Environmental Impacts of GM crops

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Look at 2 types of GM crops :

1. Herbicide tolerant crops:

Maize, soya, oilseed rape, sugar beet, (rice)
N and S America, Australia
Glyphosate (Roundup) + + +

2. Bt insect resistant crops

Maize, soya, cotton, rice
World wide including Spain, Portugal.
Lepidopteran pests +

Herbicide tolerant crops

GM : Broad spectrum herbicides: Glyphosate, glufosinate, 24D, STACKS & others being developed

Benefits

- **Reduced cost weed control**
- **Good control of most weeds**
- **Control of same/related species as crop**
- **Flexible timing**
- **Improved targeting**
- **Glyphosate replaces herbicides with poor environmental profile (toxicity, residues etc..)**
- **Less herbicide damage to crops**
- **Use of minimal/zero till systems > increased sequestering of C / reduced CO_2 emission**

Weed beet control

EC GMO Regulations

- **2001/18/EC:** Impacts of changes in cultivation, management and harvesting techniques associated with the GMO

Herbicide Effects

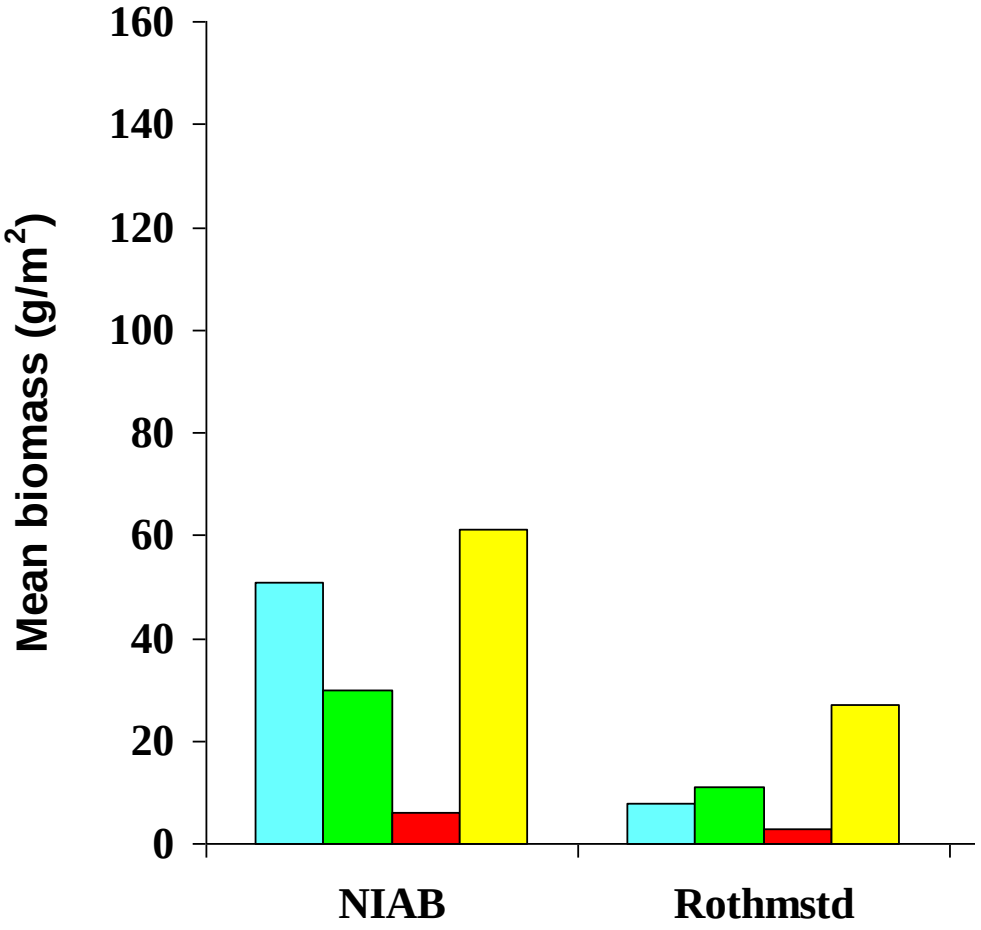
- Herbicides exclude most weed plants from crop and immediately surrounding area
- Crop contains little botanical diversity (species x number of plants)
- Base of food chain removed – effects food chain

→→ reduction in diversity (sp x n) of phytophagus spp (incl. fungi, bacteria, arthropods, inverts etc..)

