Pollen dispersion of transgenic plants: remarks and conclusions

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Well my task is the same as for all the others - how do we actually cope with risk. No technology to be introduced in this world has ever been without risk. I don't want to go into details of how many misconceptions of risks we have had in the past, misconceptions which you could also call hysteria - and sometimes, as it turned out, with real and good reasons, but also valid concerns which popped up later. Some of these concerns were even predicted. There was a Swiss engineer, considered in his time to be somewhat crazy, who predicted that carcinogenic particles emerge from car tyre rubber. Nowadays we know that this is a risk. But he just assumed it - well he had his results, but he was not listened to. So we have every reason to conduct this risk assessment process and dialogue in a very serious way, to listen to each other. I was very glad that our chairman mentioned this at the outset. What we need is less proclamation and more listening.

Being an ecologist who really knows about complexity has practically no ways and means really to predict in the long term what will happen. So I am certainly a bit more uneasy about ecological issues related to transgenic plants and field trials than some other biologists. It is certainly true that within the biological community there are differing views about the risks. One thing I have learned in this risk assessment dialogue is that it is wrong to focus solely on transgenic plants. Indeed, I notice with some pleasure that we now have a ricochet, a backlash, in the risk assessment discussion to classical breeding methods too and to other phenomena within our ecosystems, e.g. invasive plants. We have to balance out these risks. Even so, we still have to bear in mind that moving transgenes across species and inserting them into other plants is a new kind of phenomenon.

We have every reason to be very careful, but we should also bear in mind that maize, which is an absolute monstrosity, has nothing to do with nature! I just can't understand why there are people saying: here are the artificial transgenic plants and there are our well beloved and much needed natural cultivars. This is just not the truth! It is probably based on four genes - the monstrosity of maize. It's a very simple system. Geneticists will soon be able to manipulate a wheat variety which is already highly manipulated and then must be called a monstrosity. It's the language which is giving us the perspective. Indeed, I call all cultivars genetically manipulated. Some have been manipulated with new techniques, others with crossing, selection, chemicals and radiation. Think about the 20,000 radiation experiments which were done to crops all over the world, many of them outside in the field. The genomes were bombarded - oilseed rape for instance - and people just looked at what was emerging in the field. This is Frankenstein, if you ask me - randomly bombarding with gamma radiation and then looking at what the mutants are. Strikingly enough - at least for an ecologist like me - I am still astounded that nothing happened. No worst case scenario appeared during these 20,000 experiments, thousands of which were in the open. So let's be a bit more reasonable about risk assessment as a whole. And I wonder what will happen if geneticists are able to transform wheat into a monstrosity, with a thick stem and a huge spike. Would we welcome that or would we be producing horrors in our midst? Would we welcome it as the Mayas did when within a few decades these plants emerged? They opened their hearts and their spirits to these plants, creating new goddesses and creating a new spirituality of maize. This is confirmed by historians of the Mayas.

What we face is the fact that thousands of field experiments with transgenic plants have already been done. And I remember one event in 1992 when the first delegation of Chinese geneticists came to Goslar and spoke about hundreds of thousands of hectares of transgenic plants being released in the fields of China. The community of risk assessment researchers was amazed. Two years later there took place the first risk assessment conference in China and there have been follow-ups. There are lots of risk assessment activities now going on there. But in the beginning they just released and nothing has happened up to now – well, actually we don't know. This knowledge gap is something which is of course still here and people say that after thousands of field experiments with nothing happening, we can merrily go ahead. However, this is naive.

You remember the first case of an escaped transgene. It was detected not only in 1996 and published in Nature - the Valhalla of science publications - it was also done years before and published in the Journal of American Botany, but nobody looked at it. It was among those thousands of small contributions. Nobody detected it. Risk perception in the science community - one should work with a good science historian and see how things turn out with the transgenes and their risk assessment. I could tell you so many contradictory stories about this.

But here oil seed rape with a herbicide tolerance gene outcrossed within the first generation. And that was actually predicted. Before that, Crawley made his experiments by showing from average values that the non-transgenic plants are a bit more competitive than the transgenic ones. But - and he was criticised for that in Nature - it is true and it might hold true for a long time. However, population geneticists and population ecologists know about the founder populations. They know that once in a thousand times something could happen to the chromosomes when they have their meiotic phase. Something could change. A mutation could happen. Crawley was criticised for that and he responded by agreeing that a few things had been overlooked and asking how we could arrive at a long term risk assessment. And Crawley is now one of the leading people in this field. But according to the Flora Europaea Atlas, Crawley in theory didn't have to worry about wild oil seed rape because it doesn't occur in the British Isles.

