OPTIMISING CROP AGE IN THE INITIAL SELECTION STAGES OF THE NSW SELECTION PROGRAM IN AUSTRALIA

By

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Abstract

THE MAIN aim of this project was to obtain the basic information required to implement an efficient and effective breeding and selection program for the sugarcane-growing region of Broadwater, New South Wales (NSW) in Australia, with particular reference to problems associated with mixed one- and two-year cropping. Eighty seedlings from each of 40 families were planted in a family (Stage 1) trial. Two replicates of this Stage 1 trial were harvested as family plots after one year, and compared with two other replicates, which were harvested after two years growth. Twenty clones from forty families (800 clones) also were planted as 4-sett plots in families to simulate Stage 2 trials, and in 10 m plots to simulate Stage 3 trials. In the first ratoon crop of the Stage 2 trials, clonal measurements were taken to estimate the yield potential for each clone. This estimated value was then correlated to the data obtained during harvest of the Stage 2 trials. The results suggested that, in areas where two-year crops predominate, selection should be based on the data from two-year old crops. In addition, there was a strong correlation between the estimated and calculated selection index in both the one-year and two-year Stage 2 crops. However, the correlation between the one-year estimated selection index and the two-year calculated index was not significant. The results also show that family selection combined with visual selection in Stage 2 was generally more effective to identify elite clones in Stage 3 than family selection alone. Additionally, when the Brix of clones was taken into account, the efficiency of identifying elite clones was increased even further. These results have been used in conjunction with other research to rationalise the NSW selection program.

Introduction

In 1992, the Bureau of Sugar Experiment Stations (BSES) was contracted to conduct a selection program for the New South Wales (NSW) sugar industry. However, with limited experience in the NSW sugar industry and with two-year cropping systems, BSES had little information on which to construct a selection program.

Consequently, the initial NSW program was formulated based on selection theories from the one-year cropping experience in Queensland. Although the NSW breeding program had been operational for four years, information from the breeding database was not adequate for assessment of the effectiveness and efficiency of the program, since it is biased by selection. Empirical data necessary to alter or retain the structure of the NSW program was unavailable.

The focus of this project was to optimise the initial selection stages of the NSW selection program, with particular reference to problems associated with mixed one- and two-year cropping. By determining the intensity of family selection that gives the greatest genetic gain from selection, an opportunity may arise either to optimise the selection program or to evaluate more (or fewer) families in NSW.
Materials and methods

Trials were planted in Broadwater, NSW to assess the performance of a range of families and clones in the first three selection stages. Seed from 40 families was germinated at Broadwater in 1993. Twenty original seedlings from these families were planted in the selection (simulating stage 2 trials) and evaluation (simulating stage 3 trials) trials. An additional 80 original seedlings from each of the 40 families were planted at Broadwater. The purpose of these additional clones (stage 1 trial) was to allow an assessment to be made of the ranking of selection of original seedling families as one-year and two-year crops.

The 800 clones (40 families x 20 seedlings) were propagated in 1994 so that the selection and evaluation trials could be run concurrently to eliminate the year effect in the analyses. The year effect, however, was assumed non-existent in all comparisons made between one-year and two-year crops. In order to minimise costs and time, first ratoon crops were harvested as one-year crops for all stages of this project.

Stage 1 trial

Two (of the four) replicates of the additional original seedlings (Stage 1 trial) were harvested as family plots after one year. The family yields of this harvest were compared with the other two replicates, which were harvested after two years growth. Family plots were mechanically harvested and weighed to obtain cane yield (tonnes of cane per hectare, TCH). Sugar content (CCS) was estimated from the juice of eight randomly chosen stalks using standard BSES procedures (Anon., 1984).

TCH and CCS were then used to calculate sugar yield (tonnes of sugar per hectare, TSH) and net merit grade (NMG) (Skinner, 1965) for each family. NMG is a selection index incorporating TCH, CCS, and other important, non-yield, agronomic characteristics such as habit, flowering, diseases, and canopy cover. It is calculated relative to standard cultivars that are adjusted to a mean NMG of 10 (Skinner, 1965).

