BREEDING FOR A BETTER INDUSTRY: CONVENTIONAL BREEDING

By

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Abstract

A continuing supply of improved cultivars satisfying the requirements of sugarcane industries worldwide has underpinned increases in production since the 19th century. Cultivars are developed using three components: assembling a described population of parental clones; generating variable progenies by cross-pollination; and selecting useful clones. The paper summarises advances and deficiencies in these components. Movement of germplasm is facilitated by increased adoption of international export quarantine standards additional to long-accepted import procedures, which are being strengthened by molecular pathology screens. The parlous condition of the World Collections is a continuing concern, but the reluctance of sugarcane industries to finance them precludes criticism of the host organisations. The bulk of sexual recombination uses existing Saccharum spp. hybrids. This is despite the outstanding contemporary successes with basic germplasm in Argentina, Australia, and Louisiana. Managed photoperiod facilities, particularly in the tropics, are aiding planned recombinations among parental clones. Failure to use rigorous cross-pollination techniques means a low likelihood of trueness-to-label of progenies from many programs. Prediction of cross performance, using progeny trial data alone, has advanced, but more sophisticated statistical techniques may improve estimation of parental breeding value, and use of family selection for progeny populations has been beneficial. Whether high-performing combinations are predictable is currently debated. Adoption of objective selection was a major advance and will be enhanced by introducing high-speed, quality-component analyses. Inter-genotypic competition in small-plot assessment is important, and plot design should take this into account. Sugarcane improvement lacks purpose-built equipment for small-plot evaluation. Extensive G x E research has not delivered practical, usable solutions to facilitate collaboration between programs. Conventional breeding can provide solutions to many problems, but these may not be the most economical, and minimisation of selection criteria to maximise genetic gain is little understood by industry. However, conventional breeding will be the main system delivering improved cultivars for many decades. Managed photoperiod facilities, more sophisticated selection indices, and improved breeding-value estimation will facilitate this. The system will be increasingly supported by biotechnological techniques. Genetic engineering may correct highly productive, flawed clones, and may allow production of high-value products using novel genes. Regardless, conventional breeding will be pivotal in delivering such enhancements to the industry and, ultimately, to the consumer.

Introduction

Most sugarcane industries support crop-improvement programs to improve productivity by increasing sugar yield directly, through increased cane yield and sugar content, and indirectly by incorporating genetic resistance for major diseases and pests. Cane breeding is also important in providing sugar mills with a raw product—sugarcane—that is easy to mill, i.e., has acceptable fibre content and quality, and produces good quality sugar. The extent to which breeding is able to satisfy growers, millers, and refiners varies considerably. Usually, whenever an industry is faced with a new problem, breeding is often regarded as the first, and only, source of a solution. Breeding can provide solutions to many problems, but breeding will not necessarily supply the most economical solution.

Sugarcane farmers typically want cultivars that have high cane yield, high sugar content throughout the season, are resistant to important diseases and insect pests, have reasonable requirements for nutrition and water, and can produce many ratoons without losing productivity.
Sugarcane millers also want highly productive cultivars that will produce a consistent cane supply of acceptable quality. This means cultivars that do not have high fibre content or fibre that is difficult to process, i.e., fibre elements of excessively short or long length. In the mix of cultivars received, millers prefer to have those with similar fibre content and quality, i.e., minimal variance in both, so that they do not have to change the milling train to accommodate variation. These requirements are difficult to satisfy, but new cultivars should be tested for their milling characteristics so this information supports a cultivar’s release. Cogeneration and sale of electricity through efficient use of fibre is now driving a trend for cultivars with higher fibre. The economic implications of this trend have not been clarified for breeding, as higher fibre content reduces mill throughput, increases back-end losses, and reduces juice tonnage for comparable cane tonnage delivered.

Sugarcane refiners are not as concerned about productivity as they are about sugar quality. Sugar that is low in colour and has an acceptable ash/impurity ratio, in addition to other less important quality characteristics, is desired. Jackson et al. (2004) concluded that cultivars in the final stage of selection should be evaluated for colour and ash/impurity levels, but cautioned against discarding too many cultivars for these characteristics, as productivity is a more important character economically for the whole industry.