But even there - and now I have to make an acid remark - it is the plant systematists who have defined oil seed rape as a species a bit differently in UK and I bet that *Brassica campestris*, that is wild oilseed rape, is there. This has to be checked. Recently I was at a meeting in Cambridge and there was a good point made that these people working in the labs, these wonderful scientists, think that biogeographic data can be looked up in books. That is an important point I want to make: biogeographic approaches are an absolute necessity if you want to do risk assessment with transgenic crops. So I just don't believe what is published in floras and distribution map collections is adequate. It might sometimes hold true, but according to the plant geographical picture its not correct, I would say.

Pia Rufener Al Mazyad, who is in the audience, had for her thesis to look up populations of wild oil seed rape in Switzerland and she had a very hard time to find any. The first plant she ever detected after months of searching was in front of her bus station. But afterwards we found that there are good populations in the Wallis and in other places. So on this map there would now be a few more black points over Switzerland. You see the lack of data is always a factor of uncertainty. These are 1996 field releases of transgenic oil seed rape in the British Isles. Obviously from the large number we have every reason to hurry up to check out what happens.

Let me tell you what a field botanist - which is what I am - is doing to assess at least part of the gene flow risks. We had a great opportunity funded by the Swiss government to organise a risk assessment group with six researchers and one information scientist from the Universities of Neuchâtel and Bern. The information scientist had to concentrate on screening the literature in international data bases such as Biosis. The others did tests on selected hybrid zones of 20 different crop varieties which would probably be turned into transgenic crops in the future. We haven't worked with transgenic crops per se, because that's still a very complicated thing as we both know (to Pia Malnoë). I was following her potato experiments and we had to be very discreet about the locality for instance. So all these elements were put together in a safety evaluation. We did garden experiments with selected crops and their wild relatives. We did work on test areas, mapping the plants in Switzerland and their wild relatives and interestingly enough we also screened herbaria which are a fantastic documentation of knowledge of the botanists of former decades. If you know field botanists you would know about their specific interest in finding crosses and if you know the species, they just beam at you. Violets for instance: if you know the twenty or so violet species in the Switzerland and then come across a hybrid it just bumps into your eye. So it is collected, it is pressed, it's nicely analyzed etc. We have a lot of knowledge from former decades. What can hybridise in the field under natural conditions is nearly fully documented in these herbaria. And there are hundreds of thousands of sheets available in many university herbaria of Switzerland. We have screened a good sample, but not all of them. It gave us a good picture of the hybrid rates. Natural hybridisation is one of the components and it means that we can produce hybrids under field conditions observed in botanical gardens in Neuchâtel. We didn't use artificial methods such as embryo rescue, because they can take things much further and hybridise plants which would never hybridise in nature.

All these elements produced a botanical files databases and from that we derived something like a safety code on three different levels. The hybrid rate can be assessed with something which you can also assess with pollination ecology, with the dynamics of pollen flight and with the dynamics of insect pollination or wind pollination given for a certain species. It varies quite a lot, for instance maize pollen can travel hundreds of kilometres and be fertile. Pines, fir trees, are known to hybridise over 2000 kilometres. You can find pollen of wind pollinated species anywhere actually. So there is always a faint possibility, let's face that. And there is a big variation regarding hybridization rate. On the other hand you have insect pollinated species with a very small range of pollen transport. With oil seed rape we screened the literature for safety distances and it is highly contradictory. Some say 50 metres others say 400 metres and interestingly enough, sometimes the same research group gives a different value 5 years later. So there's some uncertainty there. And older literature tells you something too. A plant breeder in Germany found that a bee transported oil seed rape pollen over a distance of 15 kilometres. So then you can understand that I'm a bit edgy about these things and we have to balance out their risks. Although the development trend nowadays is to produce transgenic plants with maternal lines of inheritance where the plastids are manipulated so that the pollen has no transgene at all. That will be the road for the future and we have a list of plants where this has been done already. I think this is one of the enhancements we have to encourage the producers to do in the future, namely to produce maternal lines with all that this will mean. This I'm not conscious of at the moment because I'm not an agronomist, I'm just a simple botanist.

Hybridisation through pollen and then seed dispersal and then the simple frequency of a species within a given region of course all add to or subtract from the risk of gene spread in the future. We have combined three codes from no risk to high risk. For about eight crops we have done lots of field observation and garden experiments and drawn a number of conclusions. That means that as regards alfalfa (lucerne in German) and wild grasses we would rather see them behind bars at the moment because of the gene flow. They have maximum gene flow, even bigger than rape and radish. With these you still have the possibility of having safety distances and doing things in a suitable way. But with grasses and alfalfa this is excluded - at least in European, especially southern European lands. That's where the bio-geography comes in - with the frequency code. It is a rather differentiated picture and as you probably all know, in Switzerland, according to the forthcoming referendum, all field experiments and all field trials and cultivations out in the field would be forbidden. That's not the picture we try to develop. We try to

develop a picture where you can at least do something with transgenics. This would include also tobacco, tomatoes, beet, maize, potato, clovers. Funnily enough, if you know the reproductive biology, even clowers would be OK. But we had to know the reproductive biology first, we had to do field work. We must assess on a species by species basis and region by region.

