECD, 2003- High reliability; High applicability
OGTR, 2008- High reliability; High applicability
Owen, 2007- High reliability; Moderate applicability

Based on the consensus of the references a Very High level of certainty is assigned.

(B02) Weedy and invasive relatives

Baseline risk Negligible GE risk Negligible
Baseline certainty High GE certainty High

(B02) Weedy and invasive relatives – Risk documentation

GE Information:
N/A. This question is only applicable to the baseline. Therefore the GE risk rating remains unchanged from the Negligible baseline risk rating of weedy and invasive relatives of corn.

Baseline information:
Relatives of Zea mays ssp. mays (Zea mays ssp. mexicana and other teosintes) are reported as weedy even though they have not become established in the United States (USDA-NRCS, 2005). Zea mays L. ssp. mexicana is considered a troublesome weed of corn fields in central Mexico (Doebley, 2003; USDA NAL, 2012).
However, corn (*Zea mays* ssp. *mays*) is highly domesticated (Warwick & Stewart, 2005; Tian, et al., 2009). Many of the traits that lead to weediness in plants are absent in corn. For example, corn has limited ability to compete with other plants (Steinhardt *et al.*, 2002), lacks shade tolerance (Earley *et al.*, 1965) and depends on intentional human intervention to grow and survive, as discussed in question B01 (Andersson & de Vicente, 2010; Doebley, 2004; OECD, 2003; OGTR, 2008; Owen, 2007). Domestication involved a radical phenotypic transformation from the wild progenitor, *Zea mays* ssp. *parviglumis* resulting in an unbranched plant with seed attached to a cob and thereby making maize entirely dependent on humans for propagation (Hufford, 2012b and as discussed in question B01).

Based on the high domestication of corn in the United States a Negligible risk rate is given.

**B02 Weedy and invasive relatives – Certainty documentation**

**GE information:**

N/A. This question is only applicable to the baseline. Therefore the GE certainty rating remains unchanged from the High baseline certainty rating of weedy and invasive relatives of corn.

**Baseline information:**

Andersson & de Vicente, 2010- High reliability; High applicability
Doebley, 2004- High reliability; Very High applicability
Doebley, 2003- High reliability; Very High applicability
Earley *et al.*, 1965- High reliability; High applicability
Hufford *et al.*, 2012b- High reliability; High applicability
OECD, 2003- High reliability; High applicability
OGTR, 2008- High reliability; High applicability
Owen, 2007- High reliability; Moderate applicability
Steinhardt *et al* 2002- Moderate reliability; Moderate applicability
Tian, et al 2009- High reliability; Moderate applicability
USDA NAL, 2012- High reliability; High applicability
USDA-NRCS, 2005- High reliability; Very high applicability
Warwick & Stewart- High reliability; Moderate applicability

Based on the consensus of the references a High level of certainty is assigned.

**B03 Ability to establish**

<table>
<thead>
<tr>
<th>Baseline risk</th>
<th>GE risk</th>
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</thead>
<tbody>
<tr>
<td>Low</td>
<td>Low</td>
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</table>

**Baseline certainty**

<table>
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<tr>
<th>GE certainty</th>
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<tbody>
<tr>
<td>Moderate</td>
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</tbody>
</table>

**B03 Ability to establish – Risk documentation**

**GE Information:**

Based on the *gat* gene (glyphosate -herbicide tolerance) in corn varieties, there is no change expected that would alter the Low risk rating of the ability of corn to establish.

The data submitted for corn expressing GAT protein do not show dramatic differences or biologically meaningful increases in final stand counts or early emergence vigor of the transgenic line compared to their near isogenic non-transgenic line lacking the trait in field trials assessing agronomic characteristics in different locations (Pioneer 2007, Tables 12-14) or in percent germination experiments under different temperature conditions (Pioneer 2007, Table 10). However, there was no data provided on establishment in competition with other vegetation that could be used to support a risk rating different than the rating for the baseline WRA.
The data submitted for *gat*-maize do not indicate that hybrids derived from modified corn line would be any more competitive or vigorous in their ability to germinate or establish in different environments or reproduce or have other characteristics that would increase their capacity to compete or persist as a weed (USDA-APHIS 2009, CFIA 2009, and EFSA 2013). However, there was no data provided on establishment in competition with other vegetation that could be used to support a risk rating different than the rating for the baseline WRA.

Over a 10 year monitored period in a natural habitats, glufosinate resistant transgenic crop maize was grown in 12 different habitats (Crawley *et al.* 2001). In this study, maize was not able to persist in the field by the start of the second year. Furthermore, none of the modified corn assessed when compared to the conventional corn was found to be more invasive or persistent in the environment (Crawley *et al.* 2001). Even though the Crawley study was performed with a different herbicide gene than the GAT-transgenic corn gene (glyphosate-herbicide tolerance), there is no plausible risk hypothesis that GAT-corn would behave differently in its ability to establish or persist in the environment.

GE herbicide-resistant maize is only likely to express a fitness advantage over non-GE herbicide-resistant maize in production systems in which herbicides are routinely applied (USDA-APHIS 2014).

**Baseline information:**

Corn can be planted in stubble but does not compete well with other plants and should not be planted into living plants because it creates too much competition for small corn plants in terms of available soil moisture and light for early growth. (Steinhardt *et al.*, 2002). Corn is an extremely heavy feeder, especially on nitrogen (Cornell, 2006) but human management practices can supply nitrogen in cultivated fields. Its ability to occasionally grow in uncultivated fields and by roadsides and to volunteer in subsequent cultivated crops (Gould, 1968; OECD, 2003) suggests it may have a minor ability to establish in existing vegetation. However, if weeds are left uncontrolled corn can’t be successfully grown, and there can be a complete loss of yield, demonstrating its generally poor competitive ability (Olson and Sander, 1988). Most seed corn has a germination rate of 95% or higher but can vary considerably depending on planting conditions (Thomison, 2010).

In 2007, Monsanto field trials in which corn seed was planted to assess corn's survival outside of cultivation were planted in four different locations:

- **IL study** was agricultural land that had been converted to conservation land, was left fallow for two years, with a mix of native grasses, forbs, and weeds with an estimated ground cover of 60%. Early stand count 50 – 100%.
- **MO study** was agricultural land that was adjacent to a lake and consisted of annual grasses, broadleaf weeds, and volunteer wheat with an estimated ground cover of 98%. In the last two years the land had been cultivated with soybean (2006) and winter wheat (2005-2006). Early stand count 50 – 100%.
- **NE** was adjacent to agricultural land and contained a mixture of weeds with an estimated ground cover of 25%. The area was usually not used for crop production. Early stand count 1%.
- **TX study** was in a pasture of native grasses with an estimated ground cover of 85%. There were no (0%) early stands.

Since the Monsanto MO and IL sites had the highest estimated ground cover in which corn plants established, the risk assignment will be based on their data along with the other references. Monsanto does not explain how the percent ground cover was assessed. The MO site was highly disturbed in that it that it had experienced only a short growing season before the establishment of the experimental seedlings on May 29, 2007 but presumably they sowed an annual grass cover crop on the site earlier in spring 2007, which would be the usual practice for soil stabilization if the field was to remain fallow for the season, or perhaps in this case, was converted to be used for this experiment. Thus the MO site would have had recently planted vegetative cover
that would be “very young” and the ground would be highly disturbed at planting time. In IL, the that the plants grew poorly, as reflected by their very short height (7 – 10 inches) at the late vegetative stage, while typically a corn plant in cultivated fields will be from 30 – 80 inches tall at V10 (Yin et al., 2011; Freeman et al., n.d.). The IL site best corresponds to Low risk because it was very open with little competition for other plant taxa and appeared to be highly disturbed (only 60% ground cover after two years left fallow).

In a similar study, Raybould et al. (2012) planted several hybrid varieties and landraces in an agricultural field in the southern tip of Texas and used typical agronomic practices (herbicides, insecticides, fertilizer, and irrigation) to ensure successful stand establishment production of healthy and robust ears. At maturity, the plants were left unharvested and undisturbed, seed was allowed to disperse naturally, and the field was allowed to revert to vegetation (the buffer strips between plots having been previously allowed to revert). On average, approximately 70 next generation “feral” plants per plot established from seed produced by approximately 590 original plants per plot, although only 1-2 of these feral plants reach reproductive maturity, and they had no offspring. Given that the number of germinating seed is not known, these data are consistent with Low to Moderate Risk.

Based on the above, a low risk rating is assigned.

**(B03) Ability to establish – Certainty documentation**

**GE information:**
Overall, the weight of evidence supports a certainty rating of **Moderate**.

This certainty rating is based off the reliability and applicability ratings for two primary source (Pioneer 2007) and five secondary sources. (USDA-APHIS 2009; USDA-APHIS 2014; Crawley et al. 2001; CFIA 2009, EFSA 2013).

The reliability and applicability ratings for the five sources are as follows: Pioneer petition (High and High, respectively); the two USDA-APHIS reports (High and Moderate, respectively); two highly-cited government organization report (CFIA 2009, and EFSA 2013; High and High, respectively); and one article (Crawley et al. 2001, High and Moderate, respectively).

**Baseline information:**
Steinhardt et al. 2002- Moderate reliability; High applicability
Cornell, 2006- Moderate reliability; Moderate applicability
Gould, 1968- High reliability; Moderate applicability
OECD, 2003- High reliability; High applicability
Olson and Sander, 1988 – High reliability; Moderate applicability
Thomison, 2010- Moderate reliability; High applicability
Monsanto 2009- High reliability; High applicability
Raybould et al. 2012 is High reliability, Moderate applicability
Yin et al., 2011- High reliability; High applicability
Freeman et al., n.d- High reliability; Moderate applicability

A Moderate rating is being assigned because so many references are either moderate reliability or moderate applicability and the Monsanto reference is ambiguous about how ground cover was assessed.

