CRISPR Technology 2025:
Patent & License landscape on Plants

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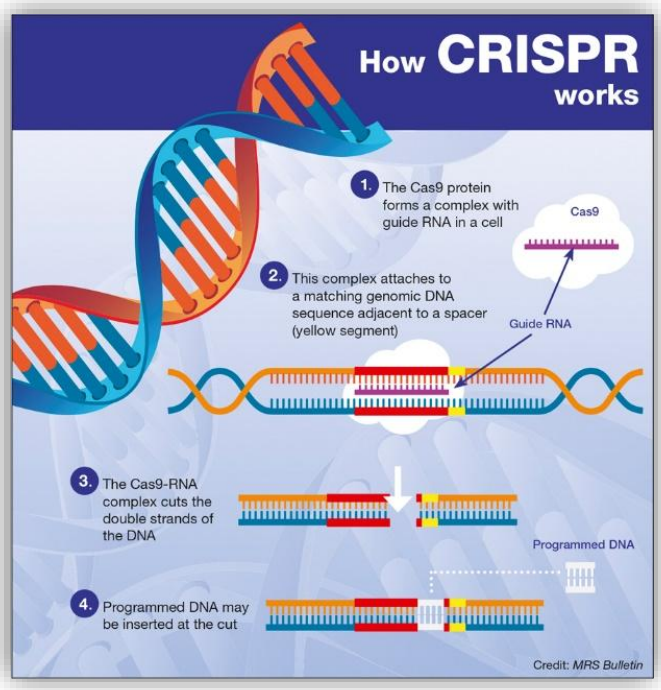
1 Introduction to CRISPR-Cas Technology: Precision Genetic Editing

CRISPR-Cas technology represents a groundbreaking tool in the field of genetic manipulation, revolutionizing our ability to edit DNA with precision and efficiency. Standing for « Clustered Regularly Interspaced Short Palindromic Repeats » (*CRISPR*) and CRISPR-associated (*Cas*) protein, this technology exploits Cas proteins and RNA molecules to achieve targeted modifications in the nucleic acid sequences, resulting in a versatile gene-editing tool. The CRISPR-Cas9 system, which is the most widely used CRISPR system, was developed in 2012 by scientists at the University of California- Berkeley and the University of Vienna, with Emmanuelle Charpentier being the primary lead. The same year, the Broad Institute of MIT and Harvard published the use of the system in eukaryotes.

At its core, CRISPR-Cas functions like a pair of molecular scissors, allowing scientists to precisely target and modify specific sections of DNA/RNA. It comprises two main components: the Cas proteins, acting as the scissors, and RNA molecules that guide these proteins to the desired location on the DNA strand.

The process commences by designing guide RNA that matches the target DNA sequence. This guide RNA then directs the Cas protein to the specific location on the DNA, where the Cas protein makes a precise cut. The cell's repair machinery then intervenes, either integrating desired alterations (*"Programmed DNA" in the scheme below*) or utilizing the cell's inherent repair mechanisms to rectify genetic anomalies. The use of a short guide RNA that can be cheaply and quickly synthesized makes it much easier to use than other gene editing techniques which can achieve similar outcomes through a much more laborious process (*ie*: TALENs).

CRISPR-Cas technology encompasses various Cas proteins, each with distinct functions and applications. Cas9, the most widely used, is an RNA-guided DNA endonuclease that precisely cleaves both strands of DNA at the location specified by the guide-RNA. Cas12 and Cas13, on the other hand, are proteins that are similar to Cas9 but have unique features. Cas12 has collateral cleavage activity, enabling it to target several DNA sequences simultaneously, while Cas13 is renowned for its ability to target RNA. These diverse Cas proteins contribute to the adaptability and innovation within the CRISPR-Cas technology landscape, paving the way for more refined and specialized applications in genetic manipulation.



The applications of CRISPR-Cas technology are vast and diverse, spanning multiple fields. In agriculture, it holds the potential to more readily create crops or animals that are more resistant to diseases, or exhibit

enhanced nutritional value. In medicine, CRISPR offers promising avenues for treating genetic disorders, cancer, and infectious diseases. Furthermore, it enables more accurate disease studies, targeted therapeutic development, and the prospect of personalized medicine.

However, along with its immense potential, CRISPR-Cas technology raises ethical considerations and challenges. The ability to edit the human genome raises concerns regarding unintended consequences and ethical boundaries, particularly in the realm of creating genetically modified humans. Thus, stringent ethical guidelines and regulatory frameworks are pivotal in guiding responsible usage.

Despite these challenges, CRISPR-Cas technology continues to evolve rapidly. Researchers are continuing to develop refined versions with new capabilities (such as prime editing and base editing), or improved performance (enhanced precision, reduced off-target effects), and expand the range of possible edits.

Overall, CRISPR-Cas technology is a powerful tool with far-reaching implications in a variety of fields, offering both remarkable opportunities and ethical dilemmas. Its continuing progress underlines the importance of balancing scientific progress, ethical scrutiny and regulatory oversight in order to harness its potential for the improvement of society while mitigating potential risks.

Sources: (1–9)

1.1 Background Patent Landscape

The group referred to as “CVC” is composed of the inventors of the first uses of the CRISPR-Cas9 system (primarily Doudna of the University of California- Berkeley, and Charpentier of the University of Vienna). This group has uncontested patents covering the generic use of CRISPR-Cas9 in any cell type (10). Their initial publication and patent did not disclose any application in eukaryotes, but they have argued that they have private data supporting this.

There is currently a dispute between four major groups over the use of CRISPR-Cas9 in eukaryotes. At the time of filing in the USA, the USA operated on the “first to invent” principle, and CVC attempted to obtain coverage of the usage in Eukaryotes in the USA. Courts in the USA did not find that the CVC group had presented sufficient evidence to favour their claims over the Broad Institute’s claims (11). CVC is continuing to challenge this ruling in US courts.

The second group is led by the Broad institute (of the Massachusetts Institute of Technology and Harvard University), which fast tracked their patent application and was the first to have a patent issued for the use of the CRISPR system in eukaryotes, despite not being the first to file for such a patent. It was, however, the first to publish an academic paper demonstrating the use in eukaryotes (12,13), followed closely by a Harvard group (14). In Europe, a mistake in assignment of patent rights by the inventors lead to their foundational patent covering the usage in eukaryotes being invalidated (15), leaving only the CVC foundational patents standing. Many derivative/non-foundational patents of the Broad Institute will still be valid, although some may be affected by the same issue. The exact extent of the scope of their valid patent protection in Europe is unclear.

The two remaining groups, Sigma-Aldrich and Toolgen, have both applied for patents applying CRISPR technology to eukaryotes before the Broad institute and CVC (10), and there are thus four groups competing for coverage of the use of CRISPR in eukaryotes. Currently Toolgen does not have any issued foundational patents. Sigma Aldrich has patents covering using CRISPR to lead to integration of introduced DNA in

eukaryotes. Sigma-Aldrich and Toolgen's more foundational claims on the general use of CRISPR-Cas9 in eukaryotes are still ungranted, and legal disputes are ongoing.

This dispute is by and large limited to the use of CRISPR-Cas9, and many patents now cover more generic gene editing, with additional claims enumerating more specific cases (as is typical for patents), such as the use of RNA-guided nucleases in general (without specifying a specific nuclease). It seems the "mistake" of the CVC group in not enumerating more specific usage cases (ie. In eukaryotes) will not be repeated, and many patents now have series of claims covering increasingly specific uses (eg.: eukaryotes> plants/fungi/animals> mammals> humans).

1.2 Report Structure

This report provides a comprehensive analysis of the patent and licensing landscape for CRISPR-based technologies applied to plants, with a particular focus on genome-edited crops and non-transgenic approaches. It begins in Section 2 with an executive summary highlighting key trends in CRISPR patenting, non-transgenic genome editing, and licensing. Sections 3 to 5 explore the patent landscape in detail—first across all domains (Section 3), then focusing on plant-specific applications (Section 4), and finally on non-transgenic genome editing approaches (Section 5), including explicitly and implicitly DNA-free methods. Section 6 examines the licensing landscape and key IP holders in the plant sector. Sections 7 to 9 provide additional contextual insights, including litigation (Section 7), developments in genome editing technologies (Section 8), and potential applications in Swiss and European agriculture (Section 9). Sections 11 and 12 present the methodology and references supporting the analysis.

2 Executive Summary

2.1 CRISPR usage in general

- There are over 23’000 patent families covering CRISPR-related technologies
- Patent growth has been exponential since 2012, driven by genome editing claims (~19,000 patent families)
- China leads, accounting for 51% of priority filings, after having overtaken the USA (36%) which led in total priority filings from 2012 to 2019. However, only 8.3% of Chinese filings are extended internationally, indicating a strong domestic focus.
- Most CRISPR patents extend protection via PCT (41%) and European (20%) routes, followed by extensions to China, Canada, Australia, the USA, Brazil, India and Germany
- Relatively few patents were filed in Switzerland (3 priority filings; 496 EP extensions).
- The Chinese Academy of Sciences and the Chinese Academy of Agricultural Sciences are the top filers, followed by the Universities in the USA involved in the invention of CRISPR-Cas9 and its application to eukaryotes
- Besides a slight increase of patents in the therapeutic-epigenetic regulation domain and targeting eukaryotic cell-organisms in Europe, the trends in Europe and Switzerland are similar to those of the global landscape

2.2 CRISPR usage in modified plants

- 5’152 patent families cover CRISPR-modified plants
    - Outside of China, filings per year peaked in 2019, whereas the growth continues within China, resulting in an overall steady increase
    - The plant patent extension distribution was broadly similar to the overall CRISPR patent distribution
    - Most patent families disclose the use of Cas9
- In contrast to the global CRISPR landscape, industrial players are the major patent holders outside of China with agricultural companies like Corteva Agriscience, Limagrain, Confluence Genetics and Monsanto – Bayer AG
- Within China academic and public institutions dominate the patent landscape
- Many players hold not only patent families covering usage in plants, but also CRISPR patents in other areas (alternative Cas enzymes/CRISPR systems, etc)
- Outside of China, most of the main players claim undefined nucleases or legacy nucleases such as ZFN, TALENs besides CRISPR for broad protection
- No direct patenting in Switzerland

2.3 Non-transgenic CRISPR editing

- The landscape is still evolving, suggesting space for further innovation and protection in Europe, particularly in light of ongoing regulatory changes that differentiate non-transgenic genome editing from traditional GMOs
- 2,350 patent families implicitly (“knock-out”, “base editing”, etc.) and 247 explicitly (“non-transgenic” or “DNA-free”, etc.) describe non-transgenic genome editing
- China leads in volume, though most filings are not extended internationally. The US dominates among internationally protected filings.
- Europe shows limited activity overall; no Swiss filings were identified. Most EP filings come from US-based actors (e.g. Corteva, Pairwise, Broad).
- European applicants include KWS Saat and Tropic Biosciences, but remain few
- Many patents cover both transgenic and non-transgenic approaches, and boundaries are not always clearly defined
- The landscape is still developing, with room for further innovation and IP filings, particularly under evolving EU and Swiss regulations

2.4 Licensing Trends

- Key patent holders include CVC, Broad, Sigma-Aldrich, and ToolGen
- Corteva holds an exclusive CVC license for agriculture and non-exclusive Broad licenses and acts as a major sublicensor
- Other players (e.g. BASF, Syngenta, Bayer-Monsanto) hold non-exclusive rights
- Academic research is generally license-free; commercial use often requires licenses from multiple holders
- Licensing is mostly non-exclusive, with rare exclusive deals focused on specific crops or traits
- Recent deals (e.g. Pairwise Fulcrum™) and growing interest in Cas12, base editors, and tools from Asian developers signal a shift toward broader technology access

3 Patent Landscape on CRISPR

3.1 Global Patent Landscape on CRISPR

There are 23'696 patent families in the present database on CRISPR (data up to and including Dec. 2024). There are 6'521 additional patent families compared to the previous report CRISPR technology: Patent & Licence landscapes published early 2024 (data until Sept.-Oct. 2023).

3.1.1 Temporal distribution of patent filings (2012-2024)

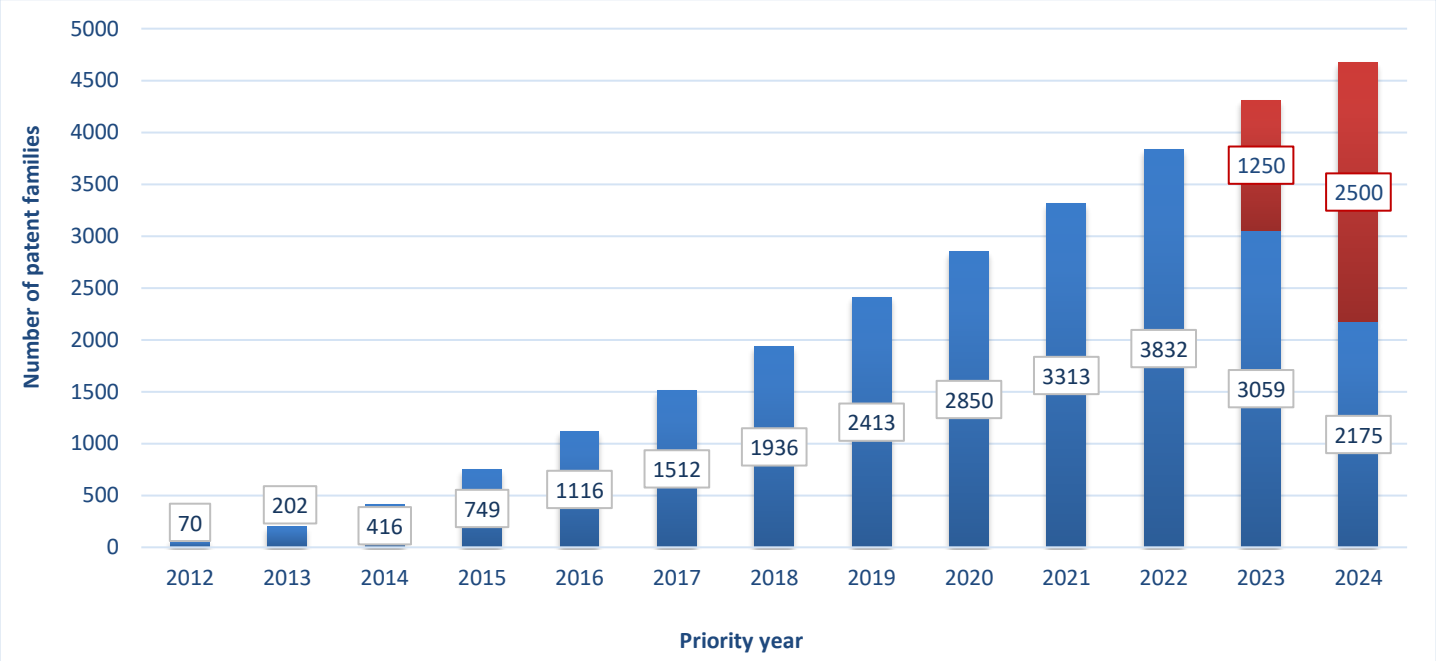


Figure 3.1.1: Number of patent families by priority year. The years 2023 and 2024 are not complete due to the delay of publication of 18 months. Therefore, an estimated 1'250 and 2'500 patent families were added to 2023 and 2024, respectively.

Figure 3.1.1 shows the patent filing of CRISPR patents over the years. 57 patent families filed between 2001 and 2011 are not included in this graph. These 57 patent families comprise:

- Methods for typing a bacterium having a CRISPR region, such as Lactobacillus bacterial strain
- The use of CRISPR associated with Cas genes, to modulate a cell's resistance to target nucleic acids or to protect against phage infections, including CRISPR-Cas sequences from *Lactococcus* and other early CRISPR families owned by Danisco-DuPont
- Cas proteins covering other Cas enzymes such as Cas6, Csy4
- Generating nucleic acid fragments, regulating production of a target RNA in a cell, including downregulating prokaryotic genes
- Patent members that were filed after 2012 but that are comprised in a patent family having the first priority date prior to 2012 due to other members

Since the groundbreaking discoveries of 2012, the field has experienced remarkable growth, with a steady and ongoing rise in patent applications each year.

3.1.2 World map of priority filings

Countries	Nb	%
CHINA	11’965	50.50%
UNITED STATES	8’565	36.15%
KOREA	744	3.14%
EUROPE	629	2.65%
WORLD	509	2.15%
UNITED KINGDOM	317	1.34%
JAPAN	264	1.11%
RUSSIAN FEDERATION	140	0.59%
INDIA	117	0.49%
AUSTRALIA	66	0.28%
SINGAPORE	41	0.17%
NETHERLANDS	39	0.16%
ITALY	29	0.12%
DENMARK	28	0.12%
LUXEMBOURG	22	0.09%
FRANCE	21	0.09%
GERMANY	21	0.09%
TAIWAN	21	0.09%
SPAIN	20	0.08%
TURKEY	18	0.08%
SOUTH AFRICA	17	0.07%
Other countries	102	0.43%

Table 3.1.2: Number of priority filings by country, and percentage of total filings.

Of the 23’696 patent families filed between 2001-2024, the priority patent applications were mostly filed in the People's Republic of China (11’965 – 50.50%) and in the USA (8’565 – 36.15%). Priority patent applications were also filed in South Korea (744, 3.14%), with the EP procedure (629, 2.65%), with the PCT procedure (209, 2.15%), and in the UK (317, 1.34%). Countries and regions (PCT and EP) outside of the USA and the People's Republic of China represent 13.35% of the priority filings.

Only three priority filings were directly in CH, by the University of Bern in 2019, Cytosurge in 2021 and Avelo in 2022 (see “3.3.1 Priority filings” for more information).

3.1.3 Temporal distribution of priority filings (2012-2022)

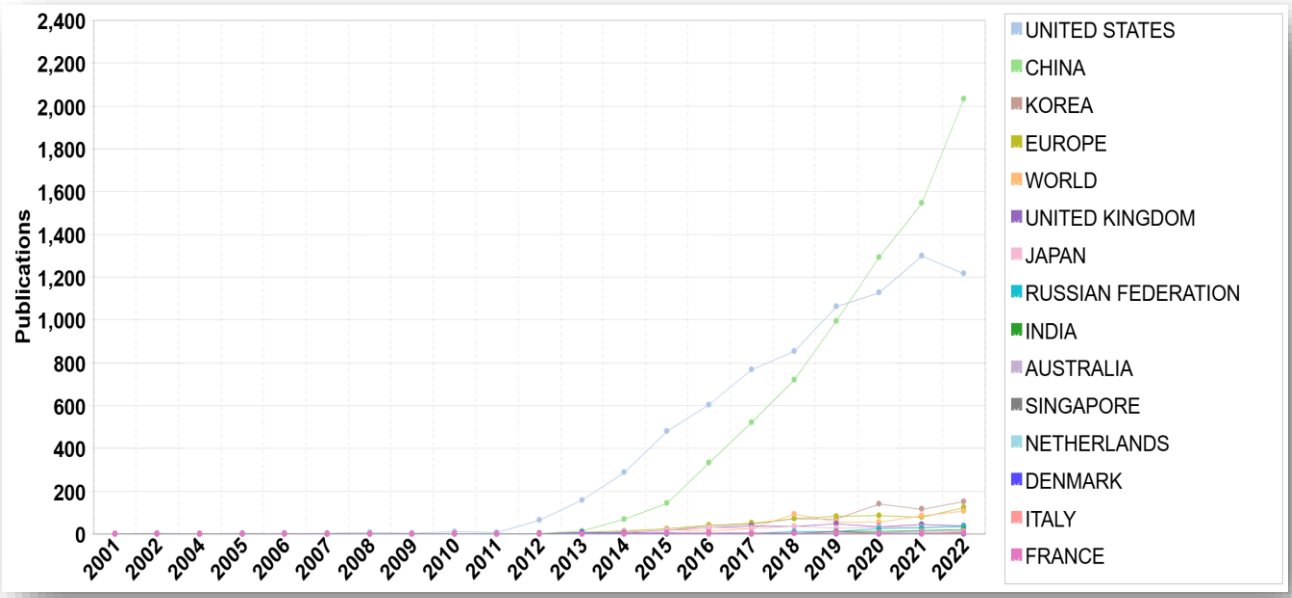


Figure 3.1.3: Temporal distribution of priority filings in each country or region having at least 10 priority filings. The years 2023 and 2024 were not included, as they are incomplete due to the delay in publication.

The first priority filings were in the USA in 2012. Notably, there is a strong increase of priority filings in the USA and the People's Republic of China since 2012 and 2015, respectively. The rate of increase has been faster in China, and thus China has become the leader in priority filings since 2020. Similarly, South Korea passed Europe in number of priority filings in 2020.

3.1.4 World map of patent extensions

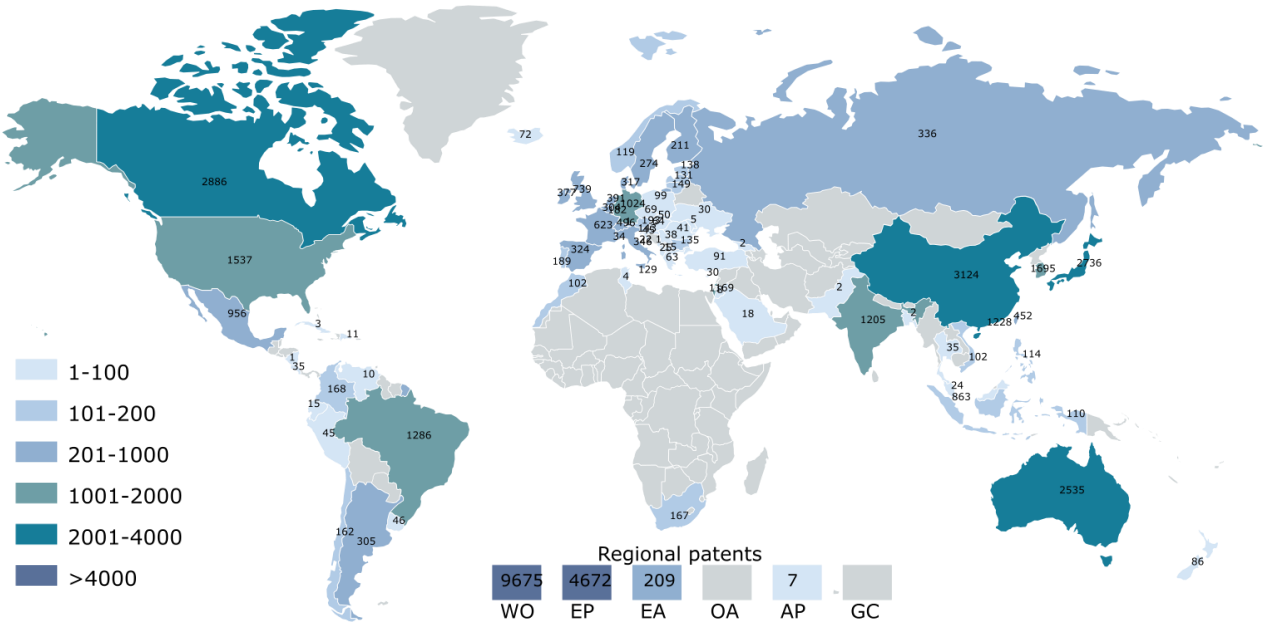


Figure 3.1.4: The countries and regions `to` *which patent protection has been extended* `from` *a priority filing in another country. WO = "World", i.e. patents extended via the Patent Cooperation Treaty filings; EP/EA/OA/AP labels are according to https://www.wipo.int/pct/en/texts/reg_des.html. That is: EP = European Patents; EA = Eurasian patents; OA = OAPI African Intellectual Property Organization patents; AP = patent extensions via the African Regional Intellectual Property Organization; GC = Gulf Cooperation Council patents. Colors for the map and regional boxes correspond with the number of patent extensions (legend at the left).*

Priority filings can be extended directly to specific other countries, as indicated on the map above, or using regional procedures (WO, EP, EA, OA, AP, GC), as indicated in the boxes at the bottom of the map. The extension of protection from priority filings has mainly occurred via the PCT procedure (9'675 patent families = 40.83%) and/or via the EP procedure (4'672 patent families = 19.72%), both in dark blue. To date, 496 families from this EP procedure have been extended to Switzerland. However, due to delays in entering the national phase, additional EP patent applications may still be extended to Switzerland in the future. No patent applications have been extended to Switzerland independently of the EP procedure. Other countries to which patents are often extended are China, Canada, Australia, the USA, Brazil and India.

For all patent families with an EP member, the world map of patent extensions shows similar trends as the global map for all patent extensions depicted above.

Notably, only 993 of the 11'965 Chinese priority filings (= 8.3%) have been extended to other countries so far (mainly via PCT). Despite China being a leader in priority filings, few of these patents have their protection extended beyond China.

3.1.5 Main patent assignees (≥ 71 patent families)

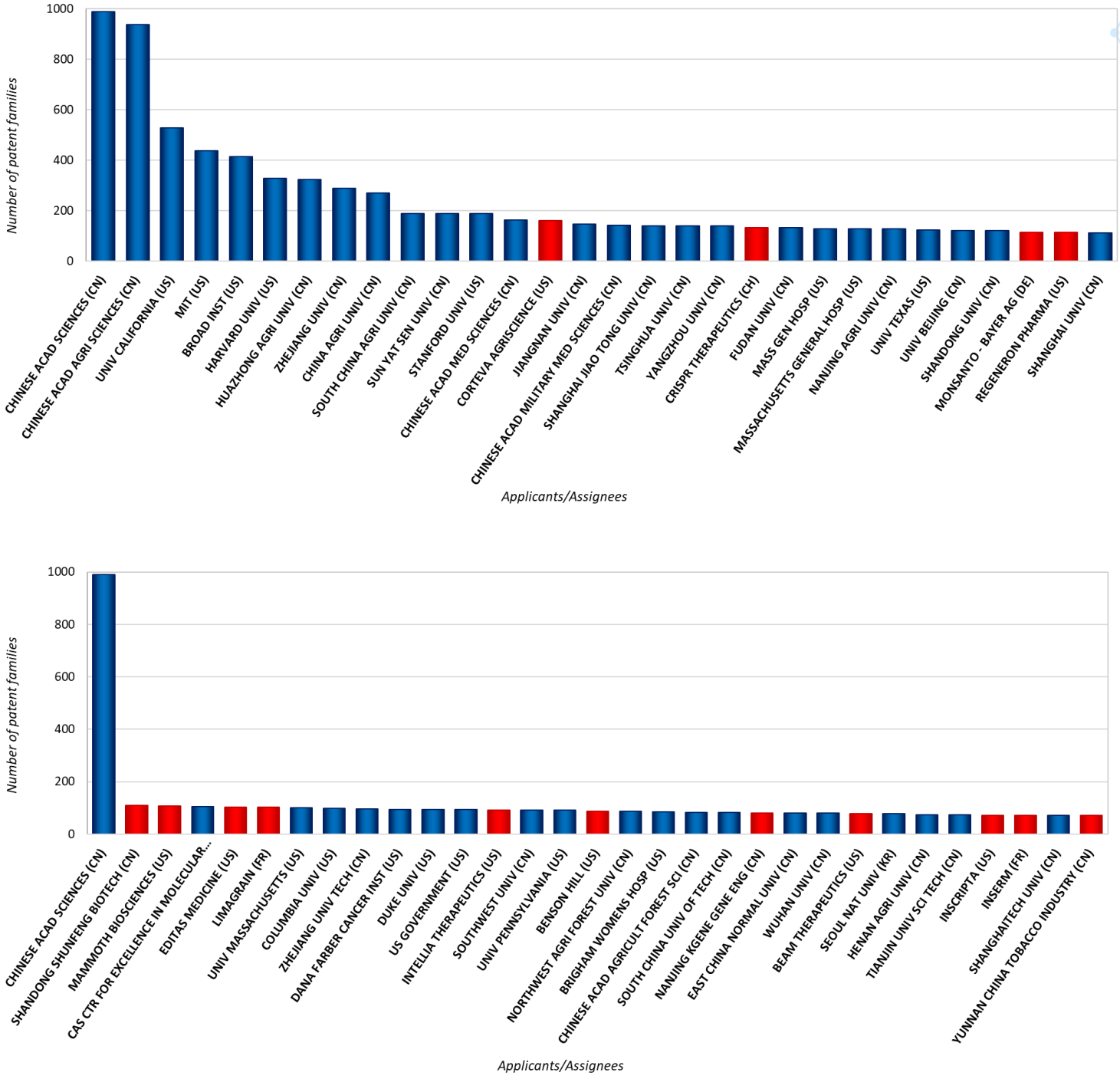


Figure 3.1.5: Top: The top 30 main patent applicants/assignees. Blue indicates public entities; red indicates private entities. Bottom: The graph continued with the next top 30, and the Chinese academy of sciences shown for comparison purposes. Affiliates & subsidiaries have been gathered under their parent company (e.g. Pioneer with Corteva Agriscience). The Chinese Academy of Sciences and the Chinese Academy of Agricultural Sciences include academic labs affiliated to them. Co-filings are counted for each co-owner: a patent application co-filed between the MIT, the Harvard University and the Broad Institute is counted once for each of these assignees.