Stage 2 trial

In spring 1995, the 800 clones were planted as 4-sett (2 m) plots in families (10 clones per family plot), in selection trials at Broadwater. Two replicates from this trial were to be harvested as a one-year crop, while the other two replicates were to be harvested as a two-year crop.

In the first ratoon crop of the one-year and two-year selection trials, clonal measurements were taken on Brix, stalk number, 2-stalk commercial cane sugar (CCS), 2-stalk weight, stalk height, stalk diameter, and visual estimate of yield. The merit of using these Stage 2 clonal measurements to make selection decisions in Stage 3 was assessed.

Stage 3 trial

The evaluation trial containing the 800 clones was planted at the same site as the Stage 2 trials. The clones were planted as individual clones in unreplicated single-row 10 m plots, simulating a Stage 3 trial. Harvest weights were collected, and CCS was determined for each clone using a 2-stalk sample.

Data analysis

Stage 1.

Spearman’s rank correlation test (Conover, 1980) was used to test for significant correlations between the two crop ages of the Stage 1 trial. This correlation test was chosen because it is a non-parametric test and therefore no assumptions are made as to the underlying distribution of the data.

Stage 2

Volume of cane per hectare (VCH) was estimated from the clonal measurements described earlier. An estimate of mass was not considered because it is not feasible to estimate weight of the very small plots (4-sett, 2 m). Field Brix allowed for the calculation of visual grade Brix (VGB), which is an adjusted estimate of the visual grade of each clone, taking into account the difference in Brix between the clone and the standards (Skinner, 1965).

Volume of sugar per hectare (VSH) and a net merit grade value based on the volumetric estimates (NMGVol) also were calculated. These estimated values were correlated (Spearman’s; Conover, 1980) to the yield data (TSH, TCH and NMG) obtained during harvest of the Stage 2 trials.

Stage 3

An evaluation was made of different selection strategies for advancing clones to Stage 3 and for identifying superior clones from Stage 2 using computer simulation. The different selection strategies of (1) family selection (Family), (2) family plus visual selection (Visual), and (3) family plus visual plus Brix (Visual + Brix) were compared. Genetic gain (Stage 2 to Stage 3) was estimated for each crop (P, 1R) and crop age (1 and 2 year) by comparing the mean NMG (in Stage 3) of the top x% of families in Stage 2 with the mean NMG of the Stage 3 trial population.
Results and discussion

Stage 1

The aim of family selection is to identify families with a high frequency of superior clones (Cox et al., 1997; Tai and Miller, 1989; Sukarso, 1986). In NSW areas where two-year crops predominate, superior families are normally selected after two years growth. However, provided there is a good correlation between the performances of families for the two crop ages, selecting superior families after one years growth would expedite the selection process and the identification of superior families.

The mean values for the four traits (TCH, CCS, TSH, NMG) measured over the 40 families are shown in Table 1. The coefficient of variation estimates in this trial ranged from 6% for CCS up to 26% for NMG, which, from previous experience, is typical for such trials in NSW. The performance of original seedling families as one-year and two-year crops was compared by calculating the correlation coefficient (r) using Spearman’s rank correlation test (Table 1). There was a significant correlation between the two crop ages for TCH (P<0.01) and TSH (P<0.05), but not for CCS and NMG. This suggests that family selection based on TCH or TSH could be applied after one year to identify families that perform well after two years growth. However, the practice at BSES is to select superior seedling families based on NMG. These data indicate that the ranking of families for NMG based on a one-year crop is significantly different to the ranking after a two-year crop. It would seem logical, therefore, that in NSW areas where two-year crops predominate, family selection in Stage 1 should be based on the data from two-year old crops. However, the current data set does not indicate whether the two-year crop is indeed the more efficient option. This would require further experimentation to compare the performance of selected families in later stages of selection, and was beyond the scope of this project.

