INITIATIVES TOWARDS MAINTENANCE, IMPROVEMENT AND UTILISATION OF SUGARCANE GERMPLASM IN FIJI

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Abstract

THE SUGARCANE GERMPLASM in Fiji is maintained by Sugar Research Institute of Fiji and it has undergone a major review in 2009 in consultation with Dr. M. Krishnamurthi, ex-director and breeder, Fiji Sugar Corporation Sugarcane Research Centre (FSC-SCRC). The steps taken were identifying varieties of breeding significance based on their parentage and the experience of the consultant; verifying the status of the clones in the existing field collection; restoring and re-planting the clones available; conducting new collections (local and international); importing varieties; and developing parental lines with Erianthus and S. robustum. A total of 3675 varieties (60%) from the total 6108 calculated from the field plans were identified for restoration and 2220 have been re-planted. The remainder will undergo molecular verification by means of DNA fingerprinting before being re-planted. A local collection of noble canes was carried out in 2009 and 76 accessions were planted at the breeding site at Dibuilevu together with 43 S. officinarum clones and 103 wild canes from the Berding and Koike collection of 1977 and commercial hybrid collections. These are being extensively used to make experimental crosses for parental line development, and a total of 828 experimental crosses have been made so far since 2009. Of these, 177 were with Erianthus arundinaceus, and the remainder were with S. robustum and varieties of IJ/IK origin. In addition, 59 backcrosses were made in 2011 using the inter-generic hybrid progeny from experimental crosses made in 2009, and germination tests are underway. On the other hand, 15 varieties have been imported from BSES Limited (Australia) and 10 from MSIRI (Mauritius) via a variety exchange program and will soon be included in the germplasm and breeding plots. The proven progenies from the experimental and backcrosses will also be included in the germplasm to broaden the gene pool. This paper discusses the initiatives taken towards improvement and utilisation of sugarcane germplasm in Fiji, taking special consideration of the achievements and work carried out in the past.

Introduction

Sugarcane has been the dominant agricultural crop in Fiji since 1874 and is of great social, cultural and economical significance. Sugarcane is thought to have originated in Papua New Guinea and the South Pacific islands but it is also possible that it was introduced by the migrating Melanesians in the early times (Brandes in Price and Daniels, 1968).
The first planting of sugarcane in Fiji for commercial purposes was on the small island of Wakaya by David Whippy but it did not achieve much economic significance until the arrival of Colonial Sugar Refining Company Limited (CSR), an Australian company, in the 1870s. Sugarcane has been cultivated on a large scale since then and continues to be the major foreign exchange earner in the agricultural sector.

The first breeding station in Fiji was established by CSR in 1902 at Rarawai, Ba on the island of Viti Levu. This is claimed to be the third cane breeding station to be established in the world, preceded by Java (1880) and Barbados (1888). The initial collections in the record had mostly imported varieties and \textit{S. officinarum} clones from Java and Hawaii to complement the then sugarcane breeding program. The natural germplasm existing in the village gardens consisted mostly of clones of \textit{S. officinarum} which were also collected and maintained at the breeding centre. CSR sponsored collections by Blaxland (1908), Baker (1914) and Jounbert (1921) from Papua New Guinea and Irian Jaya (Krishnamurthi, 1981).

The research centre was moved to Lautoka in 1957 where pioneering work in synchronisation of flowering was carried out by Daniels and Krishnamurthi (1965), which allowed the utilisation of the germplasm. This research made it possible to use the flowers from other species and genera for inter-generic and inter-specific crosses. As a result, CSR ventured into having two major programs to improve the genetic base; the first was where 100 \textit{S. spontaneum} clones were polycrossed and the second was where two \textit{S. officinarum} clones were crossed with eight \textit{S. spontaneum} clones from the above population. Concurrently, \textit{Erianthus procerus} was used for nobilisation and the progenies were found to be far superior to existing hybrids (Krishnamurthi, personal communication, 2011; Daniels and Krishnamurthi, 1965).