And now I have to say something in favour of the Americans for having started this. In this huge continent of North America, most of the crops are aliens and have no wild relatives in nature. For lots of these crops, except Helianthus and squash, they have no problem of gene flow - that is, if you don't take into account the weed populations on the acres of south east North America. But there are considerable weed populations on these acres, on these fields. This is a nasty remark about American botanists: most American botanists do not know the weed species which have been introduced from Europe to the States. I have seen that and verified it. Still, the Americans are faced with a much more favourable situation regarding potential gene flow, since wild relatives are simply lacking.

Let's be careful and not generalise, but acknowledge that there are cases regarding gene flow where you can proceed, where you can do a good job, where you can use the benefit of transgenic breeding strategies. It's possible. Let's not just ban everything. And if we proceed species-by-species we can then assess risks with step-by-step evaluations - not just across the board - but species-by-species and region-by-region. And then it can be accepted even by those geneticists and plant breeders whose values are influenced by their colleagues being shareholders in companies. Even they would be able to accept this step-by-step procedure which I illustrate in these charts that we adapted from Rissler & Mellon. Of course we would love to see this happening.

Be careful, the lax times are over, I can tell you. We have a whole plethora of risk assessment protocols in many countries already. With our Danish friends, supported by governmental agencies, the European Union and so on, we collected together some three hundred methods to assess pollination, gene transfer and population impacts. We were amazed to see how many of these methods have been produced already. We put that all in a database and we are planning to put this on the Internet, at least the first and the second volume. Our conference in January in Berne is the final event in the publication of this book. And I have done a very nasty thing to the science community for this conference. I have put together a panel of people, representatives from industry who are responsible for risk assessment protocols, for Monsanto it is Tom Nixon. He will attend the meeting and he will give us a hard time. Consider all these academics who are looking for research money and they try to strike fear into the hearts of those producing transgenic plants in order to get another million francs. This also has to be evaluated as a certain risk! (laughter). But it is a very cynical way of putting things straight. The science community has a task of course and has to fulfil what it thinks is necessary. The industrialists, they just want to go ahead. So we must find a dialogue to establish this, a dialogue of how we can proceed and still do a good job for the environment.

I just want to show you that we haven't just done excursions to the fields, but Pia Rufener Al Mazyad and her colleagues also did some meticulous analysis of hybrid zones and field characters such as the way *Medicago,* alfalfa, hybridises. We did a lot of morphometrics and statistics and there are hard data behind these risk factors for at least eight crops. We didn't have time enough for the others, which were merely evaluated according to literature data.

What I describe now is not published yet. Let me show you a chart of gene flow in nature. There are lots of possibilities and there's a complex system of channels. When you see what mankind has done, its quite a considerable amount of shifting. So all those people saying that now we start to manipulate evolution are just being ridiculous. We have done it for 8000 years and for human beings we have taken the human population literally out of selection. It is not only modern medicine which has done that. We have for many centuries been to change the environment to our own likes, to our own pleasure, to our own needs. So we have to realise that we have made the decision already, that evolution is manipulated strongly by mankind. It is not these transgenic things which are now giving us the opportunity to say: would we like to manipulate evolution or not? This is a decision we have taken thousands of years ago. The only difference is that now, with transformation - which is new - we can speed up, we can take out genes from species and put them into other species. This we have never done before. *This* is the new dimension of manipulation and it is of course a very considerable difference. But it is not an all or nothing case.

Look for instance at crossing - to give you an example - artificial crossing. I'd swear you would automatically think about all those nice plant breeders since the time of Mendel and Koehlreuter, some time before Mendel, did thousands of crossings in St Petersburg, but he didn't know exactly what he did. It was up to Mendel, working with clear cut breeding lines, to discover the Mendel crossing groups. But Koehlreuter always worked with mixed genomes. That's OK by me if you picture plant breeders as people such as these. But I think more about the unconscious breeder we have all over the world by in massive urbanisation. It means that we created millions of square miles of artificial ground into which lots of invasive species can migrate. They migrate on our shoes, even on the wheels of the planes. It's just crazy what happens. This is the most severe and gigantic genetic experiment mankind has ever undertaken and it's not possible to stop it given our mobility nowadays. Still it is a case of semi natural-hybridisation, but I would call it artificial hybridisation because human populations bring here species together which would never hybridise otherwise.

