Análisis prospectivo de los bioinsumos agrícolas en Colombia: una consulta a expertos

Prospective analysis of agricultural bioinoculants in Colombia: an expert consultation

*Diana Corina Zambrano *, Ruth Rebeca Bonilla **, Laura Avellaneda ***, Gregorio Zambrano *****

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Resumen

La productividad y sostenibilidad de la agricultura en Colombia pueden ser influidas positivamente a través del aprovechamiento de la biodiversidad para la producción de bioinsumos. Fueron analizados a mediano y largo plazo, los posibles escenarios futuros generados por las regulaciones que intervienen en el avance tecnológico de los bioinsumos, a través de la aplicación de una encuesta Delphi, con la participación de 23 expertos, teniendo en cuenta las tres dimensiones del desarrollo sostenible. Sobre la base de este estudio, se encontró que el 65% de los expertos consideran que el impacto de la innovación o el desarrollo tecnológico del uso de bioinsumos en la producción agrícola, tiene un alto impacto económico con un nivel de concordancia significativo (≥0.05). Adicionalmente, el 65% seleccionó como el mejor escenario, en el cual se den condiciones que promuevan mayor desarrollo, acceso y aplicación de los bioinsumos, de tal forma que se incremente el ritmo de incorporación de la tecnología por parte de los productores. En conclusión, más allá del nivel de desarrollo tecnológico, es necesario revisar los procesos legislativos para la comercialización de los bioinsumos, fue evidente que el éxito futuro de la industria de la producción de productos biológicos dependerá de la gestión de empresas innovadoras, la eficiente comercialización de los mismos, la educación y transferencia a los productores y el progreso de la investigación.

Palabras clave: método Delphi, bacterias promotoras de crecimiento vegetal (PGPR), agricultura ecológica, desarrollo sostenible.

Abstract

Productivity and sustainability of agriculture in Colombia can be influenced positively through the use of biodiversity for the production of bioinoculants. They were analyzed in the medium and long term, the future scenarios generated by the regulations involved in the technological advancement of bio-products through the application of a Delphi survey, with the participation of 23 experts in bio-products, taking into account the three dimensions sustainable development. Based on this study, it was found that 65% of the experts believe that the impact of innovation and technological development of the use of bio- products in agricultural production, has a high economic impact with a significant level of agreement (≥0.05). Additionally, 65% selected as the best scenario, in which conditions that promote greater development, access and application of bio-products, so that the rate of adoption of technology is increased by the producers to make. In conclusion, beyond the level of technological development is necessary to revise the legislative process for the marketing of bio-products, it was clear that the future success of the industry in the production of biological products depend on the management of innovative enterprises, efficient marketing thereof, education and transfer to producers and the progress of the investigation.

Key words: Delphi method, plant growth promoting bacteria (PGPB), organic farming, sustainable development.

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* Microbióloga Industrial, M.Sc., cPh.D., Doctorado en Ciencias Naturales para el Desarrollo -Instituto Tecnológico de Costa Rica. corina_zambrano@yahoo.es.

** Licenciada en Biología y Química, M.Sc., Ph.D., Directora Laboratorio de Suelos, Corporación Colombiana de Investigación Agropecuaria – CORPOICA. rbonilla@corpoica.org.co.

*** M.Sc en Ciencias Biológicas - Área Microbiología, Investigadora Master, Corporación Colombiana de Investigación Agropecuaria – CORPOICA. lavellaneda@corpoica.org.co.

**** Economista, estudiante Maestría en Economía. Profesional de Apoyo Planeación estratégica, Corporación Colombiana de Investigación Agropecuaria – CORPOICA. gzambrano@corpoica.org.co

Introduction

Biodiversity refers to the variety of life forms, which consist of different animals, plants and microorganisms; the genes they contain; and the ecosystems they comprise (Department of the Environment, Sport and Territories, 1999). According to Rangel (2005), Colombia is one of the two countries with the greatest expression of biodiversity at all levels, expressed as alpha (species), beta (plant communities or types of vegetation) or gamma (ecosystems) diversity. Biodiversity in Colombia is greater than in other tropical countries such as Brazil and Costa Rica (Bueno et al. 2011).

