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Full Length Research Paper

Agricultural biotechnology worldwide patent analysis and mapping

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Agricultural biotechnology (AgBio) and related areas have seen rapid growth in recent years. The speed and scope of development in the field have made it essential for researchers to be informed. The patent literature contains a wealth of detailed information about the existence for AgBio. While excellent searching tools have existed for many years for identifying patents relating to specific topics, it is only relatively recently that it has been feasible to map the complete archive of patent literature to identify important trends and competition pattern. In this work, several analysis and visualization techniques on AgBio-related patent documents between 1981 and 2009, including issued and application patent were experimented. The data sets are from the patent cooperation treaty (PCT) and the European patent offices, plus a range of national patent collections including those of the U.S.A., Japan, the U.K., France, Germany, Switzerland and Russia (SNTO). The results demonstrated the potential of information-based discovery and visualization technologies to capture knowledge regarding AgBio performance, trends of development and competition pattern through patent analysis and mapping.

Key words: Agricultural biotechnology, patent analysis, trends of development, patent map, patent distribution, competition pattern.

INTRODUCTION

Biotechnology offers new opportunities and challenges and is widely applied in agriculture. The techniques of biotechnology can be used to modify plants and animals and to change agricultural production systems on the farm. Many food processing techniques also are based on living systems. Biotechnology is used to modify food processing techniques and food ingredients. Agricultural biotechnology (AgBio) and related areas have seen rapid growth in recent years. Since the late 19th century, scientists have seen improved plant by changing gene structure. The usual methods are cross-breeding and hybridization, that is to let new plant get characteristics of two parent plant by the mating of two plants. The speed and scope of development in the field have made it essential for researchers to be informed on the progress across different laboratories, companies, industries and countries.

90 percent of human knowledge is published as patent archive and 70 percent is spread only through patent literature, which record achievement description of world-wide latest invention. Patent analysis has much application and has been widely used (Breitzman and Mogee, 2002). Previous articles have described the importance of patents as a key source of technical and commercial intelligence (Norman, 2010; Dou et al., 2005; Huang et al., 2003). The use of patent mapping to visualize large sets of patent data and to identify trends contained within that data has also been demonstrated in some research (Seymour, 2008) and other field (Lee et al., 2009). In the field of AgBio, some other patent statistical analyses on AgBio have been reported (Chan, 2006). OECD biotechnology statistics focused on biotechnology R and D and the application of biotechnology techniques to pro-duce goods or services (OECD, 2005, 2006). The study of using patent mapping to visualize patent distribution, competition status and trends of development in agricultural biotechnology based on large sets of patent data is very important.

Based on the method of patent mapping, this paper focused on the following perspective of AgBio including worldwide patent embattle, trends of development, core technologies with great value and new technologies, organizations with leading technologies, inventors and their employers with leading technologies, which are just

Table 1. Search results of SNTO patent collections with IPC main groups A01H0001 and A01H0004 counted by publication year.

Year published	A01H0001		A01H0004	
	Doc count	Percentage (%)	Doc count maximum number	Percentage (%)
2009	1079	18.3	226	9.0
2008	783	13.3	169	6.7
2007	878	14.9	152	6.0
2006	968	16.4	173	6.9
2005	242	4.1	53	2.1
2004	113	1.9	54	2.1
2003	96	1.6	61	2.4
2002	65	1.1	52	2.1
2001	71	1.2	55	2.2

some of the groups that contribute to and influence decisions made related to intellectual property in agricultural biotechnology. This paper is also to help people to streamline workflow processes, to improve decision making, to extend collaboration throughout their organization and ultimately reduce the time and expense associated with intellectual property (IP) creation and management in the field.

MATERIALS AND METHODS

The paper further develops these themes by examining the patent literature on AgBio published since 1981. Which patent collections are to be used to search for is the first question. Here, the software package used at the Johnson Matthey technology centre was Aureka (a product available from Thomson Reuters, an advanced IP management and analysis platform, the world's leading source of intelligent information for businesses and professionals) which included patent data sets from the patent cooperation treaty (PCT) and European patent offices, plus a range of national patent collections including those of the U.S.A., Japan, the U.K., France, Germany, Switzerland and Russia. They are usually called seven nations and two organizations (SNTO). These collections contain full-text patent documents, available either as PDF or HTML files. In the case of Japanese patents, a text version of the English-language title, abstract and other front page details was available, together with a PDF file of the full specification in Japanese. It must be borne in mind that, using the French and German collections would require the search in French or German, respectively and of course the results obtained would also be in French or German.