The Chinese Academy of Sciences and the Chinese Academy of Agricultural Sciences are the top players in the CRISPR Patent Landscape, illustrating the importance and the stake of Genome Editing technologies for the Chinese government. The majority of the players are public entities.

3.1.6 Breakdown by Claim coverage of patent families

Please note that patent families can be classified in several categories.

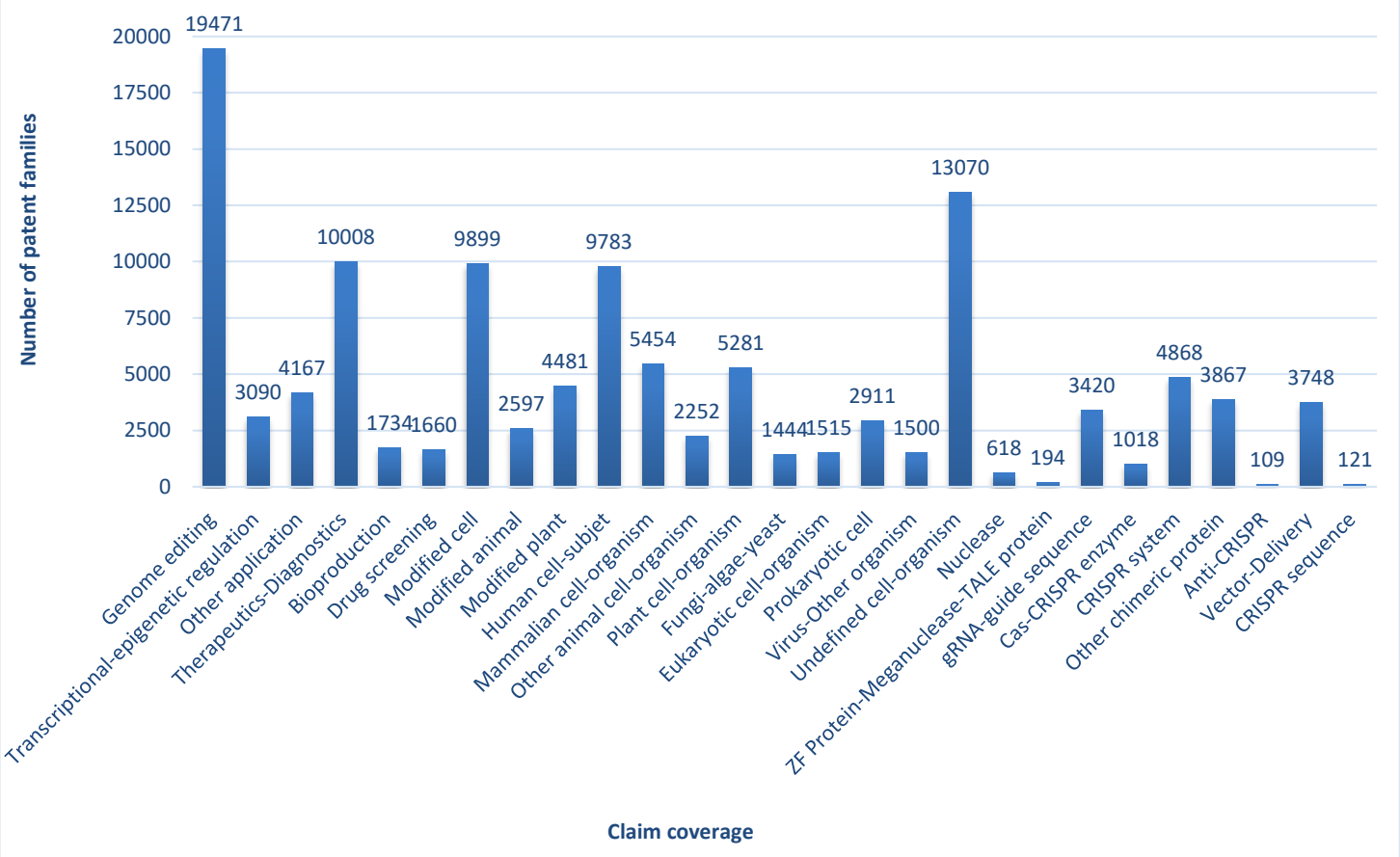


Figure 3.1.6: The number of CRISPR patent families with claims covering each area of interest.

As demonstrated in the figure above, the major areas of interest for CRISPR patent families are modified organisms (plant, animal, human, cell, unidentified), for therapeutics/diagnostics applications, in addition to genome editing.

3.2 European Patent Landscape on CRISPR

There are 629 EP priority filings on CRISPR and 5301 patent families comprising at least one EP patent application.

3.2.1 Main patent assignees (≥ 30 patent families) of all EP patents

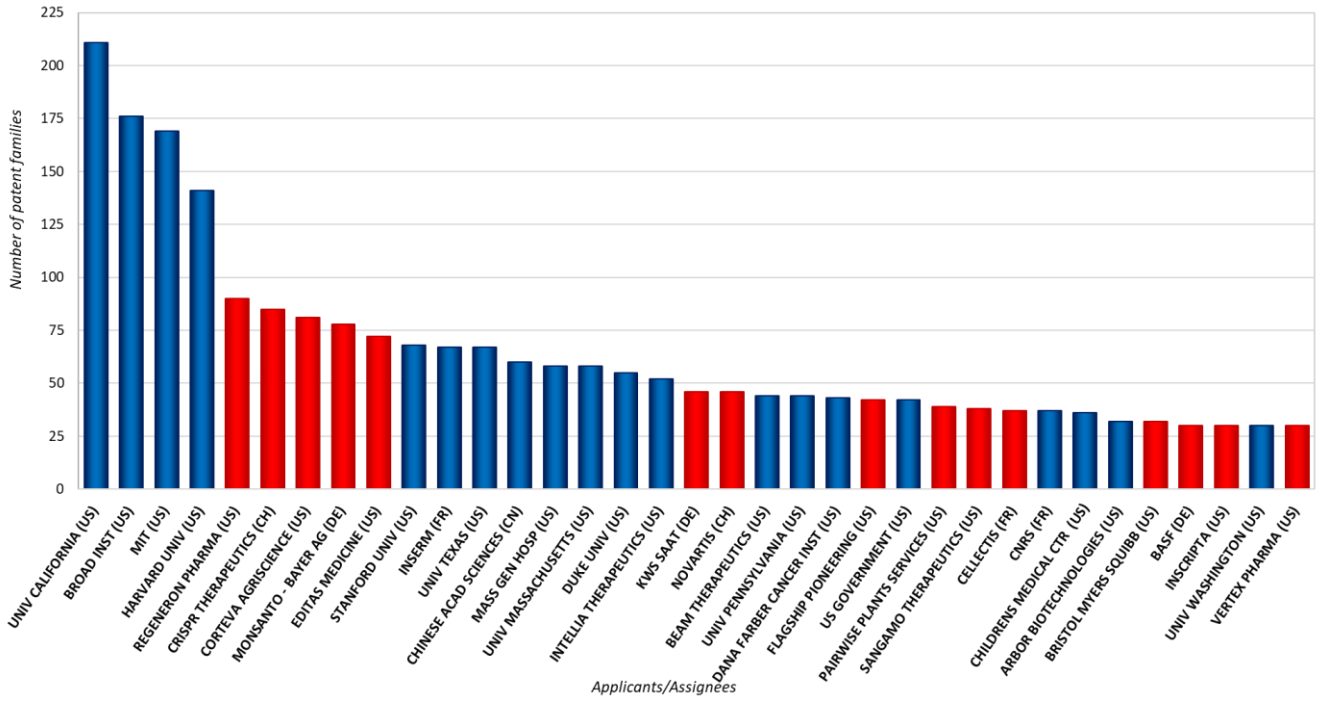


Figure 3.2.1: The top 35 main patent applicants/assignees. Blue indicates public entities; red indicates private entities. Affiliates & subsidiaries have been gathered under their parent company (e.g. Pioneer with Corteva Agriscience). The Chinese Academy of Sciences and the Chinese Academy of Agricultural Sciences include academic labs affiliated to them. Co-filings are counted for each co-owner: a patent application co-filed between the MIT, the Harvard University and the Broad Institute is counted once for each of these assignees.

Notably, the majority of players patenting in Europe are not European but are American. In contrast to the global landscape, there are no big Chinese players, as these mostly patent only within China. There are also more industrial players compared to the global landscape.

3.2.2 Breakdown by Claim coverage of patent families of all EP patents

Please note that patent families can be classified in several categories.

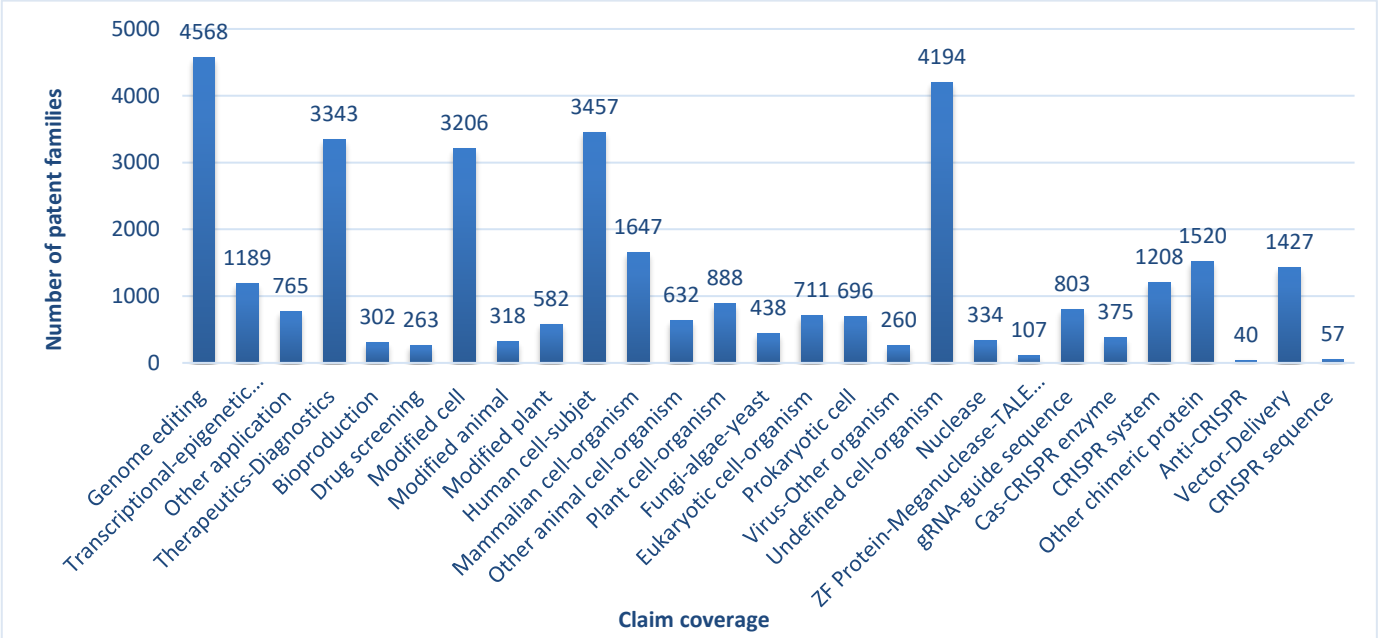


Figure 3.2.2: The claims of CRISPR patent families comprising at least one EP member covering each area of interest.

Besides a slight increase in the Transcriptional-epigenetic regulation domain and Eukaryotic cell-organisms as target, the major areas of interest for CRISPR patent families in Europe are similar to those in general.

3.3 Swiss Patent Landscape on CRISPR

There are only three priority filings on CRISPR in Switzerland and this country is designated for protection in a total of 496 patent families (e.g. especially via the European procedure).

3.3.1 Priority filings

One first Swiss priority filing filed by Cytosurge (Priority Number CH20210000119 20210209; WO2022171543 - METHOD FOR PRODUCING GENETICALLY ENGINEERED CELLS), describes a microelectromechanical system (MEMS)-based approach to directly inject genome editing components (Cas proteins and guide RNAs) into the nucleus of single cells using nanosyringes, demonstrating a high-precision, cell-level editing technique aimed at improving monoclonal culture generation. The second Swiss priority filing (Priority Number CH20190001509 20191129; WO2021105509 - CHIMERIC OPSIN GPCR PROTEINS), from a research team based in Bern, focuses on the engineering of light-sensitive chimeric GPCR proteins combining opsin and non-opsin domains. This second family will be further discussed in “4.1.12 Patent families covering Switzerland“, where its implications for sensory control and optogenetics in transgenic models are explored in more detail. The third Swiss priority filing was filed in 2022 by the company Avelo (Priority Number CH20220001271

20221027; WO2024089183 - DEVICE AND SYSTEM FOR COLLECTING AEROSOL PARTICLES AND PREPARING THE SAMPLE FOR ANALYSIS). It covers a system and device for collecting aerosol particles (e.g., from breath or the environment), concentrating them, and transferring them into an aqueous solution for analysis via immunoassays or molecular assays for pathogen detection.

3.3.2 Main patent assignees of patent families covering Switzerland (≥ 5 patent families)

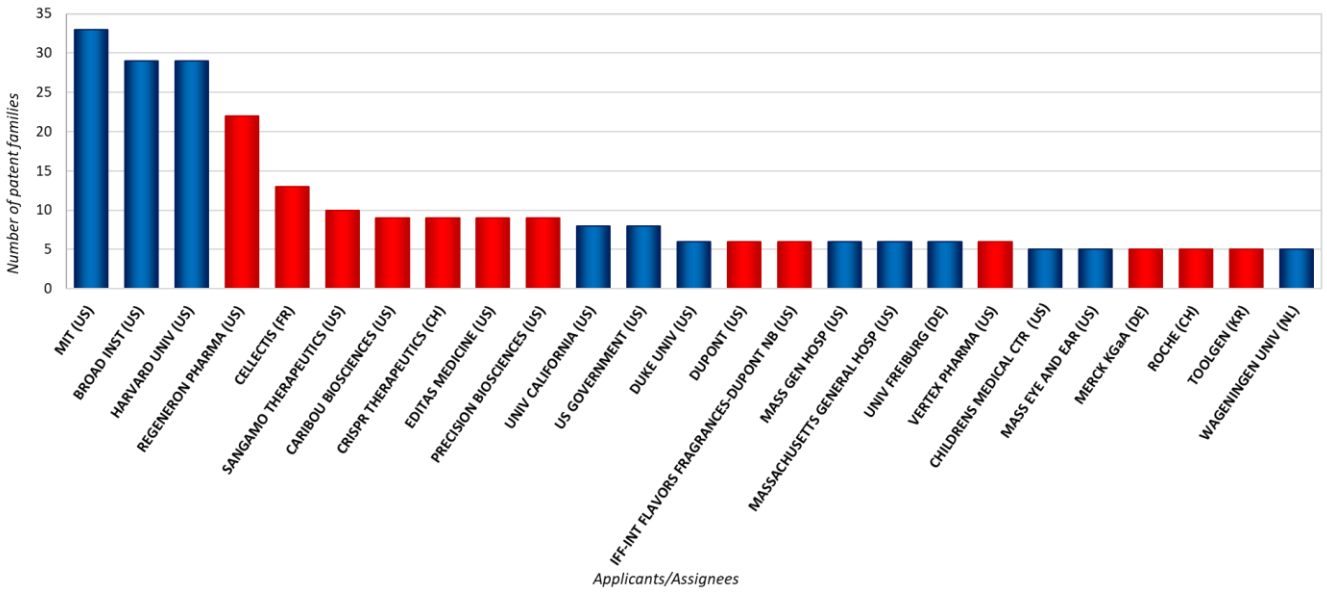


Figure 3.3.2: The top 35 main patent applicants/assignees. Blue indicates public entities; red indicates private entities. Affiliates & subsidiaries have been gathered under their parent company (e.g. Pioneer with Corteva Agriscience). Co-filings are counted for each co-owner: a patent application co-filed between the MIT, the Harvard University and the Broad Institute is counted once for each of these assignees.

Similarly to the players patenting in Europe, the majority of players patenting in Switzerland are American and the distribution between academic and industrial players is equilibrated.

3.3.3 Breakdown by Claim coverage of patent families covering Switzerland

Please note that patent families can be classified in several categories.

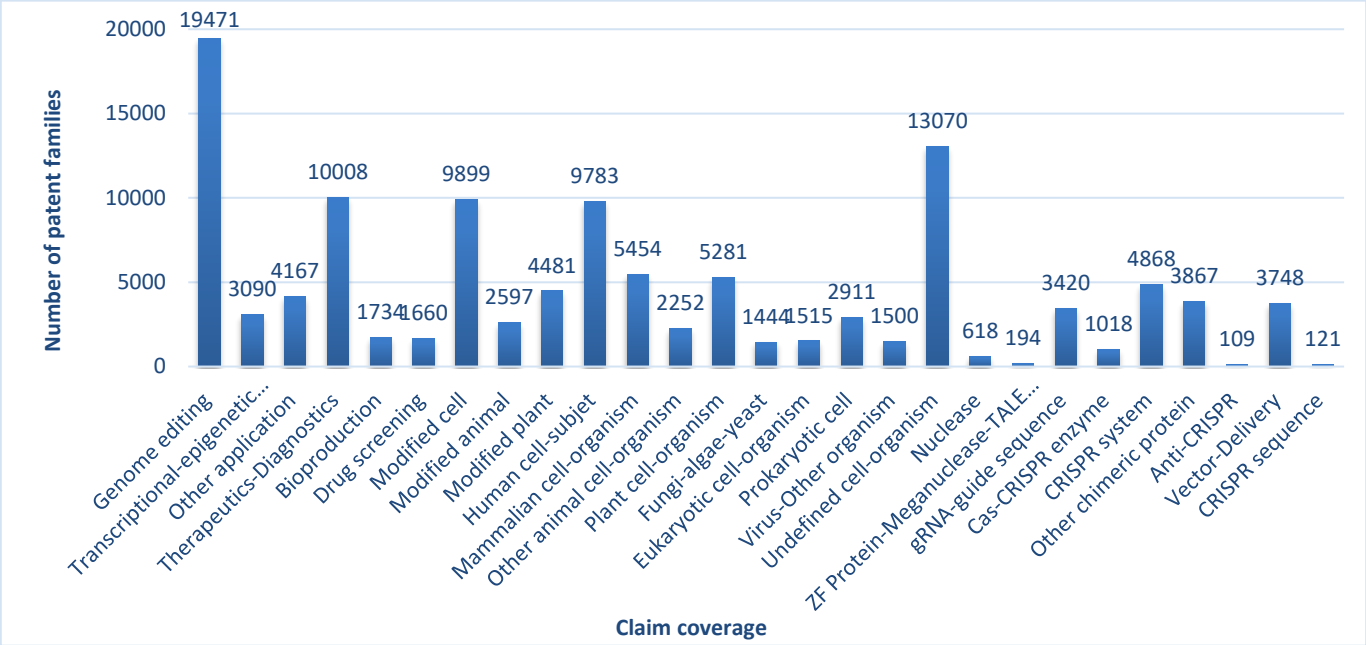


Figure 3.3.3: The claims of CRISPR patent families with a CH member covering each area of interest.

The major areas of interest for CRISPR patent families in Switzerland are similar to those in general.

4 Patent Landscape on Modified Plants & CRISPR

4.1 Non-CN priority filings and CN priority filings with extensions

There are 1852 patent families in this data set (data up to and including June 2025), comprising all patent families on modified plants, except the Chinese priority filings that have not been extended outside of the People's Republic of China. There are 465 additional patent families compared to the previous report CRISPR technology: Patent & Licence landscapes published early 2024 (data until Sept.-Oct. 2023).

4.1.1 Temporal distribution of non-CN priority filings and CN priority filings with extensions (2011-2023)

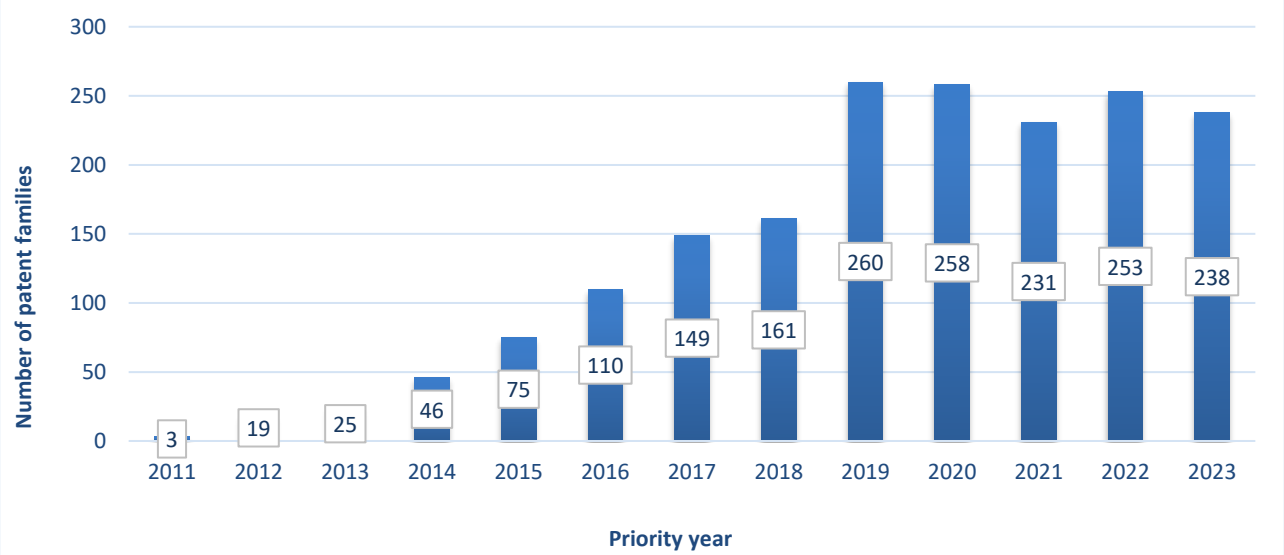


Figure 4.1.1: Number of patent families covering modified plants by priority year, excluding patents only filed in China (Chinese patents extended beyond China are included). Notably, the year 2023 might not be complete due to the delay in publication.

The increase in 2014 primarily reflects the early adoption of CRISPR techniques following the 2013 publications. The increase in patent families continued until 2019, whereafter number of filings stabilized.

4.1.2 Temporal distribution of European filings (2011-2022)

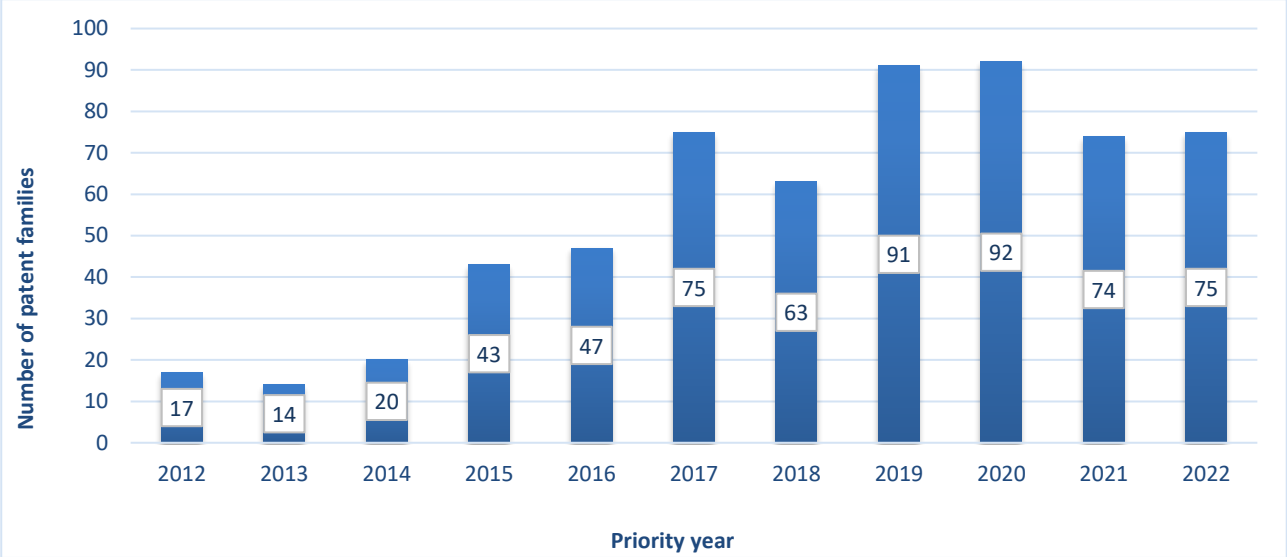


Figure 4.1.2: Number of patent families comprising at least one EP patent application, covering modified plants by priority year. Notably, the year 2021 and 2022 might not be complete due to the delay in publication.

When looking specifically at EP filings, we observe a similar upward trend starting in 2012 until 2019, followed by a slight decrease in 2021 and 2022. This drop is primarily due to the widespread use of the PCT route for EP filings, which allows applicants up to 30 or 31 months from the priority date to enter the European regional phase, leading to a natural delay in visibility for recent filings.

4.1.3 World map of priority filings covering modified plants

Countries	Nb	%
UNITED STATES	1091	58.94%
CHINA	203	10.97%
KOREA	186	10.05%
EUROPE	98	5.29%
WORLD	84	4.54%
UNITED KINGDOM	38	2.05%
INDIA	30	1.62%
JAPAN	29	1.57%
RUSSIAN FEDERATION	24	1.30%
NETHERLANDS	14	0.76%
LUXEMBOURG	9	0.49%
Other countries	45	2.43%

Table 4.1.3: Number of priority filings covering modified plants by country, and percentage of total filings.

Priority filings covering modified plants were mostly filed in the USA (1091 – 58.94%), followed by the People's Republic of China (203 – 10.97%) and South Korea (186 – 10.05%). Countries and regions (PCT and EP) outside of these three countries represent 9.83% of the priority filings. This distribution is quite similar to the previous report from early 2024, but South Korea represents a larger portion now, indicating an increase in interest over the last years.

In Europe, the UK appears to be the main patent filer, although it could be that assignees from other countries choose more often to apply directly for a European patent instead of a national one. Notably, there are no Swiss priority filings.

4.1.4 World map of patent extensions

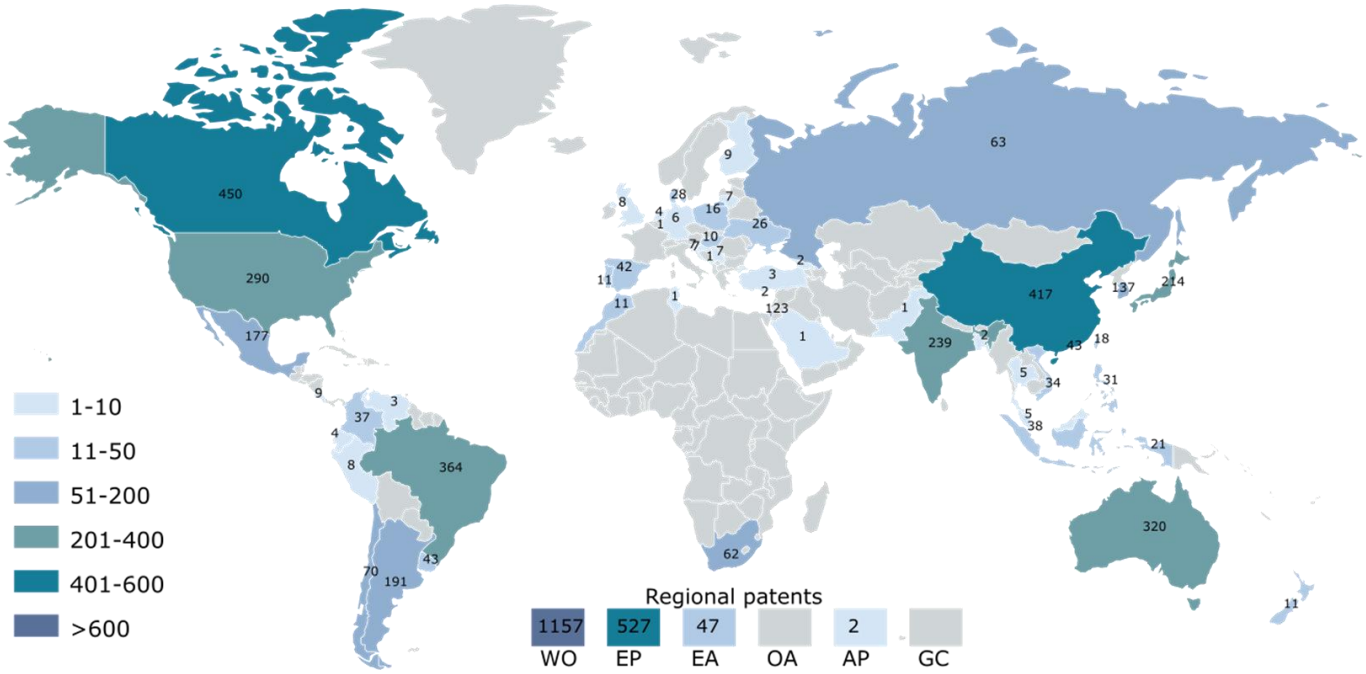


Figure 4.1.4: The countries and regions **to** which patent protection covering modified plants has been extended **from** a priority filing in another country. WO = "World", ie. patents extended via PCT filings; EP/EA/OA/AP labels are according to https://www.wipo.int/pct/en/texts/reg_des.html. That is: EP = European Patents; EA = Eurasian patents; OA = OAPI African Intellectual Property Organization patents; AP = patent extensions via the African Regional Intellectual Property Organization; GC = Gulf Cooperation Council patents. Colors for the map and regional boxes correspond with the number of patent extensions (legend at the left).