Breeders are unable to satisfy all these requirements in single cultivars, and some very useful cultivars may have serious faults that require specialised management strategies. The breeding of improved cultivars involves compromises and, although production of the perfect cultivar is the aspiration of all breeders, breeders must be aware of which issues are likely to deliver the greatest benefits. In this paper, we assess achievements in improving conventional breeding performance in recent years and speculate on possible improvements in future years. We evaluate the achievements and deficiencies in the three major components of a cane breeding program—assembly and evaluation of germplasm, recombination to create variation, and selection of clones as cultivars.

**Assembly and evaluation of germplasm**

A typical sugarcane-breeding program uses a collection of germplasm, which is likely to include basic germplasm (clones from genera and species included in the *Saccharum* complex (Daniels and Roach, 1987) as well as hybrids (*Saccharum* spp. hybrids). Basic germplasm is used in an enhancement-breeding program to introgress desired traits into a *Saccharum* spp. hybrid background to provide commercially acceptable material (a long-term approach). Hybrids are also crossed to produce potential new clones (a short-term approach).

Basic germplasm can be sourced from the World Sugarcane Collections, or secondary collections maintained at many breeding stations, while hybrid germplasm is imported from other breeding programs. The success of a breeding program may depend on the program’s ability to source and import new germplasm and its skill in using that germplasm effectively. Berding et al. (1997) reviewed the collection and use of germplasm, while Hogarth and Berding (1996) discussed the importance of international germplasm exchange to the Australian sugar industry.

**Advances**

A significant advance has been the recent development of international export quarantine standards for the maintenance of cultivars offered for international exchange. This involves maintaining clones or cultivars offered for international exchange free from diseases and insects. The material must be maintained in a glasshouse built to acceptable international quarantine standards. Previously, many countries were happy to exchange clones, but plants were collected from the nearest available ‘disease-free’ field. This proved to be a very effective way to transfer diseases around the world.

To counter this, importers habitually quarantined those clones for 1–2 years before planting them in the field, and, when diseases were discovered, the plants were destroyed. This prevented spread of diseases, but wasted quarantine resources. Most countries now realise that it is just as important to quarantine clones before dispatch to another country, as it is to quarantine them when they are introduced. Unfortunately, not everyone follows this procedure.

Quarantine of clones has been greatly enhanced by the development of biotechnological pathology screens (e.g., James et al., 2004). Many organisations now subject clones to a range of pathology screens before export and after import. These procedures have minimised the risk of disease movement among countries, and represent a major step forward in improving the safety of clonal exchange.

Another important advance has been the development of molecular fingerprinting techniques to identify clones with a high degree of accuracy (Piperidis et al., 2004), so that trueness to label for a clone...
can be assured. Labelling errors in field collections are quite common, and this technology, when fully
developed and distributed for use in major breeding collections, will help considerably to reduce errors.

All modern cultivars are interspecific hybrids that can be traced back to a few clones of basic
germplasm, principally clones of *Saccharum officinarum* L. and *S. spontaneum* L. Most sugarcane breeding
programs have attempted to improve commercial hybrids by using different clones of these basic species.
Success has been disappointing, although Burner and Legendre (1993) discussed the success of such a
program in Louisiana and Berding et al. (1997) discussed the success of one particular clone in
Queensland. The use of the technique has led to improvements in juice quality (Tai et al., 1992), disease
resistance (Burner et al., 1993), sugar yield (Srivastava et al., 1994), and general agronomic characters
(Jackson and Roach, 1994). TUC(CP)77-42, a cultivar that was bred in the United States and selected in
Argentina, is one quarter *spontaneum*, and has proved to be highly productive (Cuenya, pers. comm.). The
most ambitious program developed to exploit basic germplasm is in the West Indies (Chave, 1991;
Simmonds, 1993), and aims to redevelop *Saccharum* spp. hybrids by using basic clones that have not been
selected for any character. The success of this program is being followed with interest.

**Deficiencies**

The major deficiency in the assembly and evaluation of germplasm is the difficulty in maintaining
and accessing clonal material from the two World Collections of sugarcane in Kerala, India and Florida,
USA. These collections are maintained as international collections under the auspices of the International
Society of Sugar Cane Technologists by the Indian Council of Agriculture and the USDA-ARS without any
financial assistance from the remainder of the sugarcane world. This is a substantial impost on these two
countries, and has led to a range of problems.