After collection of selection, the search strategy is next thought about. In this case, the initial objective was to create a large set of patents relating to the AgBio, was later analyzed and refined. In the patent literature, it is unlikely that the names of agricultural biotechnology would be used in other contexts. Moreover, how to overcome the problems of different expression brought by different languages such as Japanese, German and English was a vital problem in retrieval. To improve the recall and precision of retrieval for patent information, international patent classification (IPC) was selected. The analysis was based on selected IPC codes, rather than keywords in title, abstract, claims or description as search strategy. The definition of biotechnology patents covered the following IPC codes: (Int. Cl.8) A01H1/00, A01H4/00, A61K38/00, A61K39/00, A61K48/00, C02F3/34, C07G(11/00, 13/00, 15/00), C07K(4/00, 14/00, 16/00, 17/00, 19/00), C12M, C12N, C12P, C12Q, C12S, G01N27/327 and G01N33/(53*, 54*, 55*, 57*, 68, 74, 76, 78, 88, 92) (OECD, 2005). All biotechnology applied in agriculture patents covered the following IPC classes: A01H1/00 (processes for modifying genotypes) and A01H4/00 (plant reproduction by tissue culture techniques).

In addition, the detailed patent analysis methods used in this paper were statistical methods of analysis, patent mapping, text clustering, combined qualitative and quantitative analysis.

RESULTS

The search results were “deduplicated” to exclude patent family members filed in different geographical regions in order to leave one patent per invention.

The results list and initial analysis

All patents published by the SNTO from year 1981 to 2009 were focused on. In the subfield of processes for modifying genotypes (also called IPC A01H1/00 in this paper), 11775 related patent documents were searched out and the remaining 5899 results were different innovations after been debuged. While in the subfield of plant reproduction by tissue culture techniques (also called IPC A01H4/00 in this paper), 4340 related patent documents were retrieved and the remaining 2518 results were different innovations after been deduplicated. The retrieval and analyses were carried out to show changing trends in the patent literature, organizations with leading technology, core technologies with great value, new technologies and top patent assignees, inventors and their employers with leading technologies (Tables 1 to 7).

Table 1, demonstrates the AgBio patent application trends in the past ten years. On one hand, in the subfield of processes for modifying genotypes, the proportion of application was about 1.5% every year before year 2004, while in year 2005, the proportion grew to 4.1% and in the latest (2006 to 2008) time periods, it rapidly grew to about 15% and reached 18.3% in 2009. On the other hand, in the subfield of plant reproduction by tissue

Table 2. Top assignees for the set of search results in SNTO patent collections, published between 1st January 1981 and 31st December 2009 results.

Rank	A01H0001		A01H0004	
	Assignee	Doc count	Assignee	Doc count
1	Monsanto Technology Llc.	947	Monsanto Technology Llc	217
2	Pioneer Hi Bred Int.	619	Pioneer Hi Bred Int	110
3	Syngenta Participations Ag	149	Mitsui Petrochemical Ind.	58
4	Du Pont	99	Syngenta Participations Ag	51
5	Stine Seed Farm Inc	81	Mertec Llc.	45
6	Nat Inst of Agrobio Sciences	71	D&PI Technology Holding Co Llc.	43
7	Seminis Vegetable Seeds Inc.	71	Seminis Vegetable Seeds Inc.	40
8	Mertec Llc.	69	Kirin Brewery	32
9	Basf Plant Science Gmbh	66	Jo Paper Co Ltd.	31

Table 3. Top inventors for the set of search results in SNTO patent collections, published between 1st January 1981 and 31st December 2009 results.

Rank	A01H0001		A01H0004	
	Inventor	Doc count	Inventor	Doc count
1	Eby, William H.	228	Eby, William H.	93
2	Schultze, Dennis L.	77	Schultze, Dennis L.	44
3	Page, Nathaniel J.	40	Terakawa Teruhiko	26
4	Popi, Jon	37	Knerr, Larry D.	25
5	Stelpflug, Richard G.	35	Takahashi Shigeru	24
6	Roach, Michael Thomas	31	Murakami Akira	22
7	Fabrizius, Martin Arthur	29	Katsuyama Koichi	21
8	Narvel, James	28	Murakami Kunimutsu	21
9	Stephens, Paul Alan	28	Shibata Masaru	20

Table 4. Search results (A01H0001) by top ten forward citation frequency for most cited documents for patents in SNTO patent collections, published between 1st January 1981 and 31st December 2009 results.

Rank	Document ID	Assignee	Cited by
1	US4873191	Ohio University	292
2	US4517763	University of Guelph	262
3	US4658084	University of Guelph	236
4	US4731499	Pioneer Hi Bred International, Inc.	221
5	US4658085	University of Guelph	219
6	US4677246	Dekalb Pfizer Genetics	207
7	US4812599	Pioneer Hi Bred International, Inc	179
8	US4626610	Dekalb Pfizer Genetics	136
9	US4368592	Dekalb Agresearch, Inc.	134
10	US4594810	Dekalb Pfizer Genetics	134

culture techniques, the proportion was about 2.1% every year in the earliest year (2001 to 2005) and had a sudden growth to more than 6.0% in year 2006, then held on a high level and reached 9.0% in year 2009.

