Breeding Practices in Plants and Animals

Relevant to the Genetic Technology (Precision Breeding) Bill 2022

Overview Comments

In the draft Genetic Technology (Precision Breeding) Bill, Part 1(7) sets out what it defines as "traditional processes". In all probability the government is aiming for this term to be read "traditional breeding", thereby strengthening its false narrative that genome editing is in line with or mimics "natural transformation" and/or "traditional breeding".

In reality, most lay people would not consider most of the processes on this list to be part of traditional breeding. Whether they are "traditional processes" depends on what is meant by "traditional" and that rests on questions of historical use, scope and impact.

We have included below a summary table at the end of this document to describe the processes set out in 1(7).

However, understanding of this list goes beyond a simple description of process. In plants for example, consideration should be given to: how long the approach has been in use; where is its used (field, greenhouse or critically, under controlled conditions e.g. *in vitro* methods); and at which anatomical level of the plant is the technique applied (e.g. the whole plant and its progeny; tissue levels – plant parts, organs or cell cultures; cell level – an isolated single cell, protoplast, pollen or egg cell; DNA level – nuclear DNA or extra chromosomal DNA).

Traditional Breeding

This sounds complicated but the essential factor is straightforward. Plant breeding began with the time-immemorial and still continuing process of observing growing plants and selecting the best performers to collect seed from and then grow. Simple breeding developed through ***open pollination*** and ***simple pollination*** methods within species or closely related species.

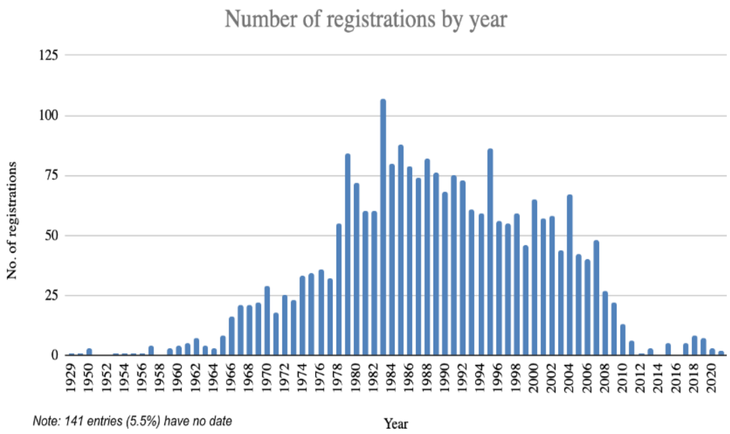
As farmers, growers and breeders sought to improve their crops they began to attempt pollination with less closely-related species and to improve pollination of species that self-pollinate. At this point they encountered what some call "species barriers" and they had to develop techniques to "bridge" or avoid these barriers. Most of these techniques still relied on the same pollination methods as above.

Since the early 20th century breeder pollination has been intensified and made more efficient through a range of management techniques to create hybridisation which has accompanied the industrialisation and commodification of farming.

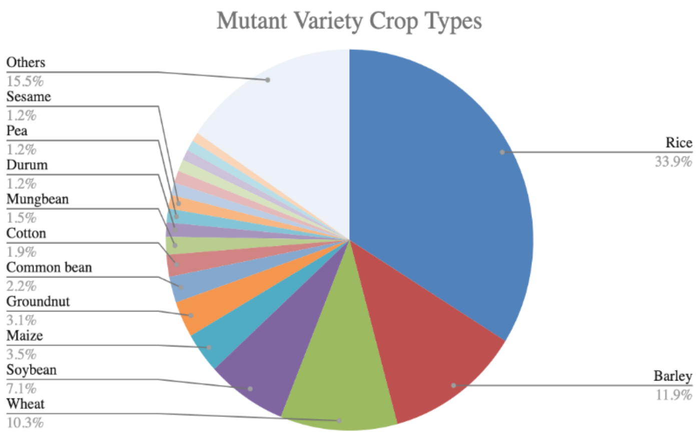
From time to time a spontaneous change occurred in the DNA of plant material – part of natural evolution – which increased the genetic pool. This has subsequently been labelled ***spontaneous mutation***.

Early Modern Breeding – Early 20th Century Developments

There were two significant developments which, like genuinely traditional breeding, operate at the level of the whole plant but which fundamentally changed plant breeding.



The discovery that radiation could create DNA changes (in the late 19th Century) led to its use in plant breeding, albeit with a slow uptake. Subsequently, chemicals were also used to create mutation and the process began to be called ***induced mutagenesis***. Its use varied in countries and in crop types but from the 1970s onwards it became a significant method of plant breeding. In recent years it has also been called ***random mutagenesis***.



The heyday of induced/random mutagenesis was in the 1980s. However, our analysis of the current FAO/IAEA [Mutant Variety Database] confirms that registration for mutation bred varieties has dropped off sharply in the last decade (see above), likely because of improvement in other forms of conventional breeding.

