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Genes Gone

Western honeybees, the only bee species bred on a massive scale

WILD

In the era of a global climate crisis, genetic pollution opens up new opportunities, but also carries the risk of a global catastrophe.

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Genetic pollution occurs when gene pools mix in an uncontrolled way. In the narrow sense, it refers to the transfer of genes from genetically modified organisms (GMOs) to natural ones. In the broad sense, genetic pollution also includes gene flow from domesticated or farmed individuals into their wild counterparts, as well as from taxa introduced by humans to naturally occurring ones. However, it is worth pointing out that the term "pollution" is somewhat imprecise, as the outcomes of this mixing of gene pools can be both favorable and unfavorable. It is their unpredictability, especially in the long term, that poses the primary concern.

An enduring controversy

In the context of GMOs, the term "genetic pollution" was popularized in a 1989 publication by the British writer Paul Hatchwell, who assessed the risks of releasing GMOs into the environment and compared the situation to opening up Pandora's box. While various chemical pollutants – poisons, pesticides, and food or drug additives – are menacing, they actually remain active and disseminate only for a limited time. Genes, on the other hand, are part of living organisms that reproduce, and so they are not limited in the same way. However, we should clearly distinguish between the creation of new gene combinations and the release of GMOs into the environment.

Concerns about the possibility of genetically modified varieties becoming crossed with their wild


CELINE SEA

Corn is an example of a human-cultivated species whose wild counterpart most likely no longer exists anywhere in nature

counterparts are indeed well-founded – particularly in the context of crops like soybeans or corn, which have dominated the market in such countries as the United States and Brazil. Releasing GMOs into the environment may entail a variety of consequences. It is a misconception to believe that modifying crops is primarily aimed at improving yields. Greater outputs are more likely to be the goal of modifications in woody species – poplars and eucalypts. Genetic modifications of cereals and legumes, on the other hand, are mainly aimed at ensuring their resistance to pests and pathogens or increasing their tolerance to plant protection products. Hence, if GMOs released into the environment find favorable conditions for survival and reproduction, they can gain a selective advantage over wild species and varieties.

The crossing of GMOs and natural organisms may have adverse, potentially even catastrophic consequences. These include the emergence of weeds resistant to plant protection products and the evolution of pests and pathogens. In extreme cases, the introduction of GMOs may lead to the extinction of local varieties of cultivated plants, as well as of their wild counterparts and the organisms that depend on them. In such cases, the risk moves from the genetic level of biodiversity up to a higher, species level. Potential interactions between the genetically modified species and other species and elements of the ecosystem are so complex that it is impossible to predict their impact on the entire environment. Supporters and opponents were expected to work out a certain common ground thanks to a technology developed in 2007 known as "GM-gene-deletor," which eliminates foreign genes from pollen and seeds. However, the effectiveness of this technology still requires validation in field tests.

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A food package advertising that the product was made from Polish-grown corn and is GMO free

Introductions

Often driven by noble intentions yet with regrettable results, humans have frequently played a role in disrupting the ecosystem equilibrium by introducing new species or lower taxa. Such introductions can be intentional or inadvertent.

Introduced species typically entail negative consequences, because they often have no natural enemies in their new environment. Their numbers therefore boom, and the established balance between predators and prey becomes upset. Well-known examples include the introduction of goats to Guadalupe Island, where they caused severe damage to grassy vegetation, and the introduction of rabbits to Australia. From a genetic point of view, however, we are interested in hybridization (i.e. crossing), when a taxon is introduced into an area inhabited by closely related taxa. In this situation, geographic isolation as a barrier to reproduction is removed. If the hybrids are fertile and favored by natural selection, the native taxon will become outcompeted, a process that is further strengthened by introgression (i.e. the gradual transfer of foreign genes into the gene pool of the native taxon as a result of repeated backcrossing). Consequently, native genotypes may be rapidly eliminated, even when the population of the introduced taxon is initially small.

Introgression is far more common and better described in plants than in animals. Flagship examples include the genus *Helianthus*, commonly known as sunflowers. Originally confined to North America, sunflowers have now spread to virtually every corner of the world. Studies of sunflowers were conducted as far back as the 1940s by the American botanist Charles Bixler Heiser, who observed the potential for hybridization between numerous species of this genus. The resulting hybrids showed very low fertility, but it was demonstrated that backcrossing could lead to the emergence of invasive forms. The popularization of cultivated and ornamental plants is currently seen as the primary cause of global invasions. Reduced competition from other plants in farms and gardens enables them to survive even in adverse climate conditions.