The collection in the USA is located on poor soil and is in a typhoon-prone area. Due to limited
funding, the collection has not been maintained to acceptable standards, clonal identities are confused, and
many clones have been lost from the collection, despite the best efforts of the dedicated staff. The
collection, however, is readily accessible to organisations outside the USA. The Indian collection is better
maintained and is in a less-stressed location. However, the Indian Government possesses a view of the
potential intellectual property present in the collection that is at odds with the agreed international status of
the collection, and there is marked reluctance to allow access to other sugarcane breeding organisations.

The lack of funding from countries that stand to benefit from the World Collections is probably
due to a lack of appreciation on the part of administrators of the role that these centres could play in the
development of the crop. If properly funded, the World Collections could form the base for international
enhancement breeding programs where basic germplasm is evaluated, hybridised, progeny evaluated, and
promising material distributed to collaborating organisations supporting the collections.

**Recombination to create variation**

Sexual recombination of genetic material using cross pollination is essential for the creation of the
new variability that is the foundation of sugarcane selection programs. Much research has been conducted
to improve flowering of sugarcane, and some research has been conducted into methods for choosing
parental combinations that have the best chance of producing superior clones. However, progress in these
areas has been relatively limited in recent years.

**Advances**

The major advance has focussed on the use of photoperiod houses to induce flowering, particularly
in tropical areas where natural flowering is sub-optimum. The use of controlled photoperiod facilities,
based on the pioneering research of Brett (1951), is well developed in temperate regions, based on the
realisation that low, sub-optimal temperatures affected flower initiation as well as pollen fertility. Cross
pollination is impossible without use of such facilities. Berding and Moore (2001) discussed the success of
a large research program in Australia that has greatly enhanced the flowering of parent clones in that
country's tropical region. In an average year, 40% of the parent collection flowers naturally at the BSES
breeding station at Meringa (down to 16% in a very poor year), while about 90% of clones can be induced
to flower in the photoperiod facility. More recently, Silva et al. (2005) have reported success in Ecuador
with a photoperiod facility based on the Australian design. Research to improve the initiation of plants in
photoperiod facilities in sub-tropical regions by varying the nutrient regime has been conducted by
Brunkhorst (2003).

Stringer et al. (1996) showed that best linear unbiased predictors (BLUPs) provided a more
effective assessment of the breeding value of parent clones than the empirical algorithm previously used by
BSES (Hogarth and Skinner, 1986); the correlation between predicted family performance based on BLUP values for parents and actual performance is 0.62 to 0.65 compared to 0.45 to 0.50 for the previous method (Cox and Stringer, 1998). This is surprising, as the BLUPs were determined on only sexual seedling data, whereas the earlier algorithm used data, in the form of selection rates, from clonal stages in addition to the seedling stage. Chang and Milligan (1992a,b) examined four statistics, including BLUPs, to identify a reliable and easily obtained cross-appraisal statistic. They found that the progeny mean was the best predictor of a cross to produce elite progeny. However, this does not help to predict cross performance before the cross has been made, and estimation of the BLUPs of parents should be an objective for the BSES program, in terms of cultivar production, in the past 40 years (Trojan to the complex nature of sugarcane genetics. Although improved statistical methodology should be able to improve these estimates, this currently is a highly debatable point—the three most successful crosses in the BSES program, in terms of cultivar production, in the past 40 years (Trojan x Co475; NCo310 x QN54-7096; QN58-829 x QN66-2008) are very unlikely to have been predicted by any mathematical technique. In fact, these parental clones are unlikely to have been nominated by any predictive technique to possess high general combining ability. This emphasises the importance of specific combining ability in cross performance, and demonstrates the need to make many crosses in order to improve the chances of identifying rare superior crosses.

**Deficiencies**

The most obvious deficiency is the general failure to use cross-pollination techniques that ensure minimum pollen contamination in crosses. Skinner (1959) showed how to minimise pollen contamination by using crossing lanterns made from material with a very close weave that excludes foreign pollen. However, although this technology has been available for almost 50 years, many breeding stations do not prevent pollen contamination. As a result, the true parentage of progenies from these programs is uncertain, and progeny assessment is prone to considerable error.

