

## SUGARCANE RESEARCH AND TECHNOLOGY TRANSFER—STRATEGIES FOR THE NEXT DECADE

By

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### Abstract

AGRONOMIC challenges required for the decades ahead will focus on (1) research and technology transfer based on multidisciplinary approaches; (2) a transition from production-oriented models to consumer-driven systems; and (3) developments that promote sustainability and concerns for environmental issues. A multidisciplinary approach ensures that scientists, growers and factory engineers are aware of the contributions of other disciplines, rather than isolated, individual efforts. This requires not a narrowly focused ‘specialist’, but rather someone with a ‘special’ interest in various disciplines, whose wide vision could make integrated contributions to developing a true Renaissance in sugar industries. The transition to a consumer-driven model requires the identification of new priorities. Technologies for sugar production will remain a priority, but greater emphasis must be directed towards technologies for using sugarcane for energy production and for value-added products. In the case of energy production, the use of sugarcane has been possible because of the availability of proven technologies, interest from investors, government regulation and consumer demand. For value-added products, the challenge for scientists lies not just in concrete research outputs, as has been the case for sugar production. Their skills for knowledge management and the vision to transfer their achievements, open new markets and generate interest in funding new research must be strengthened. Sustainability and environmental protection will continue playing a role in future research, both in the field and in factory processes. Climate change is on the agenda of challenges that agronomists and their allied specialists must address in the design and management of future production systems. The prospective use of sugarcane as a source of bioenergy to reduce carbon dioxide emissions to the atmosphere offers an opportunity for scientists, investors and consumers to work together on sustainability and environmental protection. Research achievements and projections in the sugar industry worldwide, reported in the literature as well as by the Colombian sugar industry, are used to illustrate these strategies.

### Introduction

Technology development and the strategies for responding to the consumers of sugarcane by-products in the next decade will depend on the clear identification of their consumption requirements and trends.

History shows that countries or sectors that invest greater resources in Research and Development (R&D) achieve greater socioeconomic development while responding to their consumers (OECD, 2008).

The technological advances of the last century have generated benefits for mankind, which have also been incorporated in the technology developments of our sugar agro-industries and can be linked to what is called the innovation revolution (Hockfield, 2009).

This revolution is based on the convergence of several areas of knowledge that we should maintain and strengthen. The first of these, which took man to the moon, developed communications, improved agricultural production and sustained economic development during the decade of the 1950s that was based on the convergence of engineering and the physical sciences. The second took place in the 1980s with the information explosion generated by genomics and proteomics, which accelerated innovation in the life sciences. These two supported the third, which integrates life sciences, engineering and physical sciences. Accelerating these innovations will require changes in education, sources of financing and interaction among those who have the knowledge and between them and the users of the resulting technological products.

The technological challenges depend not only on the resources and infrastructure that are available. The new technological advances that will benefit our agro-industries will depend ever more on (a) R&D and innovation based on multidisciplinary teams, teamwork and alliances with other institutions; (b) the transition from production-oriented to consumer-defined work models; and (c) developments that promote sustainability and greater relevance of environmental issues.

### **Multidisciplinary, teamwork and alliances**

Research based on multidisciplinary, teamwork and alliances highlights the importance of agro industrial researchers and professionals being aware of the contribution of other disciplines and of the knowledge from their settings in a globalised world. This contrasts with continuing to face the challenges and solutions required in an isolated fashion.

In the former case, a broader vision of the environmental settings identifies the reality of technological requirements and the opportunities for new developments. There are three principal products that are derived from sugarcane that are in demand by consumers and on which today's R&D is centred: sugar, ethanol and co-generation of electricity. Of the 1.4 billion tonnes of sugarcane produced today, approximately 75% is destined for sucrose and 25% for ethanol. The co-generation of electricity and the use of products with added value are minimal but have great potential (ISO, 2008a).

A knowledge of consumer demand and interests is decisive for defining future research. If the target is to improve the efficiency of sugar production, technology developments should not be indifferent to population growth and consumption. Income (ISO, 2004) and socio-political factors also influence future consumption. In absolute terms, large populations tend to be associated with high levels of sugar consumption. It is not surprising that the five countries with the greatest growth in consumption in absolute terms are among the ten largest in population.