Table 1—Trial mean values for cane yield (TCH), sugar content (CCS), sugar yield (TSH), and selection index (NMG) and the Spearman rank correlation coefficient (r) between one-year and two-year original seedling families.

<table>
<thead>
<tr>
<th>Statistic</th>
<th>TCH</th>
<th>CCS</th>
<th>TSH</th>
<th>NMG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 yr</td>
<td>2 yr</td>
<td>1 yr</td>
<td>2 yr</td>
</tr>
<tr>
<td>Mean</td>
<td>41.2</td>
<td>150.5</td>
<td>13.2</td>
<td>13.1</td>
</tr>
<tr>
<td>SD</td>
<td>5.6</td>
<td>34.9</td>
<td>1.0</td>
<td>0.8</td>
</tr>
<tr>
<td>CV%</td>
<td>14</td>
<td>23</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>r</td>
<td>0.606**</td>
<td>0.106 ns</td>
<td>0.371*</td>
<td>0.298 ns</td>
</tr>
</tbody>
</table>

* P < 0.05, ** P < 0.01, ns not significant.
1 SD = standard deviation.
2 CV% = coefficient of variation.

Visual selection as a predictor of stage 2 performance

Clonal measurements were taken in the first ratoon crop of the one-year and two-year selection trials at Broadwater (Stage 2). The measurements taken on each clone were used to gain estimates of the volume of cane per hectare (VCH), volume of sugar per hectare (VSH), a visual grade adjusted for Brix (VGB), and a net merit grade value based on these volumetric estimates (NMGVol). These estimated values were calculated for each clone planted in the Stage 2 trial. They were then correlated to the yield data obtained during harvest of the Stage 2 trials, as shown in Table 2.

There was a strong correlation between VCH and TCH (P<0.01) for the one-year and two-year crops. Similarly, VSH and NMGVol were strongly correlated with TSH and NMG (P<0.01), respectively, and VGB also was significantly correlated with NMG (P<0.01) for the one-year and two-year crops. Therefore, the estimated values of VCH, VSH, VGB and NMGVol could be used to select for high performing clones in Stage 2. However, for two-year crops grown in Broadwater, visual estimates must be made on a two-year crop, as the correlations between the visual estimates from the one-year crop and the harvest data from the two-year crop were not significant for all traits measured (Table 2).

Genetic gain

One of the aims of this project was to evaluate different selection strategies for advancing clones and identifying superior clones from Stage 2. The three strategies (i.e., family selection, family plus visual selection, and family plus visual plus Brix) were applied to the two-year Stage 2 trial information obtained from Broadwater.
Table 2—Correlation between estimates based on volume and actual performance of clones in Stage 2 trials for Broadwater (BW) one-year and two-year crops.

<table>
<thead>
<tr>
<th>BW visual Stage 2</th>
<th>BW actual Stage 2</th>
<th>Correlation coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>VCH:TCH</td>
</tr>
<tr>
<td>1 year</td>
<td>1 year</td>
<td>0.85**</td>
</tr>
<tr>
<td>2 year</td>
<td>2 year</td>
<td>0.86**</td>
</tr>
<tr>
<td>1 year</td>
<td>2 year</td>
<td>0.25ns</td>
</tr>
</tbody>
</table>

* P < 0.05, ** P < 0.01, ns not significant.

This trial was chosen after an examination of the genetic gains made after selecting from the different crops and crop ages. Genetic gain, as a function of family selection only, was estimated by comparing the mean NMG in Stage 3 of the top x% of families in Stage 2 (for each crop and crop age) with the mean NMG of the Stage 3 trial population (Table 3).

