Forthcoming in Paul B. Thompson and David M. Kaplan, eds., *Encyclopedia of Food and Agricultural Ethics*. Dordrecht: Springer.

Hybridity in Agriculture

Catherine Kendig, Department of Philosophy and Religion, Missouri Western State University, Saint Joseph, Missouri, U.S.A., ckendig@missouriwestern.edu

Title synonyms

Hybrid, GM, engineered crops, cross, cross-pollination, breed, breeding, biotech farming, industrial farming, farming, horticulture, plant, seed crops, agrarian, agribusiness, agrichemical, agroindustry, agronomics, agronomy, non-organic

Introduction

In a very general sense, *hybrid* can be understood to be any organism that is the product of two (or more) organisms where each parent belongs to a different kind. For example; the offspring from two or more parent organisms, each belonging to a separate species (or genera), is called a "hybrid". "Hybridity" refers to the phenomenal character of being a hybrid. And "hybridization " refers to both natural and artificial processes of generating hybrids. These processes include mechanisms of selective cross-breeding and cross-fertilization of parents of different species for the purpose of producing hybrid offspring. In addition to these processes, "hybridization " also refers to natural and artificial processes of whole genome duplication that result in the doubling or trebling of the sets of chromosomes of the organism.

This entry provides an overview of the impact of hybridity on agriculture. It begins with an historical sketch that traces the early horticulturalists' and naturalists' investigations of hybrids. This starts with the observations of Thomas Fairchild and Georges-Louis Leclerc, Comte de Buffon; and leads to the explanation of its mechanism by Gregor Mendel, James Watson and Francis Crick, and Ernst Mayr; and the eventual manipulation of hybrids and hybridization by Barbara McClintock.

Following this, the reader is introduced to a number of key terms and concepts in use within current research as well as highlighting diverse ethical concerns that center on hybridization. Recent research that attempts to ascertain the role of hybridization in adaptive change will be introduced. This will include research on the evolution of crop species, increased biodiversity, and the use of hybrids to manipulate phenotypically desirable traits in agricultural crops. The focus of the discussion is on a particularly significant type of naturally occurring hybridization, polyploidy hybridization. Polyploids are organisms which have more than two complete genomes in each cell. This kind of hybridization is ubiquitous among crop plants. The role of polyploidy in plant evolution and the affects of polyploidy on plants and animals will be reviewed. A critical discussion of its agricultural value in the production of fertile polyploid hybrids highlights key epistemological, ontological, and ethical issues. These are illuminated with reference to the distinct processes of artificial and natural hybridization.

A survey of these different kinds of hybridization includes the ethical and economic impacts of hybridity on global nutrition, the environment, and considerations of some practical implications for the agricultural industry. Tracking the role of hybrids, the process of hybridization, and the current impacts of it for agriculture requires knowledge of the history of its early conceptualization, understanding, and use. This is the topic of the following section.

Historical background

With the domestication of plants and animals, early farmers became familiar with the practice of crossbreeding as a way to produce food crops and livestock with desirable traits. They were also aware of naturally occurring hybrids in both animals and plants. But although the phenomenon of hybridity was known, the intentional crossing of organisms was not recorded until 1717. The English horticulturalist, Thomas Fairchild was the first to intentionally produce a hybrid by crossing a carnation (*Dianthus caryophyllus*) with a sweet William (*Dianthus barbatus*) in a small city garden in the London district of Hoxton.

In 1753, the French naturalist, Georges-Louis Leclerc, Comte de Buffon, discusses the infertility of hybrid offspring which are the result of the reproductive relationships (either through natural copulation or through artificial insemination) between two animals of different species. In, *The Donkey*, he discusses the case of the mule, an infertile cross between a donkey and a horse (Buffon 1753). In 1890, Wilhelm Rimpau was one of the first to develop an intergeneric hybrid crop with agricultural potential. This was Triticale. Triticale was the result of the hybridization of wheat and rye. Together with other German breeders, Rimpau built upon this new technology and made improvements in winter and spring wheat crops.