Price and Daniels (1968) collected a significant amount of data on sugarcane and related grasses in Fiji by carrying out cytological studies and suggesting availability of germplasm for introgression experiments. Brown \textit{et al.} (1969a) ventured further in studying the quantitative aspect of introgression and hybridisation and presented information on genetic variability in the progeny from inter-specific crosses with \textit{S. spontaneum}. The collections that were carried out by Berding and Koike in 1976 (Berding and Koike, 1980) and Krishnamurthi and Koike in 1977 (Krishnamurthi and Koike, 1980), both funded by ISSCT, were also planted in Fiji and most of the clones are still being maintained. The original collections by the above authors are kept at the world collections in Kannur, India and National Repository Centre, Miami in Florida, USA, supposedly available to sugarcane breeders for germplasm diversification.

Most of the data with regards to germplasm collection, diversification and utilisation during the years CSR owned the program are contained in internal reports held in the Australian Government archives in Canberra. Since 1972, Fiji Sugar Corporation (FSC) continued with the initiatives and strategies undertaken by CSR and also maintained most of the reports, which are now in the Sugar Research Institute of Fiji (SRIF) library. Most of the research came to a standstill after the first coup in 1987 when most of the experienced staff left. In 1993, the germplasm numbers, which were more than 8000 at that time, were reduced based on physical appeal (vigor, growth) and biochemical characteristics (%pocs, %fibre) following recommendations by South African consultant, Dr. Karl Nuss. It is believed that quite a few valuable clones in terms of parentage and pedigree were lost during this exercise.

Since the inception of breeding, Fiji has produced innumerable varieties (sugarcane reports by CSR). During the 1970 to 2000 period, varieties like Vatu (LF51-124), Waya (LF51-182), Spartan (LF53-4040), Homer (LF53-5132), Galoa (LF55-8283), Yasawa (LF56-1368), Vomo (LF56-1551), Mali (LF57-5104), Mana (LF60-3917), Ono (LF00-1237), Kaba (LF62-2810), Aiwa (LF73-229), Beqa (LF73-390) were produced whereas, more recently (2000 onwards), varieties
Naidiri (LF81-2122), LF91-1925 and Kiuva (LF82-2244) were released. Ragnar and Pindar came from the CSR breeding program in Australia. Interestingly, none of these varieties were a result of the introgression initiatives; however, pedigree trees will have to be developed to see any ancestral relationships. Except for Mana (the most dominant variety) and Ragnar and other varieties such as Aiwa, Kaba and the newly released variety LF91-1925, none of the other varieties have performed well in terms of adoption and continuation. It will be conducive to carry out a separate study on the adoption levels of the released varieties as well as their usage in the breeding.

For the past five years, sugarcane breeding in Fiji has been replicating and improving on the work carried out earlier i.e. consistent diversification and utilisation of germplasm in crossing. SRIF, which took over the administration of R&D in 2006, has undertaken consultations from Dr Krishnamurthi who was a breeder and director of sugarcane research in Fiji with CSR and FSC respectively.

Based on the recommendations, the germplasm is being reviewed for its maximum utilisation and, as a result, the sugarcane breeding centre is being shifted to Dobuilevu which is 300 m above mean sea level. This site is approximately 150 km from the present site in Lautoka and is suitable for natural synchronisation of sugarcane flowering. Close to 600–800 clones are made available for flowering based on sugar content, parentage and disease data with 90% of the clones flowering profusely every year (SRIF Internal Reports). This facility will have a crossing house, laboratory and breeding plots all in close vicinity. This paper describes methodologies that were adopted and results obtained, and discusses some of the challenges faced during execution of the project.

Material and methods

Germplasm restoration

The germplasm has been maintained as five sub-collections—Drasa collection, IJ/IK/IS collections, KT/BT collection, JRP collection and Fiji Collection. A review on the 6108 accessions (according to field plans and internal reports) was carried out in consultation with Dr Krishnamurthi. The criteria adopted were the recommendations by the consultant based on experience with the existing material as well as the parental history of the clones. Varieties with the same parentage were critically scrutinised and eliminated, while a few were considered for further evaluation in terms of biochemical analysis (%pocs, %fibre) and disease ratings to be conducted later.