That register, which has 2576 agricultural crops, also shows that mutation breeding was most often used in a just handful of staple crops (see above).

Hybridisation – where 'pure' genetic lines are crossed to create a new strain – was a development and part of traditional breeding. From the 1920s onwards, through the utilisation of better pollination management and techniques aimed initially at self-pollinating crops, it became a major part of plant breeding and seed production.

These two approaches are not mutually exclusive and are used in conjunction with approaches developed later.

Modern plant breeding – overturning natural limits from late 20th Century onwards

Plant breeding has faced challenges from nature or 'natural process'. Amongst the most significant have been a) the species barrier, which limits crossings with sexually ill-matched or incompatible species – including species within the same family and natural relatives; and b) removing or overcoming factors which inhibit or reduce sexual reproduction.

To meet this challenge a range of methods have been developed which use chemical interventions and some which are implemented below the level of the plant including: ***tissue cultures, cell cultures, in vitro fertilisation, embryo rescue*** and ***cytoplast and protoplast fusion***.

Irrespective of the extent to which these have been taken up by the breeding industry, it is difficult to believe that lay people would regard them as 'traditional breeding'.

GMOs, genome editing and somatic hybridisation

The culmination – to date – of overcoming nature or natural processes is ***genetic engineering*** in the form of GMOs, both transgenic and cisgenic. A process which forces the insertion of foreign genes into an organism (plant or animal). ***Genome editing*** (popularly called gene editing) describes a range of relatively new laboratory techniques; but whichever technique is used, this process also invades and alters the genome and scientifically is a genetic engineering technique.

Many people believe that ***somatic hybridisation or cell fusion*** which can be used in modern plant breeding, is also genetic engineering. It is certainly qualitatively very different from traditional breeding, yet it is listed in the Bill at 1(7) as a "traditional process" (see table below for a description of the process).

Animal Breeding

In livestock breeding the trajectory towards accelerating the evolution of the animal has followed much the same course. New traits are introduced and fertility closely controlled and monitored to ensure good rate, feed efficiency, milk and meat quality and quantity, skeletal soundness, egg quality and reproductive success. The methods used will depend on the animal, where and how it is reared and managed and its intended use in the food system.

As with plants ***sexual fertilization*** and ***spontaneous mutation*** form the basis of genuinely traditional breeding of animals.

Modern breeding in the late 20th century has brought a range of increasingly interventionist and technological approaches including ***artificial insemination, in vitro fertilisation, embryo transfer, polyploidy induction***, and the ***recovery and transfer of primordial germ cells***. Once again, although these techniques are common, it is unlikely that most lay people would regard them as 'traditional'.

In addition, when it comes to animals, most lay people are more squeamish about issues like crossing the species barrier.

Most genetically engineered animals are hidden from view: for instance, transgenic animals are routinely used in the laboratory as models in biomedical research. Transgenic pigs are being used to grow human organs such as kidneys and hearts.

Some are used to produce pharmaceuticals such as the antithrombotic ATryn (derived from the milk of genetically engineered goats), or Ruconest (extracted from the milk of genetically engineered rabbits), used to treat hereditary angioedema, or Kanuma (extracted from genetically engineered chickens) which is used to treat lysosomal acid lipase deficiency – a rare genetic condition that prevents the body from breaking down fatty molecules inside cells.

Some are now finding their way into the food system. The AquAdvantage salmon sold in North America, has DNA from an eel species inserted into it to make it grow faster,

Description of Techniques Listed in 1(7) of the Bill

The table below organises the techniques listed in 1(7) of the Bill in a 'traffic light' order from genuinely traditional to modern technological.

Plant Breeding

Method	Explanation	Examples
	Traditional Breeding	
Sexual Fertilisation	Flowering plants reproduce sexually through a process called pollination. The flowers contain male sex organs called stamens and female sex organs called pistils. The anther is the part of the stamen that contains pollen. This pollen needs to be moved to a part of the pistil called the stigma. Pollination occurs through insects, wind, animal movement (open pollination) and the physical movement of pollen by the farmer/grower/breeder.	Crops of all types produced this way
Grafting	Grafting and budding are horticultural techniques used to join parts from two or more plants so that they appear to grow as a single plant. In grafting, the upper part (scion) of one plant grows on the root system (rootstock) of another plant. In the budding process, a bud is taken from one plant and grown on another. Grafting can be used to join a genome edited plant to conventionally bred one.	Apple, Avocado, Conifer, Citrus, Grapes, Kumquat, Mango, Maple, Nut crops (walnut, pecan) Peach, Pear, Rubber Plant, Rose
Spontaneous Mutation	This is not really a breeding method as it is not in the control of the farmer/grower/breeder. It is a naturally occurring process which is part of evolution. Traditionally, when it occurs – usually through an external event such as drought, flooding, lightening or an unknown gene event – it creates new plant variation which the farmer/grower/breeder has been/is able to exploit. The new approach of agroecology of "evolutionary/population plant breeding" seeks to create biodiverse environments to benefit from this.	Can happen in all types of plants
	Early Modern Breeding	
Induced Mutation	Originally used radiation and then chemicals to force the creation of plant mutations in order to mimic "spontaneous mutation" and create a greater variety of plant material from which to select useful traits for further selection and breeding. From the mid to late 20th century, it became a significant plant breeding tool.	Variety of different historic crops