It was not until 1900 that the underlying mechanisms responsible for hybridity (and more generally, the principles of inheritance originally discovered and published by Gregor Mendel in 1866), were widely known and understood. This came when Erich Tschermak, Hugo de Vries, and Carl Correns' independently corroborated Mendel's research on the inheritance of factors in crossed hybrid generations in the common pea *(Pisum sativaum*) within their own agricultural studies.

In the late 1920s, high yield hybrid corn was developed and marketed in the United States. The discovery of the structure of DNA by Francis Crick, James Watson, Rosalind Franklin, and Maurice Wilkins in 1953, and the later development of genetics and genomics that followed, provided knowledge of the biochemical mechanisms of hybridity that would complement the practical knowledge already established in agricultural technology. In the early 1980s, the use of this practical knowledge came to fruition in its implementation within biotechnology. It was at this time that biotechnological research and agricultural practice combined in the production of a hybrid tobacco plant with antibiotic resistance in 1982. With this union of research and practice, discussion of the economic, legal, and ethical impacts with this new technology also followed apace. For instance, within the next four years, the subsequent Environmental Protection Agency gave approval for the antibiotic resistant tobacco in 1986. This laid a precedent for further biotechnologically produced hybrids. As a result of the research on tobacco and the approval for its sale, other biotechnologically produced hybrids such as soybeans, corn and cotton followed. These were approved for sale shortly after (in 1995 and 1996) in the U.S. (Wieczorek and Wright 2012).

While early horticultural and agricultural practices took as given the importance of hybridization for the cultivation of more desirable plant characteristics and higher yield crops that were better adapted to diverse environmental conditions, the role of the hybrid was still being discussed as an evolutionary anomaly amongst many zoologists. For example, Ernst Mayr formulated his highly influential Biological Species Concept (BSC) with specific reference to the exclusion of hybrids by defining species as those populations which are reproductively isolated from other population groups (Mayr 1963). That reproduction can occur between members of different species through hybridizing was a problem for his conception of species that required a solution. Mayr's solution was to deny that hybridization between organisms of different species was evolutionarily significant. He maintained that the majority of hybrids are "totally sterile" and "successful hybridization is indeed a rare phenomenon" (Mayr 1963). Mayr concluded on the basis of this reasoning, that since hybrids are rare, they only ever amount to "evolutionarily unimportant mistakes" (Mayr 1963). There was a striking disconnection between the theoretical discussions of hybrids as "evolutionarily unimportant mistakes" among zoologists, and the practical use of hybrids by farmers and agronomists. While the former denied the evolutionary impact of hybrids, the latter not only recognized it but routinely used hybrids to improve crop performance and increase yield in cultivation.

Polyploid hybridization

The term "polyploidy" was originally introduced in 1916 by the German botanist, Hans Winkler. Barbara McClintock's early research on *Zea mays L.* (maize) suggested that epigenetic silencing may have a particular evolutionarily important role in polyploids. The process of polyploidization contributes large scale genomic reconfigurations and changes in gene expression and functioning. Her later research suggested that this process might be an instance of what she referred to as "genomic shock", an event that causes increased transposable element activity and epigenetic silencing (McClintock 1984).

Rather than dismissing hybrids as insignificant sterile evolutionary dead ends as Mayr did in setting out his BSC, McClintock's research focused instead on the role of hybrids and hybridization as producing novel mechanisms of evolution: "Species crosses are another potent source of genomic modification" (McClintock 1984). The shift from hybridization being understood as an occasional taxonomic nuisance, with no evolutionary impact, to a mechanism capable of large scale genomic reconfiguration amounted to a revolution in how hybrids and the process of hybridization were viewed.

1 The role of polyploid hybridization in plant evolution

Polyploidy occurs widely in angiosperms (flowering plants) and is believed to play a significant role in plant evolution (Soltis and Soltis 2009). Polyploidization is a naturally occurring mechanism that leads to instantaneous speciation. Instant speciation refers to the formation of a new species in one generation. Speciation is usually a gradual process that takes place over thousands of generations. This kind of hybridity is the result of a doubling or trebling of the sets of chromosomes of the plant and is ubiquitous in agricultural crops (Udall and Wendel 2006). The result of polyploidization is not only genome duplication but also variation in the regulation and expression of genes from the parental diploid to the polyploid progeny.