Agricultural biodiversity is an essential sub-group of biodiversity (FAO, 2004a), which is comprised of the variety and variability of animals, plants and microorganisms that are important for food and agriculture resulting from the interaction between the environment, genetic resources and the management systems, including the practices used by the producers (Ocampo, 2012). It has been noted that the great diversity of crops, production systems, microorganisms, animal species and breeds is a measure of the importance of biodiversity for agriculture (Kumar et al. 2013). Therefore, Lobo (2008) states that agricultural biodiversity is a very important strategic asset for the development of megadiverse countries.

The diversity of microorganisms is less known than that of plant and zoological genetic resources. However, it is a genetic resource of great importance in agriculture (Lobo, 2008). Agricultural productivity and sustainability benefit from microorganisms in different ways. For example, biofertilizers are microbial inoculants that can facilitate the growth of plants and increase their productivity. These benefits have been widely reported with activities such as fixation of atmospheric nitrogen in gramineae and cereals (Collino et al. 2015), as well as improvement in nutrient absorption (Bashan et al. 2014). There are positive responses to the inoculation of plant growth-promoting rhizobacteria (PGPR) in different crops such as oil palm (Adiprasetyo et al. 2014), coconut and plantain (Mia et al. 2007; Mía et al. 2010). Recently, Fahad et al. (2015a) stated that PGPR are capable of synthesizing plant hormones that stimulate cell division and growth, helping plants to tolerate environmental stress conditions. This effect has been reported in sunflowers (Wagas et al. 2015), ornamental plants (Stetsenko et al. 2015) and corn (Fahad et al. 2015b), among others.

A wide range of microorganisms that carry out biological control of insects, pests and weeds has been reported, as well as other microorganisms associated with the plants, contributing to their growth or defense mechanisms against attacks from insects and diseases (Tilman et al. 2002). There is widespread diffusion and use of Bacillus thuringiensis, which has been applied for more than 50 years for the control of pests such as Lepidoptera (Ruan et al. 2015). According to Lobo (2008), it is known that more than 25% of agricultural losses is caused by pests, and that more than 90% is controlled by natural enemies that live in surrounding areas of the crops. Consequently, it is estimated that the replacement of pesticides by natural controllers represents USD 54 trillion per year in the United States.

Another one of the uses of biological products is based on the interaction of plants with arbuscular mycorrhiza fungi (AMF), which are a group of edaphic microorganisms that establish symbiosis with the plants, having a positive influence on their growth and development (Mujica et al. 2014). These microorganisms form an extraradical mycelium that permits a reciprocal transfer of carbon from the host and nutrients taken from the soil (Leake et al. 2004) and between the plants united by the mycelial network (Camargo-Ricalde et al. 2012). According to Mujica et al. (2014), the use of these microorganisms is feasible for any agricultural production system because of the functions that are carried out once they are associated with the plants. For example, the increase in the absorption of nutrients and water through an increase in the volume of the soil used, greater resistance to toxins, increase in translocation and solubilization of essential elements, protection against radical pathogens, increase in tolerance of adverse abiotic conditions (Smith and Read, 2008), and the stabilization of aggregates in the soil resulting from the secretion of a recalcitrant glycoprotein known as glomalin (Helgason et al. 2010).

In Colombia, the percentage of production costs for fertilization and control of pests, diseases and weeds differs depending on factors such as the product, geographical area and scale of exploitation (Perfetti et al. 2012). Therefore, in 2011, the percentage of fertilization production costs was 4.5% for carnations and 42% for palm crops in the department of Meta. Weed control amounted to 2.9% of the costs of a coffee crop in the southern area and a maximum of 12.4% for palm crops in Meta. Pest control amounted to 0.9% of the rice production costs in the department of Tolima and 14.7% for palm crops in the department of Magdalena. Disease control amounted to 1.6% of potato crop costs in the department of Nariño and 22.8% for palm crops in the department of Santander (Sánchez et al. 2013).