	It is now also called "random mutagenesis" and fell under the EU GMO regulations as a GMO technique but was given an exemption for most of the regulation due to a "history of safe use".	
In Vitro Fertilisation	In vitro fertilisation techniques with isolated angiosperm gametes have been developed recently. Zygotes, embryos and fertile plants can now be obtained from individual fusions of pairs of sperm and egg cells. These are a range of techniques designed to side-step natural barriers (such as species barriers) and natural sexual incompatibility	Wheat, rice, maize
Embryo Rescue	Embryo rescue which is used to create hybrids of largely incompatible species. It's an in vitro culture technique which is used to assist the development of plant embryos that might not otherwise survive to become viable plants. Using embryo rescue produces plants with underdeveloped seeds or that are sterile and seedless.	Seedless grapes, seedless lime, mango, papaya, banana, capsicum, onion, tomato, aubergine but also some ornamental plants. Is also being used (in development) with cereals
	Modern Breeding	
Polyploidy Induction	Multiplies the number of chromosomes in order to increase yield and in some cases robustness. It is also known as genome mutation because it affects all parts of the genome. It can occur spontaneously but is most often induced in plants by exposing their certain parts, such as vegetative buds and flower buds, to radiations of shorter wavelengths, ultraviolet rays, x-rays, gamma-rays and/or chemical inhibitors. It is a common technique to overcome the sterility of a hybrid species during plant breeding.	Wheat, peanut, oat, banana, potato, brassicas, strawberry, coffee
Somatic Hybridisation or cell fusion	Many people view this as a GMO technique. It involves: • The removal of the cell wall of one cell of each type of plant using cellulase enzyme to produce a somatic cell called a protoplast • The cells are then fused using electric shock (electrofusion) or chemical treatment to join the cells and fuse together the nuclei. The resulting fused nucleus is called heterokaryon. • The formation of the cell wall is then induced using hormones • The cells are then grown into calluses which then are further grown to plantlets and finally to a full plant, known as a somatic hybrid.	Potatoes, wheat, tomatoes, oats

Animal Breeding

Method	Explanation	Examples
Traditional Breeding		
Sexual Fertilisation	Sexual reproduction occurs in a variety of ways in animals. In some species, such as fish, the male releases sperm over the eggs after the female has laid them. In other species, such as birds and most mammals—including human beings—the male releases sperm into the female reproductive tract	All animals
Spontaneous Mutation	As with plants, this is not really a breeding method as it is not in the control of the farmer/grower/breeder. It is a naturally occurring process which is part of evolution and which creates new plant variation which the farmer/grower/breeder has been/is able to exploit.	All animals
Early Modern Breeding		
Artificial Insemination	The process of collecting sperm cells from a male animal and manually depositing them into the reproductive tract of a female.	Possible in all species using fresh semen, but high pregnancy rates using frozen semen currently only possible in cattle, or in sheep using a laparoscopic insemination technique
In Vitro Fertilisation	This approach uses an ultrasound guided needle via the vaginal wall to aspirate ova from ovarian follicles. These are then matured in vitro for 24 hours before semen is added to achieve fertilisation. Following development in an incubator for 7 days, suitable quality embryos (approx. 30% - so a lot of wastage!) are either transferred into recipient animals or cryopreserved for later transfer.	Cows, pigs
Modern Breeding		
Recovery and Transfer of	A form of embryo-stem cell breeding system. PGCs are specialised stem cells that can be isolated from embryos and which, depending on the sex of the individual embryo,	Mostly chickens

Primordial Germ Cells	will eventually differentiate into sperm or ova. Following isolation, PGCs can be cultured and cryopreserved, and after thawing be transferred back into a 'recipient' chick embryo to develop and differentiate into gametes (ova or sperm) alongside the recipient bird's own PGCs. Some of the resulting gametes (reproductive cells) will therefore be derived from the donor breed and could permit the regeneration of the breed from which the cryopreserved cultured PGCs were initially taken. PGCs can be gene edited to produce gene edited animals.	
Embryo Transfer	Also called Multiple Ovulation and Embryo transfer (MOET) this is a process whereby a donor female is given a course of hormones to promote superovulation which results in increased numbers of eggs being released by the ovary. The female is then inseminated, and the embryos are flushed from the uterus a few days later. The resultant embryos can then either be transferred fresh to a recipient female or else frozen for future use/biobanking.	Small ruminants *e.g.,* sheep, goats but can be used in cattle
Polyploidy Induction	Multiplies the number of chromosomes in order to increase yield and in some cases robustness. It is also known as genome mutation because it affects all parts of the genome.	Aquaculture