These changes may (in some cases) lead to higher fecundity, phenotypic variation, and environmental adaptedness of the polyploid. Duplication of the genome is thought to provide organisms with more resources and a potential for increased ecological flexibility. This may allow them to populate a new or extended environmental niche, have greater adaptability to stressful environments, the ability to mask recessive mutations that could have a negative impact on the organism, and possess increased vigor over diploid species. In these cases, hybridization may not be best described as a detrimental breach of species boundaries threatening species separateness (as Mayr suggests), but may instead be better understood as an evolutionary advantageous mechanism by which an organism can increase its genetic and epigenetic resources (Kendig 2008, 2013).

2 Polyploidy in agriculture

High yield crop varieties of maize, cotton, wheat, oilseed rape (canola), peanut, and sugarcane are all the result of whole genome duplication and hybridization (Udall and Wendel 2006). These crops are allopolyploids. Allopolyploids are a type of polyploid that are defined as organisms whose cells include two or more distinct genomes that can come about through hybridization of two different species. Allopolyploids are distinguished from autopolyploids which are organisms that have genomes that are identical or very similar and arise from the same species.

Studies focusing on a variety of wild and domesticated species have shown that allopolyploids have an increased ability to respond to biotic and abiotic stress in comparison to their diploid parents (Kim and Chen 2011). While by no means conclusive for all polyploids, these kinds of evolutionary adaptability have been extensively studied in recent research on domestic cotton polyploids. Polyploid cotton has been found to produce stronger fibers than diploids. As a consequence, the polyploid cotton is often preferred to the diploid cotton and has a greater market value globally.

Understanding gene expression of these and other allopolyploids has contributed to a better understanding of the different transcriptome changes of diploids and allopolyploids that can be significant for crop production. Such research may reveal how polyploid wheat and rye resist abiotic stress or insect attack. But in order for polyploidy to be used effectively as a marker for improving crops, an understanding of its effects on the whole organism needs to be known and understood (Udall and Wendel 2006). If this were possible, patterns of gene expression that are evolutionarily changeable within allopolyploids and other polyploids could be selected for and used to produce crops with desired phenotypes such as increased stalk strength, root health, resistance to disease or predation, or increase the nutritive value of crops for humans or feed grain for livestock.

3 Polyploids, homoploids, and hybridization in animals

Although many plant hybrids are fertile, animal hybrids are often sterile. However, the classic example of the mule as the evolutionary dead end of a hybrid cross cannot be generalized across all species. Animal hybrids usually occur by means of homoploid hybridization. Homoploid hybrids occur as a result of two organisms with the same chromosome number interbreeding. Differences in chromosome number complicate mitosis and frequently result in inviability of the hybrid animal.

Polyploid hybridization in animals is rarer but does occur and has been extensively studied in a variety of fish species, including the red crucian carp and blunt snout bream hybrids, as well as the widely studied chiclid fish species complex that exist as the result of multiple hybridization events.

4 A taxonomy of hybrids: natural, artificial, induced, and biotechnologically produced

Polyploid hybridization can occur naturally and can also occur as the result of intentional crossing of organisms in the case of artificial selection and breeding among homoploids or polyploids. In addition to natural and artificially produced hybrids, hybridization can also occur by chemically inducing them. For instance, polyploidization can be induced in kiwifruit by means of colchicines (see Wu et al. 2012). And perhaps the most widely discussed within the bioethics literature, hybrids can also be produced by means of biotechnological interventions to produced transgenic hybrids between diverse taxa. The focus of the remainder of this essay will be on these naturally and biotechnologically produced hybrids and their ethical impacts.

Ontological, ethical, and legal impacts of hybridity in agriculture

1. Ontological and ethical distinctions: natural and artificial hybridizing

Natural hybridization is often contrasted with *artificial* hybridization. However, natural hybridization is the occurrence of hybrids without intervention of any kind. Artificial hybridization is used in all conventional, traditional, and organic farming that relies on artificial or selective breeding. Artificial hybridization is also used in biotechnologically produced hybridizing. “Natural” and “organic” may more particularly impute the non-use of certain types of farming techniques, namely biotechnogically assisted farming techniques, variously referred to as genetically modified organisms (GMOs). These crops are the result of altering an organism’s genes by direct removal or insertion of DNA from another organism or DNA. It is a type of artificial hybridizing which occurs in the lab rather than in the field. This differs from traditional artificial breeding methods in that the organism is modified by directly making changes to the DNA to produce different phenotypes rather than breeding hybrid crosses of parents with desirable phenotypic characteristics.