Figure 4.1.4 shows the extension of priority filings covering modified plants or plant cells with CRISPR. The extensions occurred mainly via the PCT procedure (1157 patent families = 62.47%) and the EP extension policy (527 patent families = 28.46%). Most extensions to Canada (450 patent families = 24.30%), were to the People's Republic of China (417 patent families = 22.52%), to Brazil (364 patent families = 19.65%) and to Australia (320 patent families = 17.28%). These trends are similar to those observed previously in this domain. No patent applications have been filed in Switzerland specifically.

4.1.5 Main patent assignees (≥ 6 patent families)

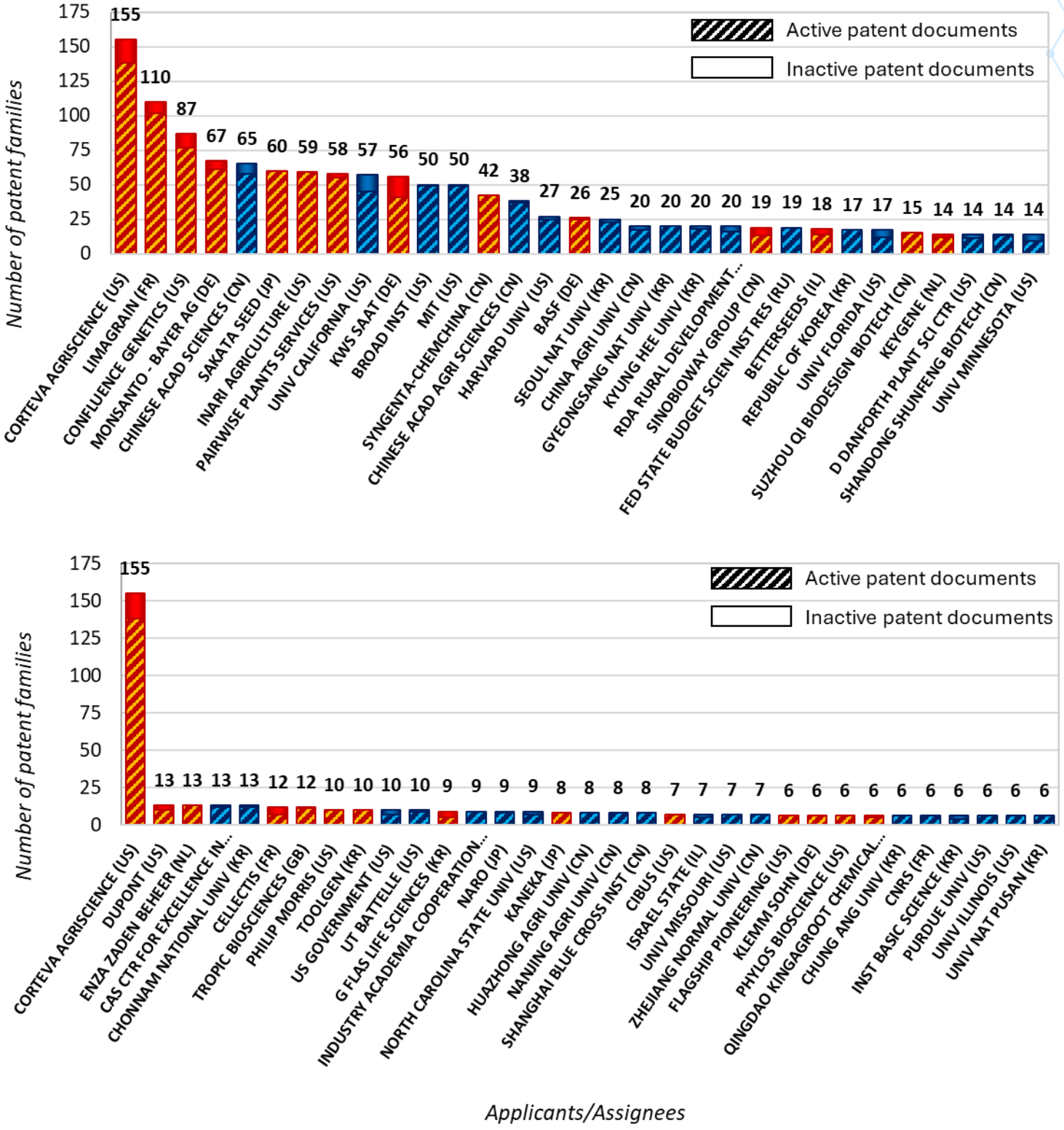


Figure 4.1.5: The main patent applicants/assignees with at least 6 patent families covering modified plants (top: The top 31 main patent applicants/assignees; bottom: the next 32 patent applicants/assignees). Blue indicates public entities; red indicates private entities. Affiliates & subsidiaries have been gathered under their parent company (e.g. Pioneer with Corteva Agriscience). Co-filings are counted for each co-owner: a patent application co-filed between the MIT, the Harvard University and the Broad Institute is counted once for each of these assignees.

The Broad Institute, the MIT, Harvard University, and the University of California have large patent portfolios covering some key pioneer patent families on CRISPR-Cas9 and more globally CRISPR enzymes and CRISPR systems for various applications. Their claims are often very broad, including applications such as plant engineering, but they are not focused on modified plants in particular. The main assignees in this field are big agricultural companies, such as Corteva Agroscience, Limagrain, Confluence Genetics (acquired the patent portfolio from Benson Hill), Monsanto – Bayer AG, Inari Agriculture and Pairwise Plants Services. In particular the first two have increased their portfolio considerably compared to the other players in the last few years (patents published between Sept.-Oct. 2023 and Dec. 2024). Overall, the landscape shows a relatively balanced distribution between industrial and academic actors among the top assignees. Notably, there are a few Chinese players, both industrial and academic, who extended their patents outside of China, such as the Chinese Academy of Sciences, Syngenta-Chemchina and Sinobioway Group. This suggests a growing internationalization of CRISPR-related plant innovation beyond traditional Western strongholds.

4.1.6 Main patent assignees that filed patents in Europe (≥ 6 patent families)

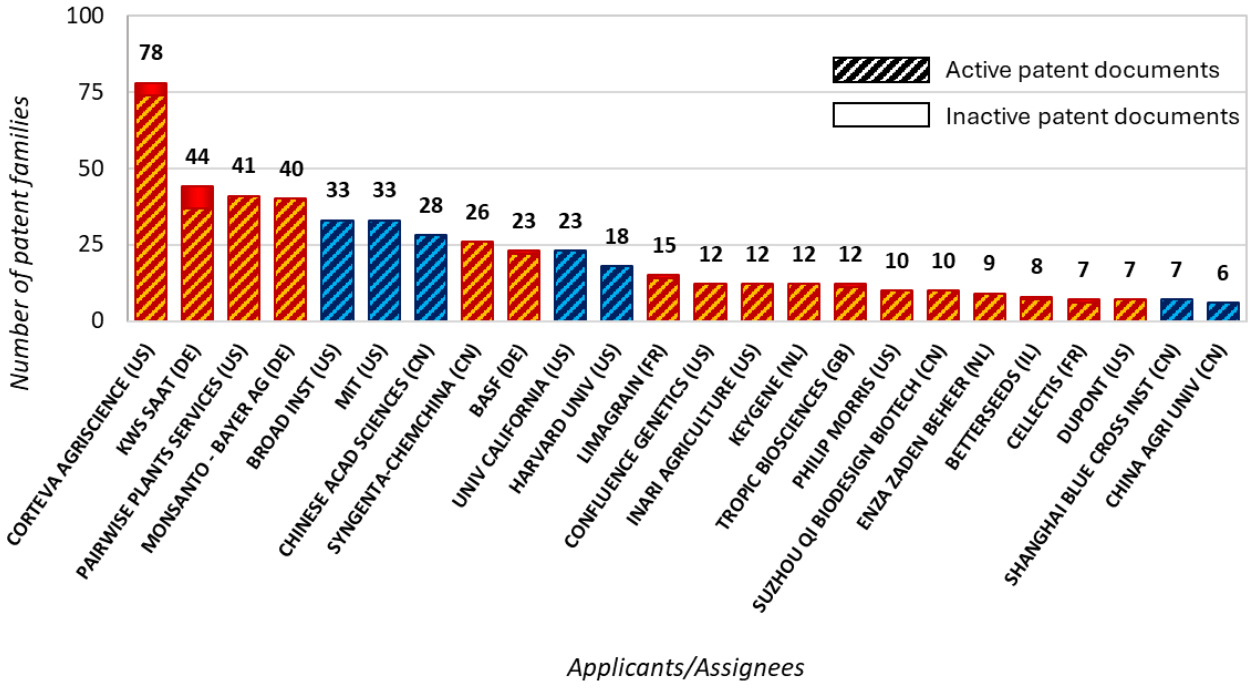


Figure 4.1.6: The top 24 patent applicants/assignees with at least 6 patent families covering modified plants. Blue indicates public entities; red indicates private entities. Affiliates & subsidiaries have been gathered under their parent company (e.g. Pioneer with Corteva Agriscience). Co-filings are counted for each co-owner: a patent application co-filed between the MIT, the Harvard University and the Broad Institute is counted once for each of these assignees.

The top filers in Europe are also among the top filers globally, with Corteva Agriscience emerging as the leading assignee in both cases. KWS Saat and Pairwise Plants Services have relatively larger portfolios in Europe, suggesting a strategic focus on this region. In contrast, Limagrain and Confluence Genetics have smaller European portfolios, which may reflect a stronger orientation toward North American markets or a more cautious approach to EU regulatory frameworks. Aside from the pioneering academic institutions (Broad Institute, MIT, University of California and Harvard University), the landscape is largely dominated by industrial players.

The following graphs focus on total non-CN priority filings and CN priority filings with extensions, given that EP filings follow similar overall trends. Slight deviations from these trends will be indicated in the text.

4.1.7 Breakdown of the patent portfolio by Claim coverage

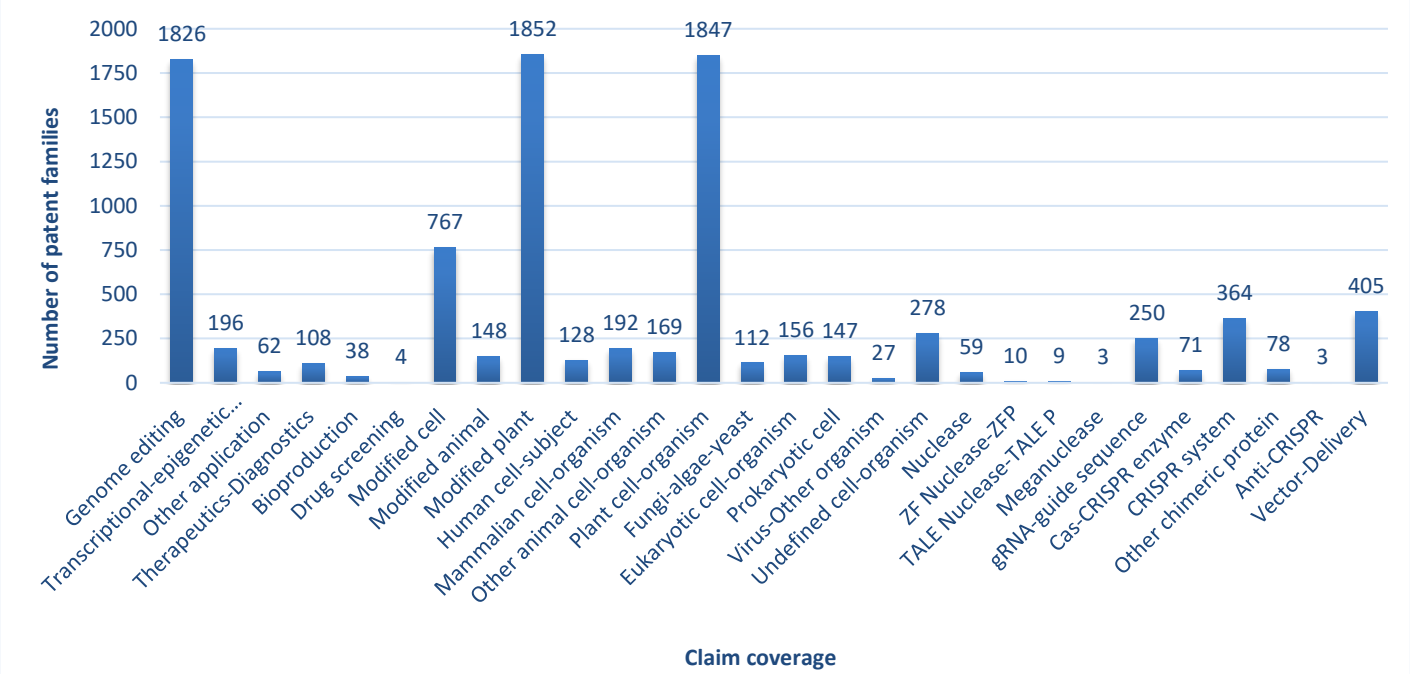


Figure 4.1.7: The number of CRISPR patent families relating to modified plants with claims covering each area of interest.

This graph shows this data subset is about the use of CRISPR for genome engineering of plants or plants cells. Unsurprisingly, modified plants, as well as plant cells are the leading claim categories, in this modified plant subset. Besides these categories, other types modified cells are also regularly mentioned, showing that claims are often broad.

Aside from the more generic “genome editing” and “modified cell” categories, note the significant protection of CRISPR systems, and vectors for such modifications. This was also observed in the previous report on CRISPR modified plants.

In Europe, there seems to be relatively more patenting of modified plant cells than modified plants.

4.1.8 Breakdown by Claim coverage - Positioning of main assignees (≥ 6 patent families)

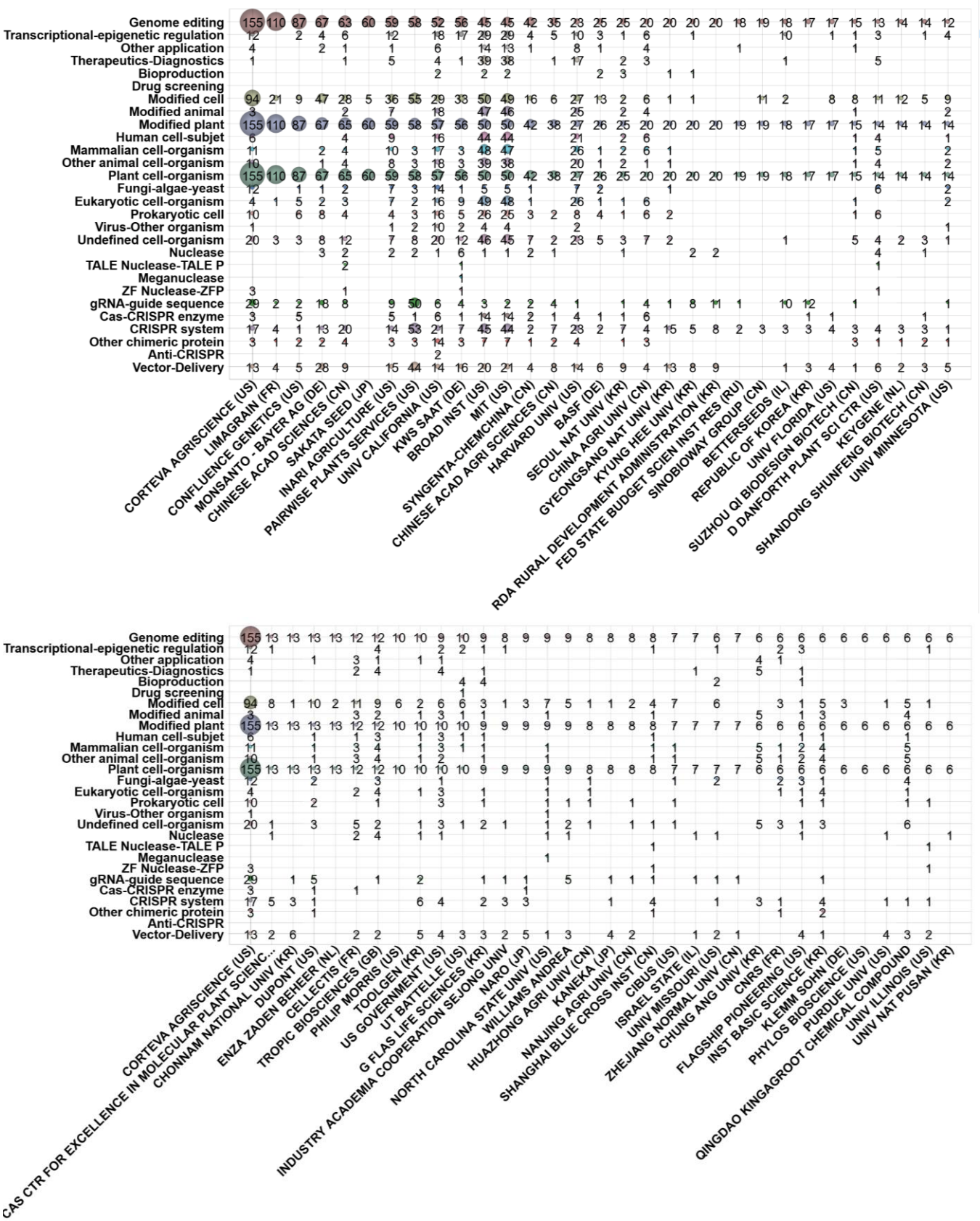


Figure 4.1.8: A breakdown by claim coverage of patent families by the top patent holders, in order (left to right and top to bottom) of patent families held. Corteva is shown again in the bottom section for comparison purposes.

The pioneer institutes (Broad, MIT, Harvard, and the University of California) hold a substantial portfolio of patents covering modified plants and plant cells. While these patents encompass plant cell and organism claims, such uses are typically included as part of broader claim strategies rather than being a dedicated area of focus. In contrast, most other patent holders concentrate their efforts specifically on plants and plant cells. The majority of assignees, particularly large agricultural companies such as Corteva Agriscience, Limagrain, Inari Agriculture, and Pairwise Plants, have portfolios focused almost exclusively on plant-related applications. Their filings are highly targeted, with limited extension into other organism types, underscoring a more specialized strategic intent aligned with crop improvement and agricultural trait development. Notably, very few patent families cover CRISPR sequences or the use of TALENs or meganucleases, highlighting a distinct gap in this landscape.

4.1.9 Breakdown of the patent portfolio by Components

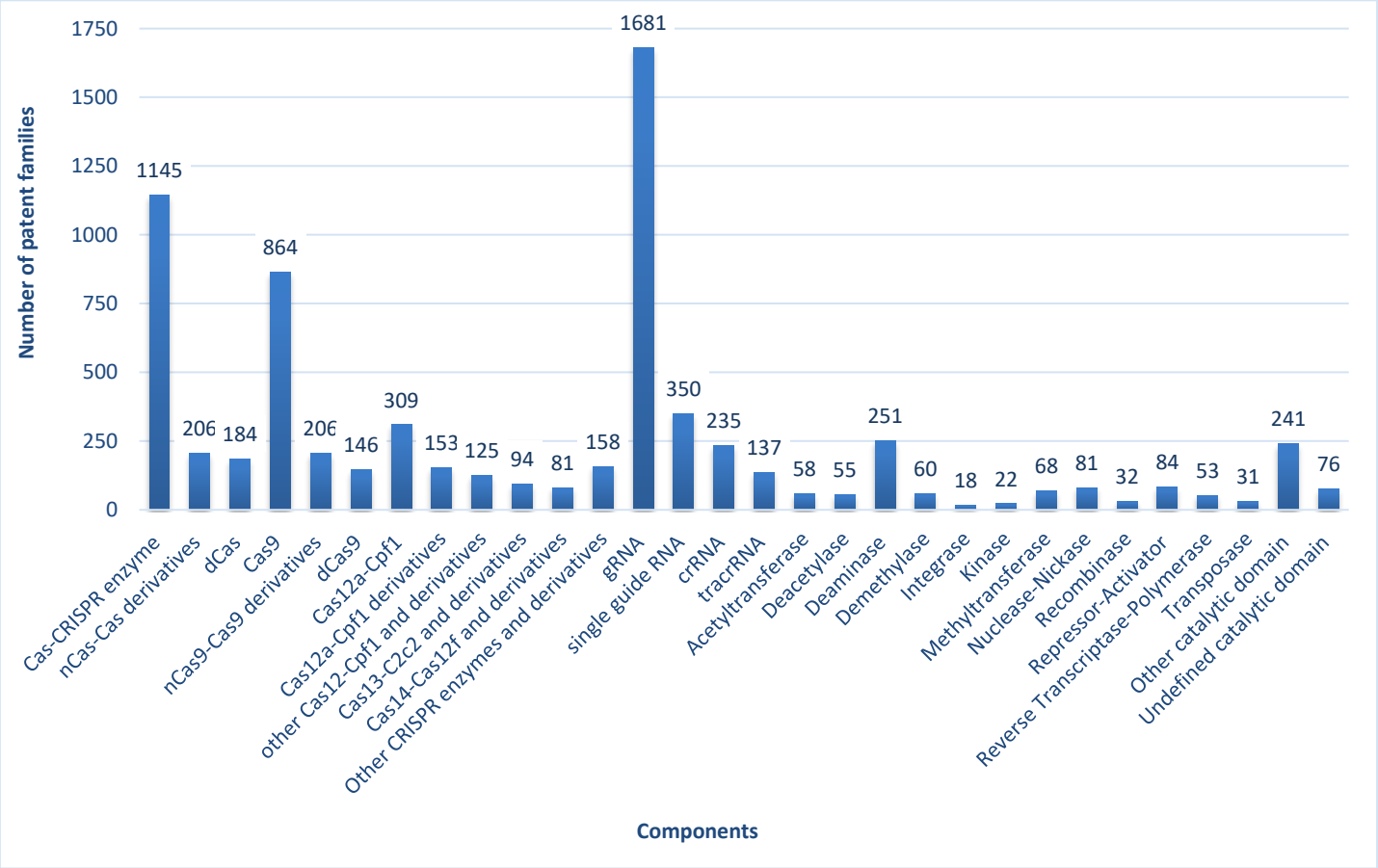


Figure 4.1.9: Number of patent families relating to modified plants with specifications disclosing the use of each component.

Notably, the most common component covered by these patent families is a guide RNA. Most patent families disclose the use of Cas9, but other nucleases are also mentioned. Cas12a-Cpf1 are the next most common Cas proteins mentioned after Cas9, followed by nCas9 and Cas9 derivatives. In addition, many other types of proteins are mentioned, such as Deaminases.

In Europe, Cas9 and gRNA appear to be less frequently patented compared to other components, indicating a stronger focus on more specialized or distinctive aspects of CRISPR technologies.

4.1.10 Breakdown by Components - Positioning of main assignees (≥ 6 patent families)

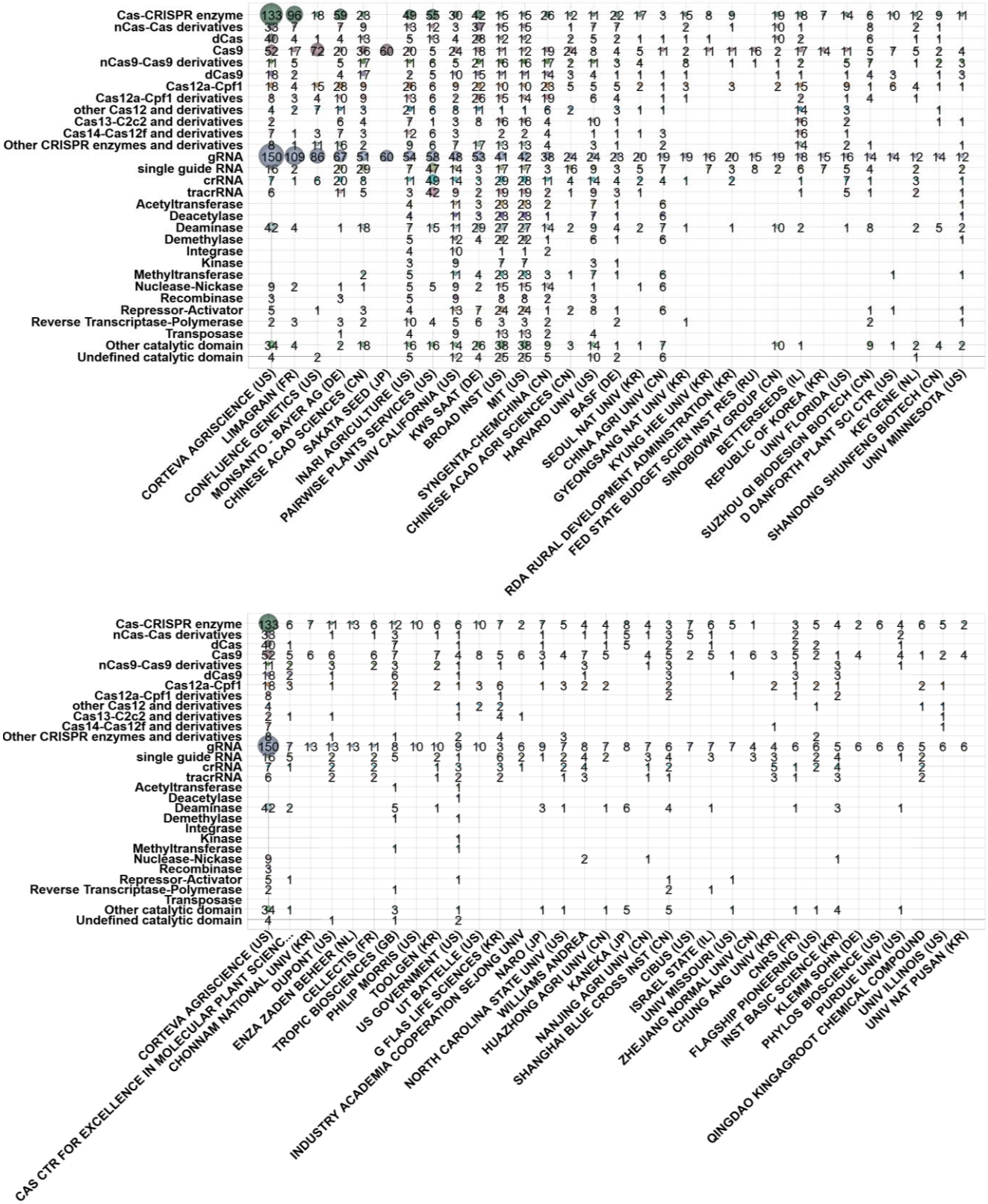


Figure 4.1.10: A breakdown by components of patent families relating to modified plants by the top patent holders, in order (left to right and top to bottom) of patent families held. Corteva is shown again in the bottom section for comparison purposes.

Outside of the foundational academic institutions, relatively few players hold extensive and diversified portfolios that span multiple technical components. Notable exceptions include KWS Saat, Syngenta-Chemchina, and the China Agricultural University, each of which has accumulated patent families across a wide spectrum of genome editing mechanisms, ranging from enzymes and guide RNAs to lesser-covered catalytic domains. This broader coverage may signal a deliberate positioning toward technological flexibility and longer-term freedom to operate.