Restoration work was carried out in all the sub-collections by re-defining the plots and roadways (by measuring, pegging and roguing out the volunteers/ cane growing in the roadway), carrying out plot assessments and identifying/ labelling clones earmarked for further review.

Germplasm diversification

The diversification initiative was first undertaken in 2009 when the inter-generic crosses were set and a local collection for noble canes was conducted.

Inter-generic crosses have been set for parental line development in the following order:

1. High-sucrose commercial and near commercial hybrids with *Erianthus arundinaceous* and *S. robustum* (2009),
2. High-sucrose commercial and near commercial hybrids with *E. arundinaceous* and other *Erianthus* species in IJ/IK collection (2010),
3. High brix commercial and near commercial hybrids with *E. arundinaceous*, *S. spontaneum* hybrids from KT/BT and JRP collections and other *Erianthus* species in IJ/IK collection (2011).
A first set of backcrosses was made in the 2011 crossing season using hybrid progeny from 2009 experimental crosses and the crosses are awaiting germination test/ fuzz sowing results.

A local collection of *S. officinarum* was conducted in the Central/ Eastern Viti Levu area from 23 to 26 September, 2009. The route taken was Kings Road from Rakiraki, Dawasamu Road in Tailevu, central Suva, Princess Road, Navua, Naitasiri and Sawani to Nadarivatu via Monasavu. All the collections have been planted at the breeding site at Dobulevu with the noble cane collection that was kept at the Institute. These collections will be assessed for flowering and use in experimental crosses.

With the intention to use the imported varieties also for diversification and introduction of new genes, MOUs have been established with BSES Limited (Australia) and Mauritius Sugar Industry Research Institute (MSIRI) as a result of which varieties have been exchanged.

The imported varieties are presently under quarantine observations and will be included in the germplasm to be used in future for crossing and parental line development.

**Results and discussion**

**Germplasm restoration**

The work done in the five sub-collections to date is presented in Table 1. Based on the total numbers calculated from the field plans, 59% of the total existing germplasm has been restored. The discussions and the challenges that were faced during execution of this initiative are discussed further under appropriate headings.

<table>
<thead>
<tr>
<th>Sub-collection</th>
<th>Collection type</th>
<th>No. of accessions*</th>
<th>No. restored</th>
<th>No. re-planted</th>
<th>% Restored</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drasa</td>
<td>Commercials, backcross progeny, imported varieties</td>
<td>4275</td>
<td>3093</td>
<td>1638</td>
<td>72</td>
</tr>
<tr>
<td>IJ/IK/IM</td>
<td>Erianthus spp./hybrids, <em>S. officinarum</em> imported commercials</td>
<td>1179</td>
<td>103</td>
<td>103</td>
<td>9</td>
</tr>
<tr>
<td>KT/ BT</td>
<td>Inter-specific hybrids</td>
<td>330</td>
<td>237</td>
<td>237</td>
<td>72</td>
</tr>
<tr>
<td>JRP</td>
<td><em>S. spontaneum</em> and its hybrids</td>
<td>324</td>
<td>199</td>
<td>199</td>
<td>61</td>
</tr>
<tr>
<td>Fiji collection</td>
<td><em>S. officinarum</em>, <em>S. edule</em>.</td>
<td>60</td>
<td>43</td>
<td>43</td>
<td>72</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>6108</td>
<td>3675</td>
<td>2220</td>
<td>60</td>
</tr>
</tbody>
</table>

*according to field plans and internal reports*

**Drasa sub-collection**

Maintenance of this sub-collection was severely affected by the introduction of cane harvesters in 2003. It is anticipated that indiscriminate harvesting of the germplasm damaged the plots as well as dispersed the planting material (cane stalks, stools) from one plot to the neighbouring plots/ beds, resulting in dead/ mixed plots which made the field verification and evaluation difficult.