Table 2 shows the top 9 patent assignees in AgBio. Monsanto Technology Llc. was ahead with 947 patents in processes for modifying genotypes and with 217 patents in plant reproduction by tissue culture techniques. Pioneer Hi Bred Int. was after Monsanto Technology Llc. with 619 and 110 patents, respectively. Syngenta Participations Ag was in third place with 149 inventions in processes for modifying genotypes and was in the fourth

Table 5. Search results (IPC main group A01H0004) by top ten forward citation frequency for most cited documents for patents in SNTO patent collections, published between 1st January 1981 and 31st December 2009 results.

Rank	Document ID	Assignee	Cited by
1	US5968830	Mississippi State University	182
2	US5019504	The United States of America as represented by the Secretary of Agriculture	110
3	US5549729	Yamashita; Thomas T	52
4	US4672035	Research Corporation	50
5	US4666844	Sungene Technologies Corporation	49
6	US4777762	Plant Genetics, Inc.	46
7	EP154204	Mgi Pharma, Inc.	45
8	EP331083	Schweizerische Eidgenossenschaft Eidgenössische Technische Hochschule (eth), Eth-zentrum Raemistrasse 101, ch-8092 Zuerich, Ch	45
9	US5258300	Molecular Genetics Research And Development Limited Partnership	44
10	US4715143	Plant Genetics, Inc.	41

Table 6. Search results (IPC main group A01H0001) by top ten top backward citation frequencies for patents in the U.S. patent collection, published between 1st January 1981 and 31st December 2009.

Rank	Document ID	Assignee	Citation
1	US7595387	Dharmacon, Inc.	270
2	US7189570	North Carolina State University	194
3	US711925	The University Of Chicago	140
4	US7244877	Monsanto Technology Llc.	116
5	US7230165	Monsanto Technology Llc.	112
6	US7356965	Weyerhaeuser Co.	87
7	US7622656	Bayer Cropscience Ag	78
8	US7622653	Bayer Cropscience Ag	78
9	US7619145	Bayer Cropscience Ag	78
10	US7622657	Bayer Cropscience Ag	78

Table 7. Search results (IPC main group A01H0004) by top ten backward citation frequency for most cited documents for patents in SNTO patent collections, published between 1st January 1981 and 31st December 2009 results.

Rank	Document ID	Assignee	Citation
1	US5969213	Dekalb Genetics Corporation	117
2	US7603807	Weyerhaeuser Nr Company	107
3	US7161064	North Carolina State University	88
4	US7356965	Weyerhaeuser co.	87
5	US7654037	Weyerhaeuser Nr Company	86
6	US7622655	Bayer Cropscience Ag	78
7	US7622653	Bayer Cropscience Ag	78
8	US7619144	Bayer Cropscience Ag	78
9	US7626097	Bayer Cropscience Ag	78
10	US7622656	Bayer Cropscience Ag	78

place with 51 inventions, which was slightly less than Mitsui Petrochemical Ind.

Table 3 illustrates the top nine inventors in AgBio. Eby, William H. had 228 and 93 inventions in the subfields of