2. Non-GMO farming and organic farming

NonGMO farming and organic farming may trade on the ideal of natural production as a contrast class to the artificiality or engineered-variety but all farming involves artificial selection and some organic farming may allow biotech tweaks but not GMOs. This demarcational fuzziness means that what kind a thing is (GMO or non-GMO, naturally or artificially produced) and therefore to what ontological category it belongs, becomes difficult if not impossible to adjudicate. This ontological fuzziness also has impacts on ownership and distribution, and has myriad ethical ramifications.

Biotechnologically produced hybrid crops bring with them a host of legal issues including liability, and intellectual property issues. Liability for GMO contamination has been discussed with regard to cross-hybridization especially in the production of soybeans, cotton, oilseed rape, and maize. Conventional farmers whose crops have been compromised due to pollen drift, (cross-pollination with transgenic crops), can be sued for patent infringement if they keep their seeds and replant them even if they did not know that these seeds are the product of an unintentional transgenic cross. Conventional farmers without a license to use the transgenic seeds can be prosecuted for using their traditional methods of seed saving, sharing, and exchanging and planting them the next year (McEowen 2004).

3 Biotechnologically produced hybrid crops (conceived of as a solution to drought and hunger)

Biotechnologically produced hybrids have been discussed as a solution to growing drought and the effects of climate change on agriculture in developing and industrialized countries as well as a solution for global hunger and malnutrition. Interest in these technologies as solutions to improve global health was expressed early on by the Director-General of the United Nations Food and Agriculture Organization, Jacques Diouf (Diouf 2001). In a press release, Diouf stated that the use of biotechnologically produced hybrids and GMOs must be considered as a possible solution to, "the supply, diversity, and quality of food products and [a way to] reduce costs of production and environmental degradation, as the world still grapples with the scourge of hunger and malnutrition." (Diouf 2001). Diouf maintained that the nutritional needs of the world have outstripped the capacity of conventional farming techniques. In order to feed the world's population, biotechnological means of increasing yield and nutritional value of crops must be seriously considered.

Many biotechnologically produced crops currently on the market are designed to withstand herbicides used to control weeds such as waterhemp, ragweed, and Palmer amaranth pigweed (e.g. IMI corn, STS soybeans, Roundup Ready soybeans, canola/rapeseed, cotton). One of the most widely discussed are crops that have been created that are tolerant to HPPD inhibitor herbicides widely used in corn production (*Successful Farming* 2012). Farmers growing herbicide-tolerant crops can limit the amount of money spent on controlling weeds (*Successful Farming* 2012). Growing these herbicide-tolerant crops also allows the farmer multiple modes of action to control a variety of weeds while not harming the yield of his or her crop.

In addition to herbicide-tolerance, agricultural companies are currently producing hybrids that solve problems of extremes of temperatures (e.g. extreme heat), drought conditions/flooding, water shortages (due to the rapid reduction of aquifers or other controversial irrigation techniques), low pollinator populations (e.g. bees), and lower yields that affect crops in the many of the western seed-crop states in the U.S. (Kansas, Missouri, Colorado, Nebraska, Oklahoma, Texas, south Dakota) (Minford 2012). To do this, seed companies isolate genes identified with controlling how plants react to stress. Some rely on selecting genetic markers to cross with desirable phenotypes, whilst others rely on single gene biotechnological approaches to add corn drought tolerance genes from bacteria to produce drought resistance transgenically (Minford 2012).

Biotechnologically produced crops have also been engineered to be resistant to insect predation. For instance, the transgenic cotton, *bacillus thuringiensis*-cotton (Bt-cotton) and Bt maize are both breed to diminish the effects of certain pests. *B. thuringiensis* is a gram-positive soil-dwelling bacterium. Bt-cotton and Bt-maize are produced with a toxin of *B. thuringiensis* which is toxic to many species of lepidopteran larvae (caterpillars) that feed on the stalks, ears, and leaves, and the coleopteran larvae (beetle grubs) that feed on the roots of cotton and maize plants (Thalmann, P. Küng, V. 2000).

