Explore the Strategy for Agricultural Biotechnology Development in Taiwan from International Trend Analysis

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Abstract

In approaching the knowledge-based economy era, the concept of agricultural technology and industry management started to transit. Under the pressure of globalization, almost every developed country emphasizes the innovation of technology or the growth of opportunity. As for the short term planning of Taiwan's government policy, the key strategy is to improve traditional agriculture by implementing the New Agricultural Movement. The background is quite important for the integral process of technological policy planning; therefore, we have tried to use the innovative information database, which includes technology foresight, literature analysis, patent analysis and development of resource inventory, to investigate the trend of international agricultural development and the niche of agricultural technology development for Taiwan.

According to the technology foresight of Japan, GMO will get into the main stream in the area of agrobiotechnology; furthermore, biotechnology and information technology will become major scientific tools. On the other hand, the concept of health and environmental protections in reforming rural life will increase the diversity of agricultural functions. Evaluation of the competitive ability of R&D in different countries, by applying international agricultural literature analysis and patent analysis, it was found that the area of food security has rapidly become the major research topic recently. This trend might be enhanced by the concern over the development of disputed gene transfer technology. Most of the Asian countries had the advantage of patent on agrobiotechnology in functional foods over Western countries, although there are some differences in technology development niche among them. Obviously, the number of patents on agrobiotechnology in Taiwan has increased, as well as in China, India and other Asian countries. If Taiwan plans to expand its agrobiotechnology industry in the future, properly exploiting its original advantages of agricultural technology will bring Taiwan closer to success.

Keywords: Agrobiotechnology, Patent Analysis, Technology Foresight

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1. Foreword

Agriculture is the foundation for national development, the livelihood of people and ecological preservation. Agriculture is crucial to the living of people and the contribution of agriculture to national economy is irreplaceable. Without agriculture, the development of other industries will be influenced. Agriculture is a vital issue for such advanced countries as the US, EU or Japan in the integration process of their industrial economies. Agricultural research institutes, as well as schools and hospitals, are necessary for all countries. Because its nature is different from that of industries and businesses, agriculture is regarded as the nation's foundation in Taiwan (Tsou & Tsai, 2003)

Taiwan focused on the improvement of production technologies at the earliest stage of its agricultural development, in order to increase the volume of its agricultural and aquacultural products because of the rapid population increase and the pressing need for food. Taiwan also exported agricultural products to earn foreign exchanges which supply the industrial development. The development of agricultural technologies are pressured to transform because of a number of factors, including industrial revolutions, the advent of knowledge-based economy, the entry to the World Trade Organization (WTO), the open of agricultural markets, the development of molecular biology and biological technologies, extensive exchanges of international agricultural trades, and the sustainable management of ecological environments. The pressures for transits can be categorized into three types. (1) Knowledge-based economy has guided the industry operation from production-oriented to market-oriented; quality and diversity has become the emphasis of agricultural development; (2) In the fields of basic sciences, molecular biology has replaced the traditional categorization of sub-industries, physiology, biochemistry, heredity, and statistics; general life science now dominates the field; (3) In the employment of science, traditional chemicals, pesticides are gradually replaced by natural biological fertilizers and biological pesticides (agrochemicals), while traditional planting and breeding are replaced by molecular breeding with disease resistant genes (Harlander, 2002).

As mentioned above, modern agricultural technology developments are influenced by molecular biology. To reach sustainability, the future agricultural developments can satisfy the need of the public – healthy, environment-friendly, safe and toxic-free – by using biological fertilizers, biological pesticides, specific GM crops, clone animals, etc. Before new technologies are invented to enhance the added values of agriculture in the 21st century, agricultural biotechnology may be the most important development trend in the international community. It has potential to influence the development of markets, and has become an important direction for agricultural innovative development for all countries (Nassar, 2006).

The agrobiotechnology development in all countries relies heavily on agricultural researches, and the marketing and branding of new products are also indispensable. The directions for agrobiotechnology and industrial development shall be based on sciences, technologies, and resources we have, and constantly injected into new knowledge and technologies. The end of agricultural development is globally sustainable management of fine, diversified, innovative agriculture.

2. The Construction and Application of Innovative Information Analysis

Taiwan is located at the subtropical zone and its agriculture is at the crucial stage of transition. Taiwan's traditional industries face several challenges. For one, the traditional small-scaled intensive farming leads to high production costs and low production efficiency.

Because farmers have lower income, farming villages suffer from serious manpower drain. The population of farming villages is aging rapidly. The second challenge is the consequence of lacking prevalent education access. Cases of insecticide abuse are found; food security is threatened and the agricultural environment is deteriorating. Taiwan entered the WTO a few years ago and thus made Taiwan's agricultural products compete against imported products. The management of Taiwan's agriculture has therefore been impacted greatly. The Council of Agriculture launched New Agriculture Movement to integrate policies regarding agriculture, farmers and farming villages, and innovations and reforms intensify the agricultural policies. The Movement covers from the first grade industries to third grade industries, from producers to customers, from producing, living to ecology. Resources for research, development and marketing have been integrated to fulfil the mission of "omni-dimensional agriculture". The sci-tech policy of The Movement aims for safe agriculture, recreational agriculture, premium agriculture, and environment-friendly agriculture. To meld into the trend of internationalization, Taiwan needs to shift the industries to knowledge-extensive, technology-extensive, and capital-extensive types of agriculture, to open up new territories for agriculture (Lee, et al., 2007).

With the advent of knowledge-based economy in the 21st century, the application of biotechnology is increasingly important for agriculture. All programs related to the transformation of Taiwan's agriculture in the future are developed towards the industrialization of agricultural biotechnology. In Taiwan, under the three-phases planning of the National Science and Technology Program for Agricultural Biotechnology, agricultural biotechnology is defined as "the application of biotechnology and the technology to produce agricultural material and to enhance the value of agricultural products". To develop strategies for Taiwan's agricultural biotechnological industries, it is required to understand global trend of agricultural biotechnological developments through international analysis. Taiwan also needs to examine the current development of its agriculture to find out the advantages and disadvantages, so as to successfully upgrade or transform agriculture industry.

