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NO-TILLAGE AGRICULTURE AND GENETICALLY MODIFIED CROPS – PROBABLE IMPACTS ON AGRICULTURAL SOILS

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Introduction

In the past few years the cultivation of genetically modified crops (GM crops) has dramatically increased. In 2004 nearly 80 million hectares worldwide of GM crops have been cultivated. Corn (*Zea mays* L.), soybean (*Glycine max* (L.) MERR.) and cotton (*Gossypium* sp.) are the GM crops with the highest market penetration [BATES et al. 2005]. Currently the GM crops plants available on the market show two different traits:

1 – Plants, especially corn, generate toxins which are fatal to the insects of European corn borer (*Ostrinia nubilalis*) and other insects like corn root worm (*Diabrotica* sp.). A major agrochemical company (Monsanto) has achieved through genetic modification, that the toxic parts of toxin of some *Bacillus thuringiensis* subspecies have been incorporated into corn genome. It has to be stated that the size of toxin transfected into corn differs substantially from the size of toxin produced by *B. thuringiensis*. The newly synthesized corn toxin is just 35 k Dalton small, compared to the original toxin, which is 135 k Dalton large [PAGEL-WIEDER et al. 2004]. Most of the research on ecological behaviour of the toxin refers to the toxin of *Bacillus thuringiensis* subsp. *kurstaki,* which is commonly called the Bt toxin.

2 – The second trait enables the genetically modified crop, especially soybean, cotton and sugar-beet, to decompose enzymatically the herbicide Glyphosate (e.g. marketed as Round-up ®) and thus to detoxify it for the cultivated crop. The herbicide is still toxic to all other plants in the field.

The possible impacts of (1) the residues of cultivated crops and (2) the used pesticides Glyphosate as well as the Bt toxin of the GM crops on solid matter of the soil will be discussed in this paper. This study is based on our own research on the behaviour on Bt toxins [PAGEL-WIEDER et al. 2004] and on our investigations on the matter and nutrient balances of farming systems [AHL 2002] and on our practical experience of the Argentinean agriculture [CAPELETTI 2005].

Results and discussion

The no-tillage agriculture system

The system of zero tillage-agriculture (or synonyms as zero tillage, conservation tillage) has been propagated by parts of the scientific community, by policy makers and by the farmers themselves. Worldwide some 70 million hectares are under reduced tillage, either as no-tillage or mulching systems. The economic advantages are seen in less expenditure by less depreciation for the machinery in operation. The political motivation is to be seen in several soil protection acts, which should prevent soils from degradation by erosion, compaction, fading of soil organic matter etc. or even lead to some carbon sequestration [DERSCH, BÖHM 2001; JANZEN 2003]. By applying these management systems an enrichment of soil organic matter occurs in top layers and on the surface of soils. Soil erosion by water is reduced through better water infiltrability and by an increase in aggregate stability. The wheel-load bearing capacity of the soil surface is enhanced [BALL et al. 1997]. On the other hand, the new tillage system leads to an additional input of nutrients (nitrogen, potassium, phosphorus), and requires distinct attention to some crop diseases, e.g. lodging disease of wheat (*Pseudocercosporella*), *Rhizoctonia* spp., and on soybean charcoal rot (*Macrophomina phaseolina*) [VALLONE 1998; WRATHER et al. 1998; GILL et al. 2001].

Regarding the cycling of carbon compounds in the soil, reduced tillage systems enlarge the pool of easily decomposable plant debris. The physical, chemical protected and mineral-bound part of the soil organic matter pool is not affected [WATTEL-KOEKKOEK et al. 2003; SEVINK et al. 2005]. The accessibility and the intense mixing between microbes and readily composable compounds are reduced [JÖRGENSEN 1994].

Reaction of Glyphosate and Bt toxins in soils

Still much research elucidate the breakdown and turnover of the herbicide Glyphosate and on the different Bt-toxins produced by GM crops.

Glyphosate has the following chemical formula:

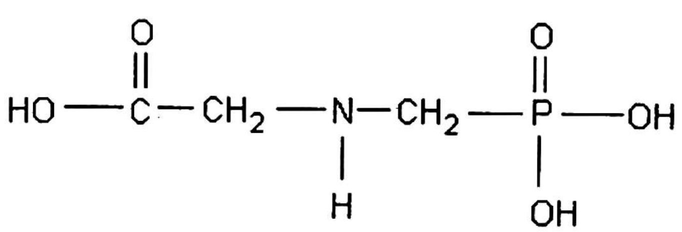

Fig. 1. N-(Phosphonomethyl) glycine (Glyphosate)
Rys. 1. Wzór chemiczny glyfosatu