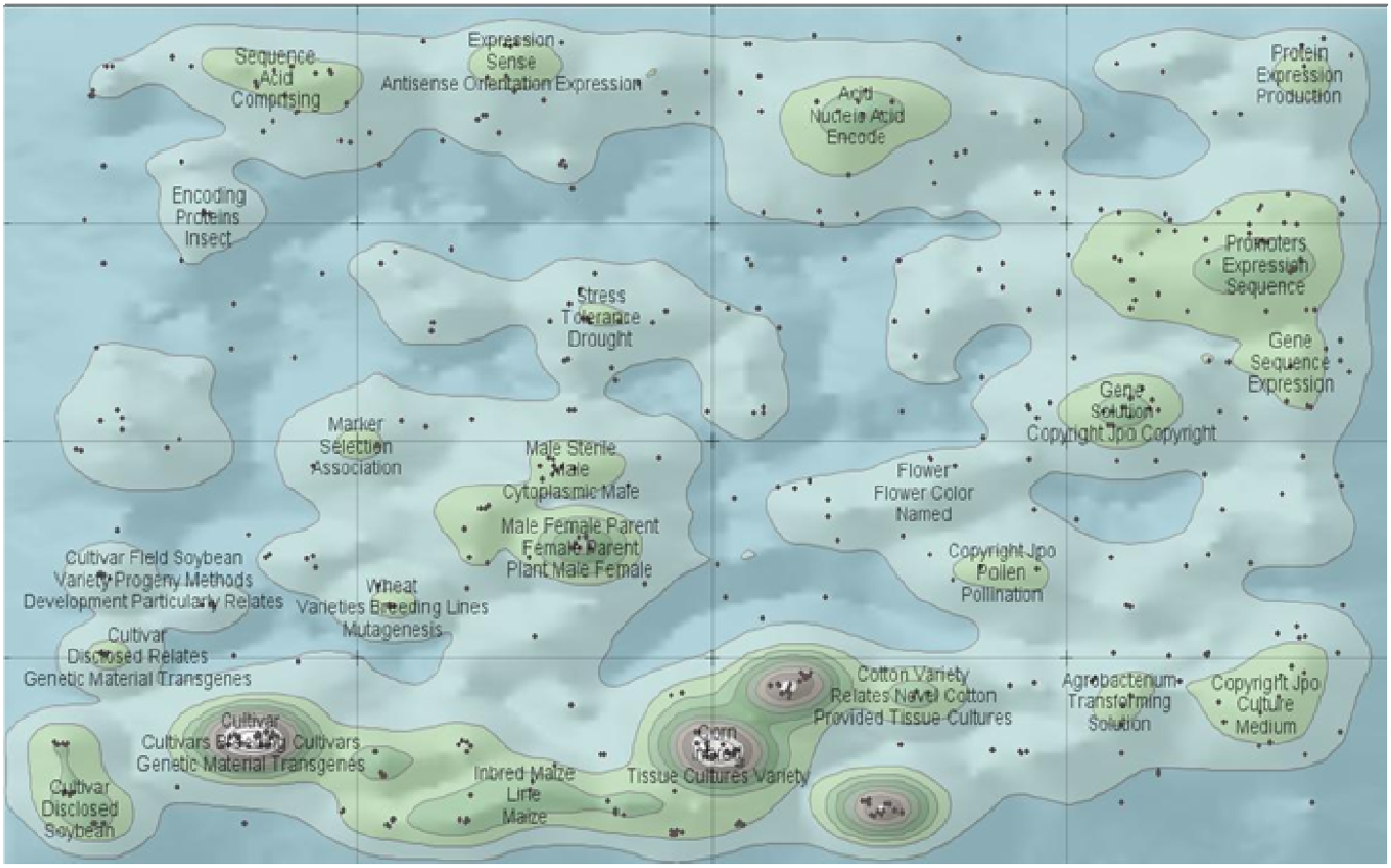

Figure 1. Processes for modifying genotypes patent map covering granted patents or patent applications in SNTO published between 1st January 1981 and 31st December 2009.

IPC A01H0001 and IPC A01H0004, respectively and was way ahead of Schultze, Dennis L, who was in second place with 77 and 44 inventions, respectively. In the third place were Page, Nathaniel J. with 40 inventions in IPC A01H0001 and Terakawa Teruhiko with 26 inventions in IPC A01H0004.

Table 4 shows the top 10 core technologies in the field of processes for modifying genotypes. The patent US48-73191 of Ohio University was cited nearly 300 times. Moreover, the patent US4517763, US4658084 and US4658085 of the University of Guelph, the patent US4731499 of Pioneer Hi Bred International, Inc., the patent US4677246 of Dekalb Pfizer Genetics were the core patent technologies and was cited more than 200 times. They were core patents in the subfield.

Table 5, shows the top 10 core technologies in the field of plant reproduction by tissue culture techniques. U.S. patent 5968830 of Mississippi State University was cited 182 times. In addition, U.S. patent 5019504 of the United States of America as represented by the secretary of agriculture was the core technology and was cited more than 100 times.

Table 6 demonstrates the top 10 new technologies in the field of processes for modifying genotypes. They were U.S. patent 7595387 of Dharmacon, Inc., U.S. patent 7189570 of North Carolina State University, U.S. application 711925 of the University of Chicago, U.S. patent 7244877 and 7230165 of Monsanto Technology Llc, U.S. patent 7356965 of Weyerhaeuser Co., U.S. patent 7622656, 7622653, 7619145 and 7622657 of Bayer Cropscience Ag.

Table 7 shows the top 10 new technologies in the field of plant reproduction by tissue culture techniques. They were U.S. patent 5969213 of Dekalb Genetics Corporation, U.S. patent 7603807 of Weyerhaeuser Nr Company, U.S. patent 7356965 of Weyerhaeuser Co. and 7654037 of Weyerhaeuser Nr Company, U.S. Patent 7622655, 7622653, 7619144, 7626097 and 7622656 of Bayer Cropscience Ag.

Patent mapping

The Aureka ThemeScapeTM tool was used to create a visualization of the document list described earlier. The results are shown in Figures 1 to 5. The resulting map looked like a mountainous island surrounded by sea. The visualization was helpful because ThemeScape grouped