The healthy development of an industry relies on three key elements: basic scientific research, technology innovation and operation model. In light of the fact that Taiwan's agricultural biotechnology industries are still at their earliest stage of development, background information is essential for the government to initiate strategies for agricultural biotechnology. In technological and industrial aspects, systematic information collection and analysis as well as important indices are required as references for policy planning. The government integrates the research and development budgets, technological resources, and technological development trends for Taiwan's agricultural biotechnology industries to lay a solid foundation for the application of biotechnology on agriculture. Strategically, Taiwan needs not only a comprehensive analysis of its agricultural technologies, but also a database of journal articles, patents, and technological resources from domestic sources and abroad. The database will benefit the integration of resources and the prediction of trends to understand the directions of biotechnological developments, which are important references for policy-making agencies to initiate agricultural biotechnology programs.

Under the circumstances that the government needs to draft new agricultural policies, this study intends to apply innovative information analysis on the technological and industrial aspects to understand the international agricultural biotechnology developments and R&D potentials and also examine Taiwan's current agricultural developments. This study concludes with objective strategic suggestions for policy-making agencies, which are responsible for planning agricultural transitions. The innovative information analysis adopted in the research includes the technology foresight trend analysis, which categorizes the national foresight programs of various countries and cross-analyzes the programs to find out the potential directions for international agricultural developments and the new roles for transformed agricultures. The ISI Web of Knowledge and the US patent database contribute to collect specific international citation and patent information to evaluate the R&D potential of agricultural biotechnology science and technology in the US, Japan, Netherlands, Taiwan and China. The researches in the countries are compared with Taiwan's researches. According to the analysis and comparison of international achievement, the study raises suggestions and niche directions for Taiwan's future agricultural biotechnology development.

3. Analysis of Global Trends of Agricultural Biotechnology R&D Development

Facing the keen competition brought by globalization, Taiwan needs to re-establish its agricultural structure to develop diversified and quality agriculture. When developing strategies to apply agricultural biotechnology to agricultural transitions, decision-making agencies shall consider raising the added values of Taiwan's traditional agriculture as the main short-term strategic goal. Moreover, technology development is dynamic and continuous, and it is important to prioritize scientific areas to invest resources. Many countries develop new methods to reflect the trends of technology development though the integration and interaction of the industries, the government, the academia and the research institute. Foresight programs can be employed as a strategy planning tool to provide a country with possible directions and scenarios of a certain technological area (Salo, 2001).

3.1 Technology Foresight for Exploring the Trends of Global Technology Development

Foresight is a systematic process to visualize the prospects of sciences, technologies, industries, economics, cultures and social developments. Through the process, one country can look for the most appropriate development strategy and technology to increase economic and social interests, or necessary institutional adjustments.

The concept of Technology Foresight was originated in the US, but Japan has invested considerable human and financial resources in large scale scientific and technological surveys every five years since 1970. Up to date, Japan has done eight rounds of Technology Foresight. The first to the fourth were technological predictions, and the results of the fifth to the eighth predictions were included in technological development to set up R&D goals and allocate resources accordingly. Cooperative administrative measures were launched to promote scientific researches in Japan. In the world, over forty countries are committed to Foresight, for example, in the UK and Germany the results of prediction are important references for decision-making for government departments to allocate resources or to formulate strategies. In France, Technology Foresight was carried out in 1995 and 2000 to assist local firms to invest limited resources to leading areas and to build technological barriers to protect huge domestic commercial interests (Cuhls & Blind, 2001).

Since Japan's first survey conducted 20 years ago, the developments confirmed about 60-70% of the predictions on agricultural affairs. It indicates the accuracy of Foresight on predicting the future. Every country has its specific natural resources, cultures, economic backgrounds, and consequently places different levels of importance on agricultural development. The study analyzes the percentage of application of biotechnology to agriculture in the Foresight surveys conducted in Japan, Germany, Korea, and the UK in the last decade. Table 1 shows a high percentage of biotechnological agendas in all areas. In Japan's sixth survey, biotechnology accounts for 54% of all agricultural agendas; in Japan's seventh survey, there were 43 biotechnological agendas which accounts for 54% of all agricultural agendas. In Korea there were 43 biotechnological agendas accounting for 49% of all agricultural agendas, and in Germany there were 36 accounting for 36%, and in the UK there were 22 accounting for 19%.

Japan's Foresight focused on how to apply biotechnology to sustainable agriculture and to lead Japan's agriculture to five strategic directions, namely grain safety, pesticide residue reduction, health improvement, food safety, and integration of production and marketing.

3.1.1 Grain Safety

Whether genetically modified (GM) food can be accepted in the markets is not a problem now, the real problem is how to make GM foods safer. Japan therefore is committed to develop appropriate technologies for plants, including genetically modifying productions of grain and improving their environmental stress-tolerance (e.g. disease resistance and cold resistance), improving photosynthesis of C_3 plants such as rice to increase grain production. Since aquatic animals do not compete against the mankind for land and crops, Japan predicts that in the future aqua-cultural products may become the major source of dietary protein. Japan will develop more marine resources and employ genetic modification and cell fusion technology to create new species that are tolerant of the change of water temperature and resistant against diseases, and produce stable aqua-cultural products that are disease resistant and productive. The strategy may reduce the food pressure which the mankind compete with the livestock. As an island country, Taiwan can also learn from the strategy.