The phosphate-group is the most important constituent in respect of the chemical behaviour of Glyphosate in soils. It is wellknown that phosphate-group containing molecules, like phytin or DNA, are bound very strongly to the iron-aquo-complexes in the soils. By this interaction the bioavailability of the molecule is reduced [FRANZ et al. 1997]. Nearly 25% of soil phosphorus occurs as phytin or as a salt of phytinic acid in the soil. Like the phosphorus acid the phytinic acid is bound to solid particles by bridging of calcium or iron cations [WILD 1988]. Furthermore, this amount of organic phosphate increases by non agricultural management systems as ley farming or permanent meadows. This enrichment of phosphate by no-tillage systems is the result of the missing intense contact of soil microorganisms and crop residues. On the contrast ploughing systems increase the bioavailability of the readily decomposable plant residues to the sessile microorganisms and therefore the turnover rates of phosphorus containing substances are higher under these management regimes.

One can expect that the Glyphosate is enriched in the soils, because similar as the phytin Glyphosate is bound onto the surface of amorphous iron hydroxides. Reactive sites on amorphous iron hydroxides can be found in all soils, however especially in Gleysols and/or in soils with a high aquic moisture regime as Inceptisols. During the course of a year some dry periods occur, resulting in an increase of the redox potential. This leads to formation of Fe^{3+} amorphous iron oxides, which are transferred into a more crystalline iron oxide and one could expect that the Glyphosate will become a bound residue, attached to the mineral matrice.

By 2002 almost half of Argentina's arable land (11.6 million hectares) were planted with soybean, almost all of it GM crops, compared with just 37,700 hectares of soybean in 1971. Soybean moved beyond the Pampas into more environmentally fragile areas, especially in the northern provinces. It is estimated that 150 million litres of Glyphosate were applied to soybean cultures in 2003, up from just 13.9 million litres in 1997. This increase is caused – besides the boost in the cultivated area with soybean – by the higher frequency of applicated Glyphosate, 2.3 applications versus 1.3 application in North America [BRANFORD 2004]. Roughly 13 litres of Glyphosate are sprayed on one hectare.

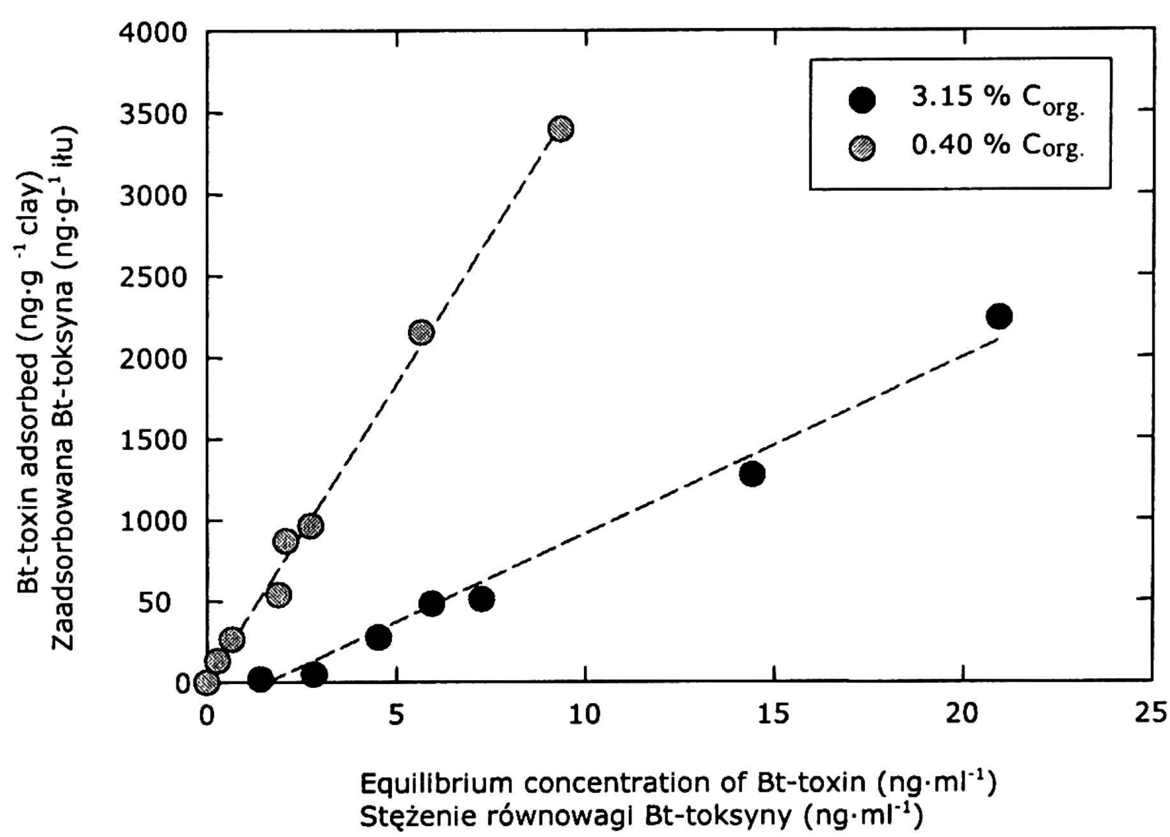

Fig. 2. Sorption isotherm of a Bt-toxin at two different horizons of a Luvic Chernozem; black circles – humose A horizon; light grey circles – cambic B horizon