**(B04) Dense thickets or monospecific stands**

<table>
<thead>
<tr>
<th>Baseline risk</th>
<th>GE risk</th>
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</thead>
<tbody>
<tr>
<td>Negligible</td>
<td>Negligible</td>
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</table>

**Baseline certainty**

<table>
<thead>
<tr>
<th>Baseline certainty</th>
<th>GE certainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>Very high</td>
</tr>
</tbody>
</table>

**(B04) Dense thickets or monospecific stands – Risk documentation**
**GE Information:**
Based on the *gat* gene (glyphosate -herbicide tolerance ) in corn varieties , there is no change expected that would alter the **Negligible** risk rating of the ability of corn to form dense thickets or monospecific stands.

This reasoning is based off of the inability of conventional corn to form dense thickets or monospecific stands (see baseline corn description), coupled with no biologically meaningful differences in growth/development between GAT corn and conventional corn (Pioneer 2007; USDA-APHIS 2009).

Pioneer (2007) results from field experiments comparing the agronomic performance and phenotypic data of corn modified with the *gat*-gene do not provide any evidence of any change in the ability of the transgenic corn plants to form dense thickets or monospecific stands without human interference (Pioneer 2007).

**Baseline information:**
The goal of corn in agriculture is to "establish the highest population per acre that can be supported with normal rainfall without excessive lodging, barren plants, or pollination problems" (Nafziger, 2014).

Morphological characteristics that could contribute to the formation of dense thickets or monospecific stands (e.g., increased tillering, rhizomes or stolons, allelopathy) are not characteristic of corn, although some cultivars and landraces can form tillers (OGTR 2008, CABI 2012). Since corn cannot grow without intentional human assistance (as discussed in question B01) (Morgenstern, 2007), except for sporadic escapes, the chance of wild thickets/monospecific stands is **Negligible**.

**B04) Dense thickets or monospecific stands – Certainty documentation**

**GE information:**
Overall, the weight of evidence supports a certainty rating of **Very high**.

This certainty rating is based off the reliability and applicability ratings for one primary source (Pioneer 2007) and one secondary source (USDA-APHIS 2009).

The reliability and applicability ratings for the sources are as follows: Pioneer petition (High and High, respectively) and the USDA-APHIS (High and High, respectively). Additionally, certainty regarding the inability of conventional corn to form dense thickets or monospecific stands outside of cultivation is based on common knowledge of a well-studied, domesticated crop plant.

**Baseline information:**
CABI, 2012 – High reliability, Moderate applicability
Morgenstern, 2007- Moderate reliability; Very high applicability
Nafziger, 2014- High reliability; Moderate applicability
OGTR, 2008 – High reliability; High applicability

Corn is a domesticated crop that has never shown monospecific stands except during cultivation. Based on the references and because it is so widely cultivated and studied, a Very High certainty rating was given for this question.

**B05) Shade tolerance**

<table>
<thead>
<tr>
<th>Baseline risk</th>
<th>Negligible</th>
<th>GE risk</th>
<th>Negligible</th>
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</thead>
<tbody>
<tr>
<td>Baseline certainty</td>
<td>Very high</td>
<td>GE certainty</td>
<td>Very high</td>
</tr>
</tbody>
</table>
Shade tolerance – Risk documentation

GE Information:
Based on the gat gene (herbicide tolerance) in corn varieties, there is no change expected that would alter the Negligible shade tolerance rating of conventional corn.

This reasoning is based off of the inability of conventional corn to fully produce under shade conditions (see baseline corn description), coupled with no biologically meaningful differences in growth/development between GAT corn varieties and conventional corn (Pioneer 2007; USDA-APHIS 2009). Conventional and GE corn prefer full sun and will not produce much corn under shade conditions.

Glyphosate tolerant corn has been commercially cultivated since 1997 with no reports found in the literature of increased shade tolerance in commercially available maize. There is no plausible hypothesis to justify that the gat gene (herbicide tolerance) in corn varieties would interfere and further modify the shade tolerance of the hybrids.

The results of field studies in the Pioneer (2007) petition provide experimental methods and directly relevant primary data, but are performed in an agronomic context. No meaningful biologically significant differences were observed on growth habit and general morphology, and vegetative vigor and development and reported in observations of field trials described in the Pioneer (2007) petition. No evidence was found in the petition submitted to APHIS and in the literature to indicate that the gat gene (herbicide tolerance) in corn varieties has altered the ability of corn to be more tolerant to shade than the hybrids used as parental lines for the GE hybrids.

Baseline Information:
All corn prefers full sun and fertile, well-drained soil for maximum yield (Tropical Forages, 2005; Drost, 2010). Corn grows in areas that allow for full sunshine since shade will not produce much corn (Mierzejewski, 2015). There was a significant decrease in measured components (grain, stover, total protein, total oil, etc.) as light was decreased and a reduction of light by even 30% caused a decrease in production of plant material (Earley et al., 1965). Kiniry and Ritchie (1984) did a shade tolerance experiment that measured effect of kernel number as it is related to what stage the corn plant was at during short-term shading. They concluded that shade does decrease kernel number but shade during the crucial early kernel development, occurring near the end of the lag period of grain filling, was the most sensitive period for shade intolerance (Kiniry & Ritchie, 1984). If you can get light to the bottom of the canopy, especially during critical grain fill periods of growth in corn or soybeans, you can increase seed weight and you can increase yield significantly” (Roberson, 2014). Experiments involving the application of shading stress using an artificial shade frame demonstrated reductions in grain yield and total dry matter across three different shading treatments (pre-silking, silking, and post-silking) compared to non-shaded controls; the yield reductions were 44%, 30% and 12% for two inbred lines and their hybrid, respectively. The yield decrease was associated most strongly with a reduction in kernel number per plant (Liu and Tollenaar 2009). Based on this evidence, a Negligible risk rating was assigned.

Shade tolerance – Certainty documentation

GE Information:
Overall, the weight of evidence supports a certainty rating of Very High.

This certainty rating is based off the reliability and applicability ratings for one primary source (Pioneer 2007) and one secondary source (USDA-APHIS 2009).

The reliability and applicability ratings for the sources are as follows: Pioneer petition (High and High, respectively) and the USDA-APHIS (High and Moderate, respectively).
Additionally, the certainty regarding the inability of conventional corn to fully produce under shade conditions is based on common knowledge of a well-studied, domesticated crop plant.

Baseline Information:
- Drost, 2010- Moderate reliability; High applicability
- Earley et al, 1965- Very High reliability; Very High applicability
- Liu and Tonnar 2009: High reliability, High applicability
- Mierzejewski, 2015- Moderate reliability; High applicability
- Roberson, 2014- Moderate reliability; Moderate applicability
- Tropical Forages, 2005- High reliability; High applicability

Because no evidence was found that corn can tolerate shade and because it is so widely cultivated and studied, a Very High certainty rating was given.

(B06) Life form and growth habit

<table>
<thead>
<tr>
<th>Baseline risk</th>
<th>GE risk</th>
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<tbody>
<tr>
<td>Very high</td>
<td>Very high</td>
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</table>

<table>
<thead>
<tr>
<th>Baseline certainty</th>
<th>GE certainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>Very high</td>
</tr>
</tbody>
</table>

(B06) Life form and growth habit – Risk documentation

GE information:
Based on the *gat* gene (glyphosate-herbicide tolerance) in corn varieties, there is no change expected that would alter the Very high rating of conventional corn.

This reasoning is based off the fact that there are no biologically meaningful differences in growth/development between GAT corn varieties and conventional corn (Pioneer 2007, USDA-APHIS 2009). No meaningful biologically significant differences were observed on growth habit and general morphology, vegetative vigor and development and reported in observations of field trials described in petitions for non-regulated herbicide tolerant 98140 corn (Pioneer 2007). No evidence was found in the petition submitted to APHIS and in the literature to indicate that genetic engineering the *gat*-gene (resistance to glyphosate) into maize hybrid cultivars has altered the life form and growth habits of maize to anything other than those of the hybrids used as parental lines for the GE hybrids.

Baseline Information:
"Maize, or corn, is a member of the *Maydeae* tribe of the grass family, *Poaceae*" (OECD, 2003; USDA-NRCS, 2015b). A very High risk rating is assigned on this risk trait.

(B06) Life form and growth habit – Certainty documentation

GE information:
Overall, the weight of evidence supports a certainty rating of Very High.

This certainty rating is based off the reliability and applicability ratings for one primary source (Pioneer 2007) and one secondary source (USDA-APHIS 2009).

The reliability and applicability ratings for the two sources are as follows: Pioneer petition (High and High, respectively) and the USDA-APHIS (High and High, respectively).
OECD, 2003 - High reliability; Very high applicability
USDA-NRCS 2015b - High reliability; Very high applicability

Based on the reliability/applicability of the above references and because it is so widely cultivated and studied, a Very High certainty rating was given.

(B07) Time to reproductive maturity

<table>
<thead>
<tr>
<th>Baseline risk</th>
<th>GE risk</th>
<th>Baseline certainty</th>
<th>GE certainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>High</td>
<td>Very high</td>
<td>Very high</td>
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</tbody>
</table>

(B07) Time to reproductive maturity – Risk documentation

**GE information:**
Based on the engineered *gat* gene (glyphosate-herbicide tolerance) in corn varieties, there is no change expected that would alter the High rating for the time to reproductive maturity of corn.

This reasoning is based off of the well-known time to reproductive maturity of conventional corn (OECD 2003; OGTR 2008), coupled with an absence of substantial differences in agronomic attributes that measure time to reproductive maturity, such as dormancy, days to 50% pollen shed, and days to 50% silking between GAT corn varieties and conventional corn (Pioneer 2007, USDA-APHIS 2009).

