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THE INHERITANCE OF ASH IN JUICE FROM SUGAR CANE

by

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SUMMARY

Ash per cent juice data were obtained for varieties within 97 crosses in original seedlings in 1979 and for varieties within 86 crosses from three factorial polycrosses in 1981, on the Bundaberg Sugar Experiment Station.

The data showed that many crosses had higher ash levels than the standard variety Q87. In experiment I, Q87 had slightly lower ash levels than Q109 and Q111, and all three were significantly lower than Q110.

It was found for experiments I and II, that 65 and 54 per cent respectively of the phenotypic variation was associated with genetic characters. As 95 per cent of genetic variation was additive, the prospects for breeding lower ash canes from low ash parents are very good. However, selections based on ash assessment may reject many varieties with other desirable agronomic characters.

Negative correlations existed between ash per cent juice and Brix. However, the correlations were too low to assume that selection for high Brix canes would result in selections with lower ash levels.

CONTENTS

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1. INTRODUCTION

Sulfated ash, normally referred to as ash, is widely recognized as an index of the concentration of inorganic ions in sugar products.

Higher levels of ash are undesirable because of deleterious effects on processing in raw sugar mills and sugar refineries. In the raw sugar mill, exhaustion of molasses is impaired by increasing ash levels due to enhanced solubility of sucrose and increased viscosity of massecuites. Similar problems pertain in sugar refineries where ash can also affect colour of refined sugar through impairment of the decolourizing process due to incorporation of ash on the char matrix. Additional process energy is required to evaporate the required extra washings and to recrystallize sugar made from high ash raw sugar.

Thus ash levels are of importance in the marketing of raw sugar. Ash in raw sugar is of further major significance to Australian raw sugar millers because of its influence on the net titre formula, and the subsequent devaluation of sugar produced.

To date the authors are unaware of any published work which establishes a link between processing techniques in sugar mills and the general upward trend to higher ash raw sugars in several Australian mill areas. Thus attention has been focussed on the agricultural sector in attempts to recognize factors associated with the ash problem.

Leverington et al. (1965) showed that potassium concentrations in cane juice were influenced by soil potassium levels and rates of potassium fertilizer. Prothero (1978) and Kingston and Kirby (1979) established links between salinity of irrigation water (expressed as electrical conductivity) and ash concentrations in juice. Kingston (1982a) showed that the status of soil with respect to salinity and exchangeable plus soluble soil potassium were factors associated with the ash problem in the Rocky Point mill area. Kingston (1982b) has reported that, on average, canes grown on podzolic soil types in several sections of the Isis area, showed significantly higher concentrations of ash in first expressed juice than did canes grown on Krasnozem soils. No reasons for this apparent difference have been advanced.

Stevenson and Daniels (1971) reported large and significant differences in juice conductivity (ash) between crosses and individual sugar cane clones in relatively unselected material in Fiji, and concluded that high ash donor parents can be located and their use in a breeding programme curtailed. However, this assumes that genetic variance is predominantly additive, and such a conclusion is not justified without experimental evidence obtained from an inheritance experiment. Albertsen et al. (1981) showed that significant differences existed between ash concentrations in juice of 18 commercial stage varieties of sugar cane in the Ord River area. Kingston (1982a,b) reported varietal differences in ash levels during studies at Rocky Point and Isis.

The study by Kingston (1982b) in the Isis area showed that there were differences in ash levels between varieties and ecological areas. There was also a significant varieties by areas interaction. Thus, the actual level of inorganic ions accumulated was dependent on factors associated with the growing environment, and the relative ash levels of varieties varied with changing environment.

Thus published research to date has shown that ash levels in cane juice and, it is assumed ultimately in raw sugar, can be influenced by conditions associated with the growing environment and possible genetic differences between varieties of sugar cane. The authors are unaware of any definitive work which could be used by plant breeders to assess the value of selection of parent canes with the view to producing progeny of lower ash levels. This report outlines results of a project based on two experiments which provide new information on the inheritance of ash producing characters in sugar cane.

2. METHODS

2.1 Experimental Methods

2.1.1 Experiment I

This was a preliminary experiment designed to show whether differences existed between crosses for ash levels. Data were collected on the Bundaberg Sugar Experiment Station in July 1979 from original seedlings planted in blocks C_1 and C_2, November 1978. The first 97 from a total of 177 crosses planted to the field were selected for study. Of the 97 chosen crosses, 22 were proven crosses while the remainder were experimental crosses.