Nearly all leading entities predominantly own patent families related to Cas9, while Gyeongsang Natural University and Sinobioway Group focus more on nCas9-Cas9 derivatives and dCas, respectively. Notably, BetterSeeds owns a broad patent portfolio in terms of Cas enzymes including Cas9, but also Cas12, Cas13 and Cas14 derivatives.

4.1.11 Breakdown of the patent portfolio by Chimeric proteins

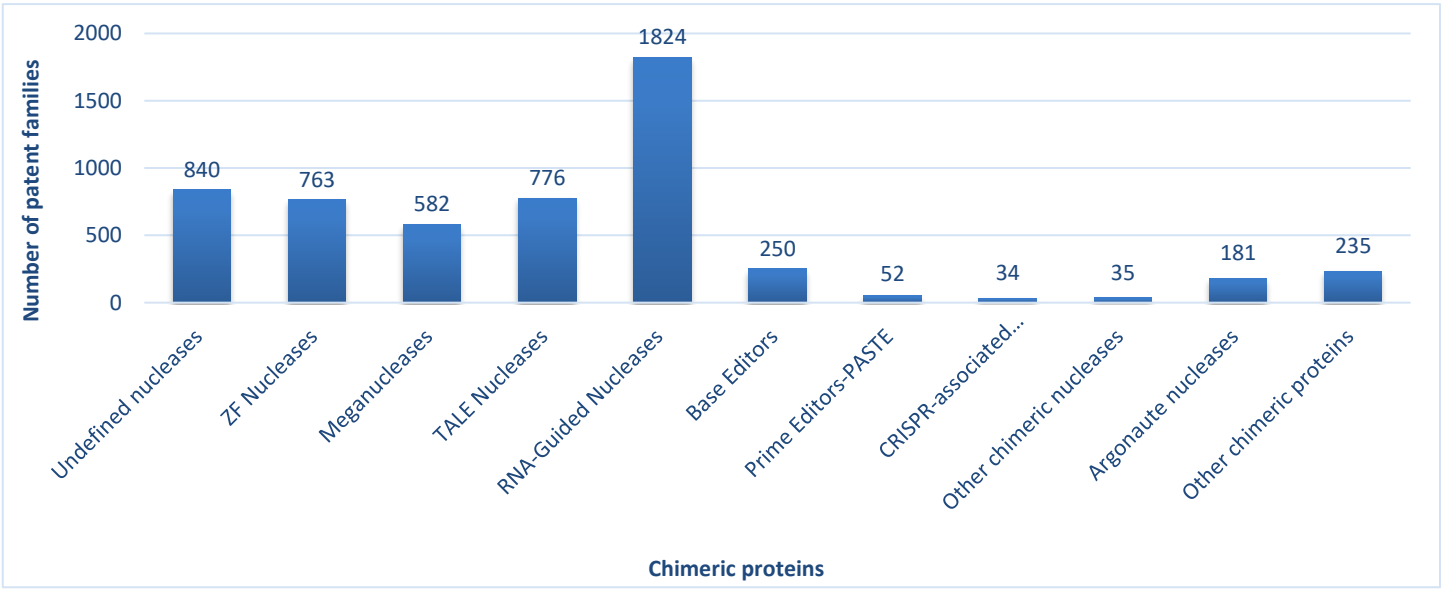


Figure 4.1.11: Number of patent families relating to modified plants with specifications disclosing the use of each type of chimeric protein.

Players in this data set claim the use of CRISPR for modifying plants but also legacy nucleases such as ZFN, TALENs besides CRISPR. More recent technologies based on CRISPR, such as Base Editors or other non-nuclease chimeric proteins are also gaining interest with increasing patent filings. In addition, note the high number of families generically covering RNA-guided nucleases.

In Europe, Base Editors are relatively more patented, indicating increased interest in more specialized and precise versions of CRISPR editing.

4.1.12 Breakdown by Chimeric proteins - Positioning of main assignees (≥ 6 patent families)

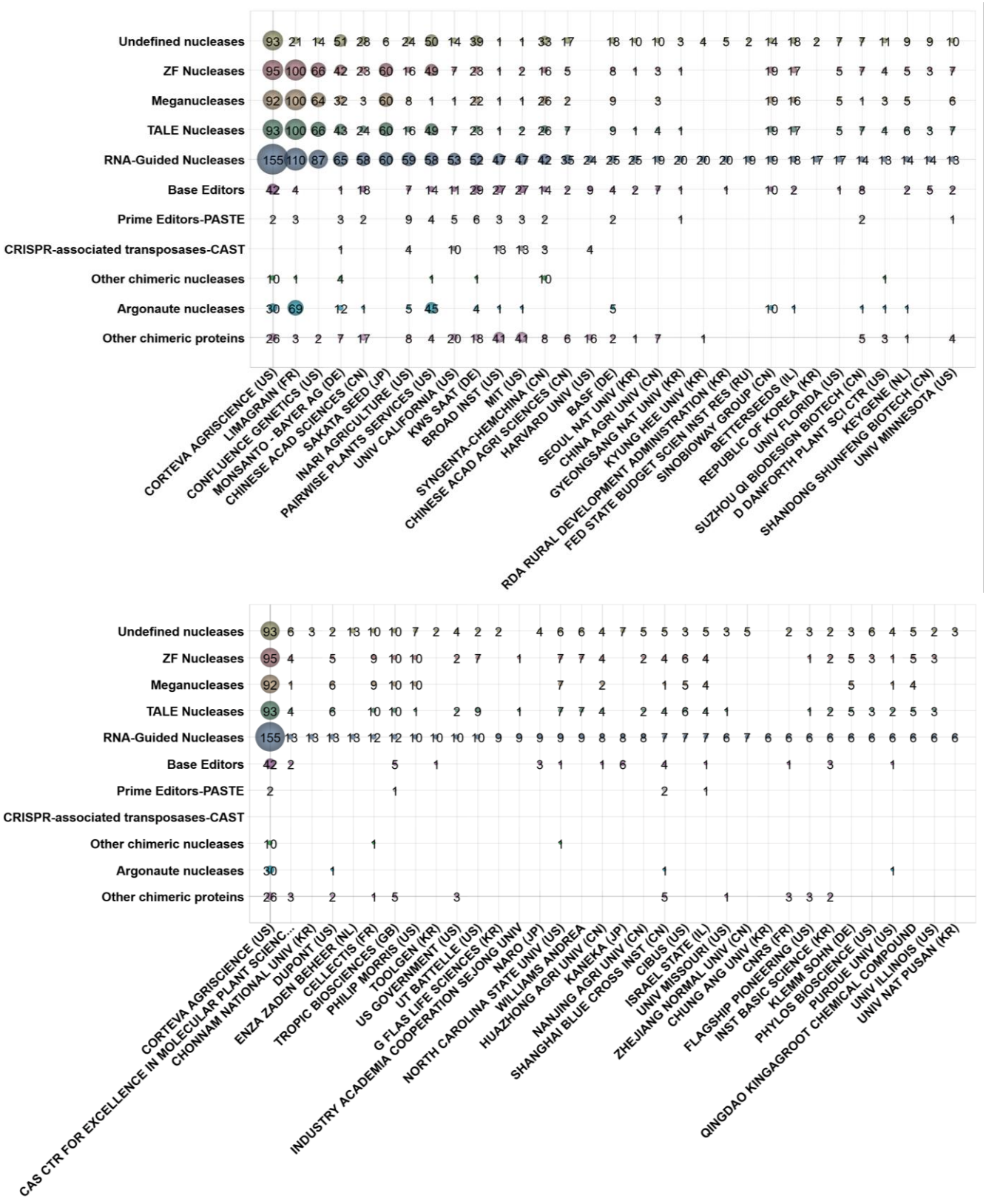


Figure 4.1.12: A breakdown by chimeric proteins of patent families relating to modified plants by the top patent holders, in order (left to right and top to bottom) of patent families held. Corteva is shown again in the bottom section for comparison purposes.

Most major players also claim undefined nucleases or legacy nucleases such as ZFN, TALENs besides CRISPR, but interestingly most Korean players do not and focus almost entirely on RNA-guided nucleases. This may reflect both a strategic emphasis on modern tools and the relative recency of these players' entry into the genome editing space. The use of recent technologies based on CRISPR (Base Editors, Prime Editors, CAST or other non-nuclease chimeric proteins such as artificial transcription factors) is mostly protected by the pioneer players (Broad Institute, MIT, Harvard, University of California). Among industrial players, Corteva Agriscience stands out for its substantial activity in base editing, while Inari Agriculture and KWS Saat appear relatively advanced in prime editing. However, the adoption of CRISPR-associated transposases (CAST) remains limited across the board, suggesting this emerging technology is still underrepresented in commercial development pipelines.

4.1.13 Patent families covering Switzerland

There are no patent applications filed in Switzerland.

4.2 CN priority filings with no extension

There are 3'287 patent families covering modified plants in this data set (data up to and including June 2025), that were only filed in China (Chinese priority filings that have not been extended outside of the People's Republic of China).

4.2.1 Temporal distribution of patent filings (2012-2024)

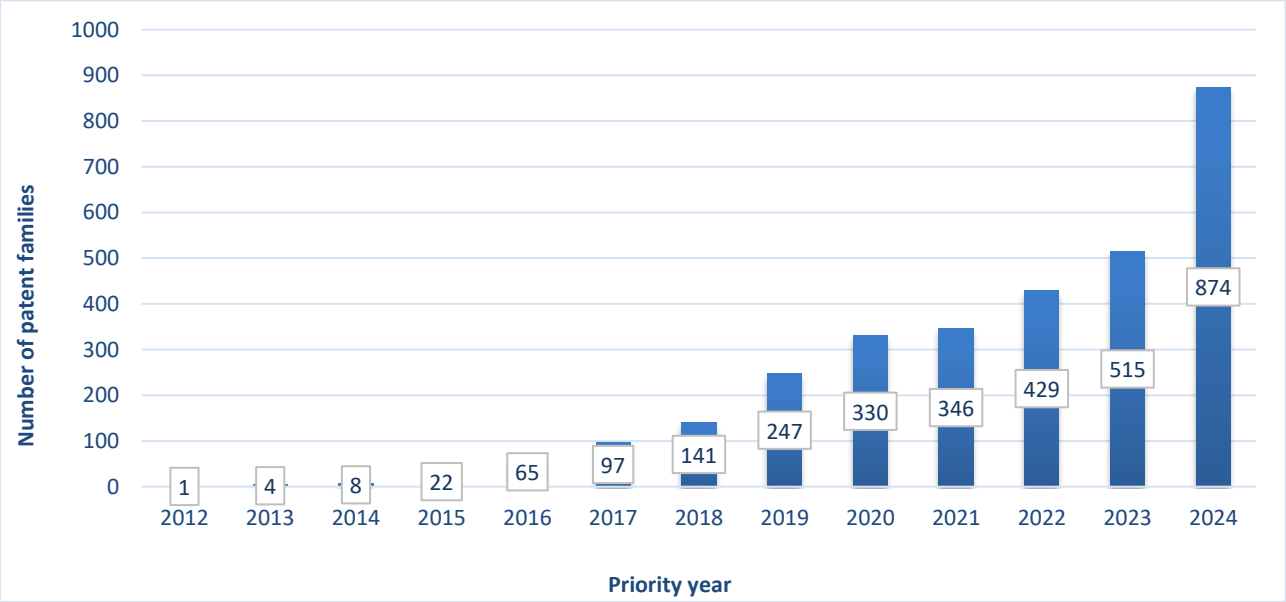


Figure 4.2.1: Number of Chinese priority filings with no extension covering modified plants by priority year (Chinese patents extended beyond China are excluded). Notably, the years 2023 and 2024 may not be complete due to the delay in publication.

Compared to the priority filings filed or extended outside of China, the increase in patent families per year is a bit behind and starts to increase from 2015, but then quickly increases, surpassing the non-Chinese priority filings. Furthermore, there does not seem to be a decrease in the number of patent applications per year hitherto. On the contrast, it only keeps on increasing exponentially, as evidenced by the high number of patent filings in 2024.

4.2.2 Main patent assignees (≥ 20 patent families)

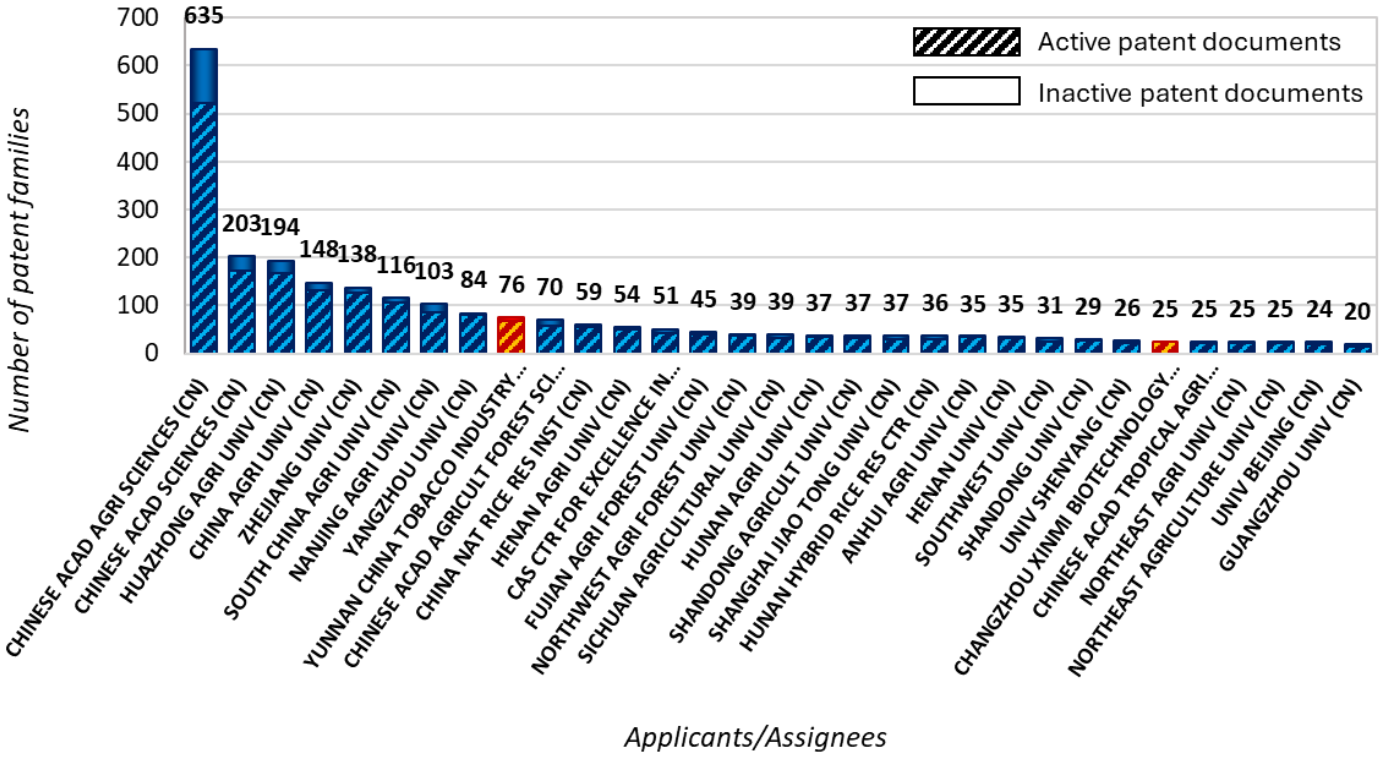


Figure 4.2.2: The top patent applicant/assignees with patent families filed only in China. Blue indicates public entities; red indicates private entities. Affiliates & subsidiaries have been gathered under their parent company. Co-filings are counted for each co-owner. The Chinese Academy of Sciences and the Chinese Academy of Agricultural Sciences include academic labs affiliated to them.

Notably, the overwhelming majority of the leading entities in China are public institutions or academic research centers. Among the top 30 assignees, only two private organizations (Yunnan China Tobacco Industry and Changzhou Xinmi Biotechnology) appear, both holding significantly smaller portfolios. This sharply contrasts with the situation outside of China, where large multinational agricultural companies are among the main IP holders in this domain.

The concentration of patent activity among public entities reflects the strategic importance of genome editing technologies in Chinese agricultural policy, as well as substantial state investment in research infrastructure and intellectual property generation. It also suggests that, while China is rapidly catching up in terms of research output and patent filings, the commercial exploitation of genome editing in agriculture may still be predominantly driven or steered by the public sector.

4.2.3 Breakdown of the patent portfolio by Claim coverage

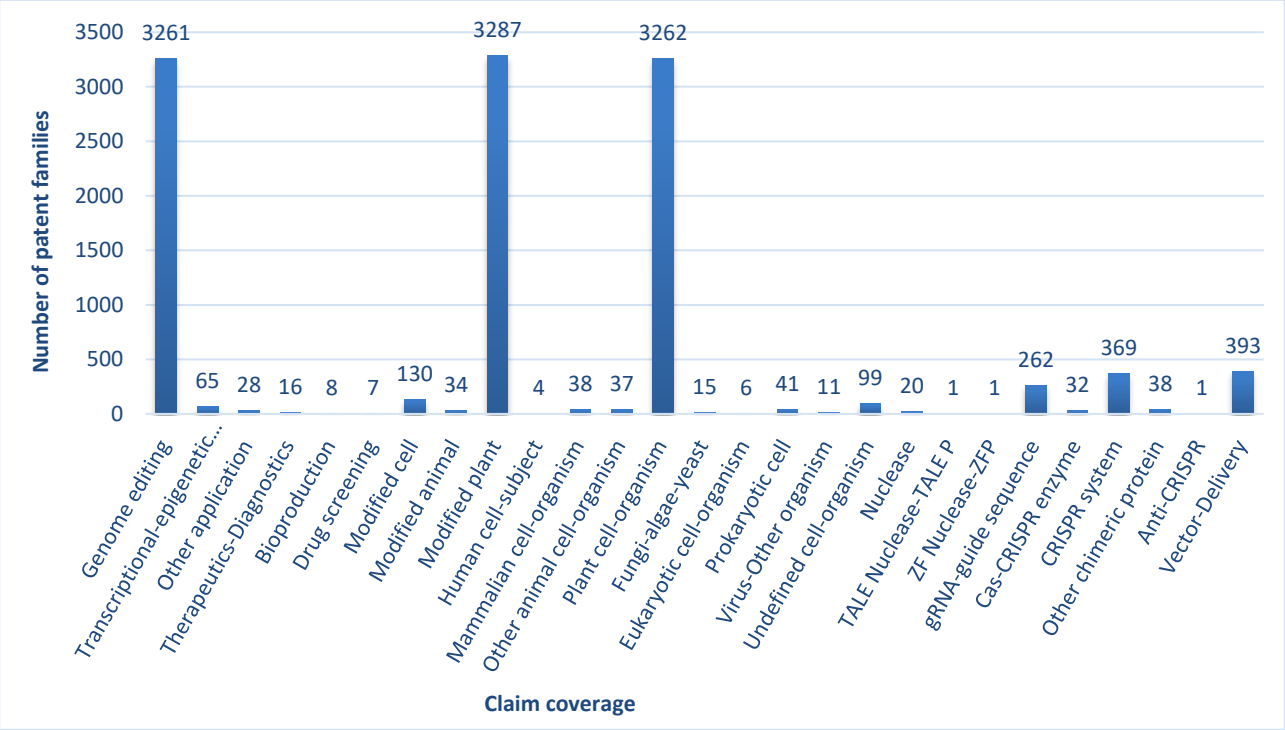


Figure 4.2.3: The number of CRISPR patent applications, filed only in China, relating to modified plants with claims covering each area of interest.

This graph shows this data subset is about the use of CRISPR for genome engineering in plants. Notably, the claims appear to be considerably less broad for the patent documents that are only filed in China, as other types of organisms are less claimed. Some players have also protected guide RNA or CRISPR systems, or vectors for such modifications.

4.2.4 Breakdown by Claim coverage - Positioning of main assignees (≥ 20 patent families)

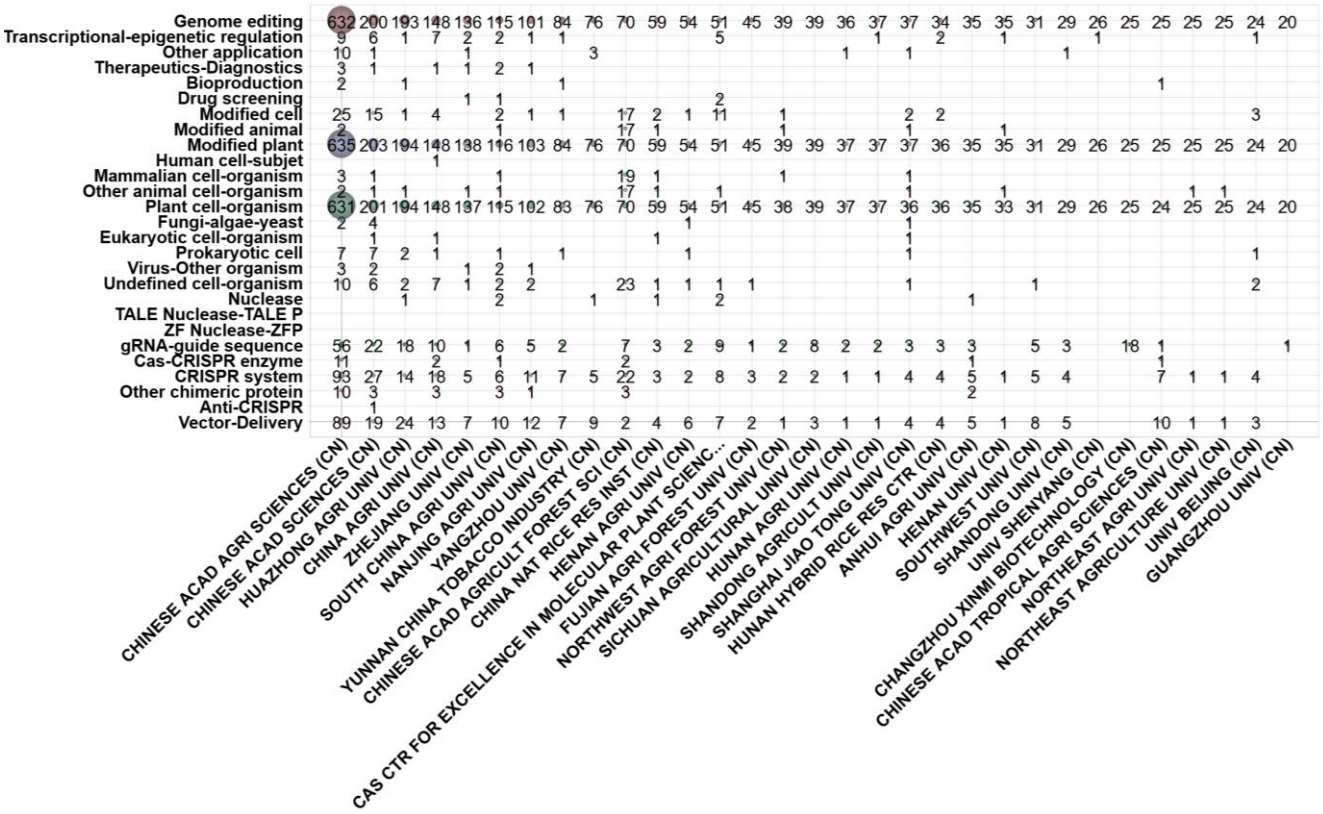


Figure 4.2.4: A breakdown by chimeric proteins of patent applications related to modified plants, valid only in China, by the top patent holders, in order (left to right) of patent families held.

Similar to the patent landscape for filings outside of China, many players not only protect modified plants and methods for their production but also extend their coverage to guide RNA and CRISPR systems. However, alternative genome-editing methods, such as nucleases, TALENs, and ZFNs, remain largely underrepresented.

Notably, very few players protect organisms beyond plants, a trend that is even more pronounced in this patent selection compared to those filed or extended outside of China. An exception is the Chinese Beijing Academy of Agriculture and Forestry Sciences, which also owns a significant number of patents on modified animals and animal cells.

4.2.5 Breakdown of the patent portfolio by Components

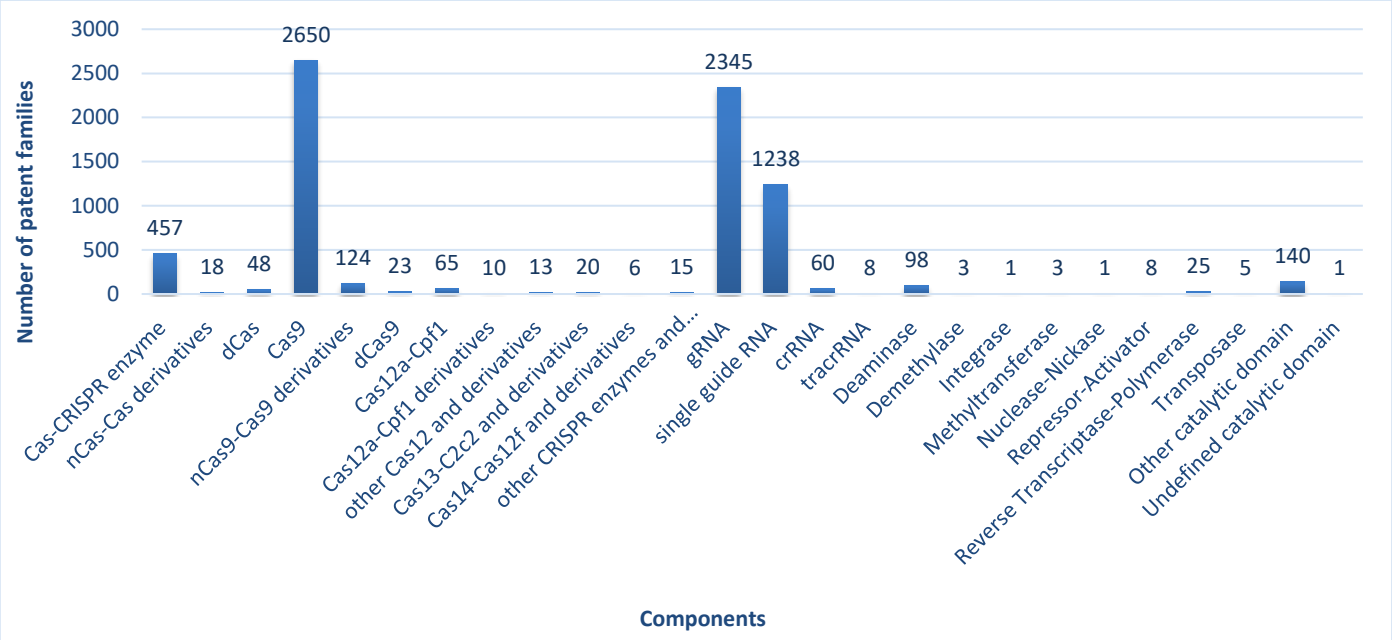


Figure 4.2.5: Number of patent families, valid only in China, relating to modified plants with specifications disclosing the use of each component.

Cas9 is the main claimed CRISPR enzyme in this focus (2'650 patent families = 80.62%). Chinese players claim predominantly gRNA (2'345 patent families = 71.34%), but single guide RNA (sgRNA) (1'238 patent families = 37.66%) is also often claimed, although sgRNA is often defined as gRNA in the definition sections of the descriptions. Again, nCas9-Cas9 derivatives are the next most commonly referenced Cas protein, followed by Cas12a-Cpf1 but to a lower extent than the patent families outside of China.