3.1.2 Pesticide Residue Reduction

To reduce the negative influence of mankind to the natural environment, especially by reducing the amount of agrochemicals, Japanese scholars predict that by 2015 the amount of biological pesticides (or bio-pesticides) can replace agrochemicals by 50%. The development of non-leguminous plants and phosphate-solubilizing technologies to increase the source of nitrogen in soil; phosphate-solubilizing microbes dissolve phosphate for the better absorption of plants. This will increase the nutrition supply and organic matters in soil, which will become fore fertile and the amount of chemicals, can be reduced. The development of environment restoration technologies, e.g. the development of inspection technologies, molecular tools of biological diversity, the restoration of forests, oceans, swamps, lowlands, and pollution relief, will assist in alleviating pollutions and restoring the ecological system. The combination of such technologies with digital technologies, i.e. remote control, can

Table 1. Comparison of the Number of Agricultural Biotechnology Agendas in Different Countries

National Technology Foresight Program	Period	Forecasting Time Frame	Biotechnology/ Agricultural Agendas
Japan's Foresight (6th)	1996-1997	30 years	45 items/84 items
Japan's Foresight (7th)	2000-2001	30 years	43 items /79 items
Germany's Foresight	1998-1999	25 years	43 items /88 items
Germany's Foresight	1996-1998	30 years	36 items /101 items
UK Foresight	1993-1995	20 years	22 items /116 items

Source: Ien, 2006.

strengthen management of natural resources and land and establish a management system for disaster warning and detection.

3.1.3 Health Improvement

The aging population is taken into serious consideration in Japan's Foresights and the next mainstream for agriculture is the new idea of "customization" according to the different needs for nutrition. Since each individual has different physical conditions (e.g. allergy, chronicle diseases) and different groups of people (e.g. the elderly) need different functional foods to prevent disease. Such design can reduce the waste of agricultural resources and the cost of national health insurance. This strategy indicates an important direction for all countries when developing health food and health industries.

3.1.4 Food Safety

GM food is more and more common but its possible influences on the environment must not be neglected. The miserable memory of the negative influences brought by industrial revolution is fresh, and there are still doubts and worries on the safety and management of GM food. That is why GM food has not prevailed in the markets. In the market of new agricultural products, GM food and organic food will be presented to customers, who can freely choose which to purchase. Japan's Foresights therefore underscored the development of inspection technologies, i.e. through the application of digital technologies, customers can inspect food on their own to protect their rights. The government and decision-making agencies are required to examine the safety of GM agricultural products from the perspectives of food and environment, to develop examinations that customers accept and raise the public awareness of GMO. The strategy to communicate with the public and to reach agreement will become an important task for Taiwan's government on food safety.

3.1.5 Integration of Production and Marketing

The integration of production and marketing is a new agenda in Japan's eighth Foresight survey. Taiwan's agriculture relies mainly on independent farmers, who are not competitive in terms of management costs. Facing the advent of globalization, it is required to accelerate the integration of agricultural chains, from breeding, R&D, production, marketing to logistics. The integration shall start to form large farmer groups (agricultural businesses) to independent farmers (family farms, production and marketing workshops) to overcome the difficulties of independent farmers when they face scale economy, and such integration will eventually make Taiwan's agriculture highly competitive. On designing production and marketing strategies, Japan tends to incorporate relevant agencies to promote agricultural production. In the framework, Japan develops various technologies and management mechanisms to ensure the quality of agricultural products and prevent pollutions during delivery. For example, from production to landing on dining tables, the food can be examined with various inspection devices such as DNA chips and optic sensor devices to prevent any harmful substances and bacteria. On the other hand, Taiwan is now including "Food Traceability" into its production and marketing management system. The development of global environment monitoring technologies is also imperative to build a system that monitors the cycles of important elements in the agricultural and aqua-cultural ecology. Such system can detect environmental problems, e.g. diseases, blights, avian flu, and problems with farms, animal farms, and fish pools, at their earliest stage. The development of the system is an important part of the strategy.

From the Foresight analysis of the five major categories of agricultural agendas, it is concluded that Japan has the most complete and comprehensive Technology Foresight Programs, and 70-80% of its technology predictions have been realized. Since Taiwan shares much in common with Japan, this research refers to Japan's Technology Foresight Programs, from which Taiwan learns. Japan's latest Foresight Programs show that biotechnology plays an increasingly important role in agricultural agendas, especially on the application of genetic modification on breeding and planting, functional food, environment restoration, vaccines for livestock, and disease diagnosis. A good majority of predictions took more time to be realised. Some issues were discussed multiple times, showing that these issues were necessary but decreasingly important, partly because the issues were realized or replaced by new technologies. In the research on Japan's five strategic goals, the discussion on grain safety outnumbers other agendas. Safe agriculture shall receive the most attention, but with the rapid development of biotechnology, problems of safe agriculture can be solved with biotechnologies in the future. The integration of production and marketing did not receive quality attention until the eighth Foresight, and the incorporation of agricultural production and marketing systems is the key to successful integration. The population is aging and birth rate declining, functional food becomes increasingly important. Pharmaceuticals will be produced in molecular farms and pastures in a more efficient way at lower costs. Japan's new agricultural programs indicate the goals for future agricultural development are grain safety and versatility of agricultural products. To fulfil the goals, imperative strategies include the production and supply based on the requests of customers, comprehensive integration, revision of subsidy policies to meet WTO regulations, and detailed planning of general agricultural resources. With supportive policies, Japan government is promoting new diet cultures to integrate agriculture with food industries, to develop regional special agricultural products according to the features of each region, which will increase the revenue of local farmers and fulfil the goal of integrating diet cultures with agricultural products and marketing agricultural products. Biotechnologies are employed to develop safe agriculture, e.g. technologies to inspect the species of important grains, and use and maintenance of regional biological resources, waste management and sewage management. The traditional production-oriented agriculture is gradually developed into environment protection-oriented agriculture. The framework for environment friendly farmers will be more complete in the future. All the above-mentioned strategic goals can be used in Taiwan as well to give biotechnology a more important role in knowledge-based agriculture.