Likewise, inadequate soil management from the use of chemically synthesized products has generated a global problem, causing the depletion of nutrients in the soil and acidification of the soil. These adverse effects have led to reductions in crop productivity (Hungría and Vargas, 2000), added to the fact that efficiency in the use of chemical products is very low and most of the product applied is wasted, because it is not absorbed by the plants (Robertson and Vitousek, 2009). Therefore, there is an immediate need to reduce the use of chemically synthesized products by complementing and optimizing fertilization with biological products. The great diversity of beneficial microorganisms offers numerous opportunities. As recommended by Marimuthu et al. (2013), use of bacteria is suitable and can be directly applied to the seeds or soil.

According to Lobo (2008), the sustainable use of diversity must be combined with biotechnology processes to make it more efficient. One of the possibilities is to explore native microbiological reserves, because they offer the potential to develop alternative technologies for small-scale farmers, who require affordable technology that does not pose an environmental and/or health risk. The production of biological products and plant extracts in Colombia has developed a market niche in recent years in the national agricultural sector. In 2008, there were 71 companies registered and endorsed by the Colombian Agricultural Institute (ICA, for the Spanish original) (Zambrano and Riaño, 2008). According to said authors, the market of biological products in Colombia is new, and it has gradually gained greater receptiveness from people interested in their production, as well as those who require them to use on their crops.

In 2010, Chaparro et al. analyzed the current outlook for access to genetic and biological resources in the projects developed by groups registered with Colciencias. They found that almost all of them developed products that mostly constitute basic research (99%), and that are unlikely to have commercial use (1%). As indicated by Cabrera and López (2008), the lack of indicators to separate basic research from research with possibilities for commercial use is a persistent and frequent problem in the different systems of access to genetic resources. Consequently, the difficulties in the operation of the access system have resulted in a substantial part of research on the country's biological and genetic diversity being developed outside of the legal framework (Nemogá, 2010).

According to Duarte and Velho (2008), it is important to take into account that Colombia has one of the most complex legal frameworks in the world. This has hindered the possibility of progress in scientific work in partnerships between universities or research centers, as well as in partnerships between science and business. Furthermore, Duarte and Velho (2009) stated that as a biodiverse country, Colombia has been gradually increasing the endogenous capacity of its science and technology research groups to carry out bioprospecting processes. However, it has not been possible to fully express these efforts, because the legal framework that regulates the exploration and exploitation of Colombian biodiversity very restrictively limits the progress of partnerships and coordinations.

The use of scenarios to study the future allows proximity to situations that could lead to important changes and the creation of explicit relationships between events that are not easily related (Bañuls and Turoff, 2011). This is how the long or medium-term impact of new or changing policies or regulations can be prospectively analyzed using events of a binary nature. Therefore, the central objective of this research was to develop a prospective analysis of agricultural biological products in Colombia through a method of consulting experts, taking into account the three dimensions of sustainable development for the construction of the tool for information collection.

Materials and Methods

The prospective study was conducted using the Delphi method (Listone and Turoff, 2002) in order to develop medium and long-term prognoses through the systematic use of the intuitive opinion of a group of experts to obtain a consensus of informed opinions.

Selection of Experts

To select the experts, a search was carried out on the Plataforma ScienTI database of Colciencias. This database had a total of 4,189 people recognized as peers by Colciencias. The first filter was carried out by area of knowledge "Agrarian Sciences", area "Agronomy", finding a total of 180 people registered. Subsequently, a second filter was carried out by area of knowledge "Biological Science", area "Microbiology", finding a total of 310 people. Their resumes were reviewed, confirming that they had developed work on the topic of biological products, and obtaining a database of 90 potential experts.

The group of 90 experts was sent the self-assessment of their competence using the SurveyMonkey® software (http://www.surveymonkey.com). The competence of the potential experts was determined through the coefficient of competence, which had to be above 0.80 to be taken into account as an expert. Competence was determined by the coefficient $K = \frac{1}{2}(Kc + Ka)$, where Kc represents a measurement of the level of knowledge about the researched topic and Ka represents a measurement of the sources of argument (Cruz and Martínez, 2012). Therefore, if $0.8 < K < 1.0$, the coefficient of competence is high, and if $0.7 < K < 0.8$, the coefficient of competence is medium.

Kc is calculated from the self-assessment by the expert candidate, determining the level of knowledge he/she considers he/she allegedly has on a scale of 0 to 10. The value selected by the candidate was divided by ten to normalize the data. The average response was multiplied by 0.1. Therefore, "0" indicates that the expert has no knowledge, while "10" means that the expert has full knowledge of the respective issue.