Future expectations of research funders will be for technological advances that contribute to a greater demand for sugar and its by-products and, consequently, generate greater productivity, income and promote sustainability. Greater income can contribute to a greater demand for sugar and its by-products and, consequently, create challenges for new technology developments. In a global economy in crisis, we are part of the solution; thus knowledge of the environmental setting is fundamental.

Technological advances and their impact on productivity in the sugar industries are evident in the last 30 years. Advances in productivity, a function of technology development (Cox *et al.*, 2005; Edme *et al.*, 2005; Cenicana, 2008; Davis, 2007) highlight the role of R&D for responding to the 2% yearly increase in the consumption of sugar, which today is 160 million tonnes. Despite the progress made in productivity, improvements have not plateaued, so there remain opportunities for improvement via multidisciplinary groups and alliances.

Increased productivity has contributed to reducing the use of the land without affecting food security through expanding the planting of cane in areas occupied by other food crops. This has been the experience of the sugar agro-industry in Colombia, where thanks to the technology developments in the last 30 years, the productivity in sugar has doubled without having to expand the crop to other farming areas (Asocana, 2007).

Sugar industries worldwide use only one-third of the plant's biomass to produce sugar, so R&D has focused on this aspect. With the potential to use the biomass as a source of energy, either for ethanol or co-generation of electricity (Leal, 2007), demands for new technology offers an opportunity for research. This means the validation and adoption of available technologies, research at the level of cane production in the field and in industrial processes, changes in attitude toward working in multidisciplinary teams, knowledge of the environmental setting, and response to the challenge of using the biomass in a sustainable production system. The updating and acquisition of new knowledge should be permanent, but we should also progress as individuals. Researchers and the organisations need to do their part in order to make full use of the strengths of the human talent and facilitate the improvement of their capacities.

Over the next ten years, the challenges will be greater given the technological advances and impacts reached thus far. This means greater knowledge and integration of other disciplines; and, although there may be a need for greater funding, integration can lead to better rationalisation in the use of the resources and capacities.

What the users of the technology expect will be based not only on the number of products but also on the benefits that they generate (Mervis, 2005). This will be accomplished by integration, teamwork and alliances. Agronomists and professionals linked to cane production will continue to play an important role in facing these challenges, but they will not necessarily be the only actors in the future scenario of agricultural research (Miller, 2008). After the 'Green Revolution' era, centred on commodities and research in organisations, the 'Evergreen Revolution' has followed, centred on the integrated management of natural resources and participatory research (Swaminathan, 2006). This should be accompanied by a continuous technology transfer and prompt adoption of innovative technologies in order to exploit them at the right moment and not when they are obsolete.

Multidisciplinarity implies interaction. Interaction of researchers with the users of their products should be emphasised in order to provide the scientific foundations for the new technologies and about the concerns that end users may have. The assumption that the user of the technology understands the scientific bases of the developments is not sufficient – the problem is not one of scientific comprehension but of satisfying their needs and concerns (Leshner, 2007).

On the other hand, there is a tendency in the minds of those who need the technology – cane producers, managers and funders – to minimise the range of actions that researchers can have. In some cases, the users feel intimidated by the idea of working with researchers. The best way to change such an attitude is through permanent interaction with them in the environment in which the work is being done (Alberts, 2009).

The culture of teamwork is now beginning to be visible, and it should become stronger in the future. A recent study of publications in the last five decades shows that work teams (reflected in the number of authors) significantly surpasses individual authors in the majority of scientific fields (Wuchty *et al.*, 2007).

The benefits of alliances are also evident in the sugar industry worldwide. One of the best examples is the International Consortium for Sugarcane Biotechnology (ICSB), which integrates 14 countries and 19 institutions in the search for genetic and molecular knowledge of sugarcane and the search for genes of agronomic interest.

All participants contribute to the definition of priorities and finance the research. This has generated knowledge that contributes to improvement and technology development that would not have been possible working in isolation (Moore, 2005).