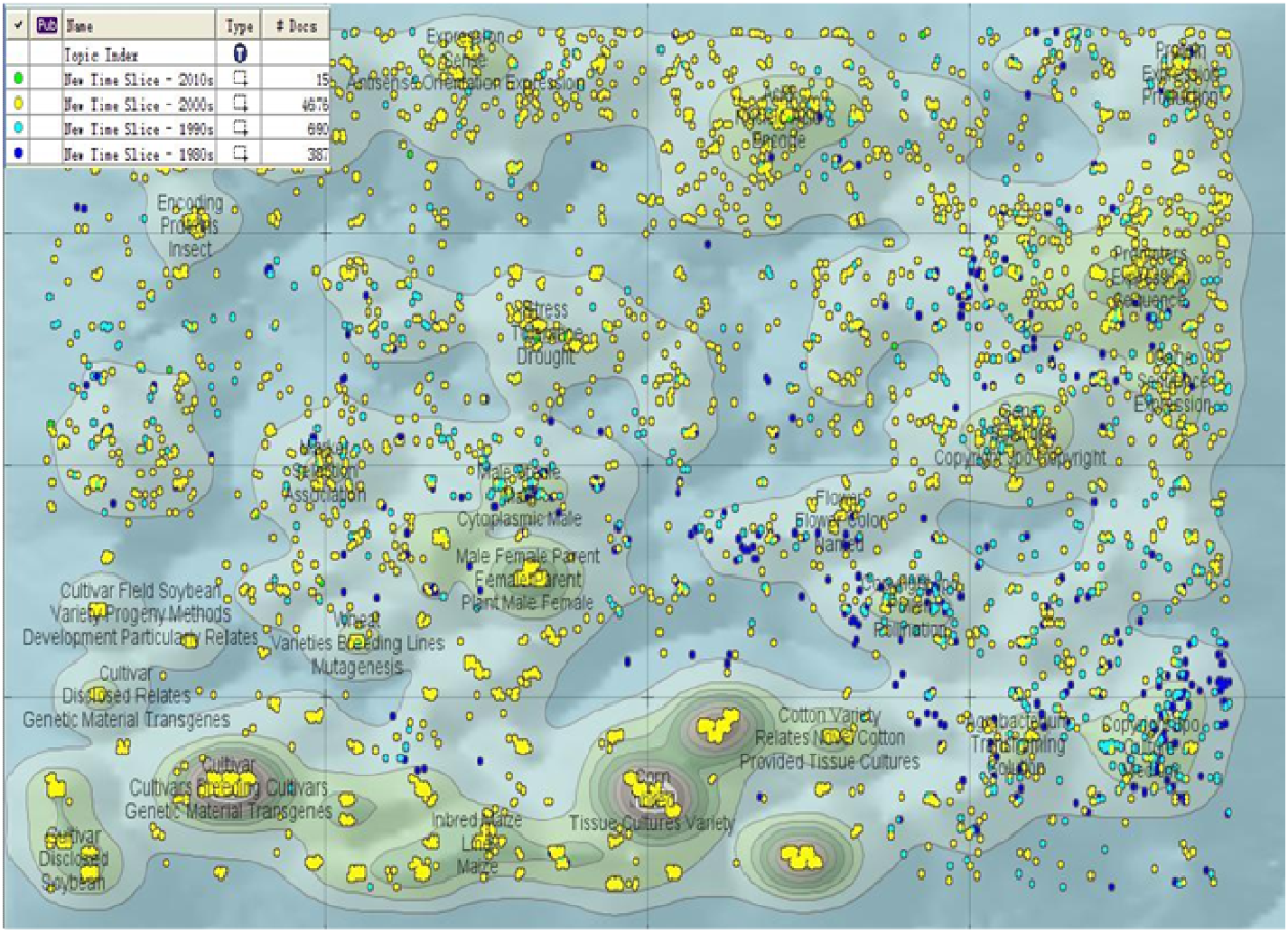

Figure 2. Processes for modifying genotypes patent map with decadal time slices covering granted patents or patent applications in SNTO published between 1st January 1981 and 31st December 2009.

together similar documents and labeled the groups according to the frequently used key terms found within those groups. The more documents contained within each group, the higher the 'mountain' appeared. The automatic labeling sometimes produced meaningful headings, but sometimes these were less obviously meaningful. Where necessary, these can be edited following an inspection of the documents contained within the groups. The dots with different color represent patent documents published in different years or periods. Clicking on specific dots displayed the original document. The contour lines enclosing particular areas were used to select groups of documents for inspection or further analysis.

From Figure 1, the clustering results show that the worldwide patents situation in the sub field of processes for modifying genotypes mainly concentrated in topics of "tissue cultures variety", "inbred corn", "breeding cultivars", "variety progeny methods", "stress tolerance drought", "agro bacterium transforming solution", "gene sequence expression", "male female parent", "encoding proteins insect" and so on.

The basic map shown in Figure 1 was further processed to create a decadal time slice to show general trends in the last 30 years (Figure 2). Figure 2 illustrates that, there were 387 and 690 inventions in 1980s and 1990s, respectively. While in the last decade, there was a sharp increase to 4676 inventions in the subfield. The figure shows the trends of development in the last 30 years from topics of "sequence expression", and "nucleic acid encode" to topics of "tissue cultures variety", "inbred corn", "breeding cultivars", "variety progeny methods" and "stress tolerance drought".