Here is an important example. There are two ancestral parent species of a wild grass genus adding to the genome of wheat. Two species have lived separately for probably hundreds of thousands of years. But early human activity brought them together in the Middle East region and in one of the centuries, nobody knows exactly, we have no time scale, it happened that these two genomes added to one bigger genome because meiosis, the reduction division did not happen and we made a superweed. We produce yearly, according to the estimates of the specialists, dozens of superweeds with our high mobility. And that's a real threat to ecosystems and it frightens me. I wrote recently an article 'Botanists to Blame' because the botanical gardens themselves are adding to this by introducing ad libitum new species to the gardens, adapting them to the climate, so they can easily escape later. I can tell you nasty cases from beautiful botanical gardens of the British colonial times in Jamaica, where they introduced a plant with purple leaves, an *Acanthaceae* called *Goldfussia* and this plant is now terribly invasive. It invades not only disturbed areas but also enters the primitive, pristine rainforests. It's the same for *Pittosporum* from New Zealand which is now carried by the birds into the pristine misty forests of the Blue Mountains of Jamaica. Its frightening to see these pure stands of *Pittosporum*. We call, the *Solidago,* an *Asteraceae* of North America 'the golden death'. Recently, I had a specialist of these *Asteracae* over to browse in our herbarium and we found four species for which we had no names. We all called them *Solidago serotina* and *Solidago canadensis* (golden rod), but there are certainly four more species involved, of which we had no knowledge. But the people in the countries where they grow, know about them. Think about the big *Heracleum* that huge umbelliferous plant (hogweed). Johannes Lid from Norway discovered some twenty years ago and documented in his Norwegian Flora, that there are at least two species involved behaving differently. *Heracleum mantegazzianum* and *Heracleum laciniatum* are the names. They are real threats to our indigenous ecosystems. But still nowbody seems to care about the taxonomy of these big plants. I bet that in case these showy things would be declared transgenic, hysteria would immediately grow and some scientists would carry out nice and costly research programmes. Now of course you should not use this as a cheap excuse to go ahead with the spread of transgenic plants, but you have to balance out what has happened already. Maybe within a hundred years we will produce a superweed which has a transgene. But if you set that against what is happening nowadays - the terrible dynamics going on - then I think we should not overreact. We should minimise threats, but we should try to be realistic about them.

One of my favourite subjects is the way Americans look at things. Al Gore at one of the biggest agricultural shows in the USA in Illinois sang the highest praises of biotechnology. He still somehow has a green image. I just wanted to illustrate how different the attitude of the Americans is towards transgenes and transgenic plants: firstly a guide, the husband of Molly Kline, teaching at the St. Louis Horticultural Society about transgenic crops which are openly displayed in the biggest of the botanical gardens in the USA. You can see from the faces of those he is addressing that they are somehow bored. They seem to say: Oh we have seen that before, now lets go to something more interesting like rose cultivars and things like that. They were just shuffled through within five minutes and it was over, there were more interesting things to see.

Another example, see here a group of people - unfortunately you can't see the long beard of this Amish farmer at Lancaster in Pennsylvania, three hours north of Washington by car. This is a Mennonite community, which got its name from my family, from Jacob Ammann, who emigrated to the States and gave the name to the Amish - so you can see how stubborn I am. This was of course a wonderful opportunity to come into contact with a real farming community for us. Now those people who know me, know that I can't stop speaking about biotechnology in such a situation. So I had to start a little provocation with these traditional farmers, these very conservative people who still work with horses and do it the right way, according to their opinion, and have a beautiful and successful agriculture. They are highly respected. They are not crazy people secluded in their own culture. So we had a discussion including some representatives of a biotech corporation on transgenic soybeans. To my amazement we developed a very nice dialogue of about one hour and it ended up by a promise from our side that we would bring them two bags of Roundup-ready soybeans the following year. And that's what will happen soon. These farmers can approach new things when it doesn't mean machines and engine use. If it is good for the soils to use an organic herbicide and if it means less tillage and higher yield, even these traditional farmers think it is worth trying out. I was really astonished. We do not know whether they will really go on after the first experiments and we must leave this to their own judgement.

I will leave out the bit I was to say about precision farming, since my time is over and I rather prefer to get into some discussion. Let me say just the following: Precision farming, with the help of satellite navigation and Geographical Information Systems helps the farmes to save energy to a considerable amount. High tech agriculture does not necessarily lead to high energy input farming.

Let me finish by saying that I do not bring up these examples about American farmers in order to avocate the same agricultural techniques without adaptation in Europe. I just want to make a point that the American farmers attitude is different from the one in Europe, specifically also the one in Switzerland.