A second deficiency is the poor estimates of breeding value of parental clones. In part, this is due to the complex nature of sugarcane genetics. Although improved statistical methodology should be able to improve these estimates, this currently is a highly debatable point—the three most successful crosses in the BSES program, in terms of cultivar production, in the past 40 years (Trojan x Co475; NCo310 x QN54-7096; QN58-829 x QN66-2008) are very unlikely to have been predicted by any mathematical technique. In fact, these parental clones are unlikely to have been nominated by any predictive technique to possess high general combining ability. This emphasises the importance of specific combining ability in cross performance, and demonstrates the need to make many crosses in order to improve the chances of identifying rare superior crosses.

**Selection**

The selection of superior clones is the ultimate aim of any sugarcane-breeding program. Typically, selection programs commence with a very large population of seedlings from a wide range of crosses, and breeders select the few superior clones from this population. Significant advances have been made in recent years to improve the efficiency of selection, but many programs are still using sub-optimal methods.

**Advances**

The major advance has been the adoption of objectivity in the evaluation of clones at all stages of selection. In the past, clones were assessed visually for yield and by refractometer Brix for sugar content in many stages of selection. In Australia, mobile weighing machines were developed in the 1980s (Hogarth and Mullins, 1989), and these machines are now used to weigh cane at all stages of selection. In addition to improving objectivity, weighing of cane has made it possible to reduce the number of stages of selection from five to three, and reducing the time to release cultivars for commercial production by up to 5 years. Mechanised weighing is now also used in many breeding programs including South Africa, Brazil, and Colombia.

Australian selection programs also now measure sugar content at all stages of selection. In most cases, this is done by traditional methods (solubles analyses, to yield Brix and polariscope reading data and, in some cases, insolubles analyses, to yield fibre data), but there has also been extensive research on the use of near infra-red spectrometry to improve automation and data collection on the parameters involved in the measurement of sugar content (Berding and Brotherton, 1999). Most R&D samples processed at BSES Meringa since 1995 have been analysed using near infra-red spectroscopy. More recently, Berding et al. (2004) have developed a high-speed laboratory analyser using a superior instrument platform that will analyse 400 samples per day and substantially reduce per sample costs. South Africa is also using near infra-red spectrometry in its program, and there has been interest in the technology from other breeding stations.

Objective measurement of cane yield and sugar content allows family selection at the original seedling stage of selection in preference to individual selection based on visual assessment of individual seedlings. Simmonds (1996) encouraged the use of family selection for clonally propagated crops, and lamented that it is only used routinely in the Australian sugar industry and a Scottish potato-breeding
program. Other sugarcane breeding programs have shown interest in family selection, but have yet to adopt it totally. Cox and Hogarth (1993) showed that the most efficient method of family selection was based on the performance of families in replicated plant crop trials, followed by individual selection within the best families in the ratoon crop. Cox et al. (1996) showed that gains in the population mean of 10–13% were obtained from family selection, three times as great as from individual selection alone.

In the past, some breeding stations planted massive populations of original seedlings, in some cases, more than one million each year. Selection of such large populations was not very effective, and there is increasing acceptance of smaller seedling populations that can be assessed objectively and intensively. The Australian experience suggests that an initial population of 25 000 seedlings, consisting of some 270 progenies, per 8 million tonnes cane production provides sufficient critical mass for an effective selection program. There also has been acceptance of the need to find rare crosses with high specific combining ability to produce cultivars with commercial potential, although there are differences of opinion on how to identify such crosses.

There is also general acceptance among breeders about the need to minimise the number of selection criteria in order to maximise genetic gain, although this is less well understood by industry personnel. As already suggested, cane breeding is often viewed as the first option for solving problems involving the plant or the plant's interaction with environmental or management factors. Cane breeding can solve many problems, but the breeders' desire to limit the number of selection criteria is driven by two considerations. Firstly, breeding does not always provide the most economical solution. Two clear examples of this occur in the Queensland industry—use of long-hot-water treatment and observance of basic phytosanitary precautions as a solution for ratoon stunting disease (Liefsonia xyli subsp. xyli Davis et al.) and addition of amylase to juice held at elevated temperatures for relatively few hours to reduce starch in juice. Both are clearly more economic solutions than pursuing cultivar development with selection criteria expanded to include both genetic resistance to ratoon stunting disease and low starch in juice. Secondly, simple mathematical considerations dictate the necessity to reduce the number of selection criteria. If we assume the probability of selecting a clone acceptable for any selection criterion is 0.001, then the probability of detecting an individual satisfying two criteria such as yield of cane and sugar content is (0.001)^2. If the list of selection criteria is expanded to six traits, a common situation, then the probability of successfully detecting the desired clone becomes (0.001)^6, a clearly impossible task. Strict culling selection for a set level for each trait is rarely practised; rather, a compromise approach to selection of multiple traits is used. This approach is driven by an appreciation that the perfect cultivar, even for a short selection criteria list, is rarely attainable.