The self-assessment of the experts' knowledge of the Kc variable was carried out by rating the following opinions: a) Improvement of production, quality control and agro-industrial processes, new biological products, and biotechnology for the environment; b)

Public perception of biotechnology, biosafety, and legal, social and economic aspects of biotechnology; c) Biotechnology innovation and development; and d) Public policy on biological products.

The Ka variable was calculated from the self-assessments by the potential experts according to six possible sources of argument on a Likert scale, displayed in Table 1 (Cruz and Martínez, 2012). Each one had to select according to his/her opinion if he/she had high, medium or low competence, and a value was assigned to each opinion. The values were not visible on the tool for information collection at the time of response.

Preparation and Launch of the Surveys

The questionnaire to consult the experts was comprised of 30 questions grouped into three categories. After the questions were designed by the authors, the form was checked by three external specialists before being sent to the experts. It was implemented taking into account the three dimensions of sustainable development with environmental, economic and social considerations (Hodson and Díaz, 2013). These opinions are summarized in Table 2.

A tool was designed based on the previous dimensions with a total of 26 questions to be assessed as low, medium or high.

In the construction of scenarios on the scale, the option of selecting one of the following two scenarios was proposed: 1) The trend and current pace of incorporation of biological products into agricultural production remains up to date; and 2) There are conditions that facilitate greater development, access and application of biological products so that the pace of incorporation into the agricultural production systems is increased (1 = Very unlikely, 2 = Unlikely, 3 = Neither likely nor unlikely, 4 = Likely, and 5 = Very likely, according to the experts' experience and knowledge).

The experts were interviewed in isolation and their opinions were collected electronically and anonymously using the SurveyMonkey® software in an attempt to eliminate the leader effect.

Practical Development and Analysis of Results

The information was analyzed using the SPSS 21.0 software for the calculation of Kendall's coefficient of concordance (Kendall's W), which represents the level of consensus between the participants (Schmidt, 1997; Schmidt *et al.* 2001). This coefficient varies between 0 and 1, indicating the degree of consensus reached by the panel (strong consensus for $W > 0.7$, moderate consensus for $W = 0.5$, and weak consensus for $W < 0.3$) (Schmidt *et al.* 2001).

Schmidt (1997) proposed two statistical criteria to make decisions about how to suspend or continue the Delphi rounds. The first criterion is a strong consensus between the members of the panel, which is determined based on Kendall's coefficient of concordance. If there is concordance, the survey process must be stopped (Habibi *et al.* 2014). Therefore, only one round was carried out in this study.

Results and Discussion

Selection of Experts

The expert self-assessment was sent to 90 people and 25 people responded, out of which, 23 were classified as experts, having K coefficients greater than 0.7. Table 3 presents the competence calculation of each participant, where it could be identified that 56% of the experts had high competence, 36% of the experts had medium competence, and 8% had low competence. The answers of the experts with a low level of competence were not taken into account in the analysis.

Preparation and Launch of the Surveys

The survey was fully answered by 23 experts who were in a medium to high range in the K value. The cal-

Table 1. Likert scale for the calculation of Ka in the tool.

Sources of Argument	Degrees of Influence of the Sources According to Experts		
	High	Medium	Low
Research carried out by you	0.30	0.20	0.10
Your acquired work experience	0.50	0.40	0.20
Work of national authors who have worked on the topic you specialize on	0.05	0.05	0.05
Work of foreign authors	0.05	0.05	0.05
Your knowledge of the status of the problem through exchanges of knowledge	0.05	0.05	0.05
Participation in groups that design programs, materials and initiatives	0.05	0.05	0.05

Table 2. Components and variables of the Delphi tool.