Pioneer submitted data on field trials assessing agronomic characteristics in different locations (Pioneer 2007, Tables 11-14). USDA-APHIS (2009) evaluated the data submitted in the petition for these traits and concurred that corn with GAT-protein compared to conventional corn had not altered the time to reproductive maturity.

As discussed in the baseline response to this question, corn generally produces one generation per year, except in tropical environments where it can be grown continuously. Detailed developer data indicate that no statistically significant and biologically meaningful differences were observed between corn modified with the *gat*-gene (resistance to glyphosate) and non-transformed comparators, in any of the time to reproductive maturity in field trials described in the petition submitted to APHIS (Pioneer 2007).

---------------------------

**Baseline Information:**
Corn is an annual (OECD, 2003; CABI, 2012; OGTR, 2008). "Corn can take from 60 to 100 days to reach harvest depending upon variety and the amount of heat during the growing season" (Albert, 2015). Corn takes a whole growing season to reach reproductive maturity thus it also has only one generation per year, except in tropical and subtropical climates where corn can be grown throughout the year with human intervention (as discussed in question B01). Corn must reach maturity before the first autumn freeze which is closely related to the normal corn crop growing season across the U.S Corn Belt. Therefore more than one generation per year is not possible (Neild and Newman, 1990), and a High risk rating is given to this question.

(B07) Time to reproductive maturity – Certainty documentation

**GE information:**
Overall, the weight of evidence supports a certainty rating of Very high.

This certainty rating is based off the reliability and applicability ratings for one primary source (Pioneer 2007 and three secondary sources (USDA-APHIS 2009, OECD 2003; and OGRT 2008).

The reliability and applicability ratings for the four sources are as follows: Pioneer petition (High and High, respectively); the USDA-APHIS (High and High, respectively); one highly-cited government organization report (OECD 2003; High and Moderate, respectively); and one Australian government OGTR report (High and Moderate, respectively).
**Baseline Information:**
Albert, 2015- Low reliability; Moderate applicability  
CABI, 2012- High reliability; Moderate applicability  
Neild and Newman, 1990- Moderate reliability; High applicability  
OECD, 2003- High reliability; Moderate applicability  
OGTR, 2008- High reliability; Moderate applicability

Based on common knowledge gained over centuries of cultivation and because the references all agree and corn does not grow without intentional human assistance (as discussed in question B01), a Very High certainty rating is assigned.

**Draft**

**B08) Propagule dispersal**

<table>
<thead>
<tr>
<th>Baseline risk</th>
<th>GE risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negligible</td>
<td>Negligible</td>
</tr>
</tbody>
</table>

**B08) Reproductive potential – Risk documentation**

**GE Information:**
Based on the *gat* gene (glyphosate-herbicide tolerance) in corn varieties, there is no change expected that would alter the Negligible risk rating of the reproductive potential of corn.

As discussed in detail above (20) there is no evidence in the data in the petition submitted by Pioneer (2007) to indicate that the introduction into corn of the *gat*-gene (resistance to glyphosate), has changed the reproductive potential of corn.

The agronomic data (Pioneer 2007, Table 12 and 13) showed no biologically meaningful differences between 98140 corn and control corn (near isolines of 98140 corn and/or conventional corn lines) with respect to yield. This data supports the conclusion that 98140 corn is comparable in agronomic characteristics to conventional corn.

No data exists on GAT transgenic corn outside of cultivation or that the reproductive potential of GE corn would be different.

**Baseline Information**: The average ear of cultivated corn has approximately 400 to 600 kernels arranged in 16 rows (Iowa State, 2014). A typical corn commercial dent corn plant produces one ear although multiple ears per plant can exist if resources (space, water, nutrients, etc.) are not limited (Iowa State, 2014; Poethig, 1994). However, most exotic varieties, as well as many commercial varieties of sweet corn and popcorn, produce two or more ears (Poethig, 1994). In the study by Raybould *et al* (2012), only 1 – 2 “feral” corn plants per 110 square meter plot reached reproductive maturity; the number of viable seed produced was not measured but would be very low per square meter. Only one reference was found that examined the ability of corn to reproduce outside of cultivation: when corn was planted in existing vegetation on land which had been in agricultural production 2-5 years previously, plants established at a high rate but very little yield was obtained (Monsanto, 2009). This suggests that the reproductive potential of corn outside of cultivation would be very low. No references were found that say corn in non-cultivated area has any potential to reproduce. The risk is therefore Negligible

**B08) Reproductive potential – Certainty documentation**

**GE information:**
Overall, the weight of evidence supports a certainty rating of Very High, the same as the baseline.

This certainty rating is based off the reliability and applicability ratings for one primary source (Pioneer 2007), and the sources cited in the baseline corn WRA.
The reliability and applicability ratings for the sources cited here are as follows: Pioneer petition (High and High, respectively).

The baseline risk rating of Very high is based on very low yield when corn was grown outside of cultivation. The certainty rating remains unchanged from the baseline since there is no plausible risk hypothesis that the gat trait has changed the reproductive potential of corn.

Baseline Information:
Iowa State, 2014-High reliability; Very high applicability
Monsanto, 2009- High reliability; High applicability
Poethig, 1994 – High reliability; Moderate applicability
Raybould et al. 2012 – High Reliability; Moderate applicability

Corn generally does not grow without intentional human assistance except as sporadic escapes, as discussed in question B01. In addition, two experiments demonstrate very low yield in corn growing without human assistance. Therefore a Very High certainty rating is assigned.

(B09) Propagule dispersal

<table>
<thead>
<tr>
<th>Baseline risk</th>
<th>GE risk</th>
<th>Baseline certainty</th>
<th>GE certainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Low</td>
<td>Very high</td>
<td>Very high</td>
</tr>
</tbody>
</table>

(B09) Propagule dispersal – Risk documentation

GE information:
There is no change in the GE risk rating from the baseline risk of Low for the propagule dispersal of corn.

Within the Pioneer petition (2007, Table 11-14 ), field data relevant to propagule dispersal is presented. There are no biologically significant differences in grain weight and dropped ears between GAT corn varieties and conventional corn (Pioneer 2007; USDA-APHIS 2009).

Moreover, there is no reason to believe the GE traits would substantively change dispersal of corn seeds or kernels.

Baseline information:
Corn requires human assistance to disperse its seeds for propagation and survival (OECD, 2003). "During its domestication from teosinte, maize lost its ability to disperse and thus survive in the wild" (Andersson & de Vicente, 2010). It has become so domesticated that seeds in cobs are tightly covered by tight husks so they cannot be separated (shattering) from the cob and disseminated without human intervention (as discussed in question B01) (CFIA, 2014; Farnham et al. 2003; (Fedoroff 2003). Additionally, the maize cob lacks any abscission layers between its basic units and the cob remains intact at maturity with no shattering (Doebley et al. 1990). Studies show that harvesting and subsequent cultivation in silage maize can cause spread of plant seeds (OGTR, 2008). In one experiment, corn seeds did not pass intact through the digestive tract of four bird species associated with corn cultivation who are known to eat corn and were not found in the fecal material from these birds (Cummings et al., 2008). Corn seed is not dispersed by the wind because it has no physical attributes to do so and corn seed remains attached to the cob. (Fedoroff, 2003). A Low risk rating is assigned because corn needs human intervention (as discussed in question B01) to disseminate the corn seed to start a new generation but it can be moved by farming equipment (Andersson and de Vicente, 2010).

(B09) Propagule dispersal – Certainty documentation
**GE information:**
Overall, the weight of evidence supports a certainty rating of **Very high**.

This certainty rating is based off the reliability and applicability ratings for one primary source (Pioneer 2007) and one secondary source (USDA-APHIS 2009).

The reliability and applicability ratings for the two sources are as follows: Pioneer petition (High and Very High, respectively) and the USDA-APHIS (High and High, respectively).

----------------------------------

**Baseline information:**
Andersson & de Vicente, 2010- High reliability; High applicability
CFIA, 2014- High reliability; High applicability
Cummings et al., 2008- High reliability; High applicability
Doebley, 2004- High reliability; High applicability
Federoff, 2003- High reliability; High applicability
OECD, 2003- High reliability; High applicability
OGTR, 2008- High reliability; High applicability

A Very High certainty level as given based on the numerous sources who reported human dependence (as discussed in question B01) of corn propagule dispersal.

(B10) Dormancy

<table>
<thead>
<tr>
<th>Baseline risk</th>
<th>GE risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negligible</td>
<td>Negligible</td>
</tr>
</tbody>
</table>

**Baseline certainty**
High

**GE certainty**
High

(B10) Dormancy – Risk documentation

**GE information:**
There is no change in the GE risk rating from the baseline risk of **Negligible** for seed dormancy in corn.

This reasoning is based off of the absence of significant seed dormancy in conventional corn (OGTR 2008), coupled to the absence of substantial differences in seed dormancy and germination between the GAT corn events and conventional corn (Pioneer 2007; USDA-APHIS 2009). The percent germination experiments under different conditions (cold and warm) conducted by Pioneer (2007, Table 10) can indirectly relate to seed dormancy. The results show that GAT corn is comparable to other corn hybrids in seed germination characteristics.

Furthermore, glyphosate tolerant corn has been commercially cultivated since 1997 with no reports found of altered seed dormancy.

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**Baseline Information:**
Seeds from one maize crop can survive over winter and germinate in warmer weather (OGTR, 2008). Maize seeds dispersed during the harvesting process can only survive for up to one year in the soil, due to their poor dormancy (Andersson & de Vicente, 2010). "One of the first effects of domestication would be a genetic removal of the dormancy trait" (Galinat, 1988). "Dormancy is not associated with modern maize cultivars although it does occur in other Zea spp." (Simpson, 1990 as reported in OGTR, 2008). A Negligible risk rating is given for lack of dormancy beyond a year.