3.2 Literature Review: Comparison of International Studies

The development of science and technologies is influential to the way of living in the 21st century and the social environment. All countries therefore are committed to the promotion of technology researches, which are considered as an important infrastructure to enhance competitiveness of a country (Huang, Chen, & Chang, 2003). In the past, quantitative analyses are used for technological literature, such as the description of technological activities, evaluations, and global science developments monitor. OECD, APEC and EU all consider the number of academic theses published as an important index to evaluate the capability of developing sciences, and believe that the analysis of the number is a way to understand the technological development process in other countries, and a way to predict future trends of technological development. In the study of academic research development process, citation analysis and content analysis are main tools to examine literature, to examine the research results in various scientific fields, and to trace academic development. The study of agricultural biotechnology is an emerging scientific area that covers agriculture, molecular biology, and life science. To understand the development trends of health food technologies in various countries, the study needs to draw up a strategy to review literatures and make use of the journal papers in Institute for Scientific Information (ISI) Database to analyze the contents of theses published in the US, Japan, Europe, China and Taiwan so as to understand their academic development and potential trends.

ISI database accommodates 127,881 journal papers on the sub-fields of agricultural biotechnology, including biological fertilizer, biological pesticides, GM plants, GM livestock and poultry, molecular inspection, environment protection, food safety, biotechnological feed, health improvement, and animal vaccines. From 1996 to 2005, the number of papers in each sub-field increased, and there is the most significant increase in the category of food safety, GM livestock and poultry, and GM plants. The numbers show that all countries are committed to the basic researches on GM animals and plants, but are restrained to regulations and social environment safety. All countries place much importance on safe agriculture, and consequently the research on safe agriculture is faster than researches on genetic modification.

The analysis of the focus of academic development in agricultural biotechnology in different countries is demonstrated in Figure 2 that shows the countries have different focuses. The US focuses on GM animals and plants, and there is much room for development in the researches on biotechnological feeds. Netherlands relies on livestock industry, and compared with the US, Netherlands places equal attention on each field. Netherlands focuses on environment protection and molecular inspections in terms of agricultural biotechnological developments, and its researches on biological fertilizers and biological pesticides does not receive as much attention as researches on other subjects. Japan used to focus on the fermentation industry and now places its attention on GM animal, GM plants, health improvement, and food safety. China is rising in recent years,

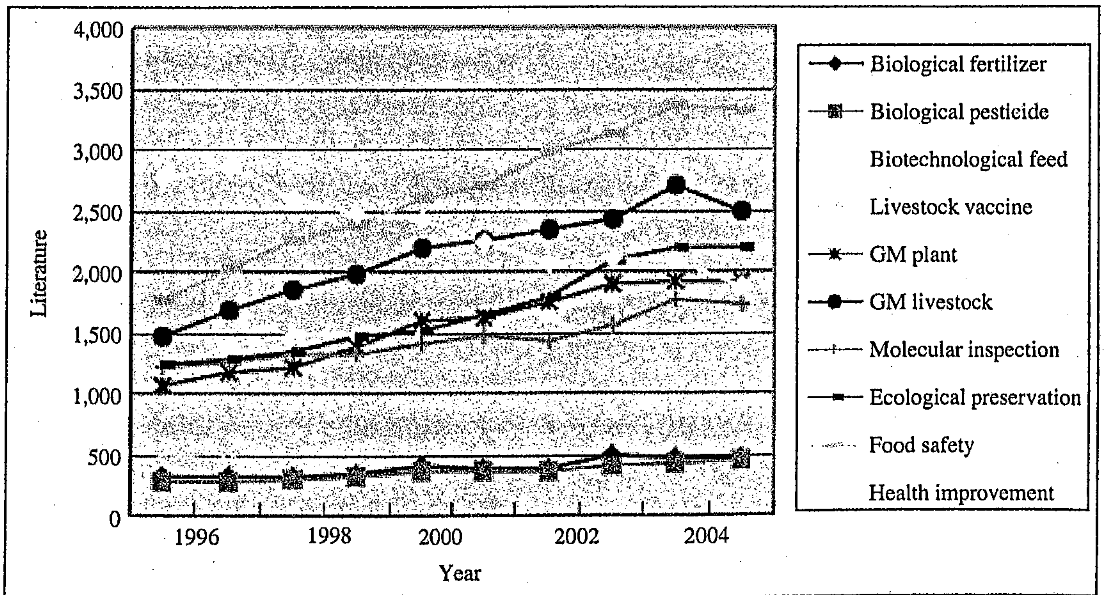

Figure 1. Growth of International Literature on Agricultural Biotechnology

Sources: ISI Web of Knowledge; Taiwan's Council of Agriculture, 2006.

and its R&D focuses on environment protection and GM plants mainly. Korea and Taiwan both make significant achievements in the studies of biotechnological feeds and biological pesticides. In general, studies of GM plants, GM livestock and poultry have become the mainstream of agricultural biotechnological developments in the international community. In comparison, Asian countries are more dedicated to food safety and health improvement, a sign of the diversified diet cultures in oriental countries (see Figure 2).