One of the frequently discussed benefits of Bt maize and Bt cotton are that farmers can reduce their reliance on airborne insecticides. This impacts not only the air quality, but also soil, and the environmental impact of these chemicals on nontarget crops and wildlife. It also provides an advantage to the farmer in terms of limiting exposure to these chemicals. The farmer can reduce his or her direct contact with the chemicals which may positively affect the health of the farmer. Planting weed and insect resistant crops also reduces the farmer's time in the field and expenditures on chemical herbicides, insecticides, and fungicides.

Biotechnologically engineered ways of increasing the nutritive value not only for human consumption but also for use in animal feed have also been explored. In the U.S. and E.U., more than 60% of corn and soybeans are used to feed livestock with corn being the major feed source in a wide variety of animals including poultry, swine, and dairy cattle (Thalmann, P. Küng, V. 2000). New transgenic hybrids increase desirable nutrients in crops fed to livestock. As a result this leads to healthier more productive livestock and potentially a lower feed bill if the farmer does not need to buy additional minerals to add to feed. For instance, crops of seed or grain can be altered to produce a more desirable composition in recombinant plants which can produce higher levels of oleochemicals, proteins, or carbohydrates (Thalmann, P. Küng, V. 2000). Some hybrids are also designed to remove things in the crop that are harmful to animals. For instance, canola is a modification of rape that reduces the euric acid within the plant which is toxic to livestock. This means that the crop can be used as a feed crop instead of just as an oilseed crop. There is a hybrid of fescue for hay that also reduces its toxicity to cattle.

Biotechnologically produced hybrid crops (conceived of as a threat)

In addition to discussions of the benefits of biotechnologically produced hybrids, there have also been considerable ethical concerns raised about the threats the production of biotechnological hybrids poses to public health and the environment. With regard to public health, these have focused on the potential of transgenic crops for carrying antibiotic-resistance that would compromise drugs currently in use to treat illnesses.

With regard to the environment, ethical discussion has focused on the potential destabilization of ecosystem balances with the introduction of herbicide resistance and insect resistant crops. With reference to socioeconomic issues, these worries have focused on the labeling and marketability of organic products. One ethical and economic concern is that products may be accidentally contaminated by means of cross-pollination from neighbouring transgenic species. This would affect farmers' ability to accurately maintain organic crops due to transgenic crop drift from other non-organic farms.

In addition to these concerns for organic food production, other worries focus on the impact of transgenic crop drift on conventional farmers who practice seed saving, sharing, and exchanging. Some recent research suggest that saving seeds from plants that produce desirable traits to plant in the following year, (to ensure that they had better crops), has been a traditional practice that has a history that goes back to that of the early Neolithic farmers (Council for Biotechnology, 2013) and continues to be a practice of traditional farmers in developing countries and socioeconomically vulnerable communities. The suggestion that the practice of seed saving, sharing, and exchanging should be curtailed to protect crops has been mooted. However, restrictions on these practices would disproportionately affect these cohorts and possibly frustrate the social and economic inequities already present. A move that itself would involve multiple ethical repercussions.

The prime ethical concern with regard to transgenic hybrid crops is the inadvertent dispersal of the transgenic crop pollen through wind or the movement of pollinating insects. The dispersal of herbicide tolerant crops to other conventionally farmed fields is of special concern as their dispersal could produce *superweeds* that would not be controlled by herbicides currently in use. In addition to concerns about the possible creation of superweeds, analogous problems may arise with regard to insects which are the focus of insecticide resistant crops. The incidence of potential *superpests*, produced as a consequence of adaptive resistance to targeted insecticide resistant crops, has also been observed and discussed (Liu et al. 1999). Concerns have also been raised about the possibility that crops bred for resistance to some pests may actually encourage the proliferation of other pest insects creating populations of secondary pests. If the primary insect predators are reduced, other secondary pests such as the boll weevil and stink bug may rebound (Liu et al. 1999). In addition to these worries, insect-resistant crops such as Bt-cotton and Bt-maize may also affect non-target species of insects such as green lacewings and other insects that are beneficial to crops. The introduction of herbicides and insecticides may have the potential to disrupt agricultural production as well as natural ecosystems in unpredictable and potentially catastrophic ways. These secondary effects would raise significant concerns for agroindustry, environmentalists, and conservationists alike.