Internally, at the level of the countries, alliances are being made; and the actors related to R&D are being integrated, such as has occurred in Australia (Maldonado and Troedson, 2009), South Africa (SASRI, 2007), and Colombia (Amaya, 2008), among others. We need to be open to joint developments for generating knowledge, technology and greater welfare in our agro-industries.

The foregoing gives an idea of the profile of the specialist required in the coming decade. This requires not a narrowly focused ‘specialist,’ but rather someone with a ‘special’ interest in several disciplines, whose wide vision could lead scientists to make significant contributions to developing a true Renaissance in our industries.

### **From production-oriented models to consumer-driven systems**

The transition from production-oriented work models toward consumer-driven work models requires going beyond the indicators of productivity. Added value, cost reduction, quality raw materials, compliance and interest in the market and consumers’ proposals need to be kept in mind in the new production model.

The production of the sugar already has technological support and experience in R&D. In the future, the refining of the current technology and incorporation of others in the development process are needed.

Cane producers will face an increased demand from the cane processors for cane with higher sucrose content and less extraneous matter. For the sugar producers, greater value can come from supplying the type of product that the consumer wants. This will range from different forms of sugar to nutraceutical products with information on their effect on health and clarity as to their origin with respect to the production system or to whether they were obtained through conventional genetic improvement or genetically modified varieties. A well-informed consumer demands better knowledge of the product.

For more than two centuries, cane has been fundamentally used to produce sugar. In the case of the production of ethanol, the transition has been relatively smooth because the same varieties and the system for producing cane in the field are used, and there were well tested industrial production technologies available in the market. Moreover, the countries that have led the production of ethanol have also had a supporting platform of government regulations, and there has been an ever-growing interest in clean energy on the part of the consumers.

Today, the use of sugarcane to produce value-added products other than ethanol faces a different scene. The challenge for R&D and innovation is even greater given that their impact will depend not only on the technology *per se*, but also on a greater capacity for managing knowledge, a vision for innovation, transfer and marketing of results and technologies, and different forms and sources of financing. The benefits derived from other products with added value are expected to have an economic impact and sustainability that will motivate new R&D and open doors for new financing.

Technology development in the world’s leading sugar industries has been financed to a great extent by the sugar industries themselves, complemented by support from the respective governments. The tendency towards networking, and the complement of external financing have the potential for generating products or patents of greater value in shorter time and with lower costs, incorporating the knowledge of researchers from different organisations.

The availability of information about external funding for the sugar industries is scarce. However, there is a growing trend in this direction, given the global financial crisis. External funding requires a change of paradigms. It is imperative that researchers be aware that, in addition to the economic support from our industries, we also have a ‘capital’ of great value. This is knowledge that we should strengthen and exploit in order to generate greater value, and be supported by an external finance.

In this sense, researchers should be more proactive and eliminate some of their rationalisations that still prevail; e.g. lack of time, ignorance in how to proceed, belief that someone else should do it, believe that is something too big and lacking aid, among others (Wells and Farnham, 2006). Such attitudes must be eliminated in future researchers if they are to attract funding with competitive proposals and based on their merits.

### Sustainability and concerns for environmental issues

Developments that promote sustainability have become current concerns, given that, in addition to the investors' expectations, there is the consumers' interest of preserving natural resources and conserving the environment. The potential for reducing carbon dioxide emissions to the atmosphere through the use of renewable energy sources such as sugarcane makes this crop an ideal option. A global vision, multidisciplinary and strategic alliances can generate a better future for the sugar industries that face these challenges.

Sustainability, understood as satisfying the needs of the current generation without compromising the needs of the future generations (IPCC, 2007), refers to the need to take into account the economic, social and environmental benefits in any production system. Unfortunately, political interests have also arisen around this topic; thus, it is imperative that researchers be informed as to what is going on in their settings in order to give an objective response based on research or to incorporate those concerns in future research.

Sugar industries around the world have been incorporating sustainability in their technology developments related to the environmental issues. If we start with the production in the field, the raw material is the genetically improved varieties. In the majority of cases, new varieties have generated greater production with the same level of natural resources (soil and water) and inputs less than those used previously. This also contributes to the social component, freeing-up arable land and improving the efficient use of the water. In the Colombian sugar industry, improvements in technology for water management (Torres *et al.*, 1996, 2004) and planting varieties that require less irrigation (Victoria *et al.*, 2002) have reduced water consumption by approximately 50% without affecting production.