→→ reduction in diversity of other species: predators, parasites etc…

* Main cause of reductions in farmland biodiversity in Europe (inc. farmland birds)

Rotation 1. Summer weed biomass assessment



IMI , Glufosinate, Glyphosate, Conventional

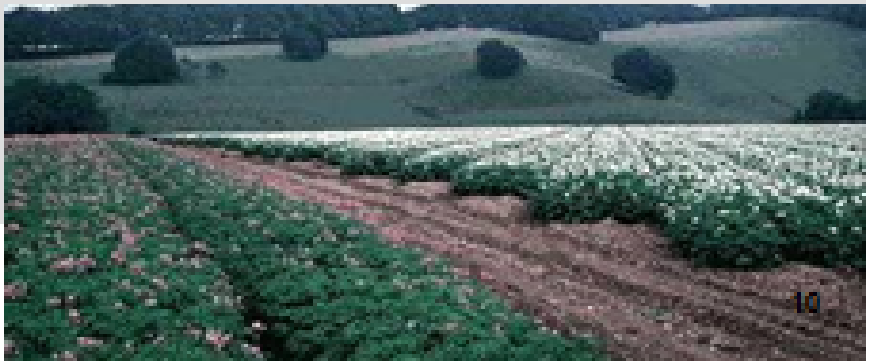
Potential Effects of HT herbicides

- Stressor – Broad Spectrum Herbicide > > continuous high level of weed control
  - Arable seedbank decline
  - Weed function – plant biodiversity and support of food webs
  - Impact on Field Margin vegetation
  - Effect – reduction in botanical diversity + local extinction from field of some plant species
  - Consequence : loss of primary element of food chain > loss through whole chains > loss of biodiversity

Environmental Risk Assessment

HT crops

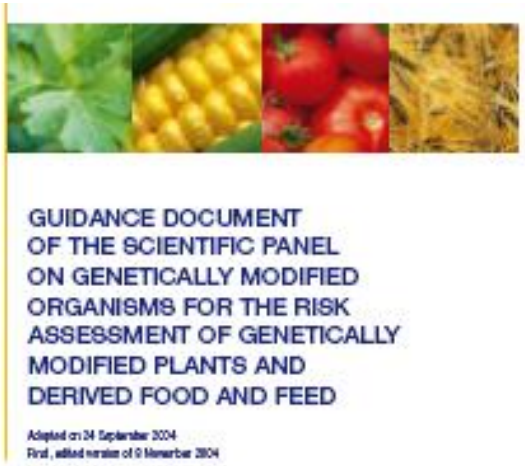
- Recognition that main Env impacts will come from the use/management of the herbicides
- Therefore ERA of GM plant + management



GMO Panel ERA Guidance Document

- **ERA include environmental impacts of the specific cultivation and management of GM plants.(cf conventional plants)**

- **ERA GM herbicide tolerant (HT) crops : evaluate the environmental consequences and impact of herbicide programmes associated with GMHT crops, (+ environmental impacts of GM plant itself).**



Revised in 2010

Resistant Weeds

- **Extensive and /or repeated use of same H →**
  - Development of resistant weeds
  - Shifts in weed populations to those that avoid the Herbicide.
  - Gene flow from crop to weeds e.g rice and beet

Weed Resistance to Glyphosate in USA

Management consequences:

- Increased use of glyphosate at higher doses
- Use of Herbicide mixtures with herbicides with poorer environmental profile

Environmental Effects:

- Greater Reduction in weed diversity (biomass x Spp.)
- Reduction in Biodiversity

ERA Guidance

Applicants describe plans to establish GMHT herbicide programmes that optimize weed management while maintaining adverse environmental impacts at or below current levels in both crop and adjacent non-crop environments. (e.g. field margins) **and prevent Weed Resistance development**

GM Insect Resistant Crops

Bacterial Toxins very specific to different orders of insects.