The basic map shown in Figure 2 was further processed to create an annual time slice covering documents published only in the period of January 2006 to December 2009 with different color dots for different year (Figure 3). The reason for this exercise was to show the changing trends in recent years. The result showed that,

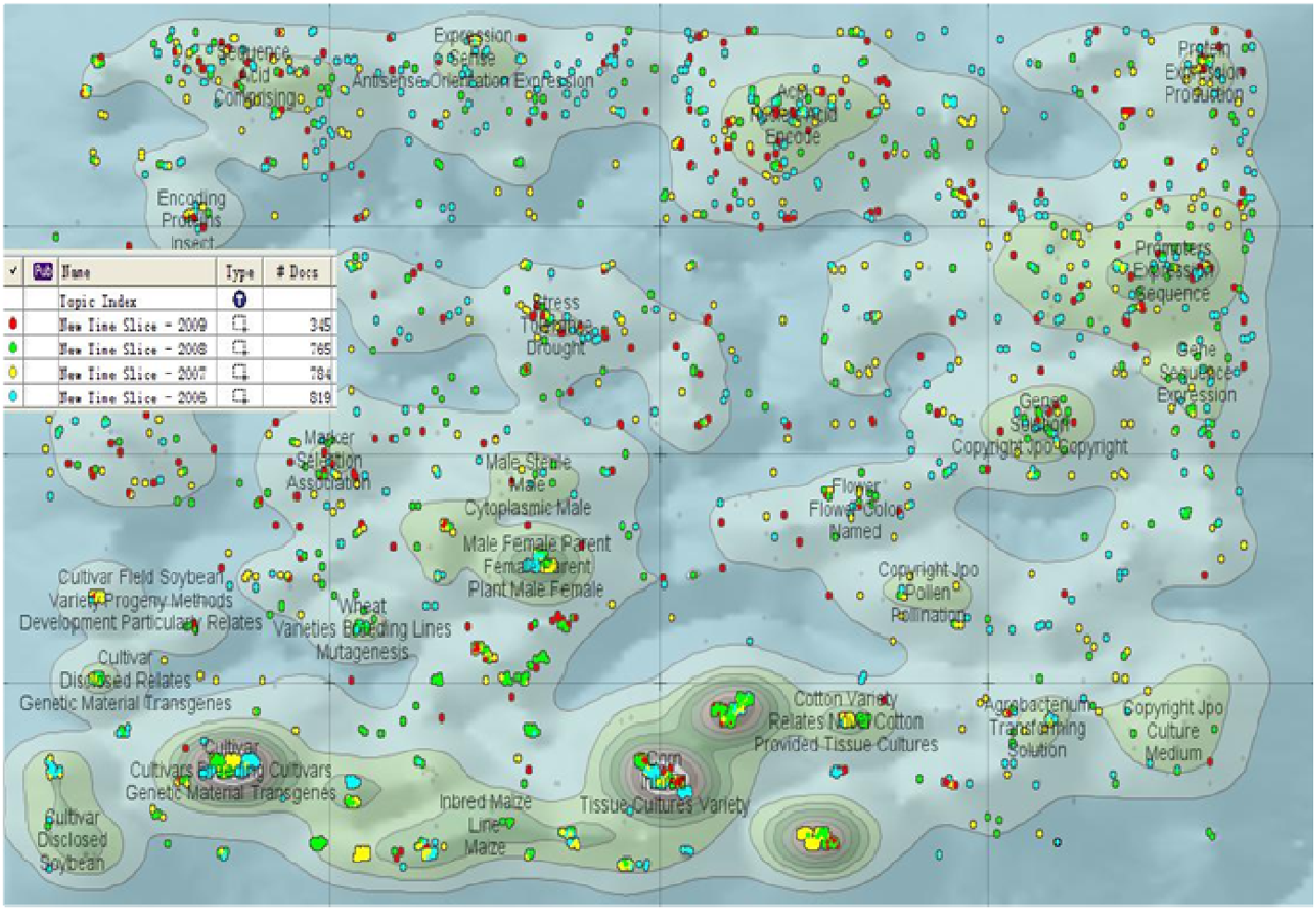

Figure 3. Processes for modifying genotypes patent map with annual time slices covering granted patents or patent applications in SNTO published between 1st January 2006 and 31st December 2009.

inventions of “breeding cultivars” in year 2009 decreased while the quantity of inventions on other topics mentioned earlier maintained a certain level.

In Figure 4, a decadal time slice covering documents published from year 1981 to 2009 was created. The reason for this exercise was to show the general trends in the last 30 years. Figure 4 illustrates that, in the last decade, the invention were turned to concentrate on the topics of “material transgenes”, “cotton and soybean variety” and “fruit and soybean produced crossing”.

The basic map shown in Figure 4 was further processed to create an annual time slice covering documents published only in the period January 2006 to December 2009 with different color dots for different year as shown in Figure 5. The result showed that many inventions were on the topic of “material transgenes cultivar” from 2006 to 2008 and the topics of “soybean variety” and “male female parents” were concentrated on in year 2007 to 2008. In year 2009, the inventions mainly concentrated on topics of “line”, “fruit produced crossing”, “gene sequence” and so on.