In the case of the cane varieties, the majority of those released are resistant to diseases and pests, which decreases the use of agrochemicals. In the control of some pests, the use of biological control is routine, which decreases the use of insecticides.

Today, field technology is targeted to specific conditions, defining the technologies, varieties and agronomic management practices in accordance with climatic zones and the cane producers (Carbonell *et al.*, 2001; Isaacs *et al.*, 2007). This site-specific agriculture approach has generated up to 30% increases in production in some zones of the Colombian sugarcane industry (Isaacs *et al.*, 2007; Viveros *et al.*, 2009). The management of the crop in the field with specific technologies and the search for environmentally friendly products will be of relevance to the final acceptance by consumers. Therefore, this should be a priority in future research.

Climate change is a reality (IPCC, 2007); and, in order to adapt or mitigate the effects of this change, future actions should consider changes of scale. We have moved from a temporal scale of the climate that affects a crop cycle for short periods of time to consider the impact of the evolution of the climate over hundreds or thousands of years on agriculture and life today on the planet. We've also moved on the spatial scale, from metres or hectares to regions and the entire globe (Steiner and Hatfield, 2008). This reality leads us to define different strategies in the management of the inputs required for producing the crop and the industrial processes. That is another reason for working together.

A focus on climate change projects a more integrated vision for future R&D. There are platforms for analysing the impacts of climate change and the measures required for mitigating them in sugarcane (Nayamuth, 2005; Schulze, 2007; Park, 2008). The use of cane for biofuels contributes not only to reducing the dependence on fossil fuels, but also to reducing carbon dioxide emissions into the atmosphere.

The Brazilian experience and their success in the ethanol production system is today a reference point for industries that are moving to the production of biofuels. We should learn from this arduous path and the weaknesses they have to overcome in this development. That will help project the research that fills the information gaps for both science and for society.

## Conclusions

R&D challenges facing the sugar industries in the next decade will depend on strategies that involve greater emphasis on changing the way of doing things more than on the development of the technology *per se*. Technological advances will be fundamental, but changes in our attitudes that promote multidisciplinary, teamwork and alliances will underpin innovations of impact that will generate greater growth of our industries, consumer satisfaction and sustainability of the ecosystems where sugarcane is produced and processed. The renaissance that we expect to occur in the world's sugar industries will depend on incorporating in our R&D the vision that prevailed in the era of Renaissance of a '*Homo universalis*' with an open mentality and interest in the advances of other disciplines that will contribute to realise the potential of today's capacities to address future challenges.

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## LA RECHERCHE SUR LA CANNE A SUCRE ET LE TRANSFERT DE TECHNOLOGIE – STRATEGIES POUR LA PROCHAINE DECADE

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**MOTS-CLÉS: Défis de la Recherche, Recherche Multidisciplinaire, la Durabilité.**