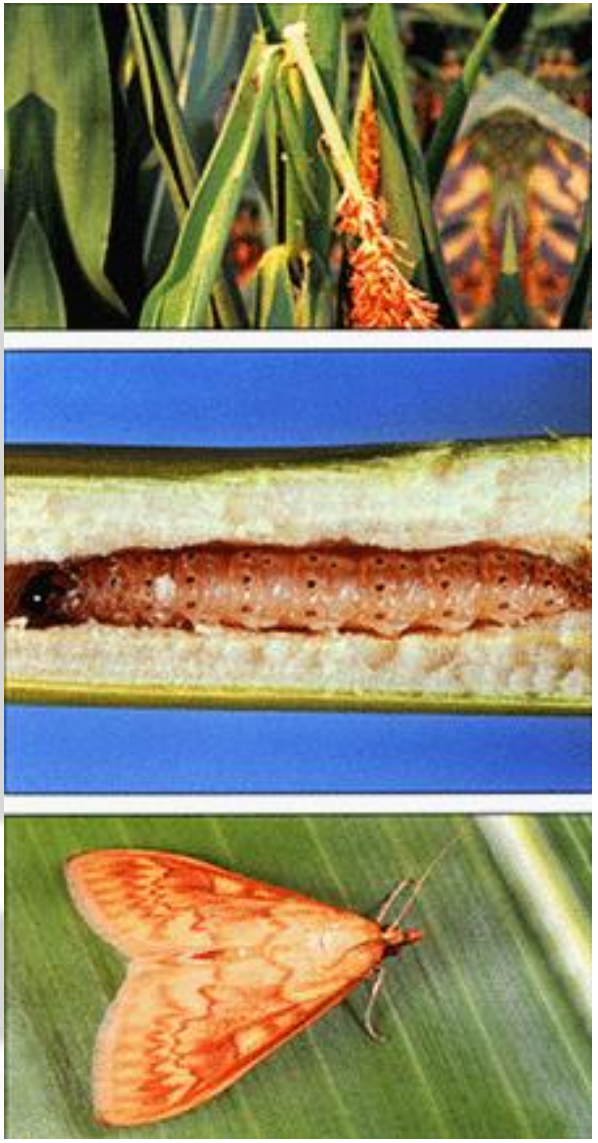
Originally developed as (organic) pesticides for control of certain leaf/stem/root eating insects

Bacterial toxin introduced into GM plants to give resistance . e.g. Maize, Cotton, Rice, potato

Cry1: Control Butterfly and Moth larvae

Cry 3: Beetles (e.g . Colorado Potato beetle, root worms)

Corn borer is a problem pest in S and E Europe and in many other countries e.g. Africa, China, N & S America.



RISK ASSESSMENT OF THE NON-TARGET EFFECTS OF BT MAIZE

- Maize MON810 is modified with a gene from *Bacillus thurigiensis* so that it expresses Cry1Ab insect toxin. **Approved for cultivation in EU**
- Grown in Spain and Portugal (CZ, Ro, SO, Ukr ?)
- Cry1Ab is toxic to **Lepidoptera** but **not** other insect orders
- Control two stem borer species ; *Ostrinia nubilalis* and Sesamia spp
- No other characters changed

Interactions between GM plant and non-target organisms

- Routes of exposure (leaves, roots, pollen…..)
- Potential impacts on Lepidoptera species