The number of papers published, however, does not relate to the quality of researches. The quality of researches needs to be evaluated with qualitative analysis, i.e. citation per paper. When the agricultural biotechnological researches conducted in the US, Netherlands, Israel, Japan, China, Korea and Taiwan are presented in Figure 3. It is found that the US is leading in the field of GM plants. The literature of the US is most frequently cited by scholars and experts in the US and other parts of the world. Israel,

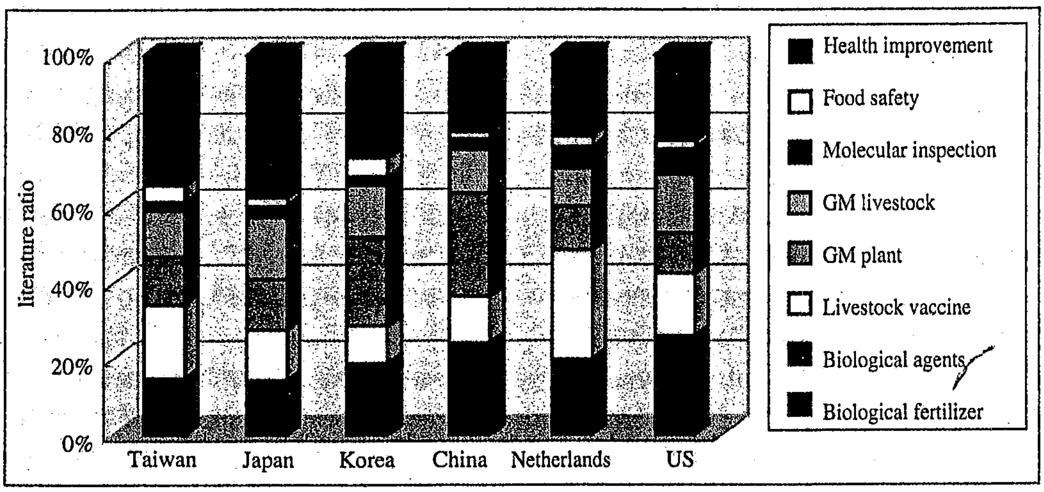

Figure 2. Focuses of Agricultural Biotechnological Researches in Different Countries from 1996 to 2005

Source: Statistics provided by ISI Web of Knowledge.

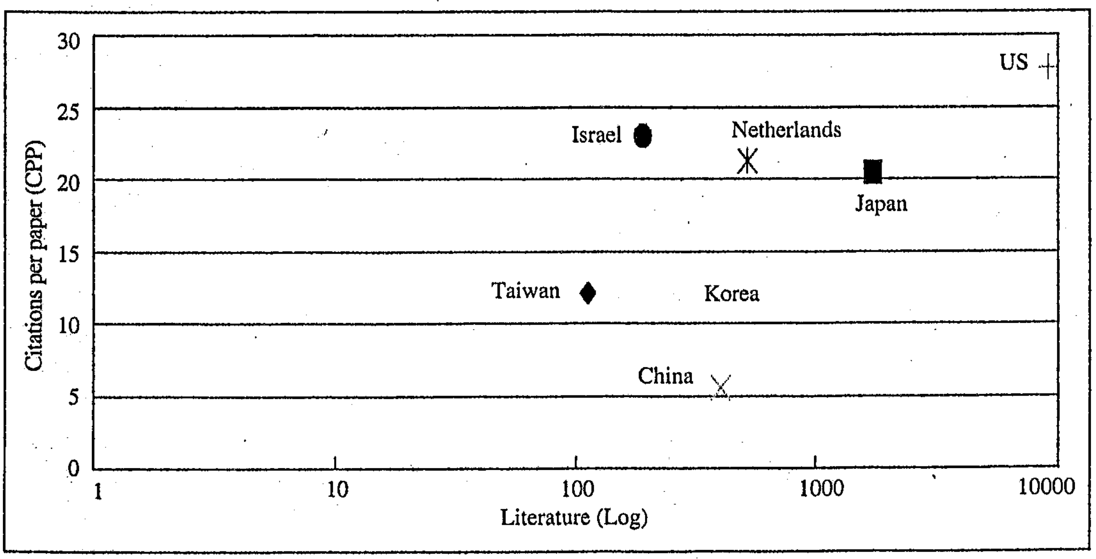

Figure 3. Academic Development Potentials on GM Plants in Various Countries

Sources: ISI Web of Knowledge; Council of Agriculture, 2006.

a country based on agriculture, has a number of large agricultural businesses, published fewer papers on GM plants than Japan and Netherlands, but its literature is cited more often than papers published in Japan and Netherlands.

The observation of the performance of research and development on GM livestock and poultry leads to the finding that the US and Netherlands have the best achievements in the area (see Figure 4). Of Asian countries, Japan is the best in all agricultural biotechnological fields. Compared with Japan, Taiwan and Korea have similar GM plant development, but Taiwan's R&D potential for GM livestock and poultry is not as strong as Korea's. The quality of Taiwan's papers is better than China's. The R&D in different areas can be understood from the comparison of R&D potential in each country, which can assist Taiwan to find its role and strength in the area in question. Such method is expected to find niche for development for Taiwan's agricultural biotechnology industries. Literature review is not limited for the evaluation of technology output but can be also used for predicting global technology development trends. Literature review therefore serves as a strategy planning tool for competitiveness assessment and reference.

3.3 Comparison of R&D Potential of Various Countries with Patent Analysis

According to World Intellectual Property Organization, only patents can make public the technological development information among various sources like journals, magazines or encyclopaedias or any other data. Patent analysis involves searching in patent databases, systematically transferring information to useful data according to the theme of researches, and demonstration of the data with diagrams and professional interpretation. In the end, the interpretation becomes the most valuable patent intelligence (Karki, 1997). Patent analysis, therefore, can help industries to find their edge, to develop specific products, and understand the patents of competitors to avoid patent infringement. Reports released by WIPO reveal that patent specifications cover 90-95% of research results, and taking advantage of patent information can save up to 60% of research