### Résumé

LES CHALLENGES agronomiques nécessaires pour les décades à venir seront centrées sur (1) la recherche et le transfert de technologie basés sur des approches multidisciplinaires; (2) une transition à partir de modèles de production orientés sur des systèmes pilotés par les consommateurs et (3) des développements qui promeut la durabilité et les préoccupations concernant les enjeux de l'environnement. Une approche multidisciplinaire permet aux scientifiques, planteurs et ingénieurs d'usine d'être informés des contributions des autres disciplines, plutôt que sur la base d'efforts individuels isolés. Il ne s'agit donc pas d'avoir un spécialiste à vision étroite, mais plutôt quelqu'un qui a un intérêt particulier dans plusieurs disciplines, et dont la vision permettrait d'intégrer les contributions pour développer une renaissance des industries sucrières. La transition vers un modèle piloté par la demande des consommateurs requiert l'identification de nouvelles priorités. Les technologies de la production de sucre vont rester prioritaires, mais une pression plus importante doit être mise sur les technologies utilisant la canne à sucre pour la production d'énergies et d'autres produits à valeur ajoutée. Dans le cas de la production énergétique, l'utilisation de la canne à sucre a été possible grâce à la disponibilité en technologies éprouvées, l'intérêt des investisseurs, la régulation du gouvernement et la demande du consommateur. Pour les produits à forte valeur ajoutée, le challenge pour les scientifiques, ne se situent pas uniquement au niveau des retombées de recherche comme cela a pu être le cas pour la production de sucre. Leur aptitude à appréhender la connaissance du management et leur vision pour le transferts des résultats, à ouvrir de nouveaux marchés et à générer de l'intérêt pour financer de nouvelles recherches doit être renforcer. La durabilité et la protection de l'environnement va continuer à jouer un rôle dans la recherche future que ce soit au champ et au niveau des processus technologiques dans les usines. Le changement climatique fait partie des challenges que les agronomes et leurs partenaires spécialisés doivent prendre en compte dans la conception et le management des systèmes de production du futur. L'utilisation prospective de la canne à sucre comme source d'énergie pour réduire les émissions de dioxyde de carbone dans l'atmosphère offre une opportunité pour les chercheurs, les investisseurs et les consommateurs de travailler ensemble sur la durabilité et la protection environnementale. Les avancées majeures de la recherche et les projections dans l'industrie sucrière à travers le monde répertoriés dans la littérature et au niveau de l'industrie sucrière colombienne, sont utilisés pour illustrer ces stratégies.

## INVESTIGACIÓN Y TRANSFERENCIA DE TECNOLOGÍA DE LA CAÑA DE AZÚCAR- ESTRATEGIAS PARA LA PRÓXIMA DÉCADA

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**PALABRAS CLAVES: Desafíos de la Investigación, Investigación Multidisciplinaria, Sostenibilidad.**

### Resumen

LOS DESAFÍOS agronómicos requeridos para las próximas décadas se centrarán en (1) la investigación y la transferencia de tecnología basada en enfoques multidisciplinarios, (2) una transición de modelos orientados a la producción a sistemas dirigidos por el consumidor, y (3) los desarrollos que promuevan la sostenibilidad y las preocupaciones en cuestiones medioambientales. Un enfoque multidisciplinario garantiza que los científicos, los cultivadores y los ingenieros de fábrica sean conscientes de las contribuciones de otras disciplinas, en lugar de esfuerzos aislados e individuales. Esto requiere no tener un enfoque en el restringido 'especialista', sino más bien a alguien con un interés 'especial' en diversas disciplinas, cuya visión amplia le daría la capacidad de hacer contribuciones integradas para el desarrollo del verdadero renacimiento en las industrias de azúcar. La transición a un modelo orientado al consumidor requiere la identificación de nuevas prioridades. Las tecnologías para la producción de azúcar seguirá siendo una prioridad, pero un mayor énfasis debe ser dirigido hacia las tecnologías para el uso de caña de azúcar en la producción de energía y productos de valor añadido. En el caso de la producción de energía, el uso de la caña de azúcar ha sido posible dado a la disponibilidad de tecnologías probadas, el interés de los inversionistas, regulación del gobierno y demanda del consumidor. Para los productos de valor agregado, el reto para los científicos consiste no sólo en los resultados concretos de investigación, como ha sido el caso para la producción de azúcar. Sus habilidades en gestión del conocimiento y su visión para transferir sus logros, abrir nuevos mercados y generar interés en financiar nuevas investigaciones deben ser fortalecidas. La sostenibilidad y la protección del medio ambiente seguirán desempeñando un papel en el futuro de la investigación, tanto en el campo como en los procesos de fábrica. El cambio climático está en la agenda de los desafíos que deben abordar los agrónomos y sus aliados especialistas en el diseño y administración de futuros sistemas de producción. El uso prospectivo de caña de azúcar como una fuente de bioenergía para reducir las emisiones de dióxido de carbono a la atmósfera ofrece una oportunidad para que los científicos, los inversores y consumidores trabajen juntos para la sostenibilidad y la protección del medio ambiente. Los resultados de investigación y las proyecciones de la industria del azúcar en todo el mundo, reportados en la literatura, así como por la industria del azúcar colombiana, se utilizan para ilustrar estas estrategias.