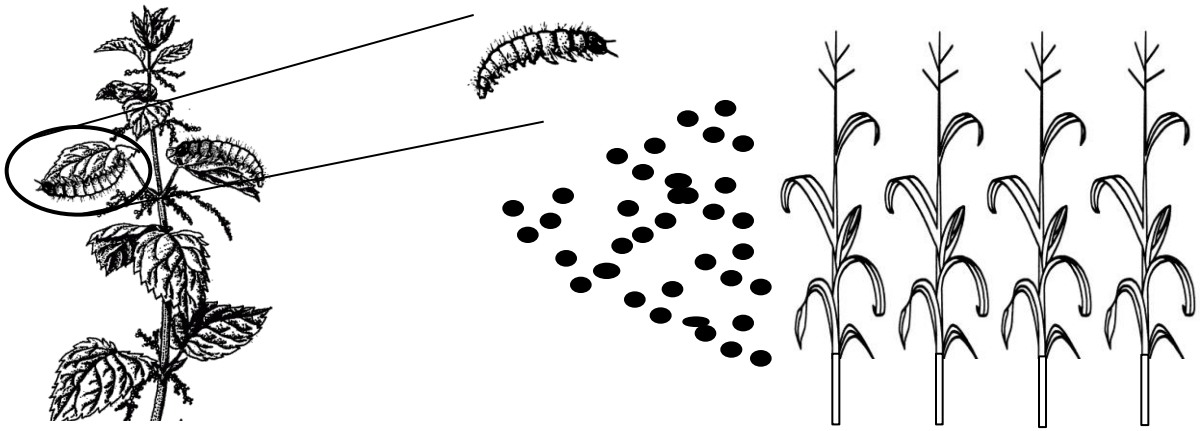
Only other Lepidoptera feeding on Maize in Europe is Army Worm = Spodoptera = pest = sensitive

But exposure of other Lepidoptera via pollen

The Problem

The pollen from GM *Bt* maize is deposited on other plants nearby or in the crop

Other Lepidoptera larvae may ingest toxic pollen while feeding on their host-plants in/near GM *Bt* maize fields



Bt-maize MON810 pollen is potentially toxic to lepidoptera larvae feeding on host plants near maize fields when pollen is being deposited

Classical studies of Monarch Butterfly in USA

Cry1Ab is toxic to larvae

Expressed in pollen

Pollen deposited on food plant (Milkweed) growing next to maize crops, when larvae present – so pollen ingested .

Study of toxicity of pollen X exposure indicated up to 3% population effect in Bt maize crop areas. This was considered acceptable …..

Toxicity to Lepidopteran species

The Peacock butterfly:
Inachis io
VERY SENSITIVE

The Red Admiral :
Vanessa atalanta
VERY SENSITIVE

The Diamond-backed moth pest:
Plutella xylostella
EXTREMELY SENSITIVE

Exposure parameters:

Maize field *C* hectares

density of host-plant = *e* per square metre within field: VERY FEW

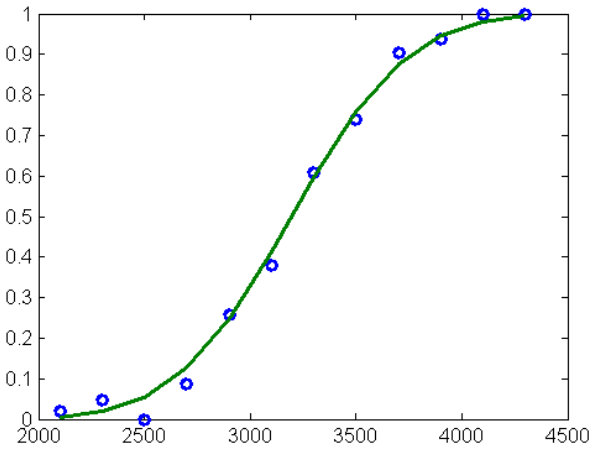
Average extent of field margin is *D* metres from edge of field

D

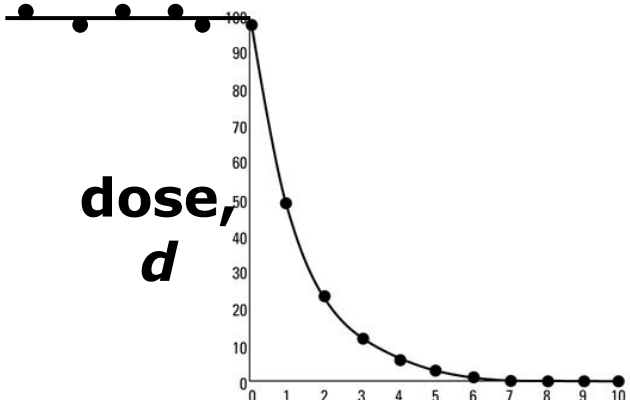
density of host-plant = *f* per square metre in field margin