(B10) Dormancy – Certainty documentation
**GE Information:**
Overall, the weight of evidence supports a certainty rating of **High**.

This certainty rating is based off the reliability and applicability ratings for one primary source (Pioneer 2007 and two secondary sources (OGTR 2008; and USDA-APHIS 2009).

The reliability and applicability ratings for the sources are as follows: Pioneer petition (High and High, respectively); the USDA-APHIS (High and High, respectively); and one Australian government OGTR report (High and High, respectively).

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**Baseline Information:**
Andersson & de Vicente, 2010- High reliability; Very high applicability
Galinat, 1988 Moderate reliability; Moderate applicability
OTGR, 2008- High reliability; Very high applicability

Based on common knowledge gained over centuries of cultivation along with the above references a High certainty rating is assigned.

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**Regeneration**

<table>
<thead>
<tr>
<th>Baseline risk</th>
<th>GE risk</th>
<th>Baseline certainty</th>
<th>GE certainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negligible</td>
<td>Negligible</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>Moderate</td>
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</tbody>
</table>

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**Regeneration – Risk documentation**

**GE Information:**
There is no change in the GE risk rating from the baseline risk of **Negligible** for regeneration in corn.

References to the regenerative ability of glyphosate resistant corn where not presented in the Pioneer petition (2007) and not found in the literature. However, there is no reason to believe the engineered traits would alter this characteristic. As such there is no evidence in the data to indicate that the introduction the gat-gene (resistance to glyphosate), has changed the regenerative ability of the plants.

No evidence was found to support the hypothesis that the gat-gene (resistance to glyphosate), would alter the development of tillers in corn. The inserted gene for the GAT enzyme changes its affinity to bind glyphosate, and there is no plausible hypothesis upon which to assume that such changes would affect the plants ability to regenerate following harvest, grazing or mutilation.

A literature search on the ability of corn to regenerate in fields did not yield results.

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**Baseline Information:**
Tillers are morphologically identical to the main stalk and are capable of forming their own root systems, nodes, internodes, leaves, ears and tassels. If the main stalk is injured by hail, frost, cultivation or animals early in the season, one or more tillers commonly form and may develop harvestable ears. However, if the damage occurs later, then tillers may not have enough time to form harvestable ears before killing frost occurs (Nielsen, 2003). Commercial varieties of dent corn rarely have tillers, while most exotic varieties as well as many commercial varieties of sweet corn and popcorn produce several tillers (Poethig, 1994).

A Negligible risk rating was assigned since most corn grown in the U.S. is dent and non-dent varieties that regenerate would only produce propagules if damage occurs relatively early in development. However, under certain circumstances, the risk rating could be Very High.

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**Regeneration – Certainty documentation**
GE Information:
Overall, the weight of evidence supports a certainty rating of Moderate. The certainty rating remains unchanged from the baseline since there is no plausible risk hypothesis that the gat trait has changed the regenerative ability of corn.

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Baseline Information:
Nielsen, 2003- High reliability; High applicability
Poethig, 1997 - High reliability; Moderate applicability.

Based on the references, common knowledge, and the variation in tillering ability among different varieties, and because corn can tolerate mutilation under some circumstances, a Moderate certainty rating is assigned.

(B12) Flood or drought tolerance

<table>
<thead>
<tr>
<th>Baseline risk</th>
<th>GE risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate</td>
<td>Moderate</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Baseline certainty</th>
<th>GE certainty</th>
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</thead>
<tbody>
<tr>
<td>High</td>
<td>High</td>
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</tbody>
</table>

(B12) Flood or drought tolerance– Risk documentation

GE Information:
There is no change in the GE risk rating from the baseline risk rating of Moderate.

Flood and drought tolerance were not specifically tested in the Pioneer petition (2007) but were just observed as part of the field trials data. In the development of Event 98140, the corn was observed for unexpected differences in responses to abiotic stress (e.g., drought, excess moisture, temperature extremes, etc.). Pioneer (2007) stated that these monthly observations were qualitative and opportunistic, and indicated that 98140 corn and near-isoline controls were similar with respect to their response to abiotic stress.

Corn has a general inability to grow without intentional human assistance (OGTR 2008), it is not likely that the GAT trait would alter the moderate rating of corn surviving drought. Glyphosate tolerant corn has been commercially cultivated since 1997 with no reports of altered flood or drought tolerance.

There is no change in the GE risk rating from the baseline risk rating.

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Baseline Information:
The major stress caused by flooding is lack of oxygen needed for the root system to function properly (Olson/Sander, 1988). "When plants reach the six- to eight-leaf stage, they can tolerate a week or more of standing water" (Nafziger, 2014). Saturated soils inhibit root growth, leaf area expansion, and photosynthesis because of the lack of oxygen and cooler soil temperatures. "Prior to V6, corn may survive only two to four days of totally saturated soils" (Butzen, 2014). The six to eight leaf stage is V5, and V6 is the 8 – 12 leaf stage. The different references have slightly different times of maximum susceptibility (prior to V5 versus prior to V6), but this difference is minor and may reflect cultivation of corn in different areas of the U.S

Drought stress is the major cause of yield reduction in corn (Wyffels, 2011; Clemson 2014; Pioneer, 2012, Shaw, 1988). "Stress during pollen shed and silking can cause more yield loss than almost any other period in the crop's development" (Nielsen, 2015). Drought later in grain fill causes the kernels not to fill completely due to loss of root function (Nafziger, 2014). "Through the late vegetative stage corn is fairly tolerant of dry soils, and mild drought and can be beneficial because roots generally grow downward more strongly as surface soils dry" (Nafziger, 2014). High temperatures during pollination can cause damage and reduce yield if plants are also under drought stress (Clemson, 2014). During peak water use (which includes the critical silking to milk stage), yield loss due to water stress is substantial and estimated at 6-8% per day of stress (Farahani and Smith, 2014). "Stressed plants are also often more susceptible to diseases, so drought stress or poor drainage should be avoided" (Cartwright et al., 2015).
Corn can survive and reproduce (albeit with a reduction in reproductive capacity) under intermittent drought/flooding, but prolonged drought/flooding has severe detrimental effects on growth and reproduction. Therefore, a rating of Moderate is appropriate.

(B12) Flood or drought tolerance – Certainty documentation

**GE information**:
Overall, the weight of evidence supports a certainty rating of High. The certainty rating remains unchanged from the baseline since there is no plausible risk hypothesis that the *gat* trait will affect this corns ability to tolerate flood or drought.

This certainty rating is based off the reliability and applicability ratings for one primary source (Pioneer 2007), one secondary source (OGTR 2008) and the fact that GAT and conventional corn have similar agronomic properties.

The reliability and applicability ratings for the sources are as follows: Pioneer petition (High and High, respectively); and one Australian government OGTR report (High and High, respectively).

Baseline Information:
- Butzen, 2014: Moderate reliability; Moderate applicability
- Cartwright *et al.*, 2015: High reliability; High applicability
- Clemson, 2014: Moderate reliability; Moderate applicability
- Farahani and Smith 2014: Moderate reliability; Moderate applicability
- Nafziger, 2014: High reliability; High applicability
- Nielsen, 2015: Low reliability; High applicability
- Pioneer, 2012: Moderate reliability; High applicability
- Shaw, 1988: High reliability; Moderate applicability
- Wyfflels, 2011: Moderate reliability; High applicability

A High certainty rating is assigned because the references all agree with each other even though there are no sources that address non-human intervention areas.

(B13) Tolerance to poor soils

<table>
<thead>
<tr>
<th>Baseline risk</th>
<th>Negligible</th>
<th>GE risk</th>
<th>Negligible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline certainty</td>
<td>Moderate</td>
<td>GE certainty</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

(B13) Tolerance to poor soils – Risk documentation

**GE information**:
There is no change in the GE risk rating from the baseline risk of Negligible for tolerance of corn to poor soil. Tolerance to poor soils was not tested in the Pioneer petition (2007) for the GAT protein.

There is no plausible mechanism by which corn with the GAT trait would alter the tolerance level of corn to poor soils, and therefore the GE risk rating is unchanged from the Negligible baseline risk rating.

Pioneer (2007) did not assess soil attributes such as the rate of respiration, the rate of nitrogen transformation and the rate of decomposition of organic matter. All field trials were performed under diverse environmental and growing conditions and using agronomic practices representative of maize production in North America. Information about differences in tolerance to poor soils was not presented in the petition, this does relate to
the growing practices for corn in the US.

No evidence, in the Pioneer (2007) petition or in the literature, was found to support that the \textit{gat}-gene (resistance to glyphosate) would alter the tolerance to poor soils in corn, and there is no plausible risk hypothesis to support this.

Furthermore, based upon the Baseline information below and the common observation that corn possesses a reduced ability to establish and reproduce in poor soils (OGTR 2008), there is no change expected that would alter the Negligible risk rating to tolerance of corn to poor soil.

Baseline information:
Corn likes rich soil with good drainage (Ross \textit{et al}., 2015; National Gardening Assoc., 2014). The ideal soil for corn is a loamy sand or sandy loam that stays moist, without being too wet (National Gardening Assoc., 2014; New Hampshire University, 2001). As a general guide, plant early corn in light soil (sand or loam) and late corn in heavier soil (silt, clay) when there is an option (New Hampshire University, 2001). Maize is not very tolerant of saline soils (OGTR, 2008). Corn can grow on a wide range of soils with different physical and chemical properties. However, management techniques and nutrient additions tuned to the particular soil characteristics are used to obtain high yields (Olson and Sander, 1988). A study in Kenya found that the effects of soil and crop management on maize in poor soils in Kenya correlate low yields and low plant vigor to poor soils where growing practices do not include the use of fertilizers (Tittonell \textit{et al}., 2008). No references were found that says that corn can grow in poor soils and survive, and cultivated fields generally need applied fertilizers (CABI, 2012; CIFA, 2014). Therefore, a Negligible risk is assigned.