Industry-based initiatives

Much of the recent ethical discussion has focused on the impacts of introducing new transgenes into the environment and their affect on production and yield. However, the performance of different crops is the consequence of multiple variables which include but are not limited to average rainfall, irrigation, drainage, nutrient content and composition of soil, drought, wind, insect control, weed management, choice of pesticides (herbicides, insecticides, fungicides etc.), existence of hedgerows or borders, local biodiversity, crop rotation practices, and harvesting times.

Industry-based actions to curtail cross-hybridization between commercial crops using biotechnologically produced hybrids and to protect the interests of traditional and organic farmers has grown in recent years. The group, Save Our Crops Coalition, aims at curtailing the inadvertent application of synthetic chemicals or fertilizers to organic crops or the inadvertent spread of these to traditionally grown crops. Other initiatives based in industry and cited in trade journals are to not to overuse one pesticide chemical (strongly discouraging a one-size-fits-all approach to weed management), and instead suggests that farmers identify weeds and adjust their control to the specific needs of their particular crops (*Successful Farming* 2012). Targeting the herbicide to the weed rather than overusing the same herbicide has been an increasingly adopted practice since the discovery of the resistance to herbicides of the group Triazine of more than 55 different weeds (Thalmann and Küng 2000).

Trade journals and the experience of individual farmers suggest that there are other impacts that farmers need to be aware of with regard to the management of hybrid crops. Increases in yield and desirable plant phenotypes such as stronger stalks, resistance to drought, pests, and herbicides used to control weeds have other impacts that affect practical crop management. Some hybrid plants have stronger stalks and have more biomass and plant residues than do traditionally produced crops. Others are bred to have less biomass and send more energy to the grain head. Because of this, hybrid plants also impact farmers' choices in buying equipment essential to harvesting and tillage. Some hybrid crops require more horsepower and torque from farm machinery to manage plant residue after harvest and remove crops during harvesting and by tillage equipment.

Farmers are aware of the mutability of crops due to accidental cross-pollination which can lead to the spreading of a particular undesirable trait throughout multiple hybrids. Practical measures to guard against this include increasing the biodiversity of crops planted in fields and ensuring that different kinds of crops are planted in the same field at different times of the year. This latter practice is called *crop rotation*. Rotating crops in the same field reduces the potential degradation of the soil. By alternating crops the nutrient composition of the soil can be maintained or improved. Crop rotation also limits the population of crop-specific diseases and insect pests and potentially reduces the number of superpests that may develop.

In addition to these considerations, trade journals have also expressed concern over the use of old herbicides with new transgenic crops. The continued use of old herbicides in an industry with new biotechnological solutions appears to some as incongruous. These herbicides are being used, in part, because of the limits on research, testing, and introducing new chemicals into crop production (*Successful farming* 2012).

Current discussion reflects the confluence of three different modes of investigation. 1) How research and biotechnology can provide new ways of understanding the mechanisms of hybridization. 2) How these mechanisms can be used in practice to increase agricultural production, and 3) how we *should* use these new technologies. The latter ethical question requires that biotechnological research and agricultural practice link up in ways that are reciprocally informative. That is, finding an ethical route to maintain sustainable agriculture using hybrids in agriculture depends not just on research methodologies and biotechnological strategies of increased production, but also the business of being a farmer.