Overview of Model

probability of mortality, *p*



dose, *d*

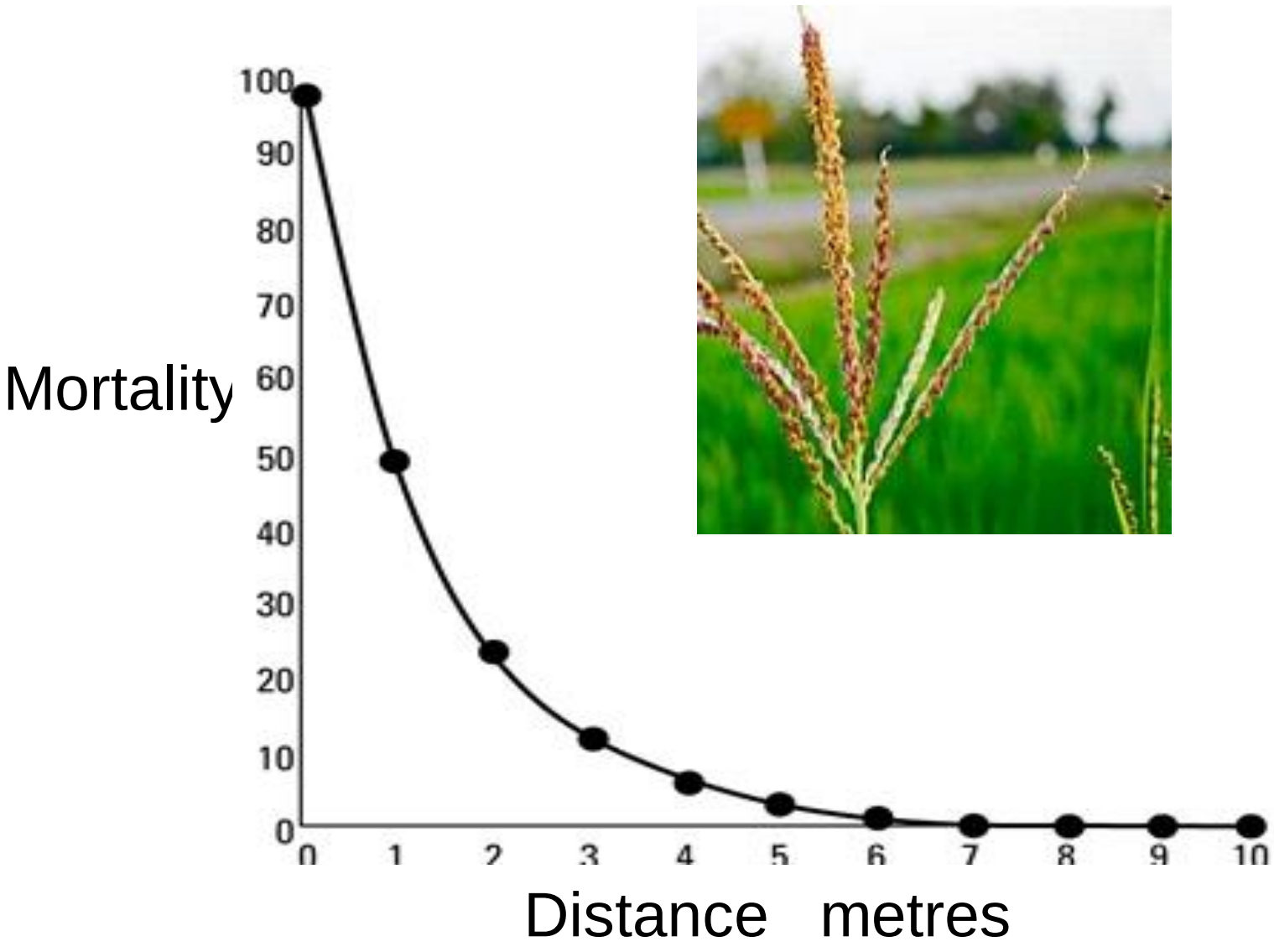


dose, *d*

distance from edge, *E*

$$p = f(d) \qquad d = g(E)$$

$$p = f[g(E)] = h(E)$$


Mortality
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
9
10
Distance metres