(B13) Tolerance to poor soils– Certainty documentation

GE information: Overall, the weight of evidence supports a certainty rating of \textit{Moderate}.

This certainty rating is based off the reliability and applicability ratings for one primary source (Pioneer 2007) and one secondary source (OGTR 2008).

The reliability and applicability ratings for the sources are as follows: Pioneer petition (Moderate and Negligible, respectively); and one Australian government OGTR report (High and Low, respectively).

Based upon the Baseline information there is no plausible risk hypothesis that would alter the Moderate certainty rating to tolerance of corn to poor soil.

Baseline information:
CABI, 2012- Moderate reliability; High applicability
CIFA, 2014- High reliability; High applicability
National Gardening Assoc., 2014- Moderate reliability; High applicability
New Hampshire, 2001- Moderate reliability; Low applicability
OGTR, 2008-High reliability; Low applicability
Olson/Sander, 1988- High reliability; Low applicability
Ross \textit{et al}., 2015- High reliability; High applicability
Tittonell \textit{et al}., 2008 – Very High reliability, High applicability

Sources were good only for cultivated corn. They were included to show how corn needs human intervention.
(as discussed in question B01). There were no sources that addressed corn growing without intentional human assistance. A Moderate certainty rating is being given because there are no sources that address soil tolerance in non-human intervention areas.

**B14) Cold tolerance**

<table>
<thead>
<tr>
<th>Baseline risk</th>
<th>GE risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate</td>
<td>Moderate</td>
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</table>

<table>
<thead>
<tr>
<th>Baseline certainty</th>
<th>GE certainty</th>
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</thead>
<tbody>
<tr>
<td>High</td>
<td>High</td>
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</tbody>
</table>

**B14) Cold tolerance – Risk documentation**

**GE information:**

There is no change in the GE risk rating from the baseline risk of **Moderate** in corn to cold tolerance.

The Pioneer petition (2007) did not address cold tolerance. The cold germination tests performed as presented in the petitions (Table 10) are not applicable for the rating for cold tolerance since the evaluations did not go beyond the germination stage.

Furthermore, the risk reasoning is based off of the references used to support the Baseline risk documentation. No new evidence or information was found that the engineered GAT trait would be any different from the baseline risk documentation.

**Baseline Information:**

Cold injury damages leaves at temperatures in the low 40s or upper 30s Fahrenheit, and photosynthesis can be reduced even if the only symptom is a slight loss of leaf color (Nafziger, 2014). The growing point region of a corn plant remains below ground until about the 5-leaf collar stage and, thus, is reasonably protected from the effects of aboveground frost (Purdue, 2002, Shaw, 1988). "Consequently, the effects of “simple” frost damage to corn are usually minor and limited to death of aboveground plant parts. Corn can easily recover from this type of damage early in its development and suffer no yield loss whatsoever" (Purdue, 2002, Shaw, 1988).

Growth decreases once temperature drops to about 41°F and prolonged cold temperatures at the seedling stage (soil temperatures to below freezing two inches below the surface) may kill corn" (Clemson, 2014, Shaw, 1988). Extended low temperatures at seedling stage that reduce the soil temperatures to below freezing two inches below the surface may kill corn but brief periods of temperatures between 32 and 28°F have very little effect on corn (Clemson, 2014, Shaw, 1988). Lethal cold temperatures for corn and soybean are those at or below 28°F (Purdue University, 2002, Shaw, 1988). Based on the references which say corn will slow its growth below 41°F, die at 28°F, but survive short periods of low temperatures, a Moderate risk rating is given.

**B14) Cold tolerance – Certainty documentation**

**GE information:**

Overall, the weight of evidence supports a certainty rating of **High**.

This certainty rating is based off the reliability and applicability ratings for one primary source (Pioneer 2007) and the Baseline risk documentation.

The reliability and applicability ratings for the one source is as follows: Pioneer petition (High and High, respectively).

-----------------------------------------------

**Baseline information:**

Clemson, 2014- Moderate reliability; Moderate applicability

Nafziger, 2014- Very High reliability; High applicability
Based on the references found on cold temperatures and the absence of conflicting reports, a High certainty rating is assigned even though there are no sources that address non-human intervention areas. A very high rating was not given because some of the references were not primary references or highly supported secondary references.

(B15) Biotic stress tolerance

<table>
<thead>
<tr>
<th>Baseline risk</th>
<th>GE risk</th>
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</thead>
<tbody>
<tr>
<td>Moderate</td>
<td>Moderate</td>
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</tbody>
</table>

(B15) Biotic stress tolerance – Risk documentation

**GE Information:**

Based on the *gat* gene (glyphosate -herbicide tolerance ) in corn varieties, there is no change expected that would alter the Moderate risk rating to biotic stress tolerance.

Pioneer (2007) did not assess the agronomic potential of ear drop in corn. Pioneer (2007) did report plant/ear height and yield (Tables 11-14) and noted no change when compared to near-isolines. Furthermore, Pioneer’s petition (2007) Appendix 5 (Table 1) shows the insect stressor categories in the field sites and years assessed and Appendix 5 (Table 2) indicates the diseases categories evaluated in field sites and the years assessed. However, no significant differences between the glyphosate resistant line and comparators in insect and disease susceptibility were observed in evaluations of plant diseases or in insect pests in field trial sites during the years assessed, 2005-2007. No differences between the engineered plant and the non-transgenic control were observed for disease occurrence or severity and response to insect pressure. (Pioneer 2007)

The rating is based upon the Pioneer petition (2007), and the USDA-APHIS (2009) assessment.

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**Baseline information:**

Biotic stress can effect corn grain directly and indirectly. Two examples of direct effects on corn yield are ear rot and ear drop diseases. Some indirect effects are a reduction of the "factory" size such as plant stunting or a reduction in "factory" output such as leaf diseases (Nielson, 2002). Across 22 states and Ontario, diseases caused an overall estimated 10.9 percent loss — or more than 1.3 billion bushels with the largest culprit being *Fusarium* stalk rot with more than 124 million bushels lost (Purdue, 2014). Corn diseases are important yield-limiting factors in many production areas of the U.S (Cartwright *et al.*, 2015). Corn has resistance to some diseases, depending on variety (Wisser, 2011, Balint-Kurti and Johal, 2009). Maize is most susceptible to damage by insects during the establishment phase when soil insects can cause up to 30% losses and necessitate replanting of the crop, and from tasselling to harvest (O’Gara, 2007).

With corn yield being decreased by as much as 30% by insects and almost 11% by diseases, a Moderate risk rating is assigned.

(B15) Biotic stress tolerance – Certainty documentation

**GE Information:**

Overall, the weight of evidence supports a certainty rating of High.

This certainty rating is based off the reliability and applicability ratings for one primary sources (Pioneer 2007) and one secondary source (USDA-APHIS 2009).

The reliability and applicability ratings for the source is as follows: Pioneer petition (Very high and high,
respectively); and the USDA-APHIS (2009) (Moderate and Moderate, respectively).

Baseline information:
Balint-Kurti and Johal, 2009- Very High reliability; High applicability
Nielsen, 2002- High reliability; High applicability
O’Gara, 2007- High reliability; Moderate applicability
Purdue, 2014- Moderate reliability; High applicability
Cartwright et al., 2015- High reliability; Very High applicability
Wisser, 2011- Very High reliability; High applicability

No conflicting references were found. Based on these references, a High certainty rating is given.

(B16) Other biology weediness traits

<table>
<thead>
<tr>
<th>Baseline risk</th>
<th>GE risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negligible</td>
<td>Negligible</td>
</tr>
</tbody>
</table>

(B16) Other biology weediness traits – Risk documentation

GE and Baseline information:
None

(B16) Other biology weediness traits – Certainty documentation

GE and Baseline information:
None

Biology risk summary

GE Information
Based on the gat gene (glyphosate -herbicide tolerance ) in corn, there are no changes in the weed risk ratings of corn.

Baseline Information:
Corn poses a Negligible biology risk. Corn has been cultivated for thousands of years and the domestication of corn has made it completely dependent on human assistance for survival. Corn does not shatter and thus the spread of corn seed is dependent on human intervention although unclean farm equipment can transfer some corn seed locally. Corn seed lacks dormancy beyond a year and regeneration is limited to plants damaged early in the season that have already produced tillers. Corn’s ability to occasionally grow in uncultivated fields and by roadsides and to volunteer in subsequent cultivated crops suggests it may have a minor ability to establish in existing vegetation but when a plant is found outside a cultivated field it cannot sustain itself or reproduce without human assistance.

Corn has some tolerance, albeit with a reduction in reproductive capacity, to stresses such as intermittent drought/flooding, short periods of low temperatures and occasional shade.

Biology certainty summary

GE Information:
There are no changes expected that would alter the certainty rating of the GAT WRA relative to the non-GE baseline corn WRA.

The Biology certainty remains Very High, the same as the baseline. The same major sources of uncertainty
For many of the traits in the WRA there was no plausible risk hypothesis upon which the gat- gene in corn would affect the risk being assessed, the data in the Pioneer petition (2007) either supported the baseline WRA or no new data was generated to address it or no other literature was found. Where data did exist, it had little or no impact on the certainty rating compared to the baseline.

Baseline Information:
Certainty for biology risk in corn is very high overall. Certainty was moderate for flood/drought tolerance, tolerance to poor soils, and ability to establish due to the moderate applicability or reliability of several references and the lack of references that address tolerance outside of cultivation.