Component	Dimension	Category
Importance for society, the economy and the environment	Economic	Decrease in agricultural production costs
	Economic and social	Competitiveness of small and medium-scale producers
	Economic	Threats and opportunities for Colombia
	Economic	Strategies for use
	Economic, social and environmental	Potential for application, industrial development, quality of life, environment and employment
Multidisciplinarity for the development of biological products	Social	Current capacity of human resources
	Economic and social	Capacity of the country in science, technology and innovation Production and sale
Perception of the Potential Development of Biological Products through Intellectual Property	Social	International consensus in terms of regulatory requirements
	Economic and environmental	Promotion of international trade, new developments, and increase in production capacity.
	Economic	Intellectual property for the use of biological products and its impact

culation of Kendall's coefficient revealed a moderate consensus (W = 0.45), which is understandable when observing that the number of experts is almost half the number of items. However, the result was significant ($X^2 = 65.22$; $p \geq 0.05$).

Importance for Society, the Economy and the Environment

The experts considered that biological products are important to reduce agricultural production costs, as mentioned by Herridge *et al.* (2008), who estimated that in Vietnam, the annual cost of nitrogen fertilization would be reduced from USD 30 million to USD 1 million per year if the chemical fertilizers were replaced with inoculants.

According to Shankar *et al.* (2011), the low efficiency of agricultural production is closely related to poor energy conversion that, in turn, is influenced by the physiological factors of the crop, the environment and other biological factors, including the microorganisms in the soil. The soil and rhizosphere microflora may accelerate the growth of plants and improve their resistance to pathogens and insects through the production of bioactive metabolites. The experts consider it to be very likely that biological products improve the competitiveness of small and medium-scale farmers.

Table 3. Results of the participants' level of competence.

Survey Participant	Kc	Ka	K	Level of Competence
1	0.8	0.9	0.9	High
2	0.5	0.5	0.5	Low
3	0.8	0.8	0.8	High
4	0.7	0.9	0.8	High
5	0.4	1.0	0.7	Medium
6	0.5	1.0	0.7	Medium
7	0.7	0.9	0.8	High
8	0.6	0.8	0.7	Medium
9	0.8	0.9	0.8	High
10	0.7	1.0	0.8	High
11	0.6	1.0	0.8	High
12	0.6	0.9	0.8	High
13	0.6	0.9	0.7	Medium
14	0.5	0.9	0.7	Medium
15	0.6	0.8	0.7	Medium
16	0.5	1.0	0.7	Medium
17	0.9	1.0	0.9	High
18	0.7	0.8	0.7	Medium
19	0.7	1.0	0.9	High

20	0.4	0.8	0.6	Low
21	0.6	0.8	0.7	Medium
22	0.9	1.0	1.0	High
23	0.7	0.9	0.8	High
24	0.6	1.0	0.8	High
25	0.8	1.0	0.9	High

The experts' opinions with a significant level of concordance (≥ 0.05) in the rated opinions about the impact of innovation or development of technology from the use of biological products in agricultural production show that 65% consider that it has a high potential, 31% consider it has a medium potential, and 4% that it has a low potential to have an economic impact. The high potential to have an impact on agricultural production was stated by Herrmann and Lesueur (2013), who highlight that particularly biofertilizers could have economic importance because they partially replace chemically synthesized fertilizers, which are increasingly more expensive. Furthermore, other authors such as Shankar *et al*. (2011) state that there is a growing worldwide consensus about the feasibility of obtaining the maximum agricultural return with the highest net profits without the use of artificial fertilizers, herbicides, insecticides and pesticides.

Montoya (2010) stated that biotechnology and life sciences are the most promising for addressing complex problems because of their capacity to develop products for several sectors of the economy in a sustainable and ecologically innovative way. Out of the experts, 52% consider that the potential for the industrial development of biological products is high, 39% consider that it is medium, and 9% consider that it is low. The perception could be explained by the difficulties that the small and medium biotechnology companies have to overcome by having a high capital coefficient and long times for return, based on the report by Montoya (2010).

Regarding the opinion that biological products could become a useful tool to increase the competitiveness of the agro-industry, 78% consider that the probability is high, 18% consider that it is medium and 4% consider that it is low. This has been widely supported by authors who state that PGPR in legume crops that fix nitrogen, such as peanuts, beans and soy beans may generate a 20–40% saving in chemical nitrogen, achieving the fixation of 50-300 kg of nitrogen in the soil and reducing the amount of urea per hectare from 55 to 220 kg (Gomare *et al*. 2013). However, despite the reported benefits, recent studies show that there is very low inventive activity and scarce industrial impact on the developments related to important crops for Colombia, such as sugarcane and coffee (Silva *et al*. 2014).