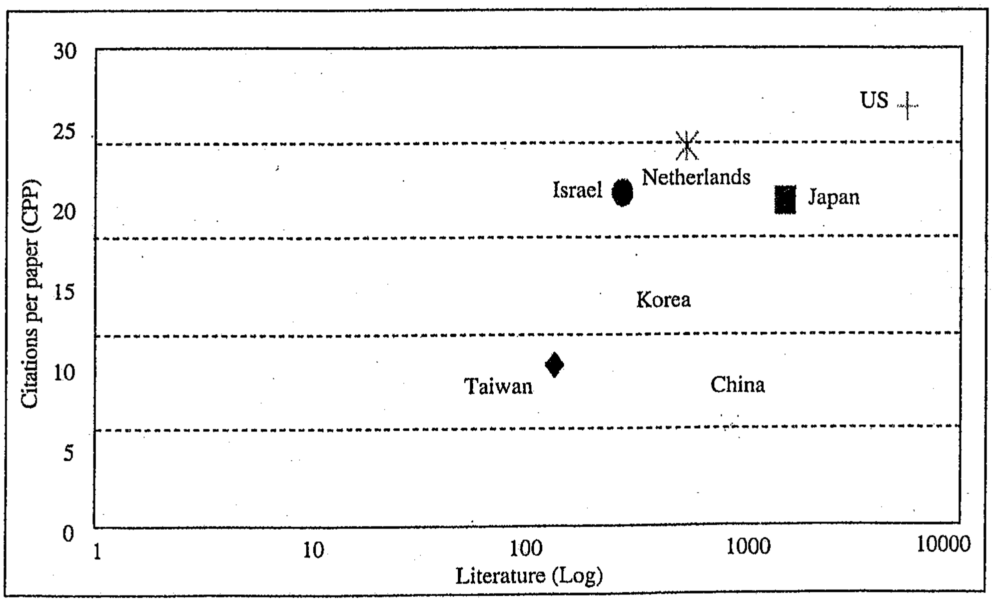

Figure 4. Academic Development Potentials on GM Livestock and Poultry in Various Countries

Sources: ISI Web of Knowledge; Council of Agriculture, 2006.

time and 40% of research budgets. This proves that patent information is the most important reference tool for technology researchers (Lee, 2003). Patents are considered as the most important tool to enhance competitiveness in the era of knowledge-based economy and technologies. Facing global keen competitions, intellectual property rights can create edges and bar competitors. Patents therefore are crucial to the R&D and market management of high-tech businesses. For countries to increase industrial competitiveness, "patents" play pivotal roles (Lin & Liu, 2004).

Patent analysis becomes an important tool to discover the change of technologies because all countries pay more attention to intellectual property rights, businesses are in a dire need to protect their research results, and patents are considered concrete and open carriers of innovative technologies. With Delphion Research Intellectual Property Network developed by Thomson, an US enterprise, the study examines and analyzes patents and statistics to uncover the development trend of mainstream agricultural biotechnology, and the expertise and focus of certain countries in these fields. The examination and analysis can serve as a reference for Taiwan's agricultural biotechnological policy making to lower the uncertainty for agro-biotechnological investments and to increase investment returns. In the end, this will assist Taiwan to find the appropriate direction for its agro-biotechnological development and relevant industries.

To begin with, the study examines patents granted before December 31, 2005, and analyzes the number of patents accordingly after the screening process. Grand total is used in Figure 5 to prevent minor changes of the number of patents in a year from blurring the trend. The first agro-biotechnological

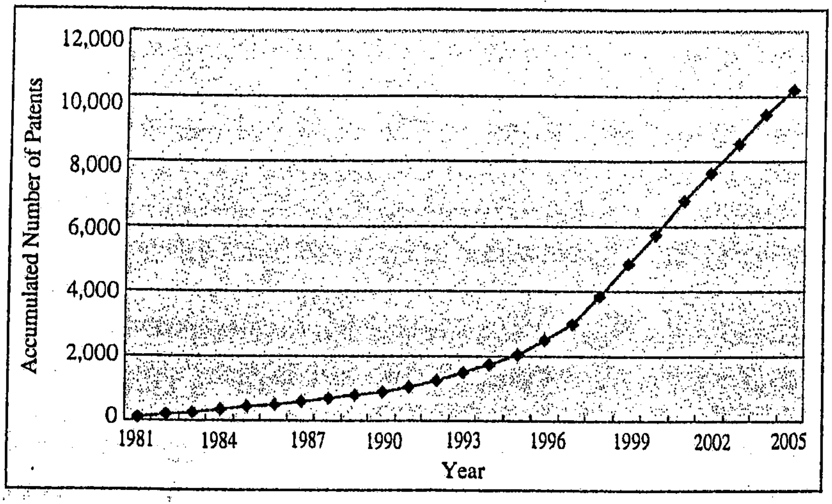

Figure 5. Global Development Trends in Agricultural Biotechnological Patents from 1981 to 2005

Sources: Delphion Database; Council of Agriculture, 2006.

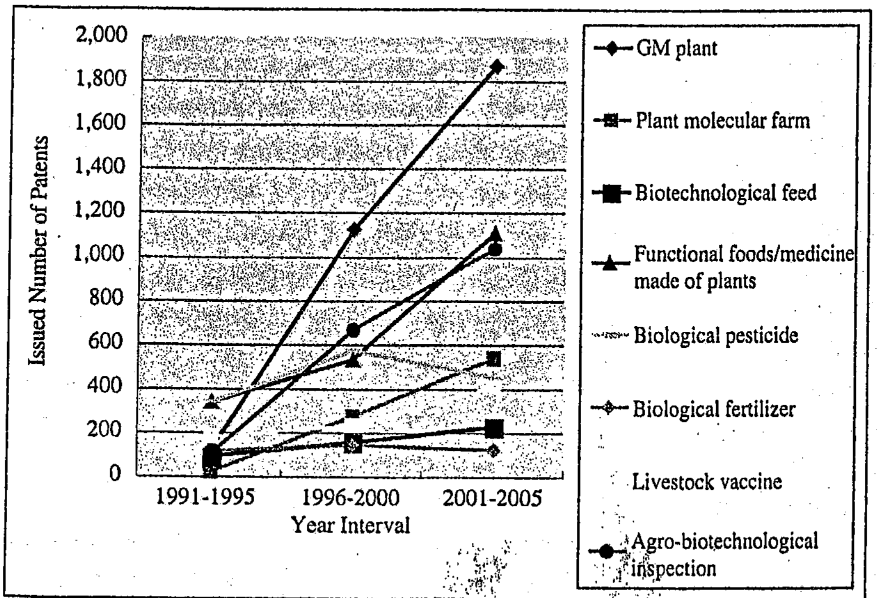

Figure 6. Analysis of the Global Trend of Patents in Agricultural Biotechnological Development