Weed risk – Impact (9 questions)

(I01) Agriculture yield

<table>
<thead>
<tr>
<th>Baseline risk</th>
<th>Negligible</th>
<th>GE risk</th>
<th>Negligible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline certainty</td>
<td>Very high</td>
<td>GE certainty</td>
<td>Very high</td>
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</table>

GE Information:
There is no change in the GE risk rating from the baseline rating of Negligible for agriculture yield.

The effect of corn with the GAT trait on the yield of other agricultural plants was not tested by Pioneer (2007).

However, apart from the GAT-herbicide tolerance benefits, corn containing the gat-gene are agronomically equivalent to their non-transgenic counterparts (Pioneer 2007).

Corn containing the gat-gene does not change the facts that:
1) Corn does not establish outside of agricultural fields without human assistance (see B03: Ability to Establish).
2) Corn has limited ability to move beyond field edges except small amounts in or on farm equipment or dispersal by small animals (see B09: Propagule dispersal).
3) Corn does not generally volunteer for more than one growing season after it is intentionally grown (see B01: Current weed and invasive status).

Therefore there should be no significant reduction in yield of other agricultural plants and no change from the baseline.

Baseline Information:
There are no reports of corn acting as a weed to reduce crop yields, other than as volunteer corn in subsequent crops. Volunteer corn is not considered in this WRA. Therefore, a Negligible risk rating was given.

(I01) Agriculture yield – Certainty documentation

GE Information:
Overall, the weight of evidence supports a certainty rating of Very High for agriculture yield. There is no change in the GE certainty rating from the baseline certainty.

This certainty rating is based off the reliability and applicability ratings for one primary source (Pioneer 2007).
The reliability and applicability ratings for the source is as follows: (Pioneer, Very High and Very High, respectively).

------------------------------------------------------------------------

**Baseline Information:**
Because corn does not grow outside of cultivated fields and because it is so widely cultivated and studied, a Very High certainty rating was given.

**I02) Agriculture quality**

<table>
<thead>
<tr>
<th>Baseline risk</th>
<th>Negligible</th>
<th>GE risk</th>
<th>Negligible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline certainty</td>
<td>Very high</td>
<td>GE certainty</td>
<td>Very high</td>
</tr>
</tbody>
</table>

**I02) Agriculture quality – Risk documentation**

**GE Information:**
There is no change in the GAT corn risk rating from the baseline rating of Negligible for agriculture quality.

Effect of yield on agricultural quality was not tested by Pioneer (2007). Even if seed or forage from the GAT corn is comingled with other agricultural plants or plant products, food and feed safety have been evaluated (EFSA 2013; FDA 2008; and FSANZ 2010).

Corn containing the GAT protein does not change the facts that:
1) Corn does not establish outside of agricultural fields without human assistance (see B03: Ability to Establish).
2) Corn has limited ability to move beyond field edges except small amounts in or on farm equipment or dispersal by small animals (see B09: Propagule dispersal).
3) Corn does not generally volunteer for more than one growing season after it is intentionally grown (see B01: Current weed and invasive status).

Therefore there should be no significant reduction in agricultural quality of other agricultural plants and no change from the baseline.

------------------------------------------------------------------------

**Baseline Information:**
There are no reports of corn acting as a weed to reduce crop quality, other than as volunteer corn in subsequent crops. Volunteer corn is not considered in this WRA. Therefore, a Negligible risk rating was given.

**I02) Agriculture quality – Certainty documentation**

**GE Information:**
Overall, the weight of evidence supports a certainty rating of Very High for agriculture quality. There is no change in the GE certainty rating from the baseline certainty evaluation.

The data submitted by Pioneer to EFSA, FDA and FSANZ support the certainty rating. This certainty rating is based off the reliability and applicability ratings for three secondary source.

The reliability and applicability ratings for the sources are as follows: EFSA (2013, High and Very High, respectively); FDA (2008, High and Very High, respectively); and FSANZ (2008, High and Very High, respectively).

------------------------------------------------------------------------

**Baseline Information:**
Because corn does not grow outside of cultivated fields and because it is so widely cultivated and studied, a Very High certainty rating was given.

<table>
<thead>
<tr>
<th>(I03) Harm to agriculturally important organisms</th>
<th>GE Information:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline risk</td>
<td>Negligible</td>
</tr>
<tr>
<td>Baseline certainty</td>
<td>Very high</td>
</tr>
</tbody>
</table>

Plant interactions with insect pests and diseases were evaluated as part of the Pioneer petition (2007, Table 13 and 14) for the GAT corn. Pioneer also presented a summary of the insect and disease ecological observations in Appendix 5. The observed severity of insect or disease stress for corn Event 98140 (GAT corn) compared to the control lines showed no qualitative differences. These results support the conclusion that the ecological interactions for 98140 corn were comparable to control corn lines with similar genetics or to conventional corn lines (Pioneer 2007; USDA-APHIS 2009).

As indicated in section (17), under Potential Unintended Phenotypes, Pioneer (2007) did analyze the acetylated amino acids in transgenic 98140 corn and control corn (Appendix 7, page 170 and Pioneer (2007) Addendum (Table A)). USDA-APHIS (2009), assessed the submitted data and concluded that the GAT corn line is comparable to the control line.

Pioneer (2007) did assess potential impact on non-target organisms, including beneficial organisms and threatened or endangered species (Section IX-J, p121). Pioneer (2007) also recorded the ecological observations (Appendix 5, Table 1 – 2; plant interactions with insects and diseases) for all the USDA-APHIS permitted field trials of 98140 corn during the 2005 and 2006 growing seasons. Pioneers assessment of these interactions (severity of insect or disease stress) on GAT corn compared to control lines detected no biologically significant differences nor qualitative differences. GAT corn is unlikely to harm non-target and beneficial organisms based upon the data from the Pioneer field observations (Pioneer 2007, Appendix 5, Table 1 – 2) and their chicken feeding study (Table 4, addendum and Section VIII-E, pg. 109 of the petition).

Moreover, Pioneer submitted to the Food and Drug Administration (FDA, 2008) an analysis of the composition of forage and grain from the transgenic 98140 corn and a near isogenic, non-transgenic control corn to assess whether the composition of the transgenic corn differs from that of non-transgenic control corn. Pioneer analyzed and measured corn forage for total amino acids, free amino acids, and five acetylated amino acids (NAA and NAG, N-acetylthreonine (NAThr), N-acetylserine (NASer), N-acetylglycine (NAGly) in corn grain. Pioneer concluded that there are no safety issues that would be expected to result from the potential increase in human and animal exposure to these amino acids. The FDA assessed the Pioneer GAT-herbicide tolerant 98140 corn line (FDA Biotechnology Notification File (BNF) 000111, 2008) and agreed with Pioneer that maize event 98140 is not materially different in composition, safety, or any other relevant parameter from maize now grown, marketed, and consumed in the U.S.

Food Standards Australia New Zealand (FSANZ, 2010) also concluded that any potential consumption of 98140 corn will not adversely affect the overall quality of protein/amino acid, vitamin, mineral, fat or fiber intakes of Australian and New Zealand populations. The European Food Safety Authority (EFSA, 2013), also came to the same conclusion.

The US EPA (2001) has determined that the bacterium from which the gat-gene was isolated, Bacillus licheniformis, was determined to present a low risk of adverse effects to human health and the environment.
Baseline Information:
No references were found that indicate corn can harm agriculturally important organisms. Therefore, a Negligible risk rating was given.

(I03) Harm to agriculturally important organisms – Certainty documentation

GE Information:
Overall, the weight of evidence supports a certainty rating of Very high.

The data submitted by Pioneer to both the USDA-APHIS (2009) and to the EFSA (2013), FDA (2008) and FSANZ (2010) support the certainty rating and one pesticide analysis and reregistration eligibility decision from US EPA (1993 and 2001). This certainty rating is based off the reliability and applicability ratings for four primary sources and four secondary sources.

The reliability and applicability ratings for the sources are as follows: the Pioneer petition (Very high and Very high, respectively); the USDA-APHIS (High and Very high, respectively); the US EPA (Very high and Very high, respectively); and the EFSA review (Very high and Very high, respectively); FDA (Very high and Very high, respectively); and FSANZ (Very high and Very high, respectively).

Baseline Information:
Exposure to agriculturally important organisms can happen in fields. Because corn is so widely cultivated and studied, a Very High certainty rating was given.

(I04) Competition with plants

Baseline risk Negligible GE risk Negligible
Baseline certainty Very high GE certainty Very high

(I04) Competition with plants – Risk documentation

GE Information:
There is no change in the GE risk rating from the baseline risk of Negligible for competition with plants.

There is no indication that corn containing the gat-gene possesses a selective advantage that would result in increased weediness (Pioneer 2007, USDA-APHIS 2009). As with other corn varieties, GAT corn lacks the ability to persist as a troublesome weed, and there would be no significant impact on current weed management practices for corn cultivation (Pioneer 2007, USDA-APHIS 2009). This rational is based on the absence of weedy traits in gat-gene maize (Pioneer 2007, USDA-APHIS 2009), and the common knowledge that corn is a poor competitor outside the agricultural environment (OGTR 2008). Even though corn containing the GAT-trait does increase the acetylation of certain amino acids (Pioneer (2007) Addendum (Table A); FDA (2008)), it would not increase the corns ability to compete with other plants since it was shown that the overall levels of NAAsp, NAGlu, NAThr, NASer and NAGly in 98140 corn grain are very low (FDA 2008).

As documented in this Weed Risk Assessment, evidence presented in the petition for nonregulated status to the USDA, assessment by the FDA (2008) and in the literature shows that GE plants expressing the GAT proteins do not exhibit new phenotypes other than herbicide resistance.