In general, selecting the best families in Stage 2 for all crops resulted in increased genetic gain in Stage 3. However, the greatest genetic gains were made when selection was based on the two-year Stage 2 trial information (Table 3). In addition, there was no real gain in waiting for the first ratoon data of the two-year crop. These results indicate that, in Broadwater, the most suitable crop to select from in Stage 2 is the two-year plant crop, and there is no real need to wait for the first ratoon data before making selection decisions. This is consistent with results from similar trials in the Burdekin region (McRae et al., 1993). Although it was not tested in this project, it is possible that the results would not be consistent if the ratoon was left for two years. However, the main purpose was to determine if a large ratooning effect would make plant crop selection ineffective. The correlation observed between both types of plant crop and ratoon after one year suggested that there were no large ratooning effects.

Table 3—Effect of family selection in the one-year plant (P) and plant plus first ratoon (1R) crops in Stage 2 for NMG, as measured by the performance of those families in Stage 3.

<table>
<thead>
<tr>
<th>Rate of family selection in Stage 2</th>
<th>Gain from selection (%) based on NMG performance in Stage 3</th>
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<tbody>
<tr>
<td></td>
<td>P (1 year)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>15.89</td>
</tr>
<tr>
<td>20</td>
<td>10.12</td>
</tr>
<tr>
<td>30</td>
<td>11.77</td>
</tr>
<tr>
<td>40</td>
<td>2.08</td>
</tr>
<tr>
<td>50</td>
<td>3.55</td>
</tr>
<tr>
<td>60</td>
<td>1.33</td>
</tr>
<tr>
<td>70</td>
<td>4.81</td>
</tr>
<tr>
<td>80</td>
<td>6.47</td>
</tr>
<tr>
<td>90</td>
<td>4.50</td>
</tr>
<tr>
<td>100</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Selection strategies

Family selection in Stage 2 was effective in advancing a high proportion of elite clones to Stage 3 (Figure 1). In addition, the percentage of elite clones identified in Stage 3 from family selection in Stage 2 was consistent up to about the top 40% of families; i.e., the percentage of elite clones identified in Stage 3 increases (from about 11 to 19%) up to 40% family selection in Stage 2. Family selection intensities greater than 40% result in a decreasing percentage of elite clones identified. These results indicate that the top 40% of families should be chosen for advancement to Stage 3 in the breeding program, and are consistent with results from the Burdekin (Kimbeng et al., 2000), Mackay (Kimbeng et al., 2001), and Bundaberg (Cox et al., 1997) regions. However, there is still scope to select elite clones from the lower performing families and this should be taken into account when advancing clones in the selection program.

The results also show that family selection combined with visual selection of individuals was generally more effective in identifying elite clones than family selection alone. Figure 1 shows clearly that, for all rates of family selection in Stage 2, the efficiency of identifying elite clones increases when visual selection also is applied. Additionally, when the Brix of clones was taken into account, the efficiency of identifying elite clones was increased even further.
Conclusions

The results from this research suggest that, in areas where two-year crops predominate, selection from family (Stage 1) and first clonal (Stage 2) trials should be based on data from two-year crops, although further experimentation is needed to clarify this for Stage 1 selection. Estimates of yield and performance can be used to predict the performance of clones in Stage 2. However, the efficiency of using these estimates for advancing clones would need to be assessed, taking into account factors such as time and resource availability for collecting the data needed to calculate the yield estimates. Although the value of family selection in sugarcane has long been recognised (Hogarth, 1971), it can be even more effective in identifying superior clones for advancement if combined with visual selection in Stage 2 and Brix measurements taken from the first ratoon crop.

Acknowledgements

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REFERENCES


L’OPTIMISATION DE LA PÉRIODE DE RÉCOLTE DANS LES ÉTAPES PRÉLIMINAIRES DU PROGRAMME DE SÉLECTION POUR LA NOUVELLE-GALLES DU SUD (NSW) EN AUSTRALIE

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MOTS CLES: Culture Récoltée sur un ou Deux Ans, Indice de Sélection, Sélection Visuelle; Sélection Familiale.