Sources: Delphion Database; Council of Agriculture, 2006.

patents emerged in 1963, and growth has been observed. Significant growth was found in the 1990s, and there have been nearly 1,000 agro-biotechnological patents every year since 1998. To examine the data from time frames, the growth rate from 1981 to 1991 was 5.4%, and 18.4% from 1991 to 2001. Patent development is growing. To examine the development in different countries with the sum of patents, (the number of agricultural patents in the US, Japan, Korea, India, Brazil, Israel and China) Taiwan has 657 patents from 1996 to 2005, and the number is larger than the numbers in Korea, Brazil, China, Israel and India, showing that Taiwan has promising potential in its agricultural research and development. To examine the performance of agro-biotechnological outputs, with the sum of agro-biotechnological patents, Taiwan is only better than Brazil and China. The comparisons show that Taiwan has superior agricultural patents but its agricultural biotechnologies are not as strong as agricultural patents, implying that Taiwan needs to give more efforts in the development of agricultural biotechnologies.

The patent analysis of sub-fields of agricultural biotechnologies covers GM plants, plant molecular farms, biotechnological feeds, animal molecular farms, livestock and aquatic vaccines, herbal health food/medicines, biological pesticides, biological feeds, and agro-biotechnological inspections. Different searching strategies are designed for each field. The strategies involve cross references of IPC codes, USPC and keywords. The development trends of sub-fields of agriculture can be observed from Figure 6. It is shown that GM plant is the fastest growing field with the most patents. There were 123 patens from 1991 to 1995, but the number leaped to over 1999 from 2001 to 2005. Patents regarding molecular farms numbered 24 from 1991 to 1995, with steady growth the number increased to 537 from 2001 to 2005. The number of patents for biotechnological feeds is not large. There were 228 patents from 2001 to 2005. Growth is observed at a lower rate. Herbal health food/medicines experienced growth from 1991 to 2005 as well, but the growth is more significant from 1996 to 2000 and from 2001 to 2005, showing that herbal food and medicines receive more attention in recent years. In regards of biological pesticides, there were 342 patents from 1991 to 1995, and 577 from 1996 to 2000. The number dropped to 452 from 2001 to 2005. Patents about biological fertilizers reached 118 from 1991 to 1995, 149 from 1996 to 2000, and 122 from 2001 to 2005. The trend of livestock vaccine is similar with the development of biotechnological feeds, only with larger numbers. The development of agro-biotechnological inspection is rapidly growing as well. There were 104 from 1991 to 1995, and 1036 from 2001 to 2005. Generally, GM plants, molecular farms, herbal health food and pharmaceuticals and agro-biotechnological inspections are sub-fields that experienced significant growth. Livestock vaccine and biotechnological feeds experienced minor growth in comparison.

Table 2 is the comparison of technology development potentials of Netherlands, Japan, Israel, India, Korea, China, and Taiwan. (The US is not included in the figure because its number of patents is too large). In the field of GM plants, the number of GM plant patents in Japan increased by year, from 7 patents, 1991 to 1995 to 72 patents, 2001 to 2005, 2 patents were cited. Japan had the most significant growth of all countries. Netherlands had 3 patents from 1991 to 1995, 26 from 1996 to 2000, and was cited once. The number dropped to 24 from 2001 to 2005. China had 1 patent from 1996 to 2000, 10 from 2001 to 2005. Taiwan had 1 patent from 1996 to 2000 and 11 from 2001 to 2005. In the field of molecular farms, Japan had significant progress, with 11 patents from 1996 to 2000, and 22 from 2001 to 2005. The number doubled. Netherlands comes close as the second place but with less significant progress. Taiwan had 1 patent from 1996 to 2000 and 5 patents from 2001 to 2005. The patents in these countries have not been cited yet, and this may be resulted from the limited scale of patents. Netherlands and Japan are main contributors to patents of biotechnological feeds, while Netherlands entered the field earlier than Japan. Netherlands reached its peak from 1996 to 2000, and the number of patents dropped to 10 from 2001 to 2005. Japan on the other hand had 16 patents from 1991 to 1995 and 18 patents from 1996 to 2000. The number climbed to 25 from 2001 to 200. To examine the quality of patents, it is found that Japanese patents are more pleasing with higher citation frequencies than Netherlands'. Take the interval between 1996 and 2000 for example, Japan had 18 patents but the patents were cited twice. Netherlands had 23 patents, but only 2 were cited. This shows that Japan continues its dedication to the development of biological feeds and has satisfactory results. Taiwan, however, is not as committed in the development of biotechnological feeds.

Progress has been found in the development of herbal health food or pharmaceuticals. Of these countries, Japan has the most impressive performance while India is very potential as well. From 1991 to 1995 Japan had nearly 60 patents and was dedicated relevant researches. From 2001 to 2005, Japan had as many as 95 patents. India started its development later with only 2 patents from 1991 to 1995, but the number leaped to 78 from 2001 to 2005. Netherlands, Israel, China and Taiwan have similar developments in this regard. From 1991 to 1995 the four countries had about 5 patents, and increased to 20-25 from 2001 to 2005. Judging from the quality of patents, Japan, India and Taiwan are experiencing satisfactory developments. From 2001 to 2005, Taiwan had only 24 patents, but three of them have been cited. Although Japan had 95 patents, only 4 have been cited. The comparison shows that Taiwan has quality patents.

