Summary

In the Northern US State Oregon plant individuals of herbicide tolerant Roundup Ready wheat (RRW) were identified in a commercially grown wheat field by a farmer in May 2013. The plants were attributed to the transgenic variety MON 71800 which was developed by Monsanto. However, genetically modified (GM) wheat was never commercialised in the USA. Field trials of this variety already discontinued in Oregon in 2001. Due to the consumers' lacking acceptance Monsanto disclaimed the introduction of that GM product on the market in 2004. The Oregon farmer's surprising discovery of herbicide tolerant wheat, even though a current source of GM wheat pollen was lacking, calls for an intense scientific dispute as well as a penetrative analysis of the species-specific behaviour of wheat in order to assess the ecological risk potential of GM wheat in more detail.

Wheat (*Triticum aestivum*) is a member of the family of the *Poaceae* (tribe *Triticeae*). Worldwide, this crop is the third frequent grown grain species with an annual production of altogether around 675 Mio. tons (2012; FAOSTAT: www.faostat.fao.org). The today cultivated hexaploide seed wheat is a crossing product of several grain species and wild grass species. Its origin is the Near East. Especially soft wheat is genetically modified. The modifications focus on herbicide resistance, product quality, resistance against the fungus *Fusarium*, harvest extent as well as tolerance against biotic and abiotic stress. The application of genetic methods for the development of wheat varieties provided with the current requested traits is not necessarily required because breeding aims can also be achieved with conventional methods. In future, genetic traits such as disease resistance, drought resistance, and low gluten levels are expected to be incorporated into wheat varieties. Wheat is mainly autogamous. However, allogamy can account for more than 5%. Despite the comparable low rate for allogamy which is a basic requirement for a successful hybridisation, gene flow from GM wheat into commercial wheat or into wild occurring related species can be extensive according to scientific findings. Climatic preconditions such as temperature or moisture have a crucial influence on pollen vitality and on the success of allogamy. Wheat is an anemophile grass species. According to scientific evidence wheat pollen is spread over an already confirmed **distance of 1,000 m and 2,750 m**, respectively from the pollen source. In a study dealing with creeping bentgrass (*Agrostis solonifera*) which is also a member of the *Poaceae*, gene flow was identified even over a distance of 21 kilometres. From these results it might be assumed, that under optimal conditions also wheat pollen could be spread over larger distances as scientifically confirmed at present.

In principle, **intraspecific as well as interspecific hybridisation** of cultivated wheat is possible under natural conditions. Crossing between various wheat varieties has already been repeatedly confirmed in scientific studies. According to the distance between pollen donor and pollen receptor, outcrossing rates of up to **6.7%** have been

proved. Interspecific hybridisation of wheat is generally possible with rye and especially with species of the genus *Aegilops*. In Europe the hybridisation rate between wheat and *Aegilops cylindrica* (jointed goatgrass) accounted for **7%**, in Oregon (USA) up to **8%**. Traits of the crop wheat can be transferred to the genome of *Ae. cylindrica* only after two backcrosses. This means that gene transfer under natural conditions is probable. The formed hybrids are able to reproduce independently and produce viable seeds. The Mediterranean species *Ae. cylindrica* was repeatedly introduced into the USA probably since the end of the 19th century. This adventive species occurs in Austria rarely on only a few sites. Hybridisation of wheat is also possible with the species *Aegilops geniculata* (ovate goatgrass).

Wheat volunteers are a prior concern in an ecological risk assessment and need special consideration. In the USA as well as in Canada volunteers have already been present on the fields for 25 years. With an **average frequency of six plant individuals/m2 (maximum reaching up to 280 plants/m2)** they range **on position 12 of the most frequent weed species**. Moreover, with an approximately five-year lasting germination rate of the seeds in the soil, the seed bank of wheat is comparatively long-lived. If wheat would be commercialized, volunteers would pose a big challenge for the purity of non GM varieties because volunteers mainly account for transgene transfer induced by pollen or seeds. Additionally, wheat is applied as a main component in the crop rotation for weed control in Western Canada.

Hence, transgenes are spread either via pollen or via seeds. Additionally, they can escape into the agroecosystem not before the harvest of a crop as volunteers and repeatedly appear unrequested on the fields during the proceeding years. In this way, volunteer plants serve as potential future source for transgenes over several years. However, transgenes can also be transferred over very large distances via humans due to transport and processing activities. Even though the escape of transgenes *per se* can not immediately and directly be identified as harm in several cases, this process increases the possibility for an ecological risk. The intraspecific dispersal of transgenes within agriculture is based on meta populations. These include the cultivated crop, the volunteer plants, potentially feral subpopulations, as well as latent populations consisting of viable seeds which occur inconspicuously and uncontrolled in agroecosystems and supply chains. Due to cultivation, proceeding transport activities and processing activities of GM wheat, the preservation of variety purity of non GM wheat might be at risk. If Roundup Ready wheat (RRW) would be cultivated in the same growing regions as Roundup Ready oilseed-rape, crucial ecological problems in cultivation attributed to cumulative effects might arise. Under these preconditions, particularly very competitive Glyphosat resistant weeds could be formed which would increasingly reinforce the already existing weed problem. The ecosystem would indirectly be affected by requiring the use of less environmentally friendly alternative herbicides or because there are no effective alternative control options. However, these cumulative effects are still not considered in an ecological risk assessment because of the usually executed case-by-case evaluation of the GM crop.

Non cultivation of GM wheat would be the most effective measurement to avoid GM wheat contamination in the supply chain as well as in the environment. The comparably high probability of intraspecific as well as interspecific hybridisation with closely related grass species of the *Poaceae* and the intense appearance of volunteers on the fields clarify the ecological concern of transgenic wheat. The establishment of regional isolation distances between fields of GM wheat and non GM wheat, temporal isolation which minimises blossoming synchronism between GM wheat and commercial wheat fields, optionally cultivation of short growing wheat varieties in comparison to the higher volunteer plants, to prevent simultaneously blossoming as well as an effective volunteer control are discussed as effective measurements to limit gene flow during cultivation of GM wheat. Above all, the extensive agricultural knowledge of farmers, their observations in the field, and their distinct evaluation should be incorporated and considered in the risk discussion.

Cultivation of GM wheat is not expected to become realized in the USA in the near future. Australia is planning commercialisation of GM wheat 2020 at the earliest. Since putting on the market of GM wheat in the European Union and in Austria is also not realistic in the next years, a current ecological risk assessment for Austria should be focussed **on wheat imports** from countries which have already conducted field trials in the past or which prospectively are planning cultivation of GM wheat in the future. In that case it is essential that the strict regulations concerning varietal purity currently applied in Austria should be adopted for GM wheat immediately. In case of detection of GM contamination in imported wheat charges, potential GM seed spillage along transport routes, in loading areas, at storehouses, in locations where several wheat varieties are mixed, as well as in processing areas such as mills would have to be investigated carefully in order to identify the ingression of transgenic wheat into the environment at once. Moreover, preventing effective measurements could be applied immediately.