The last known record of this collection being re-planted was during 1991–1993 (FSC-SCRC Annual Reports) whereas such collections are at least re-planted on every 4th crop cycle (ratoon) after carrying out a review on usage and progeny performance from respective parents (Krishnamurthi, personal communication, 2011).
The varieties maintained in this collection are from CSR (MQ, BN varieties), from the Fiji breeding program and collections (LF, FIJI), imported varieties from USA (CP, CL, H), India (Co, CoJ, R), Barbados (B, BJ), Brazil (CB), Arab Republic of Egypt (G), South Africa (NCo), Taiwan (F), Java (POJ), Puerto Rico (PR), Australia (Q), and unclassified/ from discontinued breeding programs overseas (ECP, EK, GQ, GH, MN, NC, NG, P, RP, SE, SL, SN, US).

The restoration work to date has seen a total of 1182 varieties eliminated from the original list – 983 varieties were considered to be of low breeding significance whereas 199 were found to be dead in the field (empty plots).

However, 1638 clones have already been replanted at the new site this will be followed in March–April 2012 by replanting of 1402 varieties, which at present exist as duplicates and triplicates, after DNA fingerprinting has been carried out for verification.

It is intended to re-characterise the replanted varieties based on physical appearance as well as biochemical and disease data. This will be followed by allocation of new ratings for %pocs (same as CCS in Australia) %fibre, flowering, major diseases like Fiji leaf gall (FLG) and downy mildew.

The ratings will be based on results from three consecutive crop cycles i.e. plant, 1st and 2nd ratoons. It is intended to develop a manual as well as a program into the SRIF database which will record such details to assist the breeders in setting further useful crosses. However, additional work will be required to obtain breeding as well as family values. A crossing shed for full sibling crosses is being constructed at the Dobuilevu breeding site under the ACP-EU project that will explore a comparative study on family and individual mass selection methods as early selection criteria. It is understood that these values will have to be upgraded consistently into the database as well as the manual.

**IJ/IK/IM collection**

This sub-collection has the Erianthus spp. and S. officinarum collected from Irian Java (IJ), Kalimantan (IK) and Maluku (IM) in Indonesia by Berding and Koike (1976). This sub-collection is also complemented with imported varieties from Hawaii and Java which were included after planting the collection from Indonesia.

During evaluation of this sub-collection, identifying varieties was difficult as the plots were extensively infested with the wild canes (Erianthus). As a result, it was impossible to find the roadways partitioning the plots so plot by plot assessment and rescue of most of the varieties was impractical. Again this is attributed to inconsistent maintenance and indiscriminate mechanical harvesting which may have resulted in scattering of the planting material.

It was only possible to rescue 103 varieties from alongside the roadways partitioning the beds. These constituted 9% of the total 1179 varieties supposedly present in this collection according to field plans. Mostly, this was done with respect to difference in morphological characteristics so that actual identity of the restored varieties is still vague.

**KT/BT collection**

This collection mostly includes inter-specific hybrids of S. officinarum x S. spontaneum namely Korpi × Tobago and Badila × Tobago as well as other varieties with acronyms BN, BO, BM, KM, KN which are all hybrids between S. officinarum and S. spontaneum. The collection also involves 13 S. spontaneum and its hybrids (Mandalay and SES series).

The varieties that were rescued from this sub-collection are being maintained as single stools and, as shown in Table 1, only 72% of the varieties were resurrected as some of the varieties had died.
**JRP (Joint Research Project) collection**

This collection was established under a Joint Research Project with CSR Macknade and DNPRC (David North Plant Research Centre) in 1964. The population was developed by Krishnamurthi et al. (unpublished data, 1964) by polycrossing some 100 *S. spontaneum* and selecting for sucrose and yield (Brown et al., 1969b). The total according to the field plan is 324 varieties and only 61% of these varieties were restored and planted.

The restored varieties will be used to generate several other genetic combinations with the new germplasm and progeny assessed for commercial significance. It is crucial that phenotypic information in terms of sugar, brix, yield and diseases on each variety is collected as well as breeding values and cross potential. Compiling this information will aid parent selection for future crosses. This will be initiated with commencement of biochemical and agronomic evaluation of the replanted varieties next year and is expected to produce some reliable data by the end of 2015.