Results for MON810

Table 2. Estimated population mortality rates. (For the butterflies ıd median values exclude Spain.)

region	mortality		
	I. io	*V. atalanta*	*P. xylostella*
Bonn	2.95×10^{-5}	2.95×10^{-5}	6.11×10^{-5}
Oderbruch	5.03×10^{-5}	5.03×10^{-5}	6.16×10^{-5}
Aachen	1.68×10^{-4}	1.68×10^{-4}	6.16×10^{-6}
Berkatal	2.32×10^{-4}	2.32×10^{-4}	3.04×10^{-4}
Grebbin	6.36×10^{-4}	6.36×10^{-4}	7.69×10^{-4}
Upper Rhine Valley	4.40×10^{-4}	4.40×10^{-4}	2.55×10^{-3}
Tolna County	1.91×10^{-5}	9.57×10^{-6}	1.53×10^{-4}
Po Valley (central)	4.06×10^{-4}	3.55×10^{-4}	9.79×10^{-4}
Po Valley (coastal)	—	—	5.13×10^{-5}
Madrid	0	0	1.00×10^{-9}
Ebro Valley	0	0	2.30×10^{-8}
minimum over regions	1.91×10^{-5}	9.57×10^{-6}	1.00×10^{-9}
maximum over regions	6.36×10^{-4}	6.36×10^{-4}	2.55×10^{-3}
median over regions	2.00×10^{-4}	2.00×10^{-4}	2.29×10^{-4}

Perry, J.N. *et al*. (2010)
A mathematical model of
exposure of non-target Lepidoptera to *Bt*-maize pollen expressing Cry1Ab within Europe.
Proc. R. Soc. B, 277, 1417-1425.

Maize MON810 Conclusions :

Risk to non-target organisms

- **No Hazard to range of species tested**
- **EXCEPT to Lepidoptera**

Exposure and Risk very small (quantified by model): max 0.3% population effect

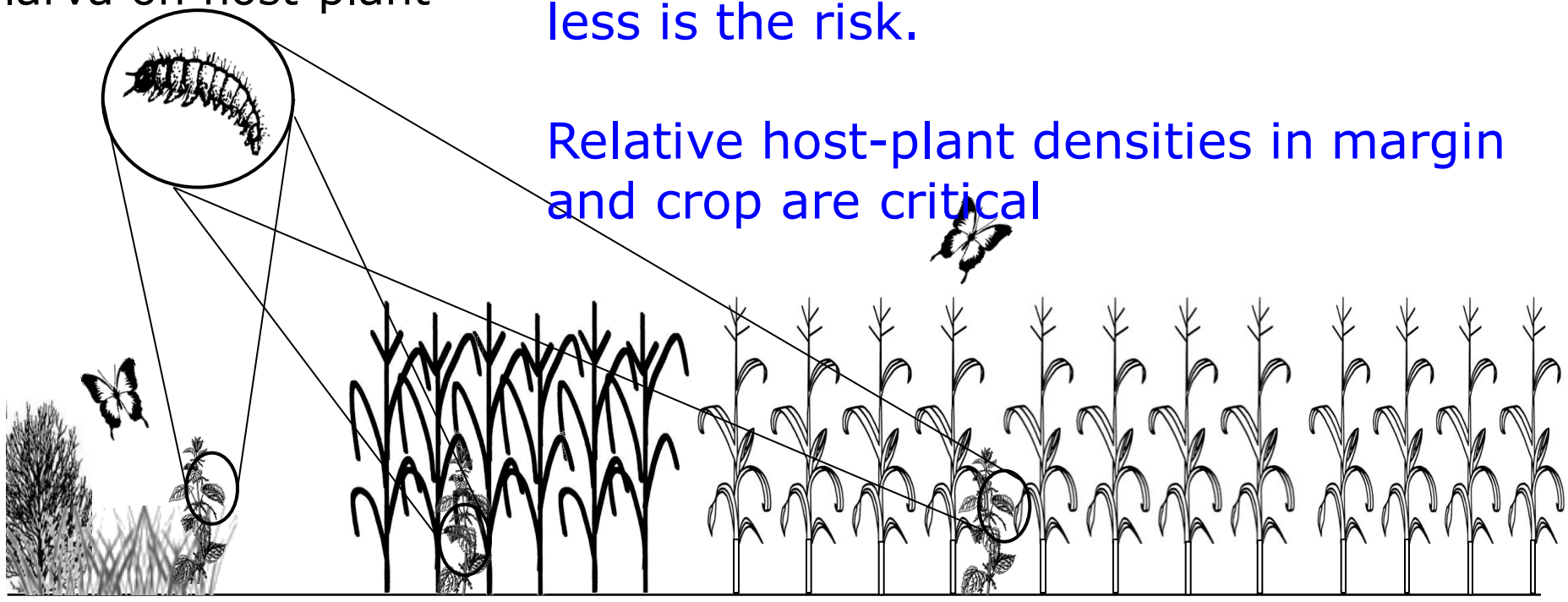
Is it acceptable ? What about other Lepidoptera species not tested…..?