Most of the gains in sugar yield per hectare over the past 30–40 years have been the result of improvement in cane yield, rather than sugar content. In Australia, cultivars such as Q124 improved cane yields by 20–30% in some areas (unpublished data). Similar improvements have been reported in Louisiana for LCP85-384, which in 2004 occupied some 93% of the Louisiana industry's area (T.L. Tew, pers. comm., 2004), raised cane and sugar production substantially, and reduced costs by allowing a lengthening of the crop cycle by one to two additional ratoon crops. In Queensland in the 1970s, the introduction and acceptance of Q90, a cultivar that dominated the tropical industry up until 1978, when it fell from favour through susceptibility to the newly introduced brown rust (Puccinia melanocephala H. & P. Syd.), raised sugar productivity by 31% relative to the superseded cultivar Pindur (Berding and Skinner, 1987). Improvements in sugar content have been more modest, although Breaux (1987) reported considerable progress from recurrent selection in the Louisiana program. Progress has been made in selection for sugar content early in the crushing season (Cox et al. (1994) in Australia; Cuenya and Mariotti (1995) in Argentina). However, genetic gain for sugar content in the main part of the crushing season is likely to be limited by the relatively low genetic variation for this character (Hogarth et al., 1981). Kennedy (2005) discusses an ambitious program in the West Indies to improve sugar content by using a recurrent selection program for Brix in which little attention was paid to other characters. Brix levels have risen dramatically, and it will be interesting to see whether clones selected from the program will make useful parents that improve sucrose content.

In addition to improving productivity, sugarcane breeding can be proud of its success in controlling most major diseases of sugarcane. Walker (1987) pointed out that most diseases are controlled by resistant cultivars—exceptions are pineapple disease (Ceratocystis paradoxa (Dade) Moreau), ratoon stunting disease (Liefsonia xyli subsp. xyli), and grassy shoot disease (probable mycoplasma). Devastating diseases such as smut (Ustilago scitaminae Syd.), Fiji leaf gall, leaf scald (Xanthomonas albilineans (Ashby) Dowson), brown rust, and orange rust (Puccinia kuehni Butl.) have all been controlled by
breeding resistant cultivars over the past 20 years. Breeders have been less successful in controlling pests, but White et al. (1998) have registered 12 germplasm clones resistant to sugarcane borer, and varying levels of resistance contribute to Integrated Pest Management strategies for borer control in many industries (Leslie, 2000).

More precise determination of clonal means should result from improvements in experimental plot techniques. A major advance has been the recognition that competition between neighbouring plots seriously distorts plot means (Skinner, 1961; Skinner and Hogarth, 1978; McRae and Jackson, 1998). In Australia, use of four-row plots in final yield trials is now standard practice, but only the centre two rows are weighed to avoid the effects of competition. Evaluation trials with a large number of clones (80–100) are now being planted in resolvable incomplete-block designs that usually improve the precision of the trials. In addition, the development of spatial analysis (Stringer and Cullis, 2002) has the potential to greatly improve statistical precision.

**Deficiencies**

In contrast to the above approach to clonal trials, many programs use a ‘horticultural’ approach to plot layout, rather than a plot layout that simulates commercial agronomy. In this, as discussed above, the multi-row plots used are planted contiguous, bordered laterally by similar multi-row plots, and separated end-on by a minimal gap (0.3–0.5 m) sufficient to allow plot separation. In contrast, the horticultural layout commonly used sees plots separated laterally by columns of several unplanted rows, and separated on-end by gaps of 2–5 m, depending on location. The features of this format are relatively short rows and large gaps between plots, both of which increase bias through competition. Some clones will make greater use of the extra space at the end of rows, and this characteristic does not necessarily mean that the clone has greater yielding ability in commercial fields. With the large spaces, the trials are pleasant to walk through, but they are unlikely to produce meaningful results.