**Germplasm diversification**

The major initiatives for diversification of the germplasm are introgression with *Erianthus* spp. as well as varieties from IJ/IK/IM series, importation of varieties and conducting a germplasm collection locally. Rauf et al. (2010) have already shown the importance of diversification in germplasm in breeding. Historically, a lot of work has been done to this effect by M. Krishnamurthi and J. Daniels in the 1950s to late 1970s and 1980s, much of which is contained in internal reports. However, the published work is noted under references and has been quoted consistently in this paper.

The setting of experimental crosses (inter-generic) has been re-introduced into the crossing program since 2009 with the emphasis on parental line development involving introgression. The natural synchronisation of *E. arundinaceous* and its availability during crossing is an added advantage as inter-generic hybrids resulting from these are expected to give commercials in fewer backcrosses (by BC1 or BC2) compared to crosses with *S. spontaneum* and *S. robustum*. (Krishnamurthi, personal communication, 2010).

A summary of experimental crosses and progenies in the last three years is presented in Table 2. The progenies from year 2009 have already undergone selection and 50 of the selections are already in the breeding plots. In 2011, 32% of them have already been utilised in backcrosses during the crossing season (April–July). However, it is important to note that none of these has been tested yet for being a true hybrid. The hybrid populations will undergo visual selection based on vigor and phenotypic features of the wild parent. The DNA will then be extracted and sent to MSIRI where it will be verified using microsatellite markers. More information is expected to become available next year. The progeny from 2010 will undergo selection soon whereas 2011 progeny will be evaluated in 2012.

<table>
<thead>
<tr>
<th>Year</th>
<th>Experimental crosses</th>
<th>No. of seedlings planted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Erianthus spp.</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Others*</td>
<td>Total</td>
</tr>
<tr>
<td>2009</td>
<td>49</td>
<td>28</td>
</tr>
<tr>
<td>2010</td>
<td>73</td>
<td>231</td>
</tr>
<tr>
<td>2011</td>
<td>55</td>
<td>392</td>
</tr>
<tr>
<td>Total</td>
<td>177</td>
<td>651</td>
</tr>
</tbody>
</table>

*S. robustum, S. officinarum, IJ/IK/IS and KT/BT varieties*
The collection and upkeep of *S. officinarum* for use in the experimental crosses for parental development is one other initiative taken by SRIF. There are a total of 119 noble cane accessions at the breeding site including 76 that were collected locally while the remaining 43 are from the collection that has been kept at the Institute for some time.

The collections were planted in 2009 but, unfortunately, they did not flower in the first year and the crop was left un-harvested. Interestingly, 42% of the *S. officinarum* did flower in this stand over crop in 2011 and all of it has been utilised for experimental crosses.

The data on seedling mortality from these crosses will become available at the end of this season while the seedling performance and hybrid verification is expected to take another year.

On the other hand, 15 varieties from BSES, Australia and 10 varieties from MSIRI, Mauritius have been imported under the variety exchange program initiated in 2010 and 2011 respectively to supplement germplasm diversification.

The varieties are currently under quarantine observation and are expected to be included in the germplasm to be made available for crossing by mid-2012.

More work on its utilisation is expected under the ACP-EU project, ‘Nobilisation of *Erianthus* spp.’ whereby several experimental crosses will be made with the *Erianthus* spp. that are to be obtained from germplasm collections abroad (Myanmar, Vietnam, Burma, New Zealand).

Conclusions

The sugarcane germplasm in Fiji has undergone restoration and diversification following the review in 2009 by Dr. Krishnamurthi. Most of the varieties from the existing germplasm have been resurrected and the re-planting is still in progress for some of the sub-collections.

The imported varieties as well as hybrids from the inter-generic crosses are expected to introduce new genes into the existing gene pool hence providing a more diversified germplasm.

However, more work in terms of molecular verification of the hybrids and gathering data on the breeding potentials/ incompatibility patterns as well as parental values will have to be carried out.

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REFERENCES