Risk management considered

Risk Management measures

The greater the distance of a larva from a source of *Bt*-maize pollen the less is the risk.

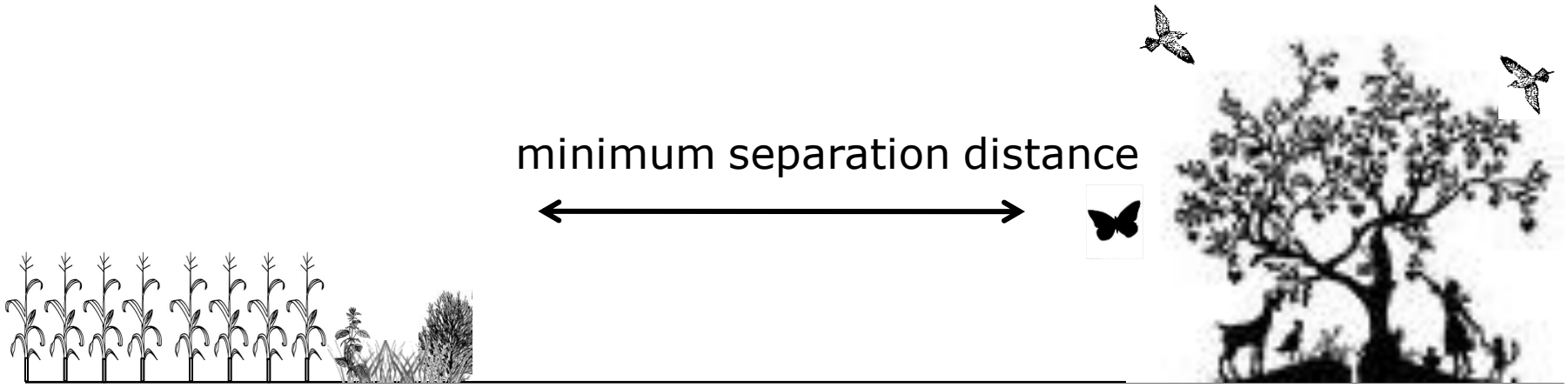
Relative host-plant densities in margin and crop are critical



margin non-*Bt*-maize crop *Bt*-maize crop

Planting non-*Bt* maize close to *Bt*-maize also refugia
To delay the evolution of resistance in corn borer

Possible Risk Management measures



Bt-maize crop

Separation distance ~40m

Protected area, e.g. nature reserve

Even for extremely sensitive species estimated mortalities are close to zero for separation distances ~40m

Conclusions HT and Bt crops

- **HT** : potential for additional harm from herbicides
  Needs careful management using IPM principles and unsprayed areas.

  Weed Resistance management required

- **Bt** : additional harmful effects unlikely but protection of sensitive species and areas may be required.

  Pest resistance management required

Thank you

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