Rys. 2. Izotermy sorpcji Bt-toksyny przez dwa poziomy czarnoziemu zdegradowanego; czarne kółka – poziom A próchniczny; jasnoszare kółka – poziom B cambic (brunatnienia)

Our own results show that the content of the organic carbon of the soil has a great influence on the physicochemical behaviour, i.e. the sorption of Bt toxin. As an example, Fig. 2 shows a Bt-toxin adsorption isotherm on two different horizons of a Luvic Chernozem [PAGEL-WIEDER et al. 2004].

Samples with lower content of organic carbon show a higher affinity towards the Bt toxin. We conclude that a shift towards systems of no-tillage might increase the capability of the sub-surface horizons (former part of the plough layer) to bind the Bt toxin. Thus within these horizons the Bt toxin content could be enhanced.

The main difference in chemical behaviour of the Bt toxin compared to the Glyphosate stems from the difference in size. The crop derived Bt toxin is roughly two hundred times larger then Glyphosate. The bioavailability and thus the persistence of the toxin in soils is closely connected to the size of biomolecule. This protein shows a high amount of reactive sides resulting from different side chains of the amino acids. This multitude of binding sides leads to a maximum desorption less than 5% of amount adsorbed. Additionally this minor rate of release might lead to an enrichment of the Bt toxins. It is stated that the bound Bt toxin still retains its insecticidal activity [SAXENA et al. 1999].

Conclusions

Quite recently companies are offering corn hybrids combining Glyphosate tolerance and European corn borer resistance <WWW.NETSEEDS.COM>. Therefore it can be expected that the amount of no-tillage management system will increase in the future. At the moment the policy makers are still resistant to the wide-spread use of GM crops. But due to economic pressure and globalization it is nearly sure that in the next decade these management tools will spread to European farmers. We expect that the combination of Glyphosate tolerance and Bt toxins expressed in one crop will have a severe influence on the quality of agricultural soils.

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Key words: no-tillage agriculture, genetically modified organism, Glyphosate, Bt toxin, Argentina

Summary

In recent years the increase in no-tillage agriculture has resulted in the increase of total herbicide Glyphosate. This is the consequences of breeding of Glyphosate resistant plant. Glyphosate (a P-containing compound) behaves like other P-components in the soil and therefore it is bound to soil Fe-hydroxides. This will result in the formation of bound residues and enrichment in the soil is very likely. The use of Bt toxin (a toxin directed mostly against the European Corn Borer) produced by genetically modified plants will lead to a change in composition of soil organic matter. The Bt toxins are proteins and bound to the

outer surface of soil mineral aggregates. They compete with the soil humic substances for binding sites. This results in a complex binding behaviour and the formation of bound residues as all other proteinaceous materials.

SIEW BEZPOŚREDNI I ROŚLINY GENETYCZNIE ZMODYFIKOWANE - MOŻLIWY WPŁYW NA GLEBY ROLNICZE

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Słowa kluczowe: siew bezpośredni, organizmy genetycznie zmodyfikowane, glyfosat, Bt-toksyny, Argentyna

Streszczenie

W ostatnich latach zwiększyła się powierzchnia gruntów, na których stosuje się siew bezpośredni (uprawę zerową), co spowodowało wzrost użycia herbicydu totalnego – glyfosatu. Zmiany te umożliwiła hodowla roślin odpornych na glyfosat (związek chemiczny zawierający fosfor). Preparat ten w glebie zachowuje się podobnie jak inne związki fosforu i jest wiązany przez wodorotlenki żelaza, stąd też prawdopodobne jest zwiększenie zawartości pozostałości tego związku w glebie.

Uprawa roślin genetycznie zmodyfikowanych wytwarzających Bt-toksynę (toksynę mającą na celu zwalczanie między innymi omacnicy prosowianki – *Ostrinia nubilalis*) będzie prowadzić do zmian składu glebowej materii organicznej. Bt-toksyny dostają się do gleby z rozkładających się resztek pożniwnych kukurydzy. Związki te są białkami, stąd też są wiązane przez zewnętrzne powierzchnie minerałów glebowych. Dlatego też rywalizują z glebowymi substancjami huminowymi o miejsca wiązań. Prowadzi to do złożonego mechanizmu sorpcji oraz powstawania pozostałości, tak jak w przypadku innych substancji białkowych.

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