4.2.6 Breakdown by Components - Positioning of main assignees (≥ 20 patent families)

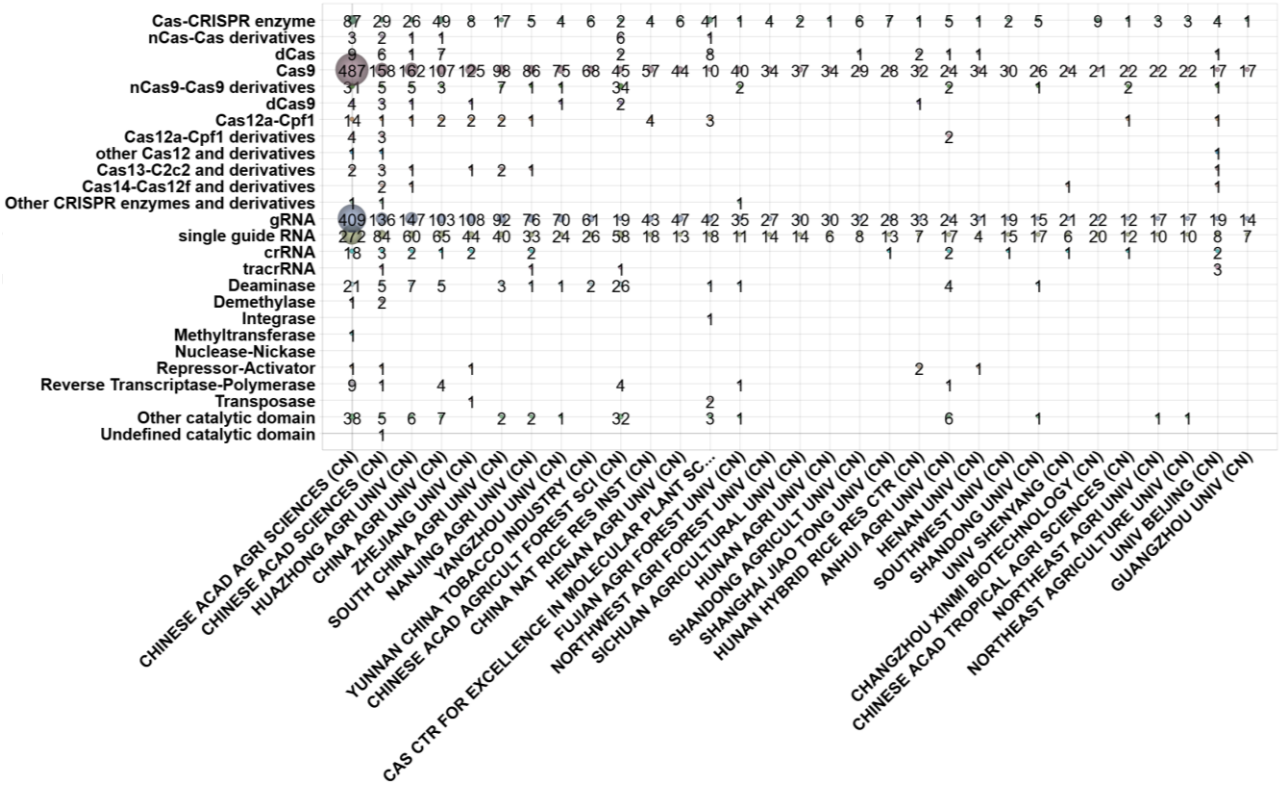


Figure 4.2.6: A breakdown by chimeric proteins of patent families relating to modified plants, valid only in China, by the top patent holders, in order (left to right) of patent families held.

Compared to filings extended outside of China, the technological focus here is even more heavily skewed toward Cas9. Other (Cas) proteins receive minimal coverage. Among the few exceptions, nCas9-Cas9 derivatives stands out as the most prominent after Cas9, particularly in patents from the Chinese Academy of Agricultural Sciences and Yunnan China Tobacco Industry. The only other components to receive measurable attention are deaminases, and to a lesser extent guide RNA variants such as crRNA and tracrRNA. However, even these are far less represented than core Cas9-based elements. Overall, this concentration underscores a highly unidirectional patenting strategy centered on a single enzyme system, with relatively little effort invested in expanding beyond the canonical CRISPR-Cas9 architecture within domestically filed patents.

4.2.7 Breakdown of the patent portfolio by Chimeric proteins

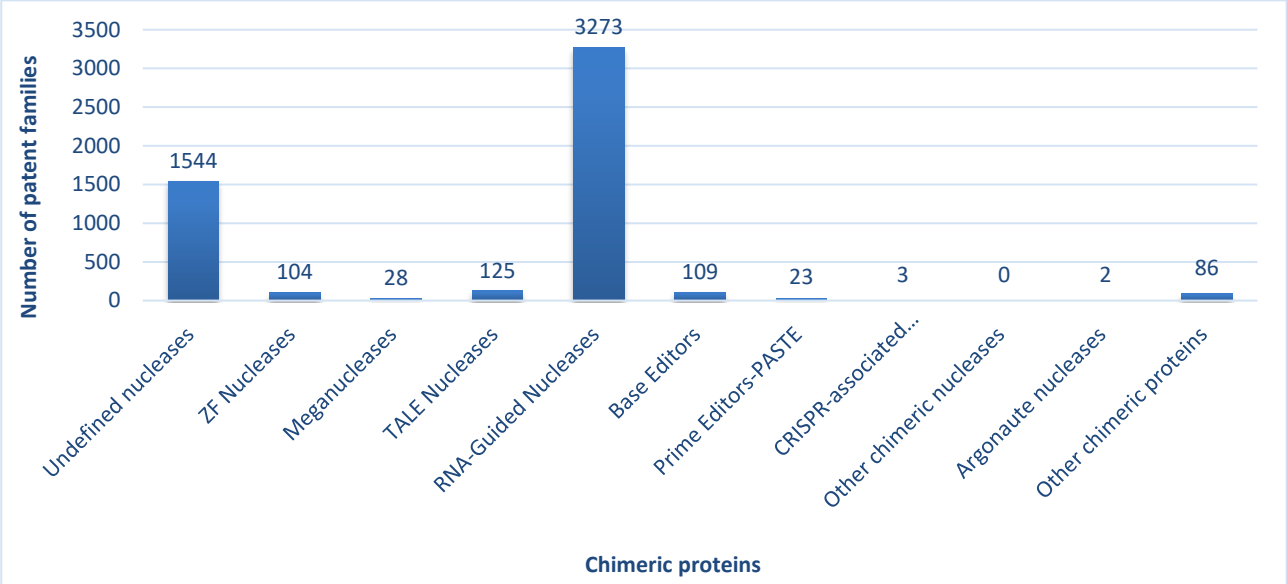


Figure 4.2.7: Number of patent families, valid only in China, relating to modified plants with specifications disclosing the use of each type of chimeric protein.

Most of these Chinese Players claim RNA-guide nucleases (3’273 patent families = 99.57%) for producing genome editing in plants and eventually an undefined nuclease. Notably, other recent technologies based on CRISPR (Base Editors, Prime Editors, CAST or other non-nuclease chimeric proteins such as artificial transcription factors) are barely covered in the plants related CRISPR patents in the People’s Republic of China, in contrast to the situation outside of China.

4.2.8 Breakdown by Chimeric proteins– Positioning of main assignees (≥ 20 patent families)

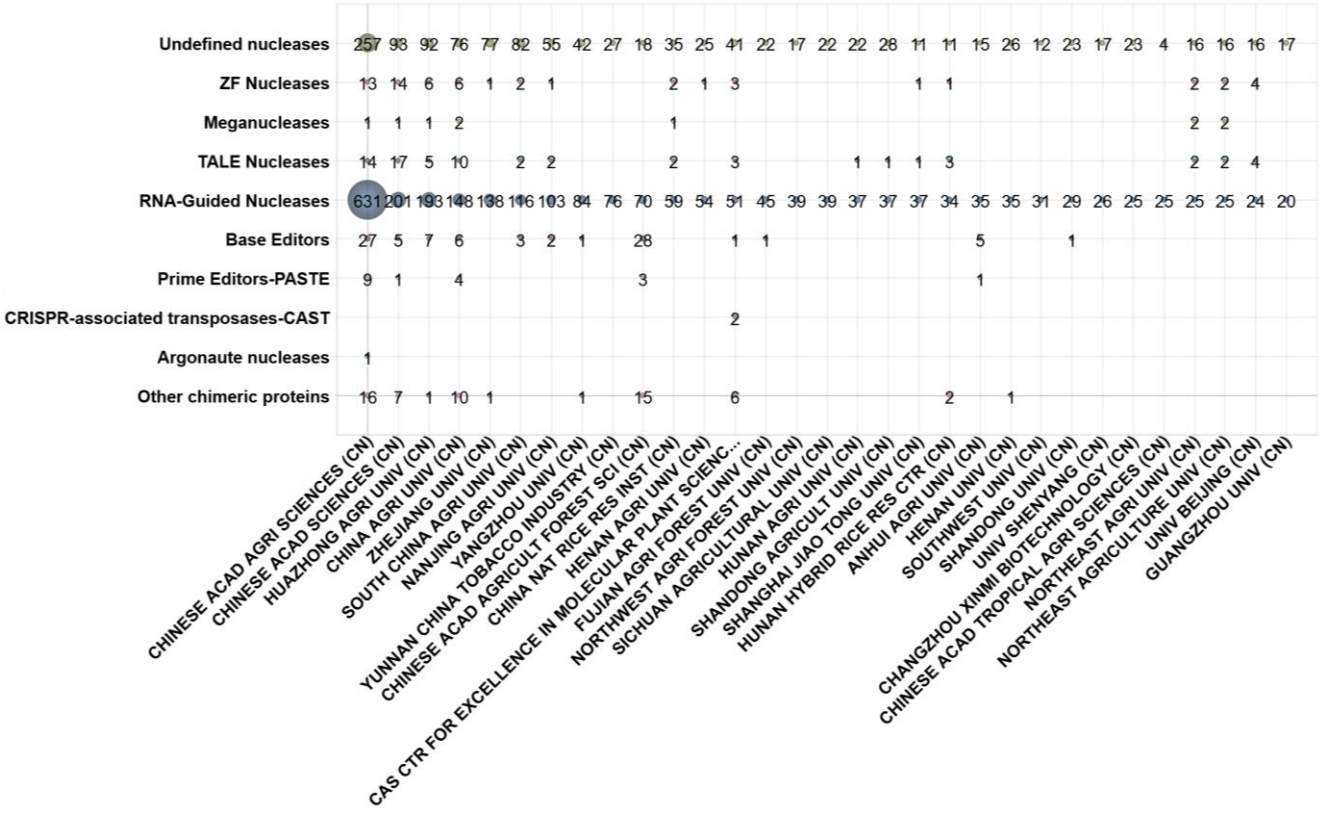


Figure 4.2.8: A breakdown by chimeric proteins of patent families relating to modified plants, valid only in China, by the top patent holders, in order (left to right) of patent families held.

Compared with section 4.1.10, other nuclease types (ZF, Mega, and TALE nucleases) are considerably less covered. Also note that the Chinese Academy of Agricultural and Forest Sciences and Yunnan China Tobacco Industry lead the base-editing category with 27 and 28 patent families, respectively, on the use of Base Editors in plants. Despite this, very few Chinese assignees appear to be actively exploring prime editors, CAST transposases, or other chimeric proteins, and tools like Argonaute nucleases are nearly absent from the landscape. Overall, the data show that while Chinese actors have embraced CRISPR-Cas systems with significant intensity, efforts to broaden IP coverage into emerging genome editing platforms remain limited to a small number of forward-looking players.

5 Patent Landscape on Non-Transgenic CRISPR-Modified Plants

In recent years, a growing number of jurisdictions, including Switzerland and the European Union, have signaled a shift in regulatory frameworks to distinguish non-transgenic genome editing from classical Genetically Modified Organisms (GMOs). This evolution stems from both scientific advances and public policy priorities, seeking to foster innovation in sustainable agriculture while addressing societal concerns over transgene-containing organisms.

Non-transgenic genome editing refers to molecular breeding techniques in which targeted genetic changes are introduced without integrating foreign DNA into the final plant product. Both the Swiss draft law on new breeding technologies and the European Union's proposed regulation on new genomic techniques (NGTs) adopt a consistent definition: non-transgenic plants are those whose genomes have been edited without the stable incorporation of foreign genetic sequences, and whose modifications could also occur naturally or through conventional mutagenesis. This includes methods such as site-directed mutagenesis and cisgenesis. These approaches often rely on DNA-free systems, such as ribonucleoprotein (RNP) complexes, that transiently edit the genome without leaving traces of the editing machinery. Because the resulting plants are indistinguishable from conventionally bred counterparts, such techniques are increasingly being considered for differentiated regulatory treatment.

This regulatory recognition creates a favorable legal and commercial environment for developers of CRISPR-edited crops that comply with non-transgenic requirements. Consequently, identifying patent families that claim such DNA-free or transient editing strategies is critical for understanding innovation trends, assessing freedom-to-operate under upcoming legislation, and positioning actors in a future deregulated market.

To assess the patent landscape in the perspective of these changing regulations, the scope of transgenic vs. non-transgenic CRISPR genome editing in plants was assessed to get an estimation of the number of patent families targeting each type of gene editing method (Figure 5). We conducted a focused extraction of patent families that implicitly or explicitly describe non-transgenic or DNA-free editing approaches. This targeted search yielded a subset **of 2'350 patent families that implicitly claim** and **247 patent families that explicitly claim non-transgenic genome editing methods**. The latter subset was based on a keyword search of patent families explicitly stating "DNA-free" or "non-transgenic" or synonyms, whereas the former also included keywords, such as "knock-out", and previously identified categories that are generally associated with non-transgenic editing, such as "Base Editors" or "Transcription-Epigenetic Regulation". In addition, a keyword search of patent families mentioning "transgenic" or "foreign DNA" or synonyms, was used to yield a subset of **2'551 patent families describing transgenic gene editing**. There is an overlap of 1'208 patent families between the two subsets, which thus include patent families covering both methods as for instance many patents claim a certain result which can be obtained in various ways. In addition, there are 1'458 patent families that do not specify transgenic or non-transgenic patent families. These likely focus more on CRISPR components or systems, or on specific products without mentioning how these can be used or achieved.

This section will first give an overview of the broad non-transgenic patent landscape, including the patent families that implicitly describe non-transgenic methods, before zooming in on the patent families that explicitly describe these methods.

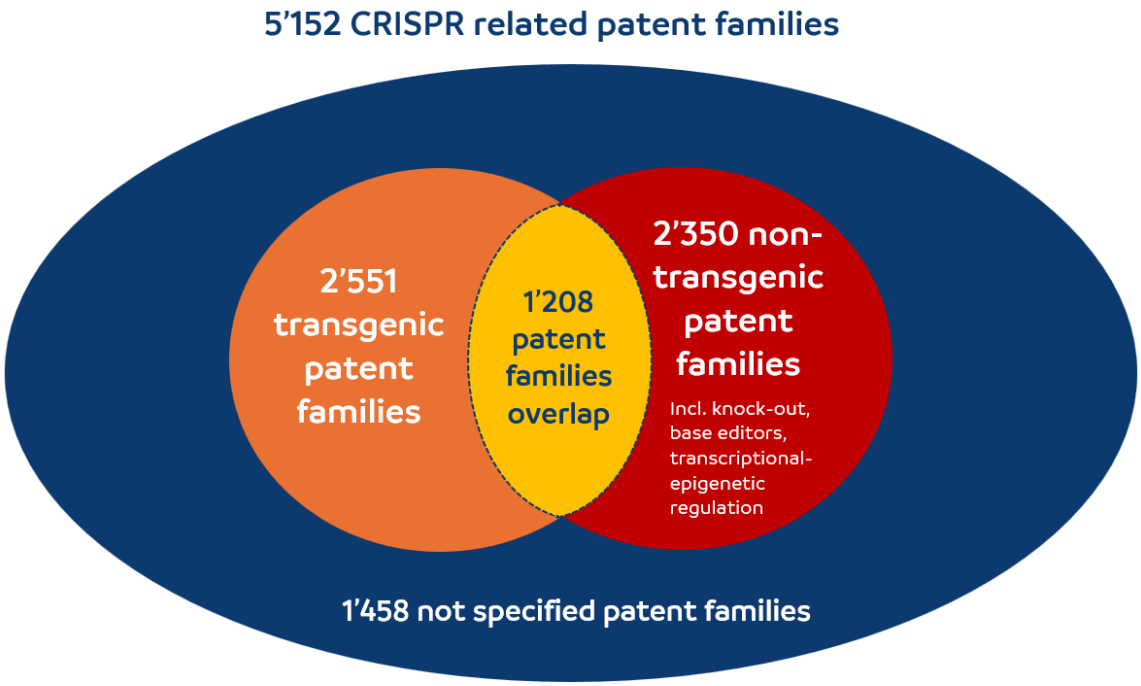


Figure 5: Number of patent families covering transgenic vs non-transgenic modified plants. These subsets are an estimation based on keyword searches and previously identified categories.

5.1 Focus on Implicitly Non-Transgenic CRISPR-Modified Plants

5.1.1 Temporal distribution of patent filings (2012-2024)

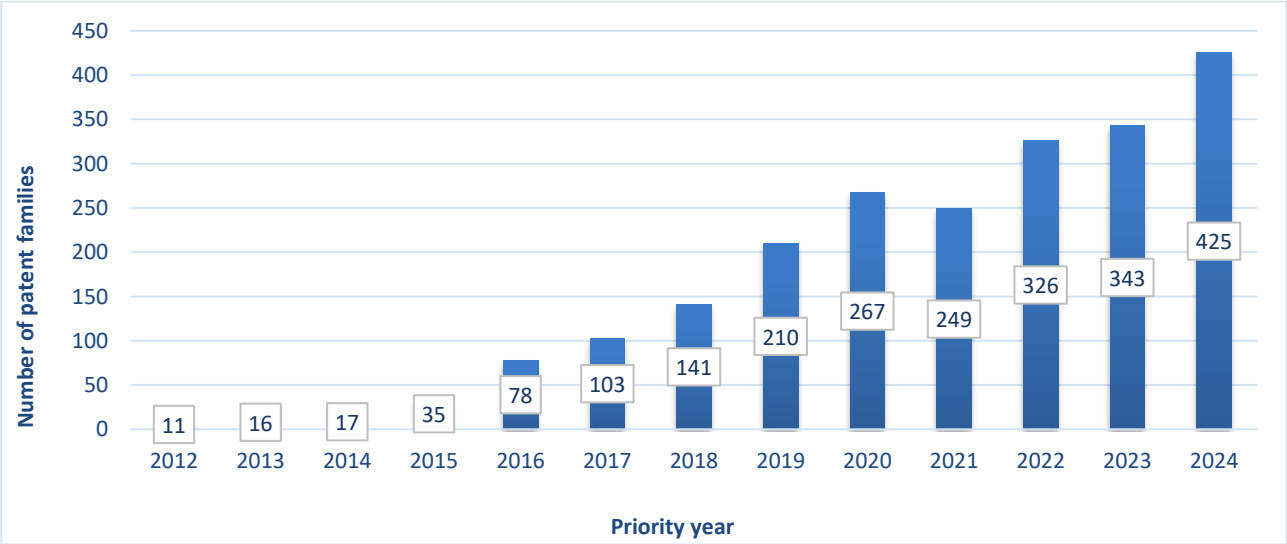


Figure 5.1.1: Number of patent families covering implicitly non-transgenic modified plants by priority year. Notably, the years 2023 and 2024 may not be complete due to the publication delay.

The number of patent families relating to implicitly non-transgenic modified plants has kept increasing since 2012.

5.1.2 World map of priority filings

Countries	Nb	%
CHINA	1754	74.96%
UNITED STATES	371	15.85%
KOREA	54	2.31%
EUROPE	48	2.05%
WORLD	40	1.71%
UNITED KINGDOM	24	1.03%
JAPAN	11	0.47%
Other countries	38	1.62%

Table 5.1.2: Number of priority filings by country, and percentage of total filings.

China leads the field of non-transgenic plant genome editing, accounting for nearly 75% of all priority patent filings. The United States ranks a distant second. Europe's contribution remains modest by comparison. Within Europe, the United Kingdom appears to play a leading role, with more filings identified than from any other individual European country, although it could also be that other countries opt more often directly for an EP application than for a national application.

5.1.3 Main patent assignees (≥ 20 patent families)

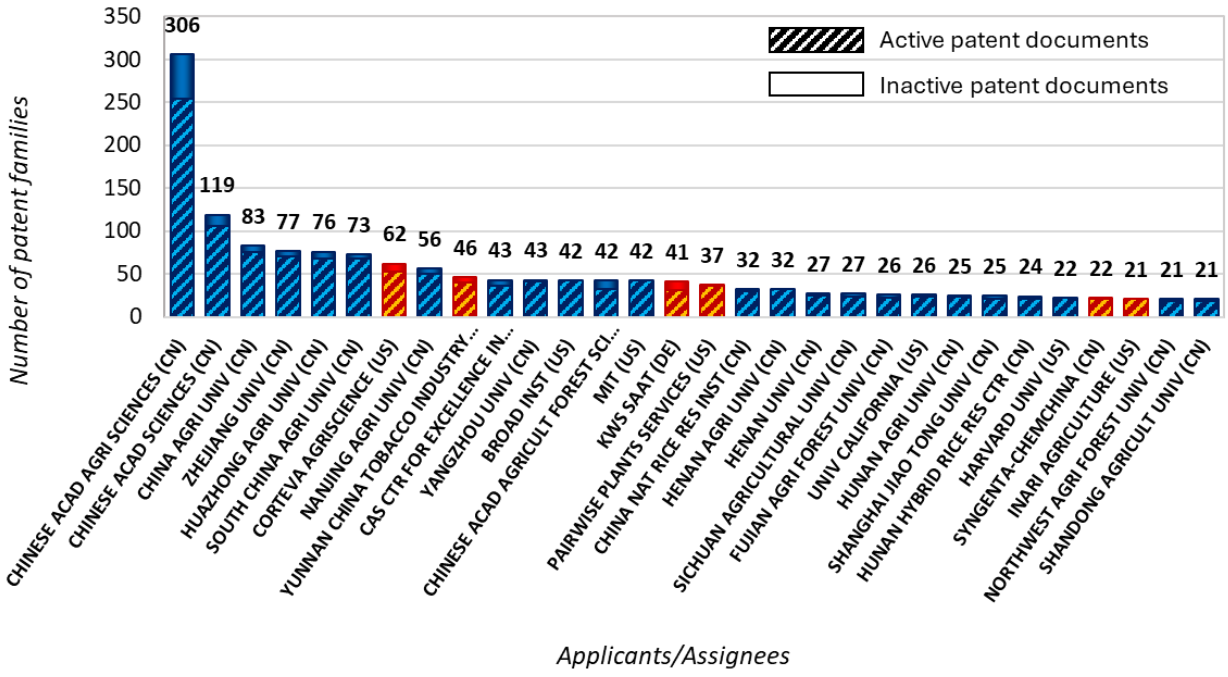


Figure 5.1.3: The main patent applicants/assignees with at least 20 patent families implicitly covering non-transgenic modified plants. Blue indicates public entities; red indicates private entities. Affiliates & subsidiaries have been gathered under their parent company (e.g. Pioneer with Corteva Agriscience). Co-filings are counted for each co-owner: a patent application co-filed between the MIT, the Harvard University and the Broad Institute is counted once for each of these applicants/assignees.

The main patent filers are Chinese academic institutions, whereas very few industrial players own more than 20 patent families on implicitly non-transgenic modified plants.

5.1.4 Breakdown of the patent portfolio by Claim coverage

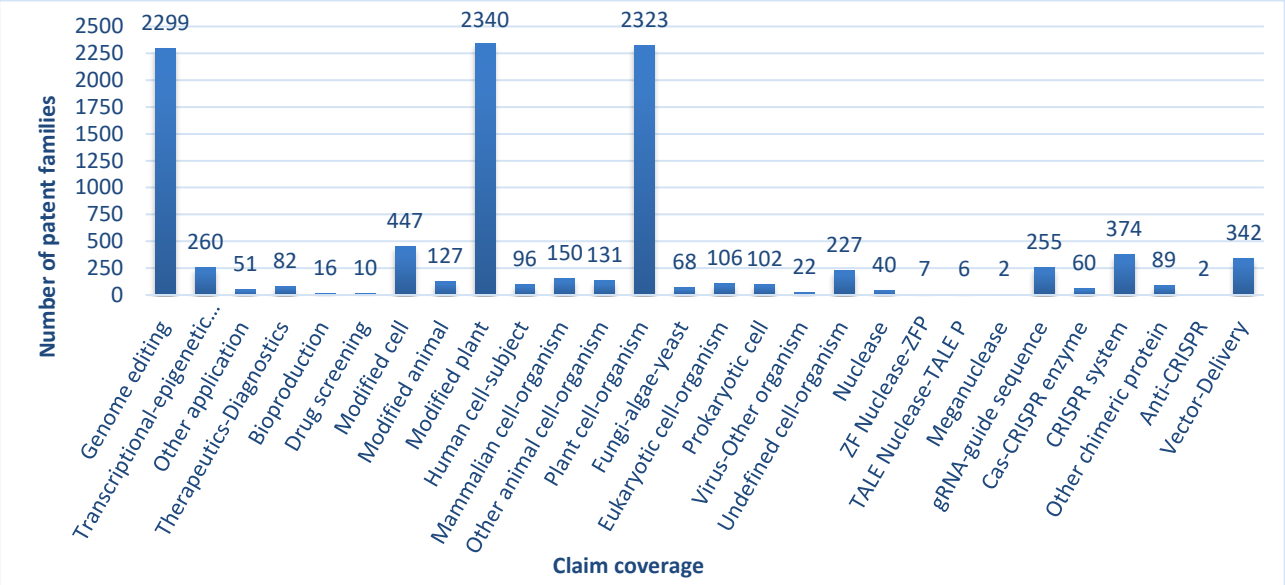


Figure 5.1.4: The number of CRISPR patent applications relating to implicitly non-transgenic modified plants with claims covering each area of interest.

The claim coverage on implicitly non-transgenic modified plants closely mirrors that of modified plants in general with Genome editing, Modified plant and Plant cell-organism dominating the claims, as expected.

5.1.5 Breakdown of the patent portfolio by Components

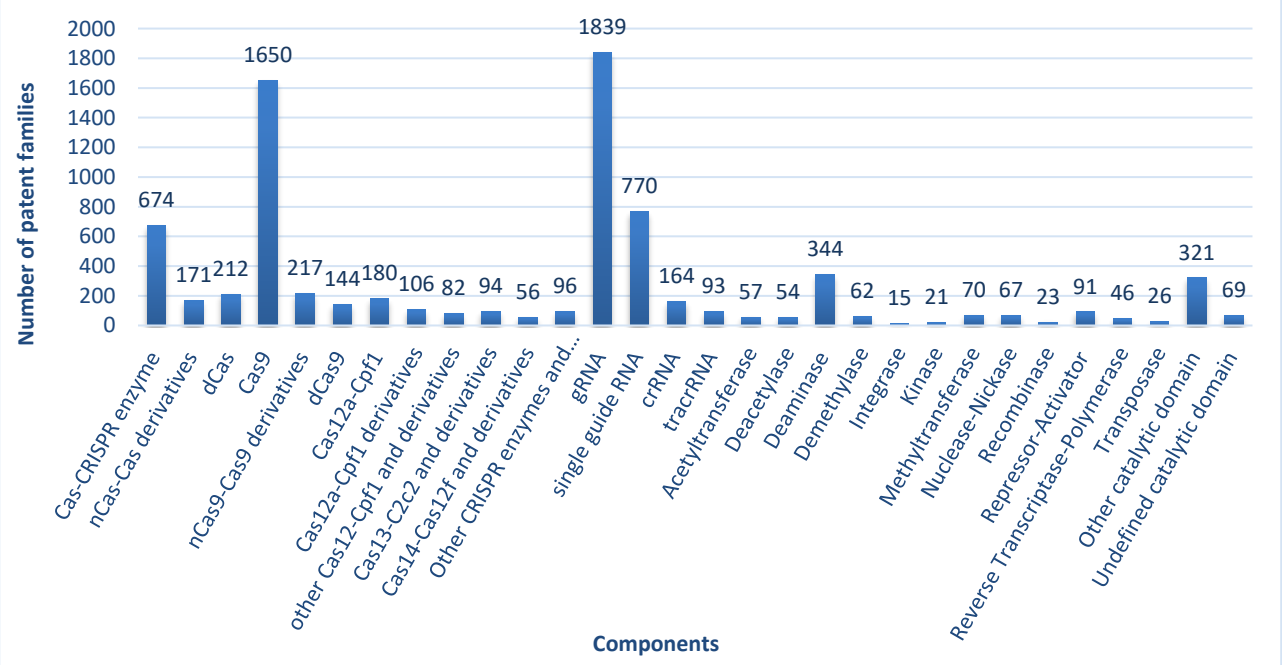


Figure 5.1.5: Number of patent families relating to implicitly non-transgenic modified plants with specifications disclosing the use of each component.

There is a similar distribution of components in implicitly non-transgenic modified plants to those of modified plants in non-CN priority filings and CN priority filings extended outside of China (Figure 4.1.9), although there are relatively more filings on Cas9, as well as on gRNA or single guide RNA, reflecting the trends in the patent landscape on CN priority filings without extensions (Figure 4.2.5).