One of the biggest differences between crop improvement of sugarcane and other major agricultural crops, mainly grains, is the almost total lack of development of purpose-built mechanical equipment for planting and harvesting. Most often, commercial equipment, often unmodified, is used for small-plot work. For example, precision planters that can plant trial plots of the same length, and that are placed precisely relative to all other plots in the trial, have not been developed. Simple tests such as measuring variation in harvested row length, or correlating yield in contiguous, weighed rows within plots, highlight the necessity for this development. This must be considered more basic, and more urgent, than statistical manipulations attempting to account for competitive effects. Similarly, mechanical harvesting uses commercial machinery that has grossly excessive capacity for the task in hand (a capability of 800 instead of 80 tonnes cane per day), is not designed or built for continual stop-start operation, and has poor operator positioning so frontal viewing of plot changes is difficult.

Despite a large amount of work being done on genotype x environment interaction in many countries, this research disappointingly has failed to define specific environmental parameters that dictate development of cultivars with regionally specific adaptation. There is also no knowledge on why cultivars may be outstanding in one country but not another. For example, NCo310 was an outstanding variety in many countries, but NCo376 performed poorly except in South Africa where both cultivars were selected. More recently, LCP85-384 has been an outstanding variety in Louisiana and Argentina, but has performed very poorly in sub-tropical regions of Australia.

Similarly, many tropical industries could be regarded as being very similar environmentally, but cultivars with general pan-tropic adaptation are virtually unknown. Research on G x E has failed to deliver practical, usable solutions that could deliver substantial synergies, and cost benefits, from collaboration among programs inter-continentally.

**The future**

We believe that further improvements will be made to the use of photoperiod facilities so that more parental clones will be induced to flower in them, and there will be greater control over the time of flowering. More countries, particularly in the tropics, will develop photoperiod facilities, once their advantages are appreciated, to extend the range of clones that can be used in their breeding programs.

With the great advances in computing power, development of improved selection indices that can account for the inherent variability and heritability of characters and their economic importance is now possible. This has resulted from work that has been done over the last 20–30 years on the quantitative inheritance of characters.
Further work is needed on the assessment of the breeding value of parents. One possibility being considered in Australia is to use data on grandparents to improve estimates of the breeding value of parents. This will only be useful if breeders can be certain of the true parentage of their parents, so improvements will be necessary in pollen control. There has also been a suggestion that the high degree of non-additive genetic variance for cane yield can be exploited by using reciprocal recurrent selection, but this hypothesis is untested.

Of course, there has been much speculation about the role of genetic engineering and molecular markers in the future of sugarcane breeding. These will be covered in another paper (Butterfield and Ulian, 2005). However, it is pertinent to point out that genetic engineering has a fairly limited scope, as it is likely to insert only one or a few genes into a clone. Therefore, genetic engineers need clones that are already highly productive but have one or two serious faults. Highly productive cultivars will continue to be produced by conventional sugarcane breeding for well into the future.

Genetic engineering, if the present negative consumer concerns can be overcome, will be a valuable adjunct to conventional breeding if it is able to correct serious faults in promising clones that would otherwise be discarded. Molecular markers have a greater chance of being used in the near future, and they would significantly enhance conventional breeding programs. Molecular markers would be especially valuable when breeding with basic germplasm, so that particular blocks of genes could be readily identified and selected.

REFERENCES


L'AMÉLIORATION VARIÉTALE POUR UNE INDUSTRIE MEILLEURE:
LE BREEDING CLASSIQUE

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MOTS-CLÉS: Amélioration Variétale, Germoplasme, Croisements, Sélection.