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Baseline Information:
Corn can not grow outside of cultivated fields except as sporadic escapes that do not persist (see B01 and B02 above). It does not compete with other plants outside of cultivation. Therefore, a negligible risk rating was given.

(I04) Competition with plants – Certainty documentation

GE Information:
Overall, the weight of evidence supports a certainty rating of Very high.

This certainty rating is based off the reliability and applicability ratings for one primary source (Pioneer 2007), and three secondary sources (USDA-APHIS 2009; FDA 2008; and OGTR 2008). The reliability and applicability ratings for the three sources are as follows: Pioneer petition (High and High, respectively); the USDA-APHIS (High and High, respectively); FDA (High and High, respectively); and the one Australian government OGTR report (High and High, respectively).

Baseline Information:
Because corn does not grow outside of cultivated fields and because it is so widely cultivated and studied, a Very High certainty rating was given.

(I05) Hydrology

Baseline risk Negligible GE risk Negligible
Baseline certainty High GE certainty High

(I05) Hydrology – Risk documentation

GE Information:
There is no change in the GE risk rating from the baseline risk of Negligible regarding hydrology.

A Negligible risk rating was assigned because there were no sources that found that the hydrology of natural areas is effected by the growth of corn. Within the Pioneer petition (2007), there was no data provided on root mass, total biomass, nor evapotranspiration, that could be used to evaluate hydrology. Furthermore, the acetylated amino acids that are higher in GAT-corn (Pioneer (2007) Addendum (Table A); FDA (2008)), would not affect the hydrology since there is no plausible hypothesis upon which to make this assumption.

Baseline Information:
Corn does not grow outside of cultivation except as sporadic escapes (See B01 and B02 above) and therefore does not have negative impacts on hydrology except as a result of the grower’s choice to cultivate it. No references about corn’s effect on the availability of water resources to future crops or other native plants was found. A Negligible risk rating was assigned because there were no sources that found that the hydrology of natural areas is effected by the growth of corn.

(I05) Hydrology – Certainty documentation

GE Information:
Overall, the weight of evidence supports a certainty rating of High. This certainty rating is based off the baseline information reliability and applicability ratings.

Baseline Information:
A High certainty rating was assigned based on the lack of non-agricultural hydrology references. Despite the fact that corn is extremely well studied, a very high rating was not used because of the possibility that the hydrology near a corn field might be effected, though no references addressing this possibility were found.

(I06) Soil quality

<table>
<thead>
<tr>
<th>Baseline risk</th>
<th>Negligible</th>
<th>GE risk</th>
<th>Negligible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline certainty</td>
<td>High</td>
<td>GE certainty</td>
<td>High</td>
</tr>
</tbody>
</table>

(I06) Soil quality – Risk documentation

GE Information:
There is no change in the GE risk rating from the baseline risk of Negligible regarding soil quality.

The rational for this is based on the absence of substantial differences in composition between gat-gene corn and conventional corn (Pioneer 2007; USDA-APHIS 2009). This absence of substantial compositional difference suggests that no nutrient uptake differences occur between corn containing the gat-gene and conventional corn (Pioneer 2007; USDA-APHIS 2009). The FDA (2008) reviewed the details of the compositional analyses as a component of the safety assessment of 98140 corn and agreed with Pioneers conclusion of no substantial differences between Event 98140 (GAT) corn and conventional corn. EFSA (2013) and FSANZ (2010) came to the same conclusions.

However, the use of glyphosate resistant corn allows for controlling weeds with a single broad-spectrum herbicide, or as a tank mix, and allows for no- or minimum- till corn cropping systems. Reducing tillage has the effect of reducing costs and effect on soil by reduction of equipment passes. No- or minimum- till maize cropping systems also have the added benefit of minimizing soil disturbance providing numerous advantages for soil and environmental quality (e.g., greater carbon sequestration, less soil and nutrient runoff, soil moisture retention, etc.).

The inserted gene for the GAT enzyme changes its affinity to bind glyphosate, and there is no plausible hypothesis upon which to assume that such changes would affect the plants ability to affect soil quality. GAT expression only affects the ability of the plant to survive if treated with glyphosate. The gat4621 enzyme in corn does increase the acetylation of certain amino acids (Pioneer (2007) Addendum (Table A); FDA (2008)), but it would not affect soil quality since the overall levels of NAAsp, NAGlu, NAThr, NASer and NAGly in 98140 corn grain are very low (FDA 2008).

Compositional analyses evaluating 83 different analytical components were assessed by Pioneer (2007) (summarized on page 110 of the Pioneer petition). Due to the absence of substantial compositional differences, there should be no change in the rate of decomposition in the soil.

Baseline Information:
The high yield of maize is a heavy drain on soil nutrients (OGTR, 2008; CABI, 2012; Salem, 2010). These effects are the result of the grower's deliberate choice to grow corn. Corn does not persist outside of managed agricultural systems, so there are no effects on soil outside of cultivated fields. Therefore a Negligible risk rating was assigned.

(I06) Soil quality – Certainty documentation

GE Information:
Overall, the weight of evidence supports a certainty rating of High.
This certainty rating is based off the reliability and applicability ratings for the baseline information ratings, as well as one primary source (Pioneer petition 2007), and four secondary sources (USDA-APHIS 2009; EFSA 2013; FDA 2008; and FSANZ 2010).

The reliability and applicability ratings for the Pioneer petition is (High and High, respectively); the USDA-APHIS (High and High, respectively); EFSA (High and High, respectively); FDA (High and High, respectively); and FSANZ (High and High, respectively).

Baseline Information:
Because corn does not grow outside of cultivated fields and because it is so widely cultivated and studied, a High certainty rating was given. Despite the fact that corn is extremely well studied, a very high rating was not used because of the possibility that soil quality near a corn field might be affected, though no references examining this possibility were found.

(I07) Fire regime

<table>
<thead>
<tr>
<th>Baseline risk</th>
<th>GE risk</th>
<th>Baseline certainty</th>
<th>GE certainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negligible</td>
<td>Negligible</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

(I07) Fire regime – Risk documentation

GE Information:
There is no change in the GE risk rating from the baseline risk Negligible in regards to fire regime. Fire regime was not assessed by the Pioneer petition (2007).

As discussed in Soil Quality (106, above), no changes in composition were observed that could affect fire load, e.g. significant increases in dry matter or oil content compared to controls.

The rational for this is based on the absence of substantial differences in composition between GAT-corn and conventional corn (Pioneer 2007, Section VIII; USDA-APHIS 2009), therefore there are no changes in the plants composition that could affect fire load. Fire regime was not tested by the Pioneer (2007).

Baseline Information:
Corn is not able to grow outside of cultivated fields and thus is not able to change the fire regime of non-cultivated ecosystems. The Negligible risk rating was given based on the familiarity with agricultural corn.

(I07) Fire regime – Certainty documentation

GE Information:
Overall, the weight of evidence supports a certainty rating of High. Therefore, there is no change in the GE certainty rating from the baseline certainty assessment.

This certainty rating is based off the reliability and applicability ratings for the baseline information ratings and from one primary source (Pioneer 2007) and one secondary source (USDA-APHIS 2009).

The reliability and applicability ratings for the sources are as follows: Pioneer petition (Moderate and Moderate, respectively); and the USDA-APHIS (2009; Moderate and Moderate, respectively).

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Baseline Information
Because corn does not grow outside of cultivated fields and because it is so widely cultivated and studied, a High certainty rating was given. Despite the fact that corn is extremely well studied, a very high rating was not used because of the possibility that the fire regime near a corn field might be affected, though no references examining this possibility were found.

<table>
<thead>
<tr>
<th>(I08) Physical obstructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline risk</td>
</tr>
<tr>
<td>GE risk</td>
</tr>
<tr>
<td>Baseline certainty</td>
</tr>
<tr>
<td>GE certainty</td>
</tr>
</tbody>
</table>

(I08) Physical obstructions – Risk documentation
GE Information:
There is no change in the GE risk rating from the baseline risk of Negligible to physical obstructions. Physical obstructions was not assessed by Pioneer (2007).

The data submitted in the petition substantiate there is no substantive change in the GE plants morphology or growth resulting from the GAT trait, and therefore there should be no physical obstruction (Pioneer 2007, Section VII, Table 11-14). Furthermore, conventional corn has the inability to establish in undisturbed environments (Gould 1968; Steinhardt et al. 2002; OECD 2003). The data submitted for gat do not indicate that hybrids derived from modified corn lines would be any more competitive or vigorous in their ability to germinate or establish in different environments or reproduce or have other characteristics that would increase their capacity to compete or persist as a weed (USDA-APHIS 2009).

Moreover, based upon (B03, Ability to establish), the risk is considered low. Glyphosate tolerant corn has been commercially cultivated since 1997 with no reports of causing physical obstructions.

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Baseline Information:
While a corn field may be crowded and tall making human or vehicular movement difficult, it does not naturally grow in dense thickets or otherwise cause physical obstruction. The Negligible risk rating was given based on the familiarity with agricultural corn.

(I08) Physical obstructions – Certainty documentation
GE Information:
Overall, the weight of evidence supports a certainty rating of Very High. There is no change in the GE certainty rating from the baseline certainty for physical obstructions.

This certainty rating is based off the reliability and applicability ratings for the baseline information ratings and from one primary source (Pioneer 2007) and four secondary sources (Gould 1968; Steinhardt et al. 2002; OECD 2003; USDA-APHIS 2009).

The reliability and applicability ratings for the sources are as follows: Pioneer petition (High and High, respectively); the USDA-APHIS (2009; High and High, respectively); and two published article (Gould 1968; and Steinhardt et al. 2002; High and Moderate, respectively).

-------------------------

Baseline Information:
Because no evidence was found that corn can be a physical obstruction and because it is so widely cultivated...
and studied, a Very High certainty rating was given.