5.1.6 Breakdown of the patent portfolio by Chimeric proteins

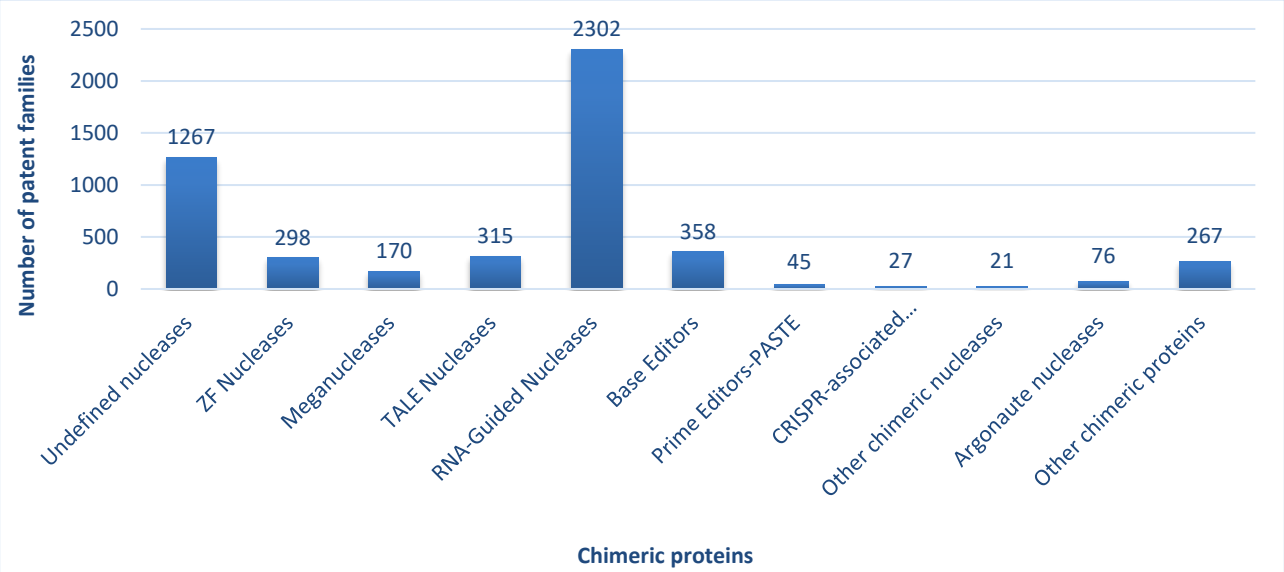


Figure 5.1.6: Number of patent families relating to implicitly non-transgenic modified plants with specifications disclosing the use of each type of chimeric protein.

RNA-guided nucleases and undefined nucleases remain the most frequently claimed chimeric proteins in the context of implicitly non-transgenic plant modifications. However, base editors also feature prominently, highlighting their growing relevance in this domain.

5.1.7 Highlight on some implicit non-transgenic technologies for modified plants

In addition to the major approaches discussed above (e.g. RNP-based editing and base editors), a number of patent families describe technologies that may enable non-transgenic modification of plants through regulation of gene expression or epigenetic changes, rather than direct alteration of DNA sequence. These include systems based on synthetic transcription factors, histone modification, or RNA-based gene silencing. While plant generation is not always the central focus of these inventions, they illustrate the growing technical diversity of tools relevant to non-transgenic breeding strategies. Such tools could become increasingly relevant as EU and Swiss regulation evolves to recognize gene expression regulation and epigenetic modulation as part of new breeding technologies. Selected examples are presented below.

Publication number & Applicant	Title	Main mechanism
WO2019/122381 KWS SAAT (DE) – 2019	Targeted transcriptional regulation using synthetic transcription factors	Uses dCas9 (nuclease-inactive Cas9) fused to transcriptional repressors or activators to up- or downregulate gene expression without cutting DNA. Targets specific promoters or genes in plants.
WO2023/028598 DONALD DANFORTH PLANT SCIENCE CENTER (US) – 2023	Engineering disease resistance by editing the epigenome	Describes plant disease resistance through epigenome editing, specifically targeted histone modifications or DNA methylation using Cas-based effectors.
WO2024/168464 CHINESE ACADEMY OF SCIENCES (CN) – 2024	SunTag system, vector and editing method for editing histone H3K4me3 in plant	Applies the SunTag system (a Cas9-based scaffold recruiting multiple effector proteins) to direct histone H3K4me3 modifications in plant cells.
WO2021/056302 SYNGENTA - CHEMCHINA (CN) – 2021	Methods and compositions for DNA base editing	Describes base editors and includes fusion constructs involving inactive Cas proteins and transcriptional or epigenetic regulators, allowing for precise editing or modulation.
WO2021/121921 BASF (DE) – 2021	Codon-optimized Cas9 endonuclease encoding polynucleotide	Codon-optimized Cas9; claims include use of inactive Cas9 fused to activators, repressors, epigenetic effectors, or deaminases. Covers imaging and regulatory uses in addition to editing.
WO2020/183414 TROPIC BIOSCIENCES (GB) – 2020	Modifying the specificity of non-coding RNA molecules for silencing genes in eukaryotic cells	RNA engineering to direct gene silencing; uses modified non-coding RNAs designed for high specificity in eukaryotic (including plant) cells.
WO2020/183419 TROPIC BIOSCIENCES (GB) – 2020	Introducing silencing activity to dysfunctional RNA molecules and modifying their specificity against a gene of interest	Describes how to confer silencing activity to otherwise non-functional RNA molecules; another RNAi-based regulatory tool.
WO2020/183416 TROPIC BIOSCIENCES (GB) – 2020	Production of dsRNA in plant cells for pest protection via gene silencing	Expression of double-stranded RNA (dsRNA) in plant cells to silence pest-related genes.

Table 5.1.7: A selection of relevant patent families on implicit non-transgenic technologies.

5.1.8 Patent families covering Europe

In line with upcoming regulatory changes that will allow genome-edited plants as long as they are non-transgenic, we reviewed patent families that implicitly describe non-transgenic CRISPR genome editing approaches and include at least one European patent member. This dataset includes 314 patent families, of which 303 active patent families, either pending (131 patent families) or granted (172 patent families). Nevertheless, most of these innovations do not originate in Europe: the priority filings are primarily from US-based applicants, and besides KWS Saat, the main patent holders, such as Corteva, Pairwise Plants, and the pioneer institutes (Broad, MIT, Harvard, University of California), are headquartered in North America. This suggests that while Europe is a key target region for protection, it currently plays a secondary role in the generation of non-transgenic CRISPR plant innovations. Still, some important European players to keep in mind are KWS Saat, Tropic Biosciences, Monsanto – Bayer, Limagrain and French labs from the National Centre for Scientific Research (CNRS).

Countries	Nb	%
UNITED STATES	191	58.95%
EUROPE	48	14.81%
CHINA	31	9.57%
UNITED KINGDOM	19	5.86%
SPECIFIC EUROPEAN COUNTRIES	14	4.32%
WORLD	12	3.70%
KOREA	5	1.54%
JAPAN	2	0.62%

Table 5.1.8: Number of priority filings by country, and percentage of total filings.

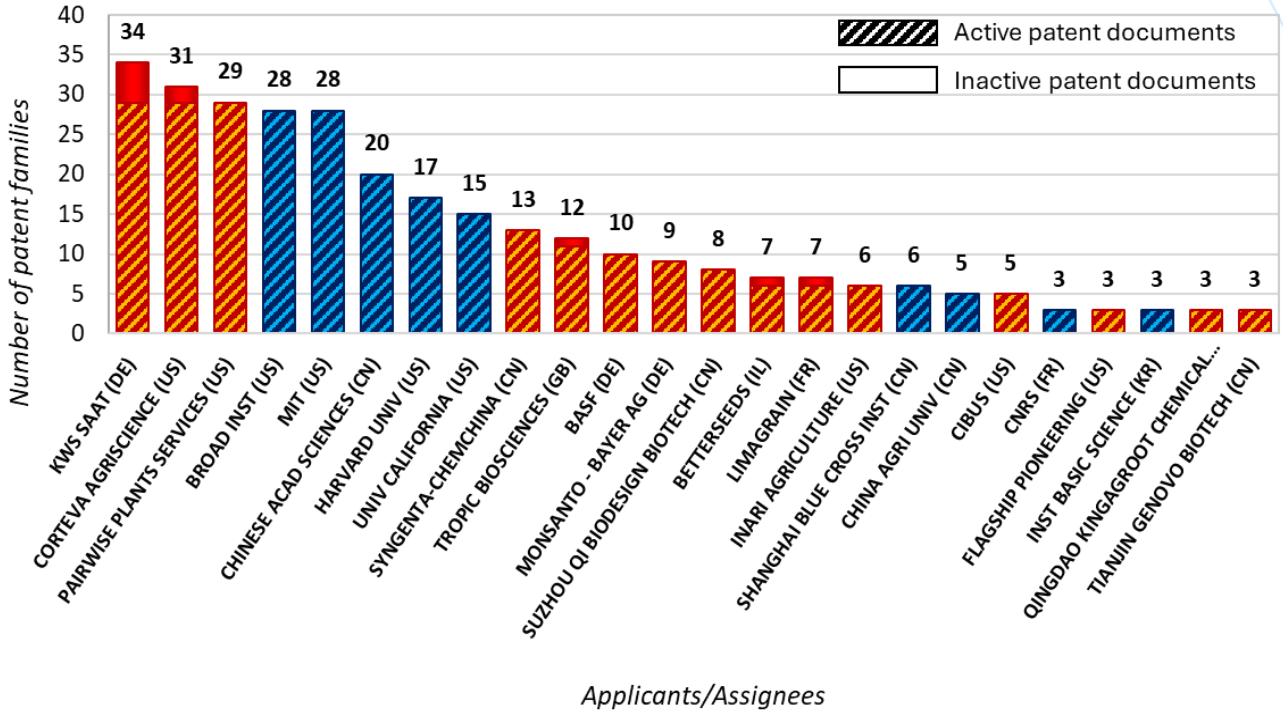


Figure 5.1.8: The main patent applicants/assignees with at least 3 patent families and an EP member covering non-transgenic modified plants. Notably, all patent families are active in this subcategory. Blue indicates public entities; red indicates private entities. Affiliates & subsidiaries have been gathered under their parent company (e.g. Pioneer with Corteva Agriscience). Co-filings are counted for each co-owner: a patent application co-filed between the MIT, the Harvard University and the Broad Institute is counted once for each of these applicants/assignees.

This geographical imbalance also points to a strategic opportunity: the evolving EU and Swiss regulatory landscape could incentivize more locally driven research and development in DNA-free editing technologies. Increased European engagement in this space would not only strengthen domestic innovation capacity but could also improve access to traits and technologies adapted to regional crop needs and public preferences.

5.2 Focus on Explicitly Non-Transgenic CRISPR-Modified Plants

This subset focuses on patent families specifically claiming that their methods or systems could be used for non-transgenic or DNA-free genome editing. These filings typically reference technical strategies that avoid stable integration of exogenous DNA into the plant genome, such as the use of Cas-gRNA ribonucleoproteins (RNPs), biolistic delivery of RNA or protein, or protoplast electroporation followed by regeneration. As such, this subset offers a solid starting point for understanding emerging strategies in this regulatory context.

5.2.1 Temporal distribution of patent filings (2012-2023)

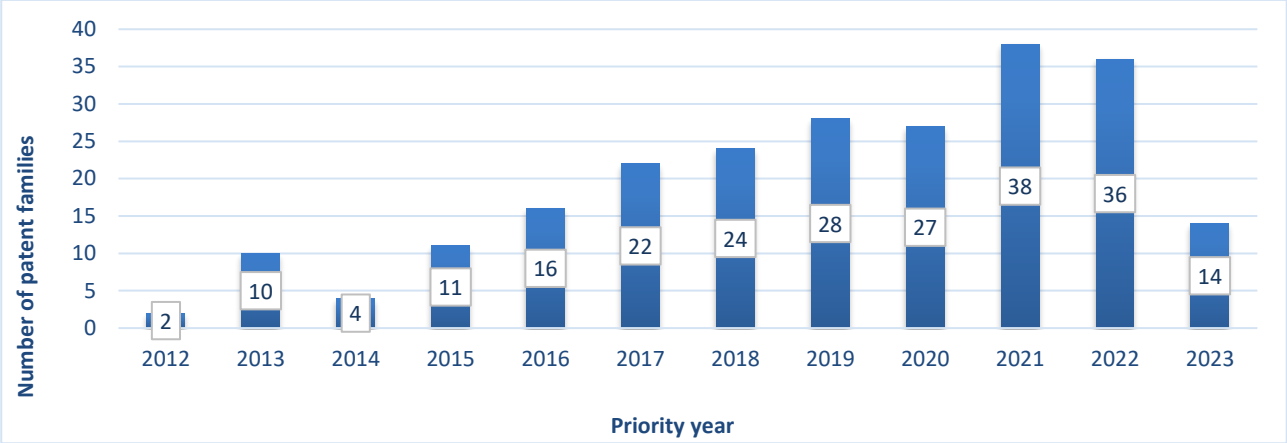


Figure 5.2.1: Number of patent families covering explicitly non-transgenic modified plants by priority year. Notably, the year 2023 may not be complete due to the publication delay.

The number of patent families relating to explicitly non-transgenic modified plants has steadily increased from 2012 through 2021, after which the curve appears to plateau. However, due to the typical publication delay, data from 2023 remains incomplete. As a result, it is too early to determine whether this plateau represents a true stabilization in filings or simply reflects delayed publication.

5.2.2 World map of priority filings

Countries	Nb	%
CHINA	140	56.68%
UNITED STATES	78	31.58%
KOREA	10	4.05%
UNITED KINGDOM	9	3.64%
EUROPE	5	2.02%
INDIA	2	0.81%
WORLD	2	0.81%
RUSSIAN FEDERATION	1	0.40%

Table 5.2.2: Number of priority filings by country, and percentage of total filings.

China and the United States are leading in the field of non-transgenic plant editing, although China is considerably less dominant in the explicitly non-transgenic subset than in the implicitly non-transgenic subset. The United Kingdom appears to play a leading role in Europe.

5.2.3 Main patent assignees (≥ 3 patent families)

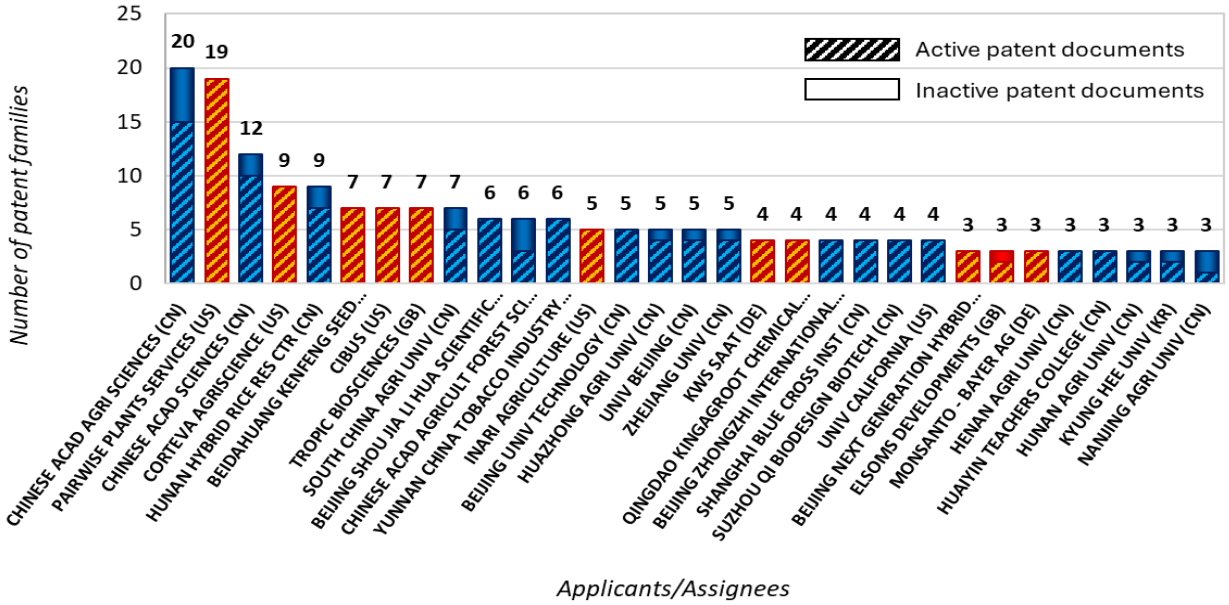


Figure 5.2.3: The main patent applicants/assignees with at least 3 patent families covering non-transgenic modified plants. Notably, all patent families are active in this subcategory. Blue indicates public entities; red indicates private entities. Affiliates & subsidiaries have been gathered under their parent company (e.g. Pioneer with Corteva Agriscience). Co-filings are counted for each co-owner: a patent application co-filed between the MIT, the Harvard University and the Broad Institute is counted once for each of these applicants/assignees.

As with the broader landscape of implicitly non-transgenic plant modification, many of the top filers are Chinese academic institutions, underscoring China's strong public-sector engagement in this area. However, the group of leading applicants also includes a relatively larger proportion of American and European players compared to the overall dataset. Among them, Pairwise stands out with a particularly strong and focused patent portfolio. In Europe, Tropic Biosciences, based in the United Kingdom, emerges as a notable contributor. This broader geographic and institutional diversity suggests that innovation in non-transgenic editing is being actively pursued across both public and private sectors, and across multiple regions, with varying strategic approaches.

5.2.4 Breakdown of the patent portfolio by Claim coverage

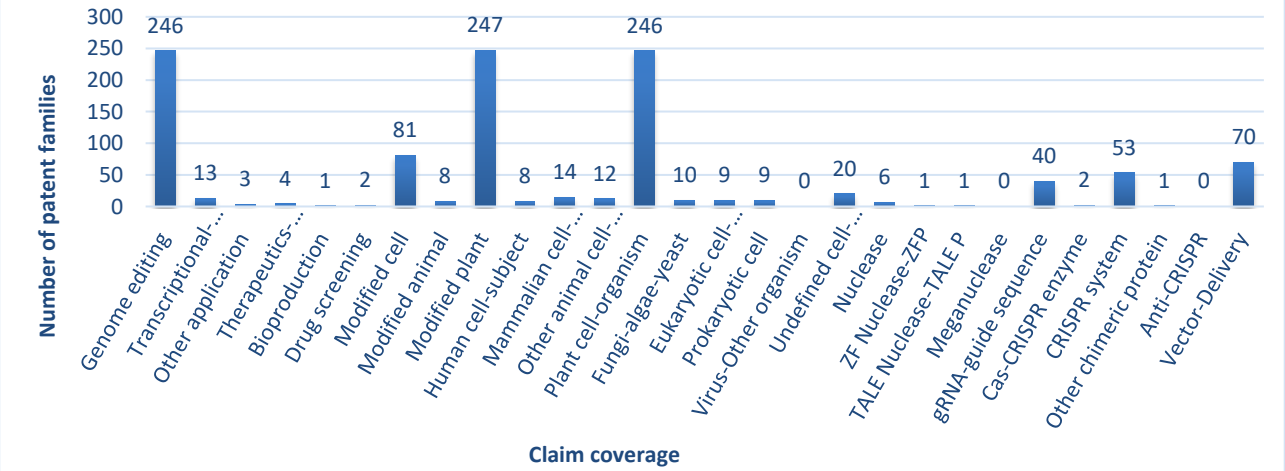


Figure 5.2.4: The number of CRISPR patent applications relating to explicitly non-transgenic modified plants with claims covering each area of interest.

The distribution of the claim coverage of explicitly non-transgenic modified plants is quite similar to the one of implicitly non-transgenic modified plants.

5.2.5 Breakdown of the patent portfolio by Components

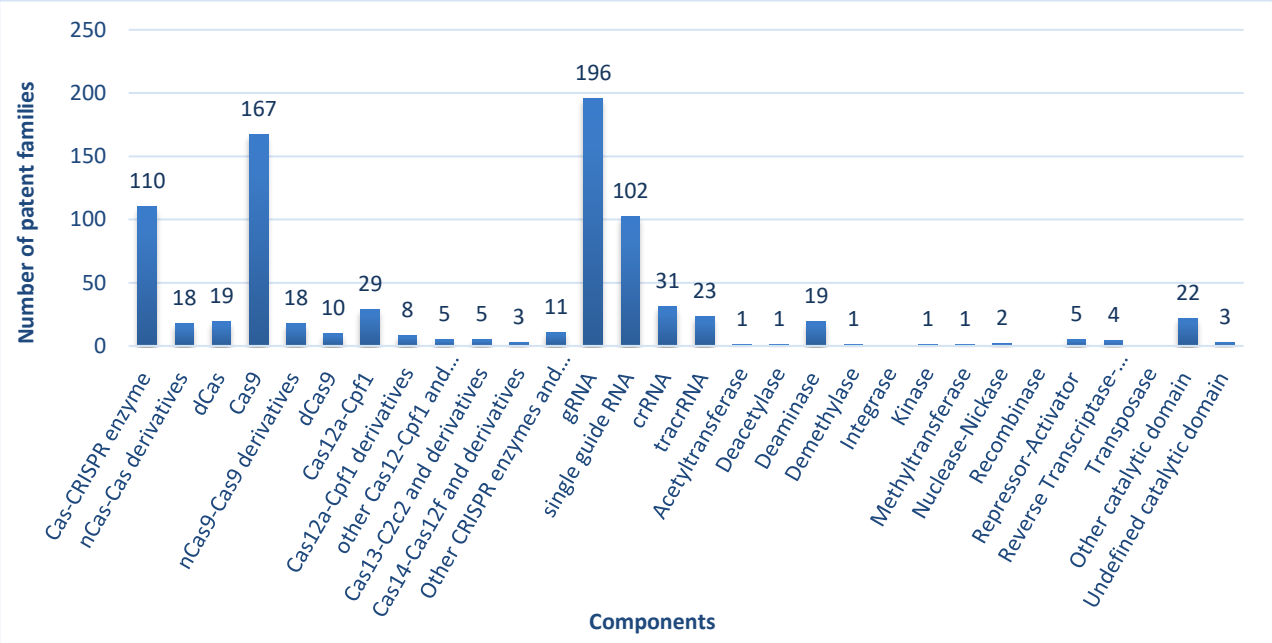


Figure 5.2.5: Number of patent families relating to non-transgenic modified plants with specifications disclosing the use of each component.

The distribution of the components of explicitly non-transgenic modified plants is quite similar to the one of implicitly non-transgenic modified plants.

5.2.6 Breakdown of the patent portfolio by Chimeric proteins

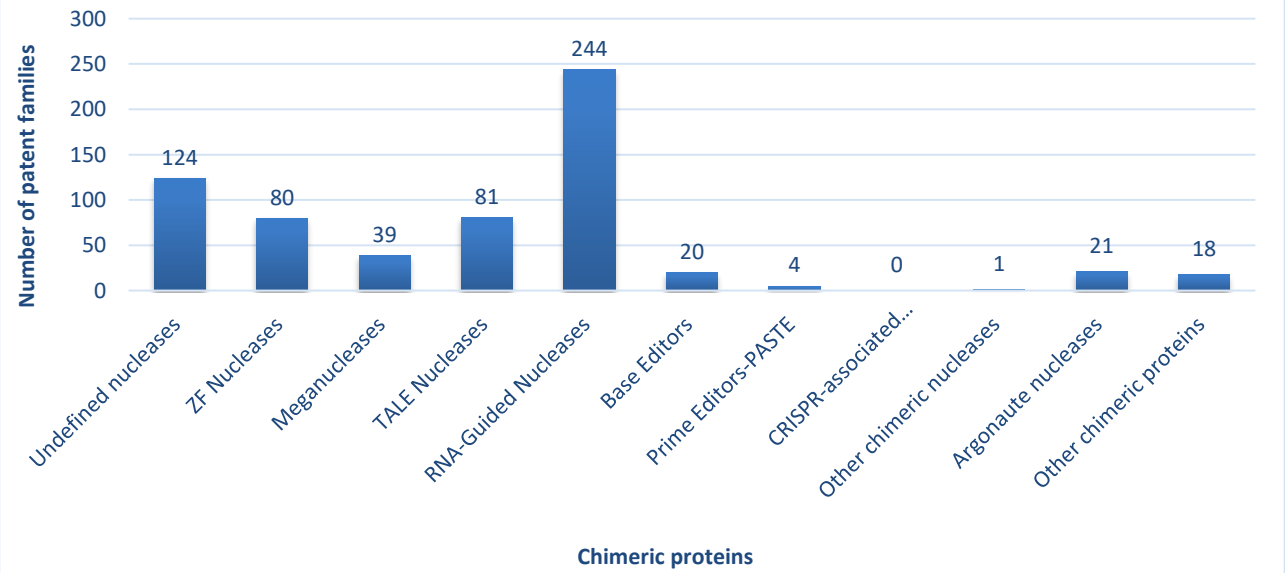


Figure 5.1.6: Number of patent families relating to explicitly non-transgenic modified plants with specifications disclosing the use of each type of chimeric protein.

The distribution of the chimeric proteins of explicitly non-transgenic modified plants is quite similar to the one of implicitly non-transgenic modified plants.

5.2.7 Highlight on some explicit non-transgenic technologies for modified plants

Table 5.2.7 shows a selection of patent families on explicit non-transgenic technologies that were chosen for their focus on non-transgenic methods.

Publication number & Applicant	Title	Delivery Method
WO2024/191759 INARI (US) – 2024	Non-transgenic delivery of guide RNA to edit a scion	A rootstock with nucleic acid encoding Cas nuclease fused to a meristem transport segment
WO2024/117677 TOOLGEN (KR) – 2023	Method for producing caaibz1 gene-edited pepper to improve drought tolerance	RNP (gRNA for the target sequence of the CaAIBZ1 + endonuclease) or vector with nucleic acids
CN115820715 BEIJING POLYTECHNIC UNIV. (CN) - 2022	Virus-induced non-transgenic gene editing method	• a recombinant vector with a Cas9 gene • a FT gene in a pEAQ-HT vector • a TRV vector containing an sgRNA gene and an FT gene
CN114790464 NE FORESTRY UNIV. (CN) – 2022	CRISPR/Cas9 system-based larch DNA-free gene editing method	Cas9 + gRNA RNP via biolistic transformation
EP3971295 FRAUNHOFER (DE) – 2020	Methods for the production of genome edited plants	Pre-assembled RNP complex delivered by laser focus in liquid near cell wall
WO2019/150200 G FLAS LIFE SCIENCES (KR) – 2019	DNA free CRISPR plant transformation	RNP complex with enhancer via injection (e.g., PEG, lipofectamine)
WO2019/219046 HUAZHONG AGRICULT. UNIV. (CN) – 2018	Method for rapidly and efficiently obtaining non-transgenic, gene-targeted mutated plant and use thereof	Transient Cas9/sgRNA via Agrobacterium, bombardment, protoplasts
CN109234310 YUNNAN INST. TOBACCO AGR. SCIENCE (CN) – 2018	Recombinant vector for rapidly obtaining non-GMO genome editing plants	CRISPR vector with color/flowering marker
EP3008186 CELLECTIS (FR) – 2014	Methods for non-transgenic genome editing in plants	Transfection of sequence-specific nuclease

Table 5.2.7: A selection of relevant patent families on explicit non-transgenic technologies.

5.2.8 Patent families covering Europe

As for patent families relating to implicitly non-transgenic modified plants covering Europe, those relating to explicitly non-transgenic modified plants covering Europe mostly do not originate in Europe. The priority filings are primarily from US-based applicants, and the main patent holders, such as Pairwise Plants, Cibus, and Corteva, are headquartered in North America.

Countries	Nb	%
UNITED STATES	53	69.74%
CHINA	10	13.16%
UNITED KINGDOM	8	10.53%
EUROPE	5	6.58%

Table 5.2.8A: Number of priority filings by country, and percentage of total filings.