Conclusions

After worldwide patent analysis and mapping in the field of agricultural biotechnology during the last 30 years, the conclusions were made as follows:

Worldwide patent distributions and trends of development were;(1) in the last 30 year, inventions in AgBio increased sharply in 2000s, especially from year 2005; 2) the inventions mainly concentrated on topics of “tissue cultures variety”, “Inbred corn”, “breeding cultivars”, “variety progeny methods”, “stress tolerance drought”, “agro bacterium transforming solution”, “gene sequence expression”, “male female parent”, “encoding proteins insect”, “material transgenes”, “cotton and soybean variety” and “fruit and soybean produced crossing”. The research showed that the trends of developments in the last 30 years were from topics of “sequence expression” and “nucleic acid encode” to topics of “tissue cultures variety”, “inbred corn”, “breeding cultivars”, “variety progeny methods”, and “stress tolerance drought” and to topics of “ material transgenes ”, “ cotton and soybean

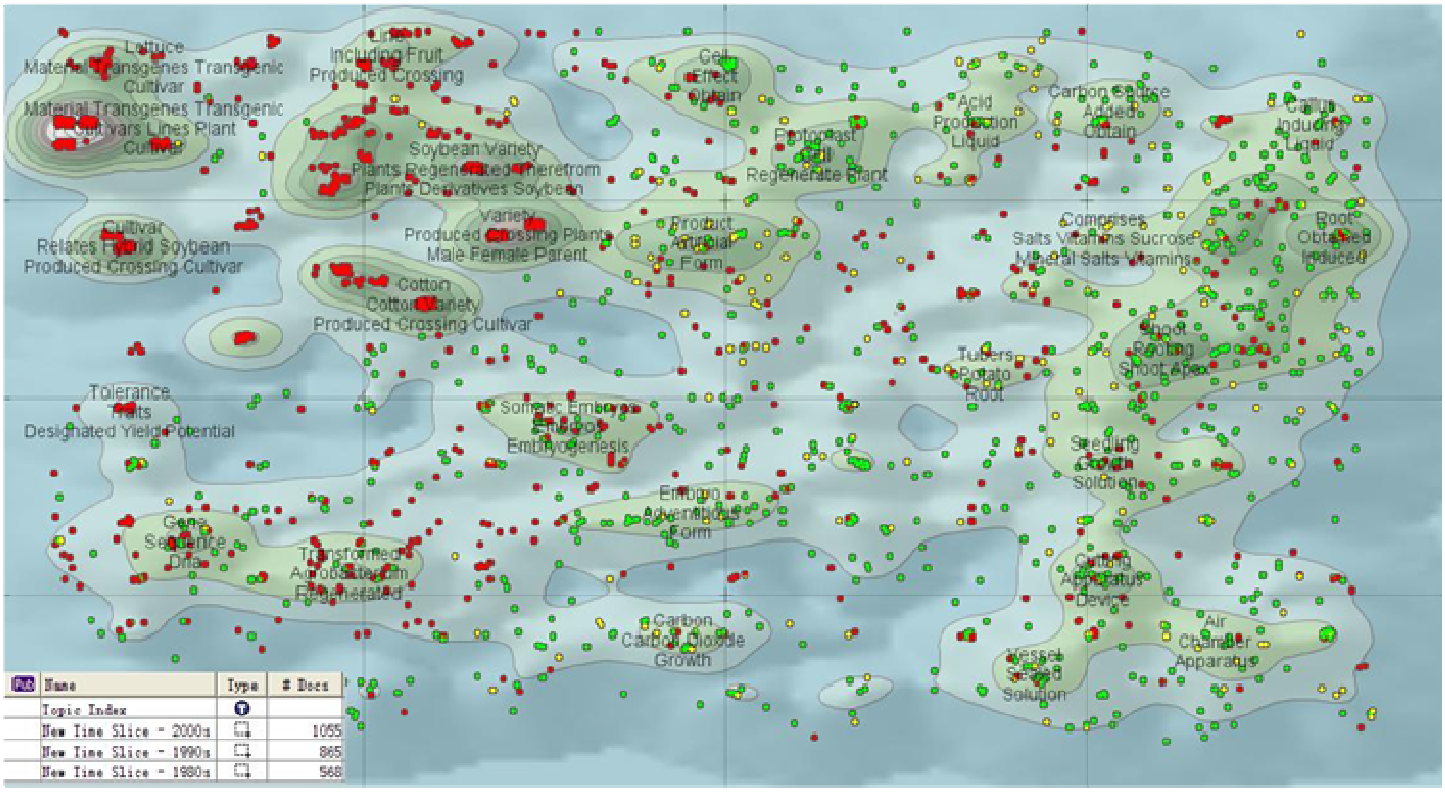

Figure 4. Plant reproduction by tissue culture techniques patent map with decadal time slices covering granted patents or patent applications in SNTO published between 1st January 1981 and 31st December 2009