Out of the experts, 70% consider that the impact on the farmers' quality of life is high, 22% that it is medium, and 8% that it is low. It was observed that this improvement could possibly be seen as the decrease in production costs that they generate, at the same time, the increase in the revenue received by the farmer. This coincides with that reported by Khalid (2012), who stated that the use of biological products is more cost-effective than the use of chemically synthesized products. Therefore, the farmers' revenue increases and the products are safer for their health and the consumers' health (Khalid 2004).

The use of inorganic fertilizers, especially nitrogen and phosphorus, has been related to the eutrophication of bodies of water. Furthermore, there is strong evidence of the decrease in biodiversity in agricultural systems and in natural and semi-natural systems from the use of inorganic fertilizers, herbicides and pesticides in agriculture. There are several reports about the acquired resistance to chemical products used for the control of weeds and pests (Andrews *et al*. 2010). This context coincides with the experts' opinions, who expressed that the incorporation of biological products has a high (79%), medium (17%) or low (4%) impact on the environment, because of the large contribution of the soil microorganisms to the sustainability of the ecosystems, acting as the main leading agents of the nutrient cycle, regulation and dynamics of organic soil matter, immobilization of carbon in the soil, and the emission of greenhouse gases. Due to the effects of the microorganisms on soil, their physical structure and water systems can be modified, and the efficiency of nutrient absorption and the health of the plants can be improved (Shankar *et al*. 2011).

The experts consider that the use of biological products has a high (48%), medium (43%) or low (8%) impact. These results are consistent with those reported by Montoya (2010) in Biocultivos S.A.; a technology company formed by the Universidad Nacional de Colombia and the professional group of rice farmers, where 24 highly-qualified jobs and 14 technician jobs were created.

Multidisciplinarity for the Development of Biological Products

The experts were requested to assess whether the current capacity of Colombian professionals is sufficient for the commercial development of biological products. In response to this question, 35% answered that it is neither likely nor unlikely, 30% that it is likely, and 35% that it is very likely. Although there was no consensus between the participants, a trend was observed to consider that the capacity of the professionals is appropriate, because no expert marked that it was unlikely or very unlikely, which were the lowest ratings. This coincides with the results presented by Duarte and Velho (2009), who stated that the groups dedicated to bioprospecting have trained human resources to conduct research in basic areas of knowledge to carry out said process, and that this academic education process reflects the Colombian policy to train human resources to Ph. D. level in foreign as well as Colombian universities.

The experiences demonstrate that as the providing country of natural resources has greater installed technical and scientific capacity, it will take better advantage of the potential for developing biological products through bioprospecting (Laird and Wynberg, 2002; Quezada, 2004). Therefore, the experts' opinion on Colombia's position with respect to other countries was consulted, and they answered with a weak level according to W = 0.119 (not significant ≤ 0.05). The first criterion was the scientific and technological skills rated by 35% of the experts as high, by 52% as medium and by 13% as low. The second criterion was the innovation capacity assessed by 22% as high, by 56% as medium, and by 22% as low. The third criterion, which was the production capacity, evaluated by 13% as high, by 79% as medium, and by 17% as low. Finally, the commercial capacity was considered by 9% as high, by 61% as medium, and by 30% as low.

Generally, the experts considered that scientific and technological skills is at a medium level. However, the opinion of a low commercial capacity must be highlighted. This same opinion was stated in 2001 by Castellanos *et al*. They proposed the need for a new kind of expert that apart from specializing in science and technology must have a greater understanding of the world of business, so that the scientists become not only generators of knowledge, but also representatives with the capacity to reach the industry to support processes of selection, negotiation, installation or transfer of technology.

Perception of the Potential Development of Biological Products through Intellectual Property

Intellectual property of microorganisms, especially patentability, has awakened the interest not only of lawyers, but also of scientists. This is because microbiological inventions could be a procedure or product, referring to the products obtained with the intervention of microorganisms, which may include inanimate matter (metabolites) or animate matter (microorganisms) (Martínez, 2014). The experts were consulted about the probability of reaching a consensus in the countries about the regulatory requirements for the use of biological products in agricultural production. The result was that 48% of the experts considered that this consensus could occur in the 2020-2024 period.