If carried out properly, introductions make it possible to obtain plant varieties and animal breeds with desirable or new traits. However, breeding companies often lack both technology and qualified staff. Research into controlled introductions is difficult to carry out and poorly funded. At the same time, progress is small and slow. As a result of higher costs coupled with ethical dilemmas and legal problems, however, genetic engineering tools are still not as widely used as traditional breeding methods.

In addition, introduction is sometimes used as a means of genetic rescue for small, isolated populations at risk of extinction. Their gene pool becomes deliberately "polluted," primarily through the introduction of individuals with a different gene pool. However, their number can't be too high, as the mixing of gene pools of populations from areas with different optimum environments often leads to outbreeding depression (i.e. a reduction in the fitness of hybrids).

Domesticated genes

By cultivating plants, humans have created thousands of varieties. Many of them differ significantly from their original forms. Such selection has resulted in a significant reduction in the genetic variability of the cultivated species. It is estimated that 90% of corn, wheat, and pea varieties have become extinct. Over the past century, about 50% of livestock breeds have become extinct, and many are now rare or declining. In the case of some species, their wild counterparts no longer exist anywhere in the world. Examples include corn, whose intensive cultivation began in ancient times in Mayan and Aztec cultures.

Although thousands of years of domestication have altered the genome of cultivated plants, they remain related to their wild counterparts closely enough to cross. We might think that wild plants can only benefit from this fact by taking over the beneficial traits of cultivated varieties. But the truth is that wild varieties are more resistant to diseases, pests, and abiotic stressors, such as drought and salinity. Crossing wild and cultivated varieties may lead to a significant decrease in this natural resistance. Therefore, the gains may not compensate for the losses. This is why a great deal of emphasis is now being placed on protecting the genetic resources of wild varieties of cultivated plants, and their seeds are being preserved in gene banks around the world.


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The DNA helix

One interesting example of genetic pollution among animals involves the western honeybee – this single species is the only one out of approx. 20,000 bee species that is bred on a mass scale. It includes several

MONIKA LITKOWIEC

Cryogenic tanks in the Kostrzyca Forest Gene Bank, used to preserve natural genetic diversity

evolutionary lineages that cross with one another. Genetic studies, however, indicate that gene flow is limited, and crossing tends to take place within individual subspecies. However, the cause behind the existing reproductive barriers has yet to be definitively established. In many countries, including Poland, native bees have been at least partially replaced by introduced bees. The disappearance of native gene pools is alarming due to the fact that introduced populations come from places with different climate conditions and therefore often have difficulty adapting to the new location. Also, the risk of outbreeding depression is higher. Conserving animal gene pools is definitely more difficult for reasons related to limited mating control.

Adaptation to climate change

In the face of ongoing climate change, do "pure" genotypes, which have evolved over numerous generations through natural selection, continue to be something valuable in their own right? There's no good answer to this question. On the one hand, we can observe the risks associated with the loss of these naturally adapted genotypes. On the other hand, genetically modified crops are believed to hold the potential to significantly slow down climate change, through reduced greenhouse gas emissions and land conversion. With an environmental catastrophe approaching, conventional agriculture is unable to meet the needs of the growing human population, despite the fact that everyone is aware of how much food gets wasted.

Climate change is projected to alter the ranges of many species, which may lead to the emergence of new zones of interspecific hybridization. These will pose a threat to the gene pools of some taxa, but also represent a unique opportunity for the evolution of new taxa, ones that can cope better in the conditions of climate change. However, their increased potential for invasiveness may prove problematic. Invasiveness has yet to be studied exhaustively, and the evaluation, control, and prevention of invasions pose extremely complex problems. The first step towards identifying potentially invasive taxa might involve using ecological niche modeling, preferably supported by genetic data. However, the potential for invasiveness depends on many factors, such as the ability to spread or compete effectively for resources. For this reason, even the most sophisticated models may prove unreliable.

Genetic pollution provokes justified controversy, chiefly in terms of the use of GMOs in food production. In industry and pharmacology, in contrast, genetic modifications meet with less resistance. Fear of the consequences of genetic pollution continues to prevail over reliable scientific studies. In turn, the findings of such studies, even if they prove groundbreaking, are delayed from finding practical applications because they require amendments to existing regulations. Genes could be said to have a life of their own, and our greatest fear lies in our inability to control them. Nature, of course, will likely find a way out of the situation without human intervention – showing little concern for the survival of the human species. ■

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