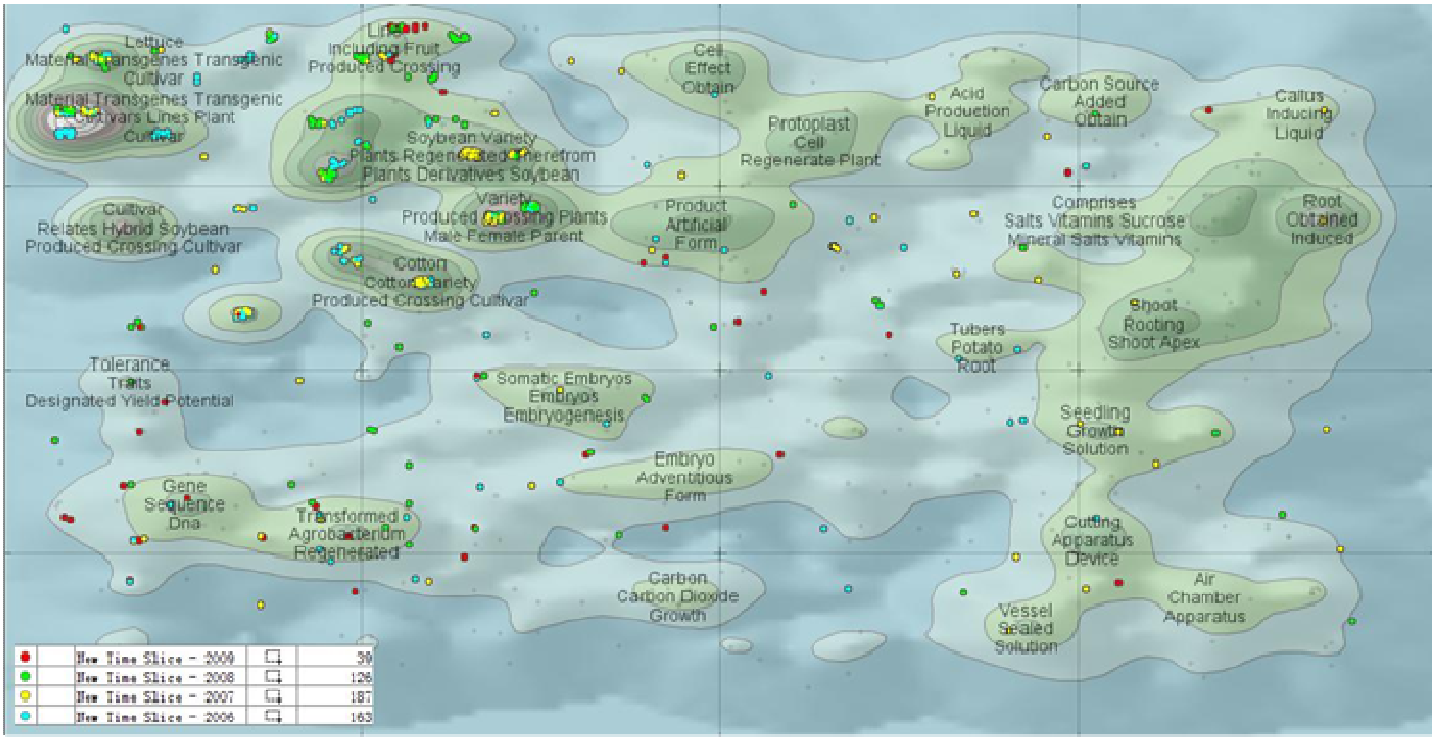

Figure 5. Plant reproduction by tissue culture techniques patent map with annual time slices covering granted patents or patent applications in SNTO published between 1st January 2006 and 31st December 2009

variety", "fruit and soybean produced crossing".

The top organizations with advanced agricultural biotechnologies were Monsanto Technology Llc, Pioneer Hi Bred Int, Syngenta Participations Ag and Mitsui Petrochemical Ind. Inventors and their employers with leading technologies in AgBio are Eby, William H., Schultze, Dennis L., Page, Nathaniel J., Terakawa Teruhiko and so on.

Core technologies with great value in AgBio were U.S. patent 4873191 of Ohio University, U.S. patent 4517763, US4658084 and US4658085 of University Of Guelph, U.S. patent 4731499 of Pioneer Hi Bred International, Inc., the US4677246 of Dekalb Pfizer Genetics, U.S. patent 5968830 of Mississippi State University, U.S. patent 5019504 of The United States Of America As Represented by the Secretary of Agriculture and so on.

New technologies and their assignees in AgBio were U.S. patent 7595387 of Dharmacon, Inc., U.S. patent 7189570 of North Carolina State University, U.S. application 711925 of The University of Chicago, U.S. patent 7244877 and 7230165 of Monsanto Technology Llc, U.S. patent 5969213 of Dekalb Genetics Corporation, U.S. patent 7603807 of Weyerhaeuser Nr Company, U.S. patent 7356965 of Weyerhaeuser Co and U.S. patent 7654037 of Weyerhaeuser Nr Company, U.S. Patents 7622655, US7622653, US7619144, US7626097 and US7622656 of Bayer Cropscience Ag.

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