According to the experts' opinions, protection through intellectual property mechanisms of biological products would allow production and development to increase a lot (52%), increase a little (26%) or to remain stable (22%). According to Gonzales *et al.* (2010), intellectual property rights are of great importance because as well as granting recognition to the creators, they grant economic retribution for the development of the products or processes.

The increase in the protection of intellectual property of biological products could occur in Colombia according to 43% of the experts if the intellectual property system is used, and according to 33% of the experts if the capacity for monitoring and negotiation of trade agreements increases. Fourteen percent does not know / does not answer, and finally 10% considers that Colombia must raise the awareness of new technology generators about the need to patent their innovations. According to Solleiro and Briceño (2003), protection of intellectual property should function as the engine of innovation and not as an obstacle to national development. However, the experts' perception is that it has limited the development of products.

Taking 2020 as a horizon, the experts were consulted as to whether intellectual property will have some kind of impact on the capacity of biotechnology innovation in Colombia, and the impact they consider to be most feasible. The experts expressed that the capacity of innovation in biological products will have an important increase (43%), will not have a significant impact on the capacity of innovation in biological products (26%), or will have an impact in terms of a decrease in the innovation capacity in biological products (13%). Four percent does not know / does not answer, and 13% responded other. The increase perceived in the experts' opinions may be attributed to well-conceived protection of intellectual property encouraging creativity, industrial development, investment and honest trade. However, some authors, such as Granados *et al.* (2009), indicate that more energetic intellectual property systems may decrease the general pace of innovation and increase the gap in knowledge between industrialized companies and developing countries.

Building Scenarios

Out of the experts, 35% (8/23) selected Scenario 1: The trend and current pace of how biological products are being incorporated in agricultural production remains up to date; and 65% (15/23) selected Scenario 2: There are conditions that facilitate greater development, access and application of biological products so that the pace of incorporation into the agricultural production systems increases.

In Scenario 1, the experts considered that in 2020, it will be possible to achieve 39 newly registered biological products with the Colombian Agricultural Institute (ICA) in the year. In response to this scenario, 38% answered neither likely nor unlikely, and 39% answered neither likely nor unlikely for Scenario 2. There is a similar result for both scenarios. The experts stated that if adequate policies are implemented for the creation of companies based on biotechnology and research, 39 biological products registered per year is a sensible number considering the dynamics of the agricultural sector and the research groups in Colombia.

The forecast up to 2029 was proposed, posing the possibility that 87 new biological products will be registered with the ICA in the year; and 50% of the experts selected neither likely nor unlikely for Scenario 1 and 35% selected likely for Scenario 2. These results show that changes need to be made in order to achieve a high number of registrations of new biological products. In other words, although Colombia has high biodiversity that has allowed it to isolate many organisms with potential, Colombian legislation tends to affect national initiatives. This can provide an incentive for illegal activity and underregistration, and even give an advantage to foreign companies. According to Nemogá (2010), in essence, the industrial potential of biodiversity cannot be exploited if the requirements of the institutional legal framework are not met. There can even be problems for publishing research results or when intellectual property rights are claimed for said results or innovations.

In response to the question of whether the Colombian agricultural sector is ready to support, absorb and take advantage of national and international scientific and technological advances in biological products, 50% of the experts that selected Scenario 1 answered that it is likely, and 52% of those that selected Scenario 2 answered that it is neither likely nor unlikely. The results indicate that it is easier for the agricultural sector to incorporate these technologies as part of their products, maintaining the current conditions, possibly because in Scenario 2, they would have to look for new markets due to the greater number of products. In either of the two cases, it is possible that the farmers who adopt this biotechnology, especially those who do so as soon as possible, would achieve benefits thanks to the reduction in costs and the increase in production. The other farmers could be at a competitive disadvantage depending on how the consumers' preferences and the regulatory systems evolve (FAO, 2004b).