Summary

The interplay between the theoretical understanding and the practical knowledge in agriculture have been both complimentary and adversarial in the understanding and use of hybrids in agriculture. The benefits and potential risks to the environment, the agriculture industry, worldwide food crop production, and global socioeconomics are just some of the ethical issues that have arisen with the use of hybrids in agriculture. An understanding of the biotechnology currently in use as well as the history of research on hybrids beginning with Fairchild, Buffon, Mendel, Mayr, and McClintock has been provided in this entry. This, combined with a survey of industry management strategies, international discussion of the use of biotechnologically produced hybrids, as well as farmer-led concerns with unintended cross-pollination fills out a picture of the role of hybridity in agriculture. Key cases for ethical discussion include polyploidy hybrid use in agriculture, herbicide resistant crops, and insect resistant crops such as Bt-cotton and Bt-maize. Ethical discussions have also centered on the practice and restriction of seed procurement, distribution systems, biotechnology development, and the effects of the use of hybrid organisms on both traditional agricultural farmers. Concerns over the potential for unintended negative effects such as the development of superpests and superweeds have also been discussed. These have wide ranging consequences that affect both the general public and the environment. Approaches intending to address the multiple aspects of the use of hybrids in agriculture in ways that are ethically responsive to concerns of all cohorts have been reviewed. These have arisen from the agricultural industry itself, trade journals, coalitions of farmers and the public, biotech companies, and the United Nations FAO. These suggest that to be successful, any integrated ethical approach must be mindful of a range of agricultural practices, communities, and future impacts.

Cross-references

Eating and Environmental Sustainability, Food Boycotts, Food Security, Agriculture and Environmentalism, Biodiversity, Cross Contamination of Crops in Horticulture, Herbicide Resistant Crops, Farms: Small vs Large, Pest Control, Community Perceptions on Food and Agriculture, Farmer-Scientist Knowledge Exchange, GMO Food Labeling, Intellectual Property Rights and Trade in the Food and Agricultural Sectors, Agricultural Ethics, Intellectual Property and Food

References

Buffon, G-L. comte de (1753/1954). L'asne. Histoire naturelle. volume 4. J. Piveteau (ed.), Paris: Presses Universitaires de France.

Diouf, J. (2001). FAO Director-General stresses benefits of biotechnology in fighting hunger and malnutrition and calls for open debate on potential risks. UN-FAO. http://www.fao.org/WAICENT/OIS/PRESS_ne/pRESSENG/2001/PREN0131.htm Accessed 3/14/2013.

Kendig, C. (2008). Biology and Ontology: An Organism-centred View. Exeter: University of Exeter. PhD dissertation. URI: http://hdl.handle.net/10036/42121. Accessed 3/12/2013.

Kendig, C. (2013). Towards a Multidimensional Metaconception of Species. Ratio 26 (3).

Kim, E-D. & Chen, Z. (2011). Unstable transcripts in Arabidopsis allotetraploids are associated with nonadditive gene expression in response to abiotic and biotic stresses. PLoS ONE, 6, e24251.

Liu, Y., Tabashnik, B. Dennehy, T., Patin, A., & Bartlett, A. (1999). Development time and resistance to Bt crops. Nature, 400, 519.

Mayr, E. (1963). Animal Species and Evolution. Cambridge: Harvard University Press.

McClintock, B. (1984). The significance of responses of the genome to challenge. Science, 226, 792-801.

McEowen, R. (2011). Legal issues related to the use and ownership of genetically modified organisms Washburn Law Journal, 43, 611.

Minford, M. (2012). Good timing for drought-tolerant corn. Corn and Soybean Digest, 72 (11), 27-32.

Soltis, P. & Soltis, D. (2009). The role of hybridization in plant speciation. Annual Review of Plant Biology 60, 561-588.

Successful Farming (2012). 11 Questions and answers about new herbicide-tolerant trait and application technology. Successful Farming, 110 (3), 37-39.

Thalmann, P. & Küng, V. (2000). Transgenic cotton: are there benefits for conservation? WWF International.

Udall, J. & Wendel, J. (2006). Polyploidy and crop improvement. Crop Science, 46(S1), S3-S14.

Wieczorek, A. & Wright, M. 2012. History of agricultural biotechnology: how crop development has evolved. Nature Education Knowledge, 3 (10), 9.

Wu J., Ferguson, A., Murray B., Jia Y., Datson P., & Zhang J. (2012). Induced polyploidy dramatically increases the size and alters the shape of fruit in Actinidia chinensis. Annals of Botany, 109 (1), 169-79.