In the area of biological pesticides, Taiwan and other countries have made some developments. Japan, Israel and India have more patents than Taiwan. Japan, with the most patents, had 28 patens from 1991 to 1995, and 30 patents for every five year after 1995. Israel has 6 to 8 patens for every five year from 1991. India had only six patents from 1996 to 2000 but the number increased to 17 from 2001 to 2005. Taiwan started its development from 1991 to 1995 but there was only 1 patent in the period. Taiwan had 6-7 patents for every five year from 1996. In comparison, Netherlands is weaker in the development of biological pesticides and

Table 2. Comparison of the Number of Agricultural Biotechnological Patents in Different Countries from 1976 to 2005

	Taiwan	Netherlands	Japan	Israel	India	Korea	China
GM plants	+	+++	++++	+		+	
Molecular farms		+	+++				
Biotechnological feeds		+++	+++				
Health food	+++	++	++++	+++	+++	+++	+++
Biological pesticides	+	+	++++	++	++		
Biological fertilizer			+++				
Livestock and poultry vaccine		++++	+++	+			
Agricultural biotechnological inspections		+	+++	++			

Keys: ++++:over 100 patents; +++: 30 to 100 patents, ++: 20-30 patens, +: 10 to 20 patents
Sources: Delphion Database; Council of Agriculture, 2006.

its number of patent is even smaller than Taiwan's. China started its development from 2001 to 2005. In terms of the quality of patents, Japan and India's progress are more eye-catching. The 28 patents Japan applied from 1991 to 1995 have been repeatedly cited for six times. The six patens India applied from 1996 to 2000 have been cited twice. Besides Japan, other countries are not so focused on the study of biological fertilizer. Taking the US for example, the US had 71 patents from 1991 to 1995, 79 from 1996 to 2000, and 57 from 2001 to 2005. The patents have been cited for 15, 8, and 9 times respectively. Japan has similar trend with fewer patents, at 16 to 23. Taiwan has one from 2001 to 2005.

Netherlands, Japan and Israel are advanced countries for patented livestock vaccine. Between 1996 and 2000, Netherlands has obtained 67 patents on livestock vaccines, but from 2001 to 2005, the number of patent dropped to 37. Japan on the other hand has steady development, and maintains at 10 patents every year. Israel witnessed significant progress from 2001 to 2005, with 11 patents. India and Taiwan have similar developments at a smaller number. In terms of the quality of the patents, only Netherlands is more successful. From 1996 to 2000, 16 of the 67 patents are cited. In the area of agricultural and biotechnological examinations, Japan, Israel and Netherlands are dominant countries, but each country has fewer than 20 patents. Japan and Israel developed significantly from 1996 to 2000 while Netherlands started its development later from 2001 to 2005. In terms of the quality of these patents, Israel had 20 patents from 1996 to 2000 and 8 of the 20 are cited, showing that Israel has a smaller number of patents but high qualities.

Different countries have different focuses on the development of agricultural biotechnology. Compared to Western countries, Asian countries are stronger in the agricultural biotechnological patents of health food and medication. The number of agricultural biotechnological patents in Taiwan is increasing, and rapid increase is observed too in China and India. According to patent analyses, Taiwan's agriculture and agricultural biotechnology have different development directions. Taiwan's edge is its agricultural patents, and its agricultural biotechnological industries need to be based on its niche agricultural foundations to achieve success. Information about patents can be processed systematically with figures and diagrams. With professional interpretations, competitive intelligence (CI) can be produced to avoid patent infringement and to seek patent niche for managers.

4. Conclusions

With the advent of knowledge-based economy, agricultural technologies and management patterns are transforming. The rapid development of innovative science and technologies allow advanced nations to employ new methods to reflect future trends of technological developments to win pre-emption. Taiwan is falling behind in the application of innovative concepts on the design of agricultural technology policies. It is imperative for Taiwan to catch up with the advanced nations. On the other hand, the borders between the scientific fields are blurring, and the traditional categorization of scientific fields is not as useful. Facing the dynamic technological developments, Taiwan needs to prioritize scientific and technological fields and choose important fields to invest its resources in. Taiwan can learn from the successful experiences of advanced nations to conduct Technology Foresight to predict the agricultural scenario in Taiwan after 20 years. According to the need of the society, priorities can be identified, and agricultural technological policies can be formulated accordingly (Chen & Ien, 2002).

Agricultural technology used to be the public property, and the Council of Agriculture is suggested to promote the idea of intellectual property protection and technology transfer licensing, and to consider including researches and technologies in the merchandising mechanism of agricultural biotechnology R&D results. Since agricultural biotechnology industry involved intellectual property, it is necessary to evaluate the patent development in Taiwan and in other countries before starting R&D to prevent infringe of protected rights and any loss (Delmer, 2003). Agricultural biotechnologies cover a large number of fields and the agreements and common consensuses of government departments are imperative when revising regulations. To formulate or revise regulations on new species, biological pesticides, biological fertilizer, and animal pharmaceuticals, a comprehensive standard shall be raised to strengthen the effectiveness of the regulations and to meet the request of relevant industries.

On industry management, Taiwan needs to expand its target market for agricultural products from domestic market to Asian countries such as Southeast Asia and China. The agricultural businesses in Taiwan are managed inside-out, searching for appropriate products and markets based on its technologies. In the latest trend in the international community in the 21st century, agricultural biotechnology industry must learn from the customer-oriented, outside-in, service industry to enter the global markets. The study indicates that the safety is an idea that all countries uphold, and Taiwan can develop some fast, accurate and inexpensive inspection technologies, and develop biotechnology service industries with the joint efforts of credible authentication mechanism to accelerate the development of safe agriculture. In addition to the development of biotechnology, the integration of technologies in various fields is important to agricultural transition. The application of information technologies on analyzing R&D results and searching for business opportunities in the market may be more important than developing biotechnologies. Innovative technologies can be used to improve the process and production methods of agricultural products to bring other benefits. In closing, the integration of resources is an important key to successful transition of Taiwan's agriculture as well. It is expected for the Taiwan government to make the most effective allocation with limited resources for specific purposes.

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