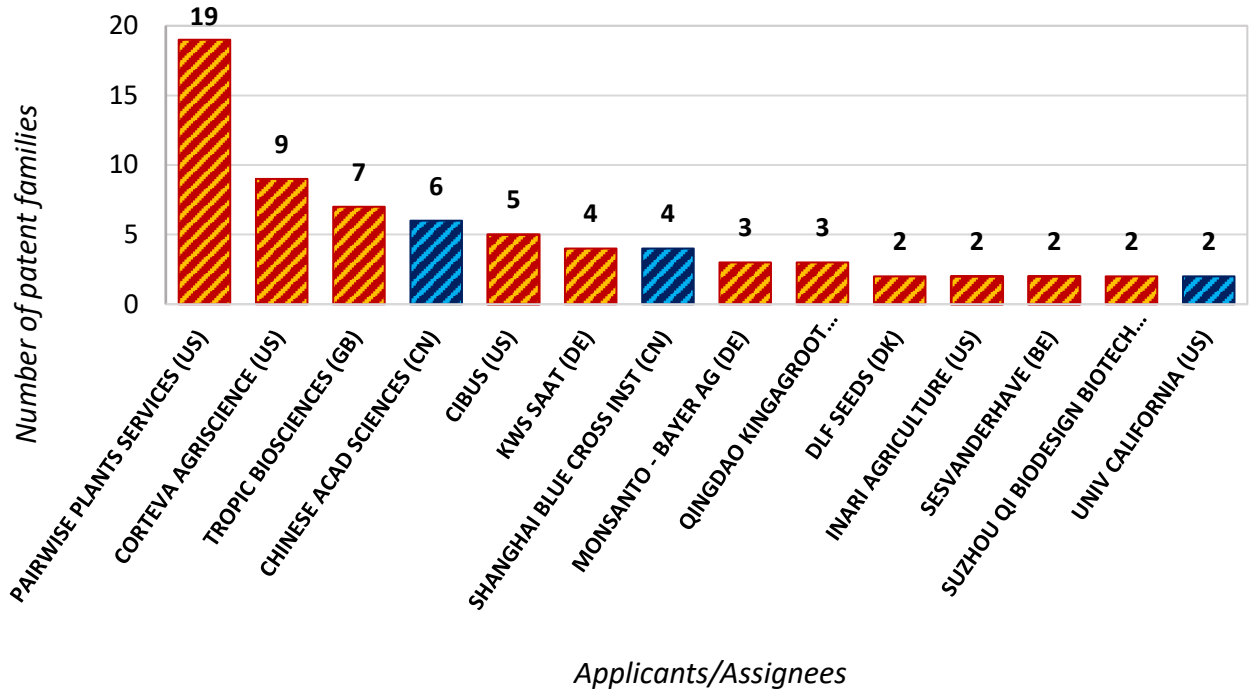


Figure 5.2.8: The main patent applicants/assignees with at least 2 patent families and an EP member covering non-transgenic modified plants. Notably, all patent families are active in this subcategory. Blue indicates public entities; red indicates private entities. Affiliates & subsidiaries have been gathered under their parent company (e.g. Pioneer with Corteva Agriscience). Co-filings are counted for each co-owner: a patent application co-filed between the MIT, the Harvard University and the Broad Institute is counted once for each of these assignees.

The technologies disclosed in these patents range from targeted gene knockouts and trait modification in tropical and row crops, to base-editing techniques and high-efficiency delivery systems. While Cas9 remains the dominant editing enzyme in this subset, a small number of patents also refer to base editors or Cas derivatives, reinforcing the alignment with non-integrative, precise genome modifications.

Several filings stand out due to their strategic focus and technical clarity:

Publication number & Applicant	Title	Focus
EP3684930 TROPIC BIOSCIENCES (GB) – 2018	Modifying the specificity of plant non-coding rna molecules for silencing gene expression	A method to alter the specificity of transcription factors in plants, with a strong emphasis on transient editing techniques.
EP3116305 CIBUS (US) – 2015	Methods and compositions for increasing efficiency of targeted gene modification using oligonucleotide-mediated gene repair	A platform for inducing targeted mutations using CRISPR without stable DNA insertion, in line with the company's known DNA-free RTDS platform.
EP3682011 ALTRIA (US) – 2018	Compositions and methods for producing tobacco plants and products having reduced or eliminated suckers	Targets agronomic traits in tobacco using CRISPR compositions delivered transiently.
EP2931897 BROAD INSTITUTE/HARVARD UNIV. (US) – 2018	Delivery, engineering and optimization of systems, methods and compositions for sequence manipulation and therapeutic applications	Offers broader protection for CRISPR delivery systems that can be implemented in a non-integrative fashion.

Table 5.2.8B: A selection of relevant patent families on explicit non-transgenic technologies.

Overall, this subset of patents highlights a clear interest from both established seed developers and newer biotech firms in positioning their portfolios for regulatory compliance in Europe. Although the dataset is not exhaustive, it reflects the leading edge of patenting activity where non-transgenic objectives are explicitly stated, a crucial factor for both freedom-to-operate and technology deployment under the new legislative framework.

6 CRISPR technology: License Landscape

Note: this section primarily explores licensing within the agricultural domain

6.1 Key points

- Two groups ("CVC" and "Broad") hold issued foundational CRISPR-Cas9 patents
    - Broad's patent protection applies only to eukaryotes, is subject to multiple challenges, and has a reduced scope in Europe
- Two groups (Toolgen and Sigma Aldritch) have pending patent applications covering usage in eukaryotes, before Broad and CVC,
    - Sigma Aldrich's granted foundational patents only cover integration/insertion of DNA within eukaryotes with Cas9
    - Sigma Aldrich and Broad have conclused cross-licensing agreements
- The CVC group holds unchallenged patents on the use of Cas9 generically in any cell
    - 4 groups (CVC, Broad, Sigma-Aldrich, toolgen) are competing for the use specifically in eukaryotes
    - CVC patent protection in eukaryotes is subject to multiple challenges, and is not valid in the USA.
- Agricultural applications of Cas9 would likely require licenses from CVC and at least one other group
- The majority of granted licenses are non-exclusive licenses.
    - Broad only grants exclusive licenses for human therapeutics
    - CVC has granted exclusive licenses in the field of Agriculture, particularly to Corteva
    - No regional or national restrictions have been noted, except for the CVC license to Regional Fish Institute, which is limited to the Asia-Pacific region
- Broad does not grant exclusive licenses in the agricultural field (only in the field of human therapeutics)
    - No license is needed from Broad for non-Commercial/academic/governmental research
    - No license is needed from CVC for academic research (governmental research policy is not specified)
- The CVC group has granted some exclusive licenses (thus a legal monopoly) in specific areas of the agricultural field, primarily to Corteva
    - Corteva does grant sub-licenses
    - Corteva has non-exclusive licenses from the Broad group
    - Licenses for CRISPR-Cas9 are not needed for purely academic research
    - Licenses for alternatives like Cas12 are still obtainable from other players
- There are multiple systems similar to CRISPR, and alternative CRISPR systems to CRISPR-Cas9
    - The CVC group's foundational patents cover only Cas9
    - Broad leads in the identification of alternative CRISPR systems
    - The widely used TALEN system patents will expire soon
- The exclusive licenses are not problematic given the plethora of Cas9 alternatives
    - Sub-licenses are given
    - The existence of these exclusive licenses encourages the invention of these other systems – the patent system is thus encouraging innovation

6.2 Background

The international licensing situation is made more complex by the dispute between four major groups:

The first group, “CVC”, is composed of the inventors of the first uses of the CRISPR system (primarily Doudna of the University of California- Berkeley, and Charpentier of the University of Vienna). In 2016 the groups of the University of California and the University of Vienna, and the respective inventors (Doudna, Charpentier) and associated companies (ERS genomics, Caribou Biosciences, CRISPR Therapeutics, Intellia Therapeutics) announced that they “have entered into a global cross-consent and invention management agreement for the foundational intellectual property covering CRISPR/Cas9 gene editing technology”(16). Thus these companies and inventors can be largely treated as a single unit for most licensing purposes.

The second group, “Broad”, is led by the Broad institute (of the Massachusetts Institute of Technology and Harvard University), which was the first to have a patent issued for the use of the CRISPR system in eukaryotes.

The two remaining groups, Sigma-Aldrich and Toolgen, have both applied for patents applying CRISPR technology to eukaryotes, and there are thus four groups competing for coverage of the use of CRISPR in eukaryotes. Currently Toolgen does not have any issued foundational patents. Sigma Aldrich has patents covering using CRISPR to lead to integration of introduced DNA in eukaryotes. Sigma-Aldrich and Toolgen’s more foundational claims on the general use of CRISPR-Cas9 in eukaryotes are still ungranted, and legal disputes are ongoing.

In Europe, Broad’s foundational patents were invalidated over issues with the assignment of patent rights by the inventors(15), leaving only the CVC foundational patents standing. Many of Broad’s derivative/non-foundational patents will still be valid, and the exact extent of the scope of their patent protection in Europe that will be upheld is unclear. In the USA, Broad’s patents were upheld, requiring parties to license the patents from both CVC (for the general use of the CRISPR technology) and from Broad (for the use in eukaryotes, and thus in plants)(11). If the cultivation of genetically modified or edited plants is is expanded in Europe, this difference would likely lead to the need to conclude separate licensing agreements for the sale of CRISPR modified plants/seed in different locations. Please see table 3.2.1 below for an overview of the major patent holders and the fields covered by their patents.

Company	IP claimants	Applications
ERS Genomics	Emmanuelle Charpentier	Animal Models, Drug Discovery, Industrial Biology, Research Tools
CRISPR Therapeutics		β-Thalassemia, Cystic Fibrosis, Muscular dystrophy, Sickle Cell Anaemia
Caribou BioSciences	University of California, Berkeley	Agriculture, Drug Discovery, Industrial Biology, Livestock, Research Tools
Intellia Therapeutics		α-1 Anti-Trypsin, CART Cells, Stem Cells
Editas Medicine	Broad Institute	α-1 Anti-Trypsin, β-Thalassemia, CART Cells, Cystic Fibrosis, Leber Congenital Amaurosis, Muscular dystrophy, Sickle Cell Anaemia, Stem Cells
Broad Institute		Agriculture, Animal Models, Drug Discovery, Research Tools

Table 6.2, An overview of the major companies, holders of IP, and areas of exploitation of the CRISPR patents (17).

Regardless of this dispute, the sheer number of patents will require any commercial actor to obtain licenses for multiple patents from multiple groups. There is no true patent pool to simplify the process of licensing.

6.2.1 CRISPR-Cas9 and Alternatives

Many of the patents held by Corteva apply only to Cas9 and the use of a single guide RNA, and there are many other suitable Cas proteins aside from Cas9. This leaves considerable opportunities for systems using alternative nucleases or dual-guide RNAs. Much of what is done by CRISPR-Cas9 is also achievable, *mutatis mutandis*, with other RNA guided systems such as CRISPR-Cas12, Fanzor/OMEGA proteins (which are evolutionarily related to CRISPR-Cas9); with DNA-guided systems such as Argonaute proteins; and with protein only systems such as TALENs and Zinc-Finger-Proteases.

Some chimeric nucleases have been paired with the CRISPR-Cas system, such as the *Cas-CLOVER* system developed by Demeetra, with an apparent goal to circumvent the CRISPR-Cas9 patents. The system in question makes use of a catalytically inactive derivative of the Cas9 protein, leading to questions of what is covered by the CRISPR-Cas9 patents – as Demeetra recently concluded a licensing agreement with the CVC group(18), it seems the question has been settled and such derivatives are covered.

The TALEN system is older (although it requires more time and labour to use) than the CRISPR-Cas9 system, thus the foundational TALEN patents will expire earlier. In the USA TALEN-modified plants occupy a large share of the market, and this system should be kept in mind. The CRISPR system's main advantage over the TALEN system is that it uses a guide RNA that can be rapidly and easily synthesized, in contrast to the TALEN system which requires a slower and more labour-intensive assembly of a plasmid from a module library. The CRISPR system is thus much more suitable than the TALEN system for high throughput applications.

The great variety of near-interchangeable systems opens many possibilities to acquire licenses for a suitable technology. This relatively large supply of suitable licenses would be expected to drive down the licensing costs. Furthermore, it would also be possible to use a reduced scope license to carry out preliminary research using CRISPR, and then switch to using an older technology such as TALENs in the later development stages when the most suitable candidates have already been selected and high through-put is no longer needed.

In recognition of the near-interchangeability of CRISPR-Cas9 with these other systems, the trend has been for more recent, non-foundational patents, to reference all these systems (or a generic system capable of cutting/modifying specific nucleic acid sequences) in the claims when appropriate. Additionally, Broad has been striving to identify alternative Cas9 proteins and systems, and is currently the leader in the identification of these alternatives(19) – recently publishing a paper which identified 188 CRISPR-linked gene modules. Despite the aforementioned wide variety of suitable systems, it remains possible that most of them will end up being held by only a few entities. This, combined with the trend for non-foundational patents to cover all systems similar to CRISPR, may mitigate the effects of the large variety of suitable systems and only lead to a modest drop in license costs.

6.3 Licensing policies

"Are licenses only granted to large organizations or also to public research institutions and SMEs or even micro-enterprises?"

The exact terms of licensing agreements are rarely made public, and when public announcements of licensing agreements are made public, the details are often quite vague. Public descriptions of the scope of the rights granted rarely specify if the rights are restricted to systems using the Cas9 nuclease or not, nor what the exact conditions or use are.

Licenses are generally granted (or not even needed) for public research institutions. One major patent holder, the Broad Institute, has publicly clarified its licensing policy (Table 6.3)(20). That policy specifically states: "*For academic and non-profit research use, no written license is necessary […] to the extent such research does not include the production or manufacture of products for sale or offer for sale or performance of commercial services for a fee*".

	BROAD INSTITUTE			
Use	Academic/non-profit/Government research	Reagents and kits for genome editing	Non-human use/research	Human Therapeutics
Licensing policy	No license needed	Non-exclusive licenses sold	Non-exclusive licenses sold	Exclusive* licenses sold

Table 6.3: Broad institute licensing policies. *Exclusive licenses are sold under the "inclusive innovation model" described in the text below

The Broad Institute explicitly states that they generally will offer exclusive licenses for Human therapeutics in order to encourage the necessary level of investment. It is unclear if exclusive licenses will be deemed suitable for any other applications, as company policies can change. The Broad Institute describes an "inclusive innovation model" in which exclusive licenses are granted only for specific genes. Under their model, third parties may be issued a license, after a predefined period of time, "for use against genes that are not being pursued by the primary licensee".

The Sigma-Aldritch licensing policy is broadly similar to that of the Broad institute(21):

- academic and non-commercial research does not require a license
- reagents and kit production licences are non-exclusive
- human therapeutic uses may be exclusive "as necessary"
- other commercial licenses may be "field-exclusive or disease or trait indication-exclusive based on availability for research, production, therapeutic and agricultural uses"

In contrast, the CVC group's publicly available licensing policy is less specific. Like the Broad institute, "purely academic" use does not require a license. The CVC group (ERS genomics) has stated that it may require a license for other types of research and cautions academic groups about selling products "even to other academic institutions", and transferring CRISPR modified organisms to non-commercial entities(22–24). They state that "ERS genomics offers affordable licensing for incubators and startups". They further encourage any group to contact them first to clarify the situation.

More generally, the publicly available data on the license landscape indicates that the major patentholders are willing to grant exclusive licenses, but these licenses are generally restricted to narrow applications and/or species, generally in accordance with the licensee's ability to exploit the scope of the license (as described in detail above for the Broad institute's publicly stated policies). Vilnius University and the University of Vienna are notable exceptions, having granted exclusive licenses for all agricultural applications.

6.4 Comparison with other fields

As mentioned above, except for human therapeutics, the general policy of the major CRISPR IP holders is to grant non-exclusive licenses. Similarly, basic research and development for non-commercial purposes does not need a license. The licensing policies here are in line with all other fields for commercial research and production.

6.5 Agricultural and non-Agricultural license landscapes

6.5.1 Agricultural license landscape

Table 6.5.1 below gives an overview of the licensing status in the field of agriculture and aquaculture.

Fundamental Patent Holder	Licensee	Field	Type
Broad, Harvard, MIT (Zhang)	Bayer-Monsanto	Seed development	Non-Exclusive
	BASF	All Agricultural Applications	
	Corteva		
	Syngenta		
	Pairwise		
	Harpe Bio	Bioherbicides	
	Vilmorin & Cie	Agricultural use (seeds), Cas9 and Cpf1	
	International Rice Research Institute	Rice variety development	
	JR Simplot	Spoiling resistant crops, Cas9	
	Yield10 Bioscience	Crop research, Cas9	
	Amfora	Crops with more protein, Cas9	
	Sustainable Oils	Camelina for Biofuels	
	Bioresource Intl.	enzyme feed additives	
University of California, Berkeley (Doudna, Caribou Biosciences) – CVC	*Corteva*	Major Row crops	Exclusive
		Agriculture/ industry applications	Non-Exclusive
	Genus	Livestock	Exclusive
	Regional Fish Institute	Fish, other non-mammalian marine animals	Non-Exclusive
	TreeCo	Tree Agriculture	Exclusive
	Harpe Bio	Bioherbicides	Non-Exclusive
	Vilmorin & Cie	Agricultural use (seeds), Cpf1 and Cas9	
	International Rice Research Institute	Rice variety R&D with Cas9	
	JR Simplot	Spoiling resistant crops, Cas9	
	Yield10 Bioscience	Crop research, Cas9	
	Amfora	Crops with more protein, Cas9	
	Sustainable Oils	Camelina for Biofuels	
	Bioresource Intl.	enzyme feed additives	
University of Vienna (Charpentier, ERS Genomics) – CVC	Evolva	Flavor/scent products/ fungal biomanufacturing	Non-Exclusive
	Corteva	All uses in plants	Exclusive
Vilnius University	Corteva	All Applications	Exclusive

Table 6.5.1: (expanded from (25) for accuracy, presentation). Overview of the license landscape for agricultural uses. Company names in italics have licenses from multiple foundational patent holders.

The license landscape is dominated by Broad and CVC. Of these two, only the ERS genomics (CVC) has issued exclusive licenses in the agricultural field (although rarely), whereas Broad has reserved such licenses for human therapeutics. ERS genomics claims to have over 100 licensees, although most are not named. Notably, the USA is the largest producer of genetically modified crops, and the foundational Broad patents are valid there (unlike in Europe), and thus rights to patents from both groups are needed for most agricultural uses in the USA. In Europe, the scope of Broad's patent protection is much smaller, but the limited adoption of genetically modified plants in agriculture limits this impact.

When the technology is specified in licensing agreements, it is almost always CRISPR-Cas9. Notably, the CRISPR-Cas9 specific patents have led many companies, including agricultural companies, to develop alternative CRISPR nucleases, which may then be used in other fields such as human therapeutics.

Agricultural Collaborations

Corteva, which has licenses from both CVC and the Broad instutite, has announced collaborations with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), International Maize and Wheat Improvement Center, the International Rice Research Institute (IRRI), and the Donald Danforth Plant Science Center. These agreements are described as collaborations, and are generally aimed at improving food security but do include licensing agreements.

Agricultural Companies with exclusive licenses

Corteva Agriscience is a major agri-biotech company that separated from DowDupont in 2019. It was formed from DuPont Crop Protection, DuPont Pioneer and Dow AgroSciences. It has been granted exclusive licenses from CVC for agricultural applications in many major crops(26), while the University of Vienna granted it(Dupoint Pioneer) exclusives licenses for all uses in plants, and Vilnius University broadly granted it (Dupoint Pioneer) an exclusive license for all applications(27). Recently in 2023, Corteva overtook Bayer-Monsanto as the dominant player in the soybean market(28). More generally, in terms of market share, it is the 2nd largest seed company worldwide(29,30). Despite the exclusive licenses of Corteva, it is notable that Coretva itself has granted licenses to numerous other companies, thus the exclusive licenses held by Corteva do not neccesarily stop other companies from making use of the technology.

Genus plc. Is a British agri-biotech company specializing in cattle and pig products. It has been granted an exclusive license by Caribou Biosciences (CVC) for livestock uses.

TreeCo (https://tree-co.com/) is a smaller agribiotech/plant breeding company which uses CRISPR to introduce edits in tree varieties, with an exclusive license from Caribou Biosciences.

Agricultural Companies with non-exclusive licenses

Monsanto, a subsidiary of Bayer chemical following its acquisition in 2018, is a major agri-biotech company, producing hybrid and genetically modified seeds. It has been granted non-exclusive licenses from Broad for seed development applications(31). It obtained non-exclusive patent rights from ERS genomics, but the details of the areas covered are not disclosed(32). It has also licensed patents from Toolgen(33). Notably it has also received exclusive licenses to the (non-foundational) portfolio of Pairwise plants for agricultural applications in wheat, corn, soybeans, canola, and cotton(34). By 2005, Monsanto controlled 24% of the vegetable seed market within the EU(35). By 2014 in the USA, it controlled 80% of the Maize seed market, and 90% of the soybean market(36). As of 2016 it controlled 23% of the worldwide seed market. In terms of total seed market share, it is currently the largest seed company worldwide(29,30).

BASF (Badische Anilin- und Sodafabrik) is a European multinational chemical company, headquartered in Germany. It is the largest chemical producer in the world. It has licensed CRISPR technology for agricultural applications. Many of its agricultural products are focused on "crop-protection" (herbicides, fungicides, pesticides), but biological controls are also within its portfolio. Often crop protection solutions involve generation of plants resistant to a treatment, such as a herbicide. In terms of market share, it is the 5th or 6th largest seed company worldwide(29,30).

Corteva Biosciences, as mentioned above, has also been granted non-exclusive licenses by the Broad institute in the field of agricultural applications. Notably, due to the nature of the claims held by Corteva and Broad (where and when Broad patents are valid), licenses/patent rights from both patent holders are needed to use the CRISPR-Cas9 system in plants/agriculture.

Syngenta is a Chinese-held company headquartered in Switzerland. Like BASF, its primary products are crop protection products, sales of which account for approximately 75% of its revenue (about 11 billion CHF). Hybrid and genetically modified seeds are its next major source of revenue. Syngenta has substantial cross-licensing agreements with DOW agrochemical in the field of genetically modified plants. It is also active in biofuel research. In term of market share, it is the 3rd largest seed company worldwide(29,30).

Regional Fish institute – A Japanese company which has licensed CRISPR technology for aquaculture of non-mammal marine animals, primarily fish. They use genetic engineering to assist in developing new fish breeds. Notably, they induce small targeted changes that could be accomplished by normal mutation in the course of natural evolution. Foreign DNA/RNA is not introduced, thus all of their products would be permitted genetic modifications under the proposed new EU regulations. The scope of the non-exclusive license is restricted to the asia-pacific region, and thus is not particularly relevant for Europe and Switzerland.

Evolva is a Swiss company that mainly produces specific chemical compounds, such as flavors and fragrances, reservatrol, etc, through a fermentation process. Many of these products are destined for consumption in foods. They make use of genetically modified fungus/yeast, which may be able to produce compounds normally only produced by plants or other organisms. Revenue in 2022 was approximately 15 million CHF.

Harpe BioHerbicide is an American company specializing in weed control. The licensing deal with Corteva and Broad was announced in September 2023(37), and is thus a very new player in the market. The aim of the licensing deal is to develop crops resistant to Harpe's Bioherbicides.

Vilmorin & Cie is a French seed company owned by the industrial agriculture industrial company Groupe Limagrain. It has licensed the use of CRISPR-Cas9 from Corteva as well as the use of CRISPR-Cpf1 and Cas9 from the Broad institute(38). In term of market share, it is the 4th largest seed company worldwide(30).

Sustainable Oils, Inc., is a renewable fuel company that uses the oil from camelina seeds as the primary input material for biofuel production. It has concluded non-exclusive licensing agreements with with Corteva Agriscience, the Broad Institute of MIT, and Harvard for CRISPR-Cas9 and related gene IP to develop improved varieties of camelina. They are interested in traits such as increased oil yield, faster maturation, and drought tolerance. Biodiesel is the primary fuel product, but other fuel types may be produced, such a jet fuel.

JR Simplot is an agricultural company headquartered in the USA that is notable for the production of browning and bruising resistant potatoes. It signed agreements with Corteva and Broad in 2018(39).

Comparison with other fields/countries

As noted, while the licensing policies here are in line with all other fields for commercial research and production, there are some significant differences with regard to license requirements in different jurisdictions.

Countries like the USA, which allow organisms (not just traits, methods, etc.) to be patented, are outliers. Despite being an outlier, the USA is the leading market for genetically modified agricultural products due to its overall agricultural output and the looser regulations on the use of genetically modified organisms in agriculture.

Despite this difference, similar protections for most cases would be granted in other countries through mechanisms such as protection of plant varieties. The major differences in licensing requirements is that within the EU and Switzerland the breeder's exemption and farmer's privilege apply. No licensing agreement is needed to make use of these two exemptions. It is also worth noting that while breeder's exemption does not require a license to derive new varieties from a CRISPR edited organism, a license would be needed to use CRISPR technology in the production of those derivatives. For this particular case, Swiss law provides for a compulsory licence for research tools (Art. 40b PatA).

6.5.2 Non-Agricultural license landscape

The key players in the non-agricultural CRISPR-Cas9 license landscape are quite similar to those of the agricultural license landscape: A group comprising the Broad institute; one comprising the University of California, Berkely, Emmanuelle Charpentier and the University of Vienna (CVC); Toolgen; and Sigma-Aldrich Life Sciences. Notably, Sigma-Aldrich and the Broad institute have concluded cross-licensing agreements for Cas9, where both entities can grant access to their shared IP.

Some of these key players also negotiated together. The agreements between the major player are as follows:
Caribou Biosciences, ERS Genomics, CRISPR Therapeutics, Emmanuelle Charpentier, University of Vienna: a Global cross-consent and invention management agreement in 2016.
The Broad Institute of MIT, Harvard & Sigma-Aldrich Life Sciences reached a cross licensing deal in 2019(40). Sigma-Aldrich was then aquired by Merck KGaA (MilliporeSigma) in 2015. Merck, the Broad Institute, and Harvard signed a non-exclusive CRISPR license framework in 2019.
Regarding Dupont, the company has licenses from: Vilnius University (2015), Caribou Biosciences (2015), ERS Genomics (2017).

Other notable CRISPR-Cas9 licensing agreements are as follows:

Licensor	Licensee	Date
Broad Institute	Transposagen	2016
Broad Institute	Rockefeller Uni. MPEG-LA	2017
CVC	Bayer	2016
CVC / Broad / Sigma	Horizon Discovery	2017/ 2014 /2022
Sigma Aldrich	Horizon Discovery	2022
CVC and Broad	Thermo Fisher	2018
Merck (Sigma)	Integrated DNA Technologies	2018
Merck (Sigma)	genOway	2018
Merck (Sigma)	Promega	2019
Broad/ MIT /Harvard /CVC	Thermo Fisher	2018
CVC	Demeetra	2023
Integrated DNA Technologies	Graphite Bio	2021
Harvard	Colossal	2021

The ThermoFisher license example is likely the most common form of licensing, where licenses from both the Broad and CVC groups will be needed.

Another notable example is that of Horizon discovery, which has licensed CRISPR-Cas12a technology in addition to CRISPR-Cas9 - Mammoth Biosciences (Doudna, University of California, Berkeley) licensed its CRISPR-Cas12a patents to Horizon Discovery in 2020 & 2021. The Demeetra licensing agreement is also notable, as they had previously argued that such a licensing agreement was not needed: "*The constraints placed by organizations that govern CRISPR/Cas9 licensing have forced many researchers to look to other solutions entirely. Our Cas-CLOVER technology, which edits genes more precisely than CRISPR, is covered by patents that are distinct from those of CRISPR, so our commercial users can wield greater freedom*."(41) Their technology in fact used an inactive Cas9 derivative fused to another nuclease. This still illustrates the demand for Cas9-independent CRISPR methods. Licensing agreements for non-Cas9 based systems include:

In Pharma:

Licensor	Licensee	Date
Emendo	Takeda	2019
Mammoth Biosciences	Bayer	2022
Metagenomi	Moderna	2021
Life Edit Therapeutics	Novo Nordisk	2023
ERS genomics	Algenscribe	2023

In Ag/plants:

Licensor	Licensee	Date
Benson Hill Biosystems	Ricetec	2019
	Novozymes	2018
	Agribody	2018
	Bioheuris	2023
	Embrapa	2018
Inari	Eden Enterprise	2021
Cibus	GDM seeds	2021

6.6 New CRISPR licensing deals identified since initial report publication

Since the publication of our Spring 2024 report, the CRISPR licensing landscape in agriculture has rapidly evolved. This update captures newly disclosed deals that expand the use of advanced genome editing technologies across crops, geographies, and innovation models. From next-gen enzyme licensing to strategic joint ventures, these new agreements reflect the accelerating momentum in gene-edited crop development.

Pairwise Grants Full CRISPR Fulcrum™ License to Solis Agrosciences to Accelerate Gene-Edited Crop Innovation (Jun. 2024)

Pairwise has licensed its proprietary Fulcrum™ Platform, a suite of advanced CRISPR-based editing tools, to Solis Agrosciences to support trait development in both row and specialty crops. The platform includes SHARC™, base editing, and REDRAW™ templated editing technologies, enabling precise modification of plant traits. Solis will use these tools in R&D, while its clients can obtain
commercialization licenses through Pairwise. This collaboration expands access to cutting-edge CRISPR capabilities across agriculture. Pairwise continues to lead in agricultural innovation through licensing, partnerships, and internal development efforts across a broad range of globally important crops.