(109) Other impact weediness traits

<table>
<thead>
<tr>
<th>Baseline risk</th>
<th>Negligible</th>
<th>GE risk</th>
<th>Negligible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline certainty</td>
<td>High</td>
<td>GE certainty</td>
<td>High</td>
</tr>
</tbody>
</table>

(109) Other impact weediness traits – Risk documentation

GE and Baseline information:
None

(109) Other impact weediness traits – Certainty documentation

GE and Baseline information:
Not applicable

Impact risk summary

GE Information:
There are no changes to any impact risk characteristics, and thus no change to the baseline impact risk rating of Negligible.

Baseline Information:
Corn is an agricultural crop that does not have a significant impact on cultivated or natural environments except as volunteer corn in subsequent crops; volunteer impacts are not considered in the WRA. Corn cannot grow outside of cultivated fields except as sporadic escapes that do not persist and have little to no ability to compete for resources.

Impact certainty summary

GE Information:
There are no changes to any impact certainty characteristics, and thus no change to the baseline impact certainty rating of Very high.

Baseline Information:
Certainty for impact risk in corn is very high.

Overall summary

Risk summary

GE Information:
Due to a lack of changes in risk characteristics, the gat gene does not increase the weed risk posed by conventional corn. The GE risk remains Negligible; the same as the baseline.

Baseline Information:
Zea mays ssp. mays poses a negligible weed risk based on this analysis. Domestication has made corn dependent on human assistance for survival. The occasional corn plants found outside a cultivated field do not form self-sustaining populations.

Certainty summary
**GE Information:**
The overall certainty for the risk assessment of corn with the inserted *gat*-gene remains **Very High**; the same as the baseline.

**Baseline Information:**
There is very high certainty associated with this risk assessment. Corn is well studied, well referenced and well known. The lack of research and quality references on some of the questions has minimal impact on the certainty ratings since familiarity with corn is so high.

**Bibliography**

**GE References Information:**


Food and Drug Administration (2008) Biotechnology Consultation Note to the File BNF No. 000111; GAT4621 and ZM-HRA proteins; Corn Transformation Event 98140; Unique Identifier DP-098140-6


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**Baseline References Information**


Freeman, Arna, Mullen et al. (n.d.) " By-plant prediction of corn forage biomass and nitrogen uptake at various sensing and plant height measures." Oklahoma State University, Department of plant and soil sciences,


Hufford et al. (2012a) “Teosinte as a model system for population and ecological genomics.” Trends in Genetics 28(9): 413-419.

Hufford et al. (2012b) "Comparative population genomics of maize domestication and improvement." Nature 489(7415): 191-197.


Tian, Stevens & Buckler (2009) "Tracking footprints of maize domestication and evidence for a massive selection event in the early domestication history of maize." PNAS, 106(Supplement 1); 9979-9986.


Wilkes (1977) “Hybridization of maize and teosinte, in Mexico and Guatemala and the improvement of maize.”


Yin, McClure, Jaja et al. (2011) "In-Season Prediction of Corn Yield Using Plant Height under Major Product (3); 923-929.

Young & Hart (1997) "Control of volunteer sethoxydim-resistant corn (Zea mays in soybean (Glycine max)."
Corn Production Maps and Charts

ArcGIS Retrieved October 2, 2015

<table>
<thead>
<tr>
<th>Country</th>
<th>Established-weed/cult</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>Yes-cult</td>
<td>Zea mays-1049N</td>
</tr>
<tr>
<td>Austria</td>
<td>No weed</td>
<td>Zea mays 1012N-1030N</td>
</tr>
<tr>
<td>Belgian</td>
<td>Yes casual</td>
<td>Zea mays 1012N-1030N</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>No weed/Yes casual</td>
<td>Zea mays 1012N-1030N; Zea mays 400-U</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>Yes cult</td>
<td>Zea mays-241-N</td>
</tr>
<tr>
<td>France</td>
<td>Yes</td>
<td>Zea mays 1012N-1030N</td>
</tr>
<tr>
<td>Greece</td>
<td>Yes; yes casual</td>
<td>Zea mays 1012N-1030N; Zea mays-1142U</td>
</tr>
<tr>
<td>Ireland</td>
<td>No weed; yes casual</td>
<td>Zea mays 1012N-1030N; Zea mays 519-N</td>
</tr>
<tr>
<td>Italy</td>
<td>No weed/Yes exotic&amp;cult</td>
<td>Zea mays 1012N-1030N; Zea mays-1265N; Zea mays-1149U; Zea mays-251-U</td>
</tr>
<tr>
<td>New Zealand</td>
<td>Yes casual; weedy?</td>
<td>Zea mays 919U; Zea mays 382-W</td>
</tr>
<tr>
<td>Country</td>
<td>Cultivation</td>
<td>Z. mays Range</td>
</tr>
<tr>
<td>---------------</td>
<td>-------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Portugal</td>
<td>Yes</td>
<td>1012N-1030N</td>
</tr>
<tr>
<td>Romania</td>
<td>Yes cult</td>
<td>1264N; 1154U</td>
</tr>
<tr>
<td>Spain</td>
<td>No-weed/yes</td>
<td>1012N-1030N; 1270U</td>
</tr>
<tr>
<td>Sweden</td>
<td>No weed</td>
<td>1012N-1030N</td>
</tr>
<tr>
<td>Taiwan</td>
<td>Yes</td>
<td>777N</td>
</tr>
<tr>
<td>Turkey</td>
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</tr>
<tr>
<td>Ukraine</td>
<td>No weed/Yes</td>
<td>1012N-1030N; 643uc_pdf</td>
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<td>United Kingdom</td>
<td>No weed/yes</td>
<td>1012N-1030N; 519-N</td>
</tr>
<tr>
<td>Randall reference #</td>
<td>Location covered</td>
<td>Notes</td>
</tr>
<tr>
<td>---------------------</td>
<td>------------------</td>
<td>-------</td>
</tr>
<tr>
<td>Zea mays 317-UZ</td>
<td>British Isles</td>
<td>Zea mays is not known in the wild, but was apparently domesticated about 7000 years ago. Can be a relic or an escape from cultivation, a casual plants whose seeds are found in bird-seed, pet food and food refuse on tips.</td>
</tr>
<tr>
<td>Zea mays 382-W</td>
<td>unknown</td>
<td>This is a chart with non-explained headers. Can't make a judgement.</td>
</tr>
<tr>
<td>Zea mays 400-U</td>
<td>Czech</td>
<td>Refers to Zea mays only being in human made habitats as a casual inhabitant.</td>
</tr>
<tr>
<td>Zea mays 519-N</td>
<td>Britian &amp; Ireland</td>
<td>Zea mays can be a relic or an escape from cultivation.</td>
</tr>
<tr>
<td>Zea mays 611-Z</td>
<td>unknown</td>
<td>This site is only for seed identification and seed containment.</td>
</tr>
<tr>
<td>Zea mays 777N</td>
<td>Taiwan</td>
<td>Zea mays is annual plant that can be used for forage.</td>
</tr>
<tr>
<td>Zea mays 812-UC</td>
<td>England</td>
<td>Zea mays is called non-native but never mentioned it as a weed.</td>
</tr>
<tr>
<td>Zea mays 819-N</td>
<td>Europe</td>
<td>Zea mays is alien to Europe or non-native. Never mentioned it as a weed.</td>
</tr>
<tr>
<td>Zea mays -907W</td>
<td>Germany</td>
<td>Zea mays is called non-native but never mentioned it as a weed.</td>
</tr>
<tr>
<td>Zea mays- 919U</td>
<td>New Zealand</td>
<td>Zea mays is called a casual inhabitant that passively regenerates only in the immediate vicinity of the cultivated parent plant.</td>
</tr>
<tr>
<td>Zea mays- 1154U</td>
<td>Romania</td>
<td>Zea mays is intentionally planted and can escape. &quot;an alien plant that reproduces occasionally in an area, but requires repetitive introductions for its persistence&quot;</td>
</tr>
<tr>
<td>Zea mays 1157CN</td>
<td>Galapagos</td>
<td>Zea mays was never mentioned.</td>
</tr>
<tr>
<td>Zea mays 1220-U</td>
<td>Belgium</td>
<td>Zea mays is in agriculture only.</td>
</tr>
<tr>
<td>Zea mays 1264N</td>
<td>Romania</td>
<td>Zea mays is deliberately grown and is a casual inhabitant.</td>
</tr>
<tr>
<td>Zea mays-241-N</td>
<td>Ethiopia</td>
<td>Zea mays mentioned as major crop not a weed</td>
</tr>
<tr>
<td>------------------</td>
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<td>---------------------------------------------</td>
</tr>
<tr>
<td>Zea mays-251-U</td>
<td>Italy</td>
<td>Zea mays is a casual, non-native inhabitant.</td>
</tr>
<tr>
<td>Zea mays-643uc</td>
<td>Ukraine</td>
<td>Zea mays can occasionally escape beyond cultivation but can't survive.</td>
</tr>
<tr>
<td>Zea mays-1049N</td>
<td>Australia</td>
<td>Zea mays is cultivated with an occasional roadside growth.</td>
</tr>
<tr>
<td>Zea mays-1142U</td>
<td>Greece</td>
<td>Zea mays is a casual/alien inhabitant.</td>
</tr>
<tr>
<td>Zea mays-1149U</td>
<td>Spain</td>
<td>Zea mays is a casual inhabitant from agriculture.</td>
</tr>
<tr>
<td>Zea mays-1265N</td>
<td>Italy</td>
<td>Zea mays is an exotic plant.</td>
</tr>
<tr>
<td>Zea mays-1270U</td>
<td>Spain</td>
<td>Zea mays is used in cultivation</td>
</tr>
</tbody>
</table>