Résumé

Le développement continu de variétés améliorées qui répondent aux besoins de l'industrie sucrière mondiale a permis une augmentation soutenue de la production depuis le XIXe siècle. Des variétés sont produites à partir de trois composants : le maintien du germoplasme des parents évalués, la création par croisements de progénitures variées et la sélection des meilleurs génotypes. L'article résume les progrès et les lacunes de ces composants. Les échanges de germoplasme sont facilités par l'adhésion croissante aux normes internationales de quarantaine, en sus des procédures d'importation établies de longue date et qui sont aujourd'hui renforcées par les techniques de diagnostic moléculaire des maladies. L'état précaire des collections mondiales est un souci constant, mais la résilience des industries sucrières à les financer exclut toute critique à l'encontre des institutions hôtes. Dans la majeure partie des croisements, des hybrides de Saccharum existants sont utilisés, en dépit des succès contemporains exceptionnels de l'utilisation du germoplasme de base en Amérique, en Australie et en Louisiane. Les systèmes de contrôle de la photopériode, en particulier dans les tropiques, facilitent les croisements planifiés entre les parents désirés. Faute de pouvoir utiliser tout le potentiel des croisements souhaités, nombre de combinaisons restent inexploitées dans plusieurs programmes d'amélioration variétale. L'évaluation du potentiel des croisements, utilisant uniquement les données des valeurs familiales obtenues dans les essais, a progressé, mais des techniques statistiques plus sophistiquées pourraient améliorer l'estimation du potentiel intrinsèque des parents ; de plus, l'utilisation de la sélection familiale a été bénéfique. Mais la capacité à prévoir les combinaisons génétiques les plus performantes fait toujours l'objet de débats. L'adoption de critères de sélection objectifs a été une avancée considérable et sera dynamisée avec l'utilisation au laboratoire d'analyses plus performantes pour des caractères de qualité. La compétition intergénérique dans des évaluations d'essais à petites parcelles est importante et le dispositif expérimental devrait en tenir compte. Les programmes d'amélioration variétale manquent d'équipements appropriés pour leur évaluation. Les nombreux travaux de recherche sur l'interaction génotype x environnement n'ont pas apporté de
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PALABRAS CLAVE: Mejoramiento Genético, Germoplasma, Polinización Cruzada, Selección.

Resumen

UN ABASTECIMIENTO continuo de cultivares mejorados que los requerimientos de la industria azucarera ha apoyado los incrementos en producción desde el siglo 19. Los cultivares son desarrollados usando tres componentes: se forma una población definida de clones parentales; se generan progenies variables por polinización cruzada; y se seleccionan los clones útiles. Este documento resume los avances y deficiencias en estos componentes. El movimiento de germoplasma se facilita con la adopción generalizada de normas de cuarentena para exportación internacional, adicionales a los procedimientos de importación aceptados desde hace mucho tiempo, los cuales se han fortalecido con los filtrados de patología molecular. El estado precario de las Colecciones Mundiales es una preocupación creciente, pero la reticencia de las industrias azucareras para financiarlas favorece el criticismo de las organizaciones que las tienen. La mayoría de recombinaciones sexuales usan híbridos existentes de Saccharum spp. Esta es la razón de losnotables éxitos contemporáneos con germoplasma básico en Argentina, Australia, y Louisiana. Instalaciones con fotoperiodo regulado, particularmente en los trópicos, están ayudando las recombinaciones planificadas entre clones parentales. Problemas en usar técnicas rigurosas de polinización cruzada implican una baja posibilidad que las progenies de muchos programas sean verdaderas. Las predicciones del desempeño de los cruzamientos usando únicamente información de ensayos de cruzamientos han mejorado, pero técnicas estadísticas más sofisticadas han mejorado las estimaciones de los valores de cruzamiento parental y el uso de selecciones de familia para las poblaciones de progenies ha sido beneficioso. El hecho de que las combinaciones de alto desempeño sean predecibles está aún en debate. La adopción de una selección objetiva fue un gran avance y será reforzada introduciendo análisis de componente de calidad y de alta velocidad. La competencia inter-genotípica en estimaciones de lotes pequeños es importante y el diseño de lotes debería tomar esto en cuenta. Al mejoramiento de caña de azúcar le falta equipo diseñado específicamente para evaluaciones de lotes pequeños. Investigación extensa sobre la interacción Genotipo x Ambiente no ha generado soluciones prácticas y usables que faciliten la colaboración entre los programas. El mejoramiento genético convencional puede aportar soluciones a muchos problemas, pero probablemente no sean la más económicas y la minimización de los criterios de selección para maximizar la ganancia genética es poco comprendida por la industria. Sin embargo, el mejoramiento genético convencional será el sistema principal que genere cultivares mejorados por muchas décadas. Instalaciones de fotoperíodo regulado, índices de selección más sofisticados y estimaciones mejoradas del valor de los cruzamientos lo facilitarán. El sistema será apoyado cada vez más por las técnicas biotecnológicas. La ingeniería genética podrá corregir clones defectuosos de alto rendimiento y podrá permitir la producción de productos de alto valor usando nuevos genes. A pesar de todo, el mejoramiento genético convencional será determinante en generar tales aumentos a la industria y en última instancia, al consumidor.