Corteva Invests $25M in Pairwise, Forms Joint Venture to Advance Climate-Resilient Gene-Edited Crops (Sept. 2024)

Corteva and Pairwise have launched a five-year joint venture, backed by Corteva's $25 million equity investment, to accelerate the delivery of advanced gene-edited solutions in agriculture. Combining Pairwise's Fulcrum™ Platform with Corteva's breeding and genetics expertise, the initiative will focus on improving crop resilience to climate change and enhancing productivity across food, fuel, and fiber crops. The partnership will generate and test gene edits across diverse traits and crop types, including corn, soy, and wheat. As the first major initiative under Corteva Catalyst, the collaboration signals a bold step toward scaling innovation in sustainable agriculture.

genXtraits Licenses Pairwise's Fulcrum™ Platform to Develop Climate-Resilient, Nutrient-Enhanced Crops (Nov. 2024)

California-based genXtraits Inc. has licensed Pairwise's Fulcrum™ gene editing platform to develop novel crop traits by precisely editing repressor sequences that control master regulator genes. Unlike conventional approaches that disable genes, genXtraits uses proprietary algorithms to activate genes responsible for

complex traits like drought tolerance and improved nutritional profiles. The agreement grants genXtraits global development and commercialization rights to new crop varieties containing Fulcrum™-enabled edits. This collaboration positions genXtraits to accelerate innovation in climate-adaptive agriculture by engineering dominant traits that enhance performance under stress and support the development of nutrient-fortified food crops.

Pairwise Licenses Fulcrum™ CRISPR Platform to CIMMYT to Advance Climate-Resilient Crops for Smallholder Farmers (Jun. 2025)

Pairwise has licensed its Fulcrum™ gene editing platform, including the advanced SHARC™ CRISPR enzyme, to CIMMYT for use in 20 countries. This agreement empowers CIMMYT and its partners to enhance key smallholder crops like maize, wheat, sorghum, millets, pigeon pea, and groundnut. Fulcrum's precision tools—enabling cutting, base, and templated editing—will accelerate the development of climate-resilient, nutrient-rich crop varieties tailored to local environments. The collaboration supports food security and sustainable agriculture in the Global South by offering a scalable, CRISPR-based alternative to time-intensive conventional breeding, extending real-world gene editing benefits to the most vulnerable farming systems.

ToolGen Transfers CRISPR-Cas9 Technology to Nulla Bio (Dec. 2023)

ToolGen, a Kosdaq-listed gene editing company, has signed a technology transfer agreement with Nulla Bio, a Korean crop genetic editing startup. The deal grants Nulla Bio rights to utilize ToolGen's CRISPR-Cas9 platform for agricultural applications. While financial details were not disclosed, the agreement reflects ToolGen's continued effort to expand the use of its proprietary gene-editing tools beyond biomedical fields. Nulla Bio will leverage the platform to develop innovative crop traits, enhancing productivity and resilience. This move signals growing momentum in Korea's agri-biotech space, with CRISPR tools now increasingly applied to food security and sustainable agriculture initiatives.

ToolGen and PlantArcBio Launch Strategic CRISPR Soybean Project (Dec. 2024)

ToolGen and PlantArcBio have formed a strategic partnership to develop gene-edited soybeans with tolerance to two different herbicide types. The collaboration integrates ToolGen's proprietary CRISPR-Cas9 platform with PlantArcBio's DIPPER™ gene discovery system. Funded with $2.16 million by the Korea-Israel Industrial R&D Foundation, the project aims to deliver innovative soybean varieties that support sustainable agriculture. The partners plan to expand their joint development efforts to additional crops and traits, combining high-throughput gene discovery with precision editing technologies to address agricultural innovation challenges.

Cibus and Loveland Products Collaborate to Develop Herbicide-Tolerant Rice for Southern U.S. Market (Feb. 2024)

Cibus has entered a U.S. development agreement with Loveland Products, a subsidiary of Nutrien Ltd., to integrate herbicide tolerance traits into Loveland's elite Dyna-Gro rice genetics. The collaboration will utilize Cibus' RTDS®-based Trait Machine™ system—a crop-specific, high-throughput breeding process that enables gene editing without foreign DNA integration. Targeting the southern U.S. rice market, the partnership aims to address urgent weed control challenges. Cibus' technology allows direct editing of elite germplasm, enabling faster, precise trait development. The resulting traits are indistinguishable from those developed through conventional breeding, aligning with emerging global standards for non-transgenic crop improvement.

NovoCrops Secures Global License to HuidaGene's hfCas12Max® for Crop Gene Editing (June 2024)

NovoCrops Biotechnology and HuidaGene Therapeutics have announced a global licensing agreement enabling NovoCrops to apply hfCas12Max®, a newly developed DNA editing system, across major crop development programs. Created through HuidaGene's HG-PRECISE® platform, hfCas12Max® offers improved on-target efficiency and reduced off-target activity compared to widely used Cas systems. The deal includes upfront, milestone, and royalty payments. NovoCrops will incorporate hfCas12Max® into its industrial crop breeding platforms, accelerating agricultural innovation. This marks a strategic expansion of China-originated gene editing tools into the global agricultural sector, reinforced by HuidaGene's fast-tracked U.S. patent for hfCas12Max® and robust IP protections.

YolTech and Wimi Bio Partner to Apply YolCas™ CRISPR System in Agricultural Gene Editing (June 2024)

YolTech, a clinical-stage biotech company specializing in in vivo gene editing, has entered a strategic partnership with Wimi Bio to advance the use of its proprietary CRISPR editor, YolCas™, in agricultural applications. YolCas™, developed via YolTech's HEPDONE® platform, enables precise and efficient gene editing in both prokaryotic and eukaryotic systems. The collaboration combines YolTech's innovation in gene editing tools with Wimi Bio's expertise in agricultural breeding to pursue breakthroughs in crop development. Both companies aim to drive innovation in agricultural biotechnology, addressing global needs for more efficient and sustainable food production.

Syngenta Expands Academic Access to Optimized CRISPR-Cas12a via Shoots Innovation Platform (Jun. 2024)

Syngenta has announced a global initiative to provide academic researchers access to its optimized CRISPR-Cas12a genome editing tools and gene-editing-enabled breeding technologies. Offered through the Shoots by Syngenta platform, the tools are licensed for non-commercial research to accelerate crop innovation and sustainability. The initiative aims to support breakthroughs in climate resilience, productivity, and biodiversity without introducing foreign DNA. By fostering collaboration between Syngenta's 6,000+ scientists and the academic ecosystem, this program enhances transparency and global access to advanced breeding technologies.

6.7 Conclusion

Since the first publication of this landscape, the recent wave of licensing deals has expanded the application of genome editing technologies across a wide range of crops, geographies, and collaboration models. Pairwise's Fulcrum™ platform features prominently, with agreements involving Solis, genXtraits, CIMMYT, and Corteva. genXtraits stands out for its distinctive use of CRISPR to activate master regulator genes, an alternative to conventional gene disruption.

At the platform level, tools like hfCas12Max® and YolCas™ illustrate a shift from standard CRISPR-Cas9 to next-generation, high-fidelity editors. Notably, these systems were developed by companies originally focused on therapeutics and are now being strategically licensed into agriculture. This therapeutics-to-agriculture crossover reflects a broader trend in the Life Sciences. Just as China has become a major developer and licensor of innovative pharmaceuticals, a similar model seems now to be emerging in agricultural biotech. Asian players, particularly in China and Korea, are increasingly licensing their proprietary genome editing technologies globally, underscoring the region's growing role in IP generation and cross-border technology transfer. Taken together, these developments signal a maturing ecosystem increasingly

oriented toward trait stacking, accelerated development cycles, and wider international access. In parallel, Syngenta's decision to open its optimized CRISPR-Cas12a tools to academic researchers through the Shoots platform underscores the growing role of public-private collaboration in expanding global access to advanced, non-transgenic breeding technologies.

No Switzerland-specific licensing cases were identified; however, institutions or companies operating in Switzerland are indirectly affected through European license coverage and global IP agreements.

7 CRISPR related litigation

Note: This chapter is reproduced from the previous edition of the report (early 2024), as the litigation landscape has not significantly evolved since then.

7.1 CVC claims of CRISPR-Cas9 use in Eukaryotes, Broad interference proceeding

After Broad published a paper describing the use of CRISPR-Cas9 in eukaryotes and filed a patent covering the same, CVC sought to invalidate Broad's patent. On the basis of their earlier patent covering the use of CRISPR-Cas9 in cells generically (and with publications showing its use in prokaryotes), they initiated an interference proceeding against Broad with the Patent Trial and Appeal Board (PTAB) of the U.S. Patent and Trademark Office. The board found that the two patents covered different inventions (one generically covering the use in any cell, and another concerning the application in eukaryotes specifically), and could co-exist.

At the time of the filing of the foundational CVC and Broad patents in the USA, the USA operated under a "first to invent" principle, rather than the now-standard "first to file system". CVC then initiated another proceeding with the PTAB and attempted to prove to that they had been the first to invent the use of CRISPR-Cas9 in eukaryotes. In September 2020, the PTAB found their evidence unconvincing and ruled against CVC and in favor of Broad. This ruling was confirmed in another case in 2022 (11). As the rest of the world operated on the first to file principle at the relevant time, this dispute was limited to the USA and appears to be settled.

7.2 Rockefeller University and the Broad Institute dispute

Dr. Luciano Marraffini of Rockefeller University was listed as a co-author, alongside authors from Broad, on the first scientific paper describing the use of CRISPR-Cas9 in eukaryotes. Bizarrely, conflicting patent applications were filed that were identical except for differing lists of inventors. In the USA, Rockefeller University and the Broad institute agreed to submit the matter to binding arbitration. In 2018 that arbitration process resulted in the inventorship remaining excluding Dr. Marraffini and the ownership resting with Broad. Notably, the two groups are co-owners of other CRISPR related patents, and Dr. Marraffini is listed as a co-inventor on applications related to use of CRISPR in prokaryotes (42). When they filed the extension to the EPO, Dr. Marraffini was not listed as an inventor, but the EP application claimed the priority date of the application which included Dr. Marraffini as an inventor. As a result of European rules about the listing of inventors on patents, the European patent office revoked the foundational patent held by the Broad institute covering the use of the CRISPR-Cas9 system in eukaryotes in 2018 (15).

7.3 Synthego-Agilent RNA modification dispute

In May 2023, the USPTO PTAB invalidated all 63 claims of two patents (0,337,001 and 10,900,034) held by Agilent (43). These patents were both directed towards the use of chemically modified guide RNAs for Cas proteins. The claims were invalidated on the grounds that they were obvious in view of prior art (i.e.: the invention was not "non-obvious"). This is essentially equivalent to finding that there was a lack of an inventive step (in the parlance of the EPC). The extensions to the EP are still pending, but it is possible that the EU similarly find that they lack an inventive step.

7.4 Corteva-Inari seed dispute

This dispute does not necessarily involve CRISPR-modified plants nor the CRISPR technology. Given the extensive use of CRISPR-Cas9 technology used by Corteva and the nature of the dispute it is nonetheless relevant and is thus included here. In 2023, Corteva filed a lawsuit against Inari, alleging that "Inari purloins high quality seeds, including Corteva's protected seeds, and makes slight genetic modifications to those seeds […] then seeks patent protection for the resulting modifications [and] intends to commercialize seeds containing these modifications" (44) Corteva alleges that Inari acquired "hundreds of varieties of Corteva's protected seeds", although which varieties these are, and whether or not they include CRISPR modified varieties is unclear. The only specific variety mention concerns the seeds of transgenic maize covered under Corteva's US patent No. 8,575,434, which included patent protection of the seeds. Note that Breeder's exemption does not apply to US patents, which can protect the seeds themselves. Corteva alleges that Inari illegally obtained the seeds through ATCC and exported them to Belgium (where such patent's on the seeds themselves are not valid, and Breeder's exemption applies). Corteva notes that ATCC made the protected seeds available for public inspection but expressly prohibited using those seeds for commercial purposes.
This lawsuit is ongoing. While it does not concern CRISPR specifically (or perhaps at all), it illustrates the type of disputes that may equally arise for CRISPR modified varieties. This dispute mainly results from the different exemptions to patentability in the USA compared to Europe, and Breeder's rights.

7.5 Toolgen patent claims

A principal issue with Toolgen's patent claims are that they stem from a provisional patent application filed in the USA, which was generally not up to normally standards (45). In Australia, Toolgen has been unsuccessful at linking their patent applications to the earlier provisional application (i.e.: they were unable to claim the priority date of the provisional application for the later application) (46).

8 Expected patent and licensing landscape trends

Conventional CRISRP-Cas systems (such as CRISPR-Cas9) utilize an RNA template (guide RNA) to direct the Cas nuclease to a DNA sequence, where it induces a double strand break. This break is often repaired by cellular processes such as non-homologous end-joining (NHEJ). This type of DNA modification is useful for knocking out genes. When a donor template is added, the double strand breaks can be repaired by homologous recombination to introduce targeted changes and insertions, including large insertions of transgenes. These more conventional methods are often less efficient or specific than desired. This led to the development of more advanced CRISPR based techniques.

Base Editing uses a guide RNA to bring a base editing enzyme (deaminase fused to a Cas enzyme, such as a Cas nickase) to a specific nucleotide of DNA. Notably, no DNA is cut. This class of enzyme is capable of making four kinds of changes: C to T, T to C, A to G, and G to A. This type of targeted change can introduce very specific DNA changes, without the randomness of NHEJ or the relatively low efficiency of homologous recombination and is ideal for correcting or introducing point mutations. Although not all base conversions are currently possible, and off-target effects remain a consideration, base editors are intrinsically non-transgenic when delivered as ribonucleoprotein (RNP) complexes or transient constructs, making them highly relevant to the evolving regulatory frameworks in Switzerland and the European Union.

A newer method was developed called Prime Editing. This method uses a modified Cas protein is only able to cause single strand “nicks” rather than double strand breaks. The modified Cas protein is fused to a reverse transcriptase which allows it to introduce new DNA sequences into a specified site. This chimeric protein uses a prime editing guide RNA (pegRNA) to simultaneously specify the target site and serve as a template for the reverse transcriptase to introduce the desired edit. This method is capable of inserting up to 200 bases at a time, or deleting over five thousand bases at a time, with greatly reduced off-target effects. When paired with recombinases, insertions of over five kilobases are also possible.

Yet another method involves CRISPR-associated transposases or CAST (Cas enzymes, such as catalytically inactive Cas fused to transposase). The basis for this system was the discovery that some transposons had nuclease-deficient CRISPR–Cas systems for RNA-guided integration into the genomes. Soon enough similar systems were engineered to use the CRISPR system to direct integration of DNA. On-target efficiencies using this system approach 100%, and the system is capable of introducing very large (over 11 kilobases) DNA sequences. The system can also be used to knock-out genes by targeted gene disruptions.

These recent strategies have been recently developed for various applications, including for genome engineering of plant cells and organisms. Applications of Base Editors, Prime Editors and CAST in plants respectively comprise 286, 36 and 34 patent families. Some companies have already positioned themselves on these emerging technologies by filing dedicated patent families: Pairwise Plants Services (Base Editors, Prime Editors), Syngenta-Chemchina (Base Editors), Limagrain (Base Editors, Prime Editors), KWS SAAT (Base Editors, Prime Editors), Bayer/Monsanto (Prime Editors, CAST), Bioray Laboratories (Base Editors) or Suzhou Qi Biodesign Biotech (Prime Editors). Academic players have been also involved in these technologies: laboratories affiliated with the Chinese Academy of Sciences (Base Editors, Prime Editors), the Chinese Academy of Agricultural Sciences (Base Editors, Prime Editors), China Agricultural University (Base Editors,

Prime Editors), Hanyang University & Korea University (Base Editors), or Shanghai University (CAST) to name a few.

In parallel, delivery technologies remain a major area of innovation. While developments in human gene therapy (e.g., lipid nanoparticles or viral vectors) have advanced rapidly, delivery in plant cells often relies on optimized Agrobacterium vectors, biolistic methods, or nanoparticles. The need for precise and transient delivery, especially for DNA-free or non-transgenic applications, continues to drive interest in such methods.

Finally, broader technological convergence is also influencing the field. Automation, digital phenotyping, and robotics are increasingly integrated into modern agriculture. For example, recent patents describe image-based plant/weed differentiation methods designed for automated weeding platforms, illustrating the growing overlap between genome editing and digital agriculture.

Together, these developments suggest that while foundational CRISPR tools remain important, emerging techniques such as base and prime editing are likely to play a central role in next-generation plant breeding, particularly in the context of non-transgenic regulatory exemptions.

9 Possible Applications to Plant Breeding and Agriculture in the EU and Switzerland

9.1 A note on farmer's privilege and breeder's exemption

The Farmer's privilege and breeder's exemption are still valid, and nothing in the CRISPR patents interferes with them. It is also worth reiterating that while breeder's exemption is still valid, a license would be still be needed to make use of CRISPR breeding methods for commercial purposes. For this particular case, Swiss law provides for a compulsory licence for research tools (Art. 40b PatA). Deriving new breeds from CRISPR edited plants by traditional methods would still be allowed. However, the commercialization of a derived breed containing the patented trait would still be a patent violation, and thus would require a license.

Indirectly, the technical ease and efficiency of CRISPR based techniques may render more traditional, non-patent protected methods, uncompetitive. While CRISPR-Cas gene editing is relatively easy to use compared to earlier gene editing techniques, the up-front costs of setting up an appropriate laboratory environment to carry out CRISPR-assisted plant breeding is still greater than that of more traditional breeding methods. Therefore, small plant-breeding entities may still not make use of the CRISPR-Cas technologies for reasons unrelated to licensing.

9.2 Possible Applications

The potential of CRISPR technologies for agriculture in Switzerland and the European Union is closely tied to evolving regulatory frameworks. Both regions are moving toward the authorization of non-transgenic genome editing, notably under Swiss draft legislation on new breeding technologies and the EU's proposal on New Genomic Techniques (NGTs). These proposals focus on DNA modifications that do not involve the integration of foreign genetic material, in particular, targeted mutagenesis and cisgenesis.

Should these regulatory reforms pass, they would allow the commercialization of certain CRISPR-edited crops in Switzerland and the EU for the first time, provided they meet defined non-transgenic criteria.

To illustrate, CRISPR-based modifications relevant to future European applications may include:

- **Base editing** – Precise single-base changes without cutting DNA, useful for mimicking natural variants or introducing disease resistance traits.
- **Gene deletions or knock-outs** – Disabling genes to confer traits such as non-browning or resistance to environmental stress.
- **Cisgenic modifications** – Introducing or modifying genes from sexually compatible species.

While classic transgenic applications remain restricted, these other approaches could form the basis for regulatory approval. However, uncertainty persists for borderline cases, such as allele swapping between varieties of the same species, which may or may not fall under transgenic definitions.

The following is a non-exhaustive list of agricultural products commercialized or in development, and what modification categories they would fall under:

Transgenic Plants

Company	Method/transgene	Description
Norfolk Health produce	Snapdragon transcription factors	Increased antioxidant tomato (Purple tomato)
		Purple tomato' with high GABA
Okanagan Specialty Fruits	Agrobacterium tumefaciens- plasmid RNA interference	Non-browning apples (Fuji, Granny, Gala, Pink and Honey and Golden varieties)

Base editing

Company	Method	Description
Corteva	CRISPR	Higher yield waxy corn
		Corn with extra starch
		Drought-resistant maize
BetterSeeds	CRISPR	Mechanized harvesting compatible cowpea
		Allergen free nuts
		Heat and herbicide resistant tomatoes
		Reduced "growing and harvesting" cost cucumbers
Agrisea/Alora	CRISPR	Salt resistant rice
Nexgen Plant	CRISPR	Virus resistant tomato
Covercress	CRISPR	High yield pennycress
Calyxt	TALEN	Mildew-resistant wheat
		Improved-quality alfalfa
		Soybean oil with 20% less saturated fatty acids
		Soybean oil with no trans-fat
		High-fibre wheat
		Non-browning potato
Cold Spring Harbor	CRISPR	High-yield tomato, more fruit and fewer leaves and branches
Yield10 Bioscience	CRISPR	Camelina with increased oil content
		Camelina with enhanced omega-3-oil content
University of Minnesota	CRISPR	Drought- and salt-tolerant soybean
Iowa State University	TALEN	Disease-resistant rice

Deletions

Company	Method	Description
GreenVenus	CRISPR	Non-browning avocado
		Non-browning lettuce
Pennsylvania State	CRISPR	Non-browning mushrooms
Pairwise	CRISPR	Less pungent mustard greens
Corteva	CRISPR	Amylopectin enriched waxy corn,
VitisGen3	CRISPR	Powdery mildew resistant grapes

These products demonstrate the growing interest in precision traits that align with sustainability goals, food waste reduction, and adaptation to climate change.

While no CRISPR-modified transgenic crops are currently on the EU or Swiss markets, the shift toward non-transgenic pathways may open doors for locally bred, genome-edited varieties—especially if intellectual property and licensing frameworks evolve in parallel.

10 Conclusion

The global patent landscape for CRISPR-modified plants shows strong and sustained growth, particularly since 2012. China has emerged as the clear leader in terms of priority filings, followed by the United States. While Chinese filings are numerous, they are often not extended internationally, suggesting a more domestic focus. In contrast, US-based actors, both public and private, are filing widely across jurisdictions, including Europe. These trends also extend to the subset of patents covering non-transgenic genome editing, where most innovation appears to be driven by institutions and companies based in China and North America.

In Europe, and especially in Switzerland, the picture is more subdued. European applicants contribute relatively few filings overall, and even fewer specifically target non-transgenic genome editing approaches. Among the European countries, the United Kingdom appears slightly more active, although this may partly reflect procedural differences: many European applicants may file directly through the European Patent Office rather than via national offices. In Switzerland, the level of activity is particularly low. There are no priority filings or extensions of patents on modified plants in Switzerland.

The patent landscape surrounding non-transgenic genome editing, defined as approaches that avoid stable integration of foreign DNA, is in active development. While the number of filings mentioning DNA-free techniques such as RNPs and base editors is increasing, the distinction between transgenic and non-transgenic use is not always explicit, and many patents cover multiple strategies within the same claims. This evolving state reflects a field in transition, where new entrants still have room to define and protect focused innovations, particularly in line with emerging regulatory clarity in Europe.

That said, the current situation in Europe offers some breathing room. The number of active, granted European patents focused specifically on non-transgenic plant genome editing remains relatively low. Many of the leading applicants are not European, and the technologies they protect often aim for broad applicability across multiple systems, crops, or regions. This may reflect the relatively recent emergence of DNA-free editing strategies, the complexity of the regulatory environment, or simply a lag in filing activity. This suggests that, at least for now, research and early-stage development activities in Switzerland may benefit from a relatively open landscape.

In summary, Europe, and Switzerland in particular, has not yet fully entered the race in patenting CRISPR-edited plants, especially in the emerging field of non-transgenic approaches. The evolving legal and commercial context presents both a challenge and an opportunity: on the one hand, Swiss stakeholders must remain vigilant, especially as more targeted filings appear in Europe; on the other, the current state of the landscape leaves room for new entrants to position themselves strategically. Continued monitoring will be essential to track how this space evolves, both in terms of innovation and enforceable rights, as CRISPR applications in agriculture move from proof-of-concept toward broader deployment.

11 Methodology

To develop a comprehensive patent landscape on CRISPR-based technologies, the following multi-phase methodology is employed to ensure accurate, relevant, and actionable insights:

1. Define Objectives and Scope

The first step is to define the scope and purpose of the patent landscape. This includes setting goals (e.g. identifying key players, global and technological trends) and delineating the technical boundaries of CRISPR applications, such as genome editing tools, delivery systems, diagnostics, or agriculture.

2. Develop Search Strategy

A precise and comprehensive search strategy is essential for capturing all relevant CRISPR-related patent data.

Keyword Selection & Classification Codes

The search strategy began with the identification of core technical terms related to CRISPR, such as “CRISPR,” “Cas9,” “Cas12a,” “Cas13,” “guide RNA,” and terms like “genome editing” and “gene knock-out/knock-in”. Variants and synonyms were also included to maximize coverage, for example, “Clustered Regularly Interspaced Short Palindromic Repeats” and “Cas protein.” To broaden the retrieval of relevant technologies, International Patent Classification (IPC) and Cooperative Patent Classification (CPC) codes were eventually incorporated into the search strategy. For instance, code C12N15, which covers mutation or genetic engineering and DNA/RNA-related inventions, can be used to capture genetically engineered applications.

Use of Boolean Logic

Boolean operators such as *AND*, *OR* were employed to refine the search and reduce irrelevant results. A representative query might be structured as: (CRISPR OR "Cas9") AND ("gene editing" OR "C12N15"), combining keywords and classifications for targeted retrieval.

Search Fields

The selected keywords were systematically searched across multiple document fields, primarily the title, abstract, and claims. Full-text searches were also performed where necessary to ensure comprehensive inclusion of relevant documents.

Timeframe and Jurisdictions

No restrictions were applied regarding publication timeframe or geographical jurisdiction. This approach ensured the creation of the most exhaustive and globally comprehensive patent dataset available on CRISPR-related technologies.

Patent Database Selection: FamPat

To ensure comprehensive coverage, Orbit Intelligence from Questel was used. This platform provided robust search capabilities and extensive global patent collections. Patent families in all disciplines made up of documents published by 77 offices. Questel-Orbit has developed a definition of family which combines the EPO's strict family rule with additional rules which allow applications filed beyond the 12 months fixed by the Paris Convention (intellectual families) to be taken into account, the different definitions of patent offices of

what an invention is, in particular for Japanese publications, the links to the parent EP and/or PCT application and the links between provisional US applications and published US applications.

Priority: Bibliographic data for the United States and most of Europe from the early 1920s. Other data, including abstracts, from the early 1970s.

Manual Screening

Approximately 55,000 patent families were manually reviewed to identify and retain only those directly relevant to CRISPR. This labor-intensive curation step ensured the exclusion of noise and improved the accuracy and specificity of the final dataset.

3. Data Collection and Cleaning

Patent Analysis and Visualization

The curated patent families were imported into the Intellixir analysis and visualization platform (also from Questel) to generate actionable insights from large volumes of data. This tool facilitated the identification of key innovation trends, assignee collaboration networks, technology clusters, and keyword evolution, supporting strategic landscape exploration.

Data Normalization

To ensure analytical consistency, key data elements such as assignee names (e.g., “MIT” vs. “Massachusetts Institute of Technology”) were cleaned and standardized. This step was critical for reliable statistical analysis and meaningful visualization outputs.

4. Data Categorization

Patent families were categorized manually or using AI assistance (e.g., for Chinese priority filings with no foreign extensions), based on three main technological breakdowns that are covered in the title, abstract and or claims of selected patent families:

Chimeric proteins: including RNA-Guided Nucleases, Base Editors, Prime Editors-PASTE, Other chimeric proteins…

Claim coverage: Genome editing, Transcriptional-epigenetic regulation, Other application, Modified cell, Modified animal, Modified plant, different types of cells to be modified with CRISPR, protected CRISPR system…

Components: focused on core molecular elements of the CRISPR systems such as Cas9, nCas9-Cas9 derivatives, dCas9, sgRNA, crRNA, tracrRNA, Deaminase, Transposase, Repressor-Activator…

In the case of the present report on Plants, the dedicated category Modified Plants was also used for generating a dedicated sub-database inside the global patent landscape on CRISPR. Therefore, after analyzing the full landscape, we can go deeper in the analysis focused on Plants created with CRISPR-based technologies.

5. Analysis and Visualization

Once the CRISPR patent database was structured and cleaned, multiple layers of analysis were performed to extract strategic insights and uncover technology dynamics.

Temporal Analysis

Filing trends were examined over time to detect peaks in innovation, emerging technology waves, and shifts in scientific focus—such as the evolution from traditional Cas9-based systems toward base editors, prime

editors, and RNA-targeting enzymes like Cas13. These trends reflect the rapid diversification of CRISPR toolkits and the growing maturity of gene-editing applications.

Geographic Analysis

Patent filings were mapped across major jurisdictions (e.g., US, China, Europe, Japan) to evaluate global patenting strategies.

Main players and assignee Landscape

Key stakeholders were identified through assignee analysis, revealing the dominant patent holders, their portfolio size, and collaborative networks.

Technological breakdown

The evolution of technologies across time and assignees was then analyzed. Graphs depicting technological breakdowns (e.g., by CRISPR components, applications, types of cells, or editing types) enable a clear visualization of how each assignee is positioned across distinct innovation areas. This analysis helps reveal strategic focus, R&D specialization, and competitive strengths or gaps within the CRISPR patent landscape.

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