Résumé

Le but principal du projet était d’obtenir les informations nécessaires pour la mise sur pied d’un programme d’amélioration variétale efficace, pour la région cannière de Broadwater en Nouvelle-Galles du Sud (New South Wales) en Australie. L’accent était mis plus particulièrement sur des problèmes liés aux cultures récoltées sur un ou deux ans. Quatre-vingts plantules issues de quarante familles ont été plantées dans un essai d’évaluation familiale au stade 1. Deux répétitions de cet essai ont été récoltées, par famille, après un an et comparées à deux autres répétitions qui ont été récoltées après deux ans de pousse. Vingt clones de quarante familles (800 clones), issus de boutures et regroupés en famille, ont également été plantés pour simuler le stade 2 et dans des parcelles de 10 m pour simuler le stade 3. Des mesures ont été prises sur chaque clone pour estimer leur rendement à la première repousse du stade 2 et cette valeur a été corrélée avec les données obtenues à la récolte du stade 2. Les résultats obtenus suggéraient que, dans les endroits où les récoltes sur deux ans prédominent, la sélection devrait être basée sur les données des récoltes de deux ans. De plus, il y avait une forte corrélation entre l’indice de sélection estimé et celui calculé, autant dans les récoltes d’une année que dans celle de deux ans au stade 2. Cependant, la corrélation entre l’indice de sélection estimé sur la récolte annuelle et bisannuelle n’était pas significative. Les résultats démontrent également que la sélection familiale combinée à la sélection visuelle au stade 2 de sélection, était généralement plus efficace que la sélection familiale simple pour identifier les génotypes prometteurs au stade 3. L’identification des génotypes prometteurs était améliorée avec la prise en considération du Brix. Ces résultats ont été utilisés en même temps que d’autres projets de recherche pour rationaliser le programme de sélection de la Nouvelle-Galles du Sud.
OPTIMIZACIÓN DE LA EDAD DE COSECHA DE LOS ESTADOS INICIALES DEL PROGRAMA DE SELECCIÓN DE NSW EN AUSTRALIA

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PALABRAS CLAVE: Mezcla Uno, Cultivos Bienales; Índice de Selección; Selección Visual; Selección por Familia.

Resumen

EL PRINCIPAL objetivo de este proyecto fue obtener la información básica requerida para establecer un programa eficiente y eficaz de mejoramiento y selección de caña de azúcar para la región de Broadwater, New South Wales (NSW) en Australia, con especial énfasis en los problemas asociados con cultivos de uno y dos años. Ochenta plantulas por cada una de cuarenta familias fueron sembradas en un ensayo de familia (Estado 1). Dos repeticiones del Estado 1 fueron cosechadas como familia al año, en comparación con otras dos repeticiones que fueron cosechadas a los dos años de crecimiento. Veinte clones de cuarenta familias (800 clones) también fueron sembrados en parcelas de 4-trozos en familias, simulando los experimentos del Estado 2, y en parcelas de 10 m para simular los experimentos del Estado 3. Durante la primera saca de los experimentos del Estado 2, se tomaron medidas en los clones que estimaron el potencial de producción de cada clon. Estos valores estimados se correlacionaron con los datos obtenidos durante la cosecha de los experimentos del Estado 2. Los resultados indicaron que en las áreas donde predomina las cosechas de cultivos de dos años, la selección debe estar basada en los experimentos cosechados a los dos años. Además, se encontró una correlación bastante fuerte entre el índice estimado y calculado de selección para las cosechas anuales y de dos años en el Estado 2. Sin embargo, la correlación entre el índice estimado para la selección anual y el índice calculado para los dos años no fue significativa. Los resultados también indicaron que la selección por familia combinada con la selección visual en el Estado 2 fue generalmente más eficaz en la identificación de los mejores clones que la selección por familia en el Estado 3. Además, cuando el Brix de los clones se tuvo en cuenta, la eficacia en la identificación de los mejores clones fue todavía mayor. Estos resultados se han utilizado conjuntamente con otra investigación para racionalizar el programa de la selección de NSW.