The experts were asked that if they were responsible for making the decision of what strategy would they recommend to improve the current status of the country in the production of biological products ($W = 0.337$; $X^2 = 29.677$; ≤ 0.05), taking into account opinions such as collaboration with foreign companies. The results show that 35% of the experts consider that it is neither likely nor unlikely that collaboration with foreign companies could contribute to the development of the industry of biological products in Colombia. The tendency of this answer was predictable according to the reports by Martínez (2014), who stated that in developing countries and in the emerging economies, concerns have arisen that have led to them being against the appropriation and patenting of genes by corporations belonging to industrialized countries.

The opinion that hiring scientists and technical professionals in companies could contribute to the development of the industry of biological products was rated by 9% of the experts as very unlikely, by 4% as neither likely nor unlikely, by 17% as likely, and by 61% as very likely. The "very likely" result is confirmed by a report made by the European Commission that states that the creation of a researcher job position may generate up to 400 direct and indirect jobs in the long term. Despite this statement and the general consensus that the presence of researchers, specifically of those with a Ph. D., is key to encourage technological innovation in companies, a person with a Ph. D. is still an unknown figure for companies, and somebody who works in academia or public research (Community of Madrid, 2012).

The experts were consulted about the Triple Helix Concept (Etzkowitz and Leydesdorff, 1995), and whether they would recommend promotion of industrial coordination - research and technological development centers. In their opinion, 4% answered very unlikely, 0% unlikely, 4% neither likely nor unlikely, 13% likely, and 78% very likely. A high percentage of the experts answered very likely. However, aspects must be taken into account, such as the one stated by Gutiérrez (2004) in a model in which the agents unravel as moving spheres. Each one of which may perform roles of the other sphere, and cannot be static and remain pigeonholed, meaning that the flow of knowledge can be in an opposite direction to the traditional one. This means that knowledge may flow from private industry toward academia with an interactive effect in which technological innovation generates new questions of basic research.

Regarding whether they would suggest the government's support as a recommendation, 5% of the experts answered very unlikely, 0% unlikely, 5% neither likely nor unlikely, 27% likely, and 64% very likely. The last percentage shows the relevance and need for the Colombian Government's intervention. In 2011, the CONPES 3697 document was issued on policies for the commercial development of biotechnology through the sustainable use of biodiversity. This document proposes strengthening institutional capacity for the commercial development of biotechnology, promoting the commercial, sustainable and productive use of biological and genetic resources, as well as their derivatives; the creation of financial instruments to strengthen biotechnology-based companies; adjustment and review of the regulatory framework regarding access to genetic resources and their derivatives; and adjustment and updating of regulations about the production and sale of biotechnology medication and therapeutic plant products. The same CONPES document recognizes the difficulties that Colombia has experienced in the application of regulations regarding Andean Community: Decision 391 Common Regime on Access to Genetic Resources. This led to the reorganization and changing of the Ministry of the Environment and Sustainable Development with respect to this topic (Buitrago, 2012).

The probability that the experts recommend the disclosure of results was rated by 5% as very unlikely, by 5% as unlikely, by 0% as neither likely nor unlikely, by 36% as likely, and by 55% as very likely. The results show that the disclosure or transfer of results is of vital importance. In accordance with one of the key factors in the Mexican case according to Gutiérrez (2004), in the National System of Innovation, state governments, companies and academia are the essential elements, but they are not the only ones. The elements also include productive sectors in general, research centers, the financial system, technical universities, intermediary organizations that support business activities, service providers, product designers and consumers. The generation and transfer of scientific and technological knowledge are the essential subject of exchange, learning and interaction between the agents.

Conclusions

The technological prospect is a tool that may generate information of great support for public and private decision-makers, providing more detailed knowledge of the scenarios that may occur in the medium and long term in the development of the biotechnology industry of biological products, which allow the objectives to be coherently established and specified with lower levels of risk and uncertainty based on expert opinions.

The experts considered that the most likely and positive scenario for Colombia is having the conditions that facilitate greater development, access to and application of biological products, so that the rate of incorporation into the agricultural production systems increases. This indicates that the advances toward making the production of biological products in Colombia more business-oriented needs to go beyond technological development. It is necessary to revise the processes of promotion and support of Colombian biotechnology-based companies to allow sustainable development through the use of biodiversity. It is clear that the future success of the industry for the production of biological products will depend on the management of innovative companies that have the initiative of hiring researchers, the commercialization of products, and the education and transfer of technology to the producers or general public.

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