A six-stalk sample was cut from each of 10 varieties per cross, along with 10 similar sized samples from the secondary standard varieties Q109, Q110 and Q111. A stool of the primary standard variety Q87 was planted in the centre row of each three-row planting of the crosses. In order to obtain an estimate of environmental variation, 10 six-stalk samples of Q87 were selected from five areas within the portion of the field which supplied the samples described above. A total of 1 050 samples was collected.

Juice samples were obtained after stalks were crushed in a laboratory mill. Electrical conductivity of the juice (mS/cm at 20°C) was determined for each sample along with refractometric Brix at 20°C as measured by a water jacketed dipping refractometer. A 100 mL sample of all juices was frozen. On completion of the crushing operation sulfated ash determinations were made on 121 juice samples which spanned the range of electrical conductivities encountered in juices. These data yielded the following equation for conversion of juice conductivity to sulfated ash:

$$\text{Ash \% juice} = e^{(0.181 \times \text{conductivity mS/cm} - 1.8498)}$$

$$R^2 = 0.95$$

2.1.2 Experiment II

Data for Experiment II were collected in July 1981 from original seedlings planted in November 1980 in the Fiji inheritance experiment in block C_2 on the Bundaberg Sugar Experiment Station. The data were obtained from two field replications of each of three factorial polycrosses. Table 1 shows the number of female and male parents used to establish each polycross, while Appendices B, C and D detail the parents used in the crosses.

Table 1

Numbers of parents used to derive factorial polycrosses

Factorial	Number of female parents	Number of male parents	Number of successful crosses
I	4	5	19^+
II	5	3	14^+
III	7	8	53^+

+ Factorials were incomplete due to germination failures in fuzz. Missing values were estimated by the least squares method.

A six-stalk sample was cut from each of 10 varieties per cross (five per replication) in each factorial and from 15 stools of the standard variety Q87 in each replication. Because seven of the 86 successful crosses were represented in only one replication, a total of 855 rather than the potential of 890 samples were processed.

Juice was extracted from stalks in a laboratory mill after which electrical conductivity and refractometric Brix values were obtained for each sample. As in Experiment I, a sample of each juice was frozen to allow later derivation of an equation to relate juice conductivity to ash per cent juice. The resulting calibration equation based on 102 samples was:

$$\text{Ash \& juice} = 0.126 \times \text{conductivity mS/cm at } 25^{\circ}\text{C} + 0.041$$

$$R^2 = 0.80$$

In both experiments, ash per cent juice was also found as a percentage of Brix, as this is the measure of ash of most importance to sugar mills.

2.2 Statistical and genetical methods

2.2.1 Experiment I

Two statistical analyses were possible:-

(a) The variance of standard plants could be found. This was an environmental variance and had two components - a plant to plant sampling variance (equivalent to sampling variance within a plot) and plot to plot variance (equivalent to a whole plot error variance).

(b) An analysis of variance of the crosses could be performed. Unfortunately, as no replication was used in this experiment, any estimate of genetic variance from the analysis of variance would be confounded with plot to plot error. Consequently, these estimates of genetic variance would be biased upwards, and have been omitted from the report. The analysis could show, however, whether differences between crosses were greater than differences within crosses and, by inference, whether there was much genetic variance for the character being analysed.

2.2.2 Experiment II

As in Experiment I, the variance between Q87 plants was equal to plot to plot variance plus plant to plant variance.

An analysis of variance was performed for each factorial of crosses, and the sums of squares and degrees of freedom for the various sources of variation were added to give a combined analysis. Degrees of freedom and expected mean squares for the combined analysis were:

Source	**d.f.**	**Expected mean squares**
Females, F	13	$\sigma^2_W + 5\sigma^2_E + 10\sigma^2_{MF} + 57.7\sigma^2_F$
Males, M	13	$\sigma^2_W + 5\sigma^2_E + 10\sigma^2_{MF} + 57.7\sigma^2_M$
F X M	57	$\sigma^2_W + 5\sigma^2_E + 10\sigma^2_{MF}$
Error	71	$\sigma^2_W + 5\sigma^2_E$
Sampling	660	σ^2_W

where σ^2_W = within plot variance

σ^2_E = plot to plot environmental variance

σ^2_{MF} = variance component due to male x female interaction $= \frac{1}{4}\sigma^2_D$

σ^2_M = variance component due to differences between males $= \frac{1}{4}\sigma^2_A$

σ^2_F = variance component due to differences between females $= \frac{1}{4}\,\sigma^2_A$

σ^2_D = non-additive genetic variance

and σ^2_A = additive genetic variance

Further $\sigma^2_W = \sigma^2_s + \frac{1}{2}\,\sigma^2_A + 3/4\,\sigma^2_D$

where σ^2_s = plant to plant environmental variance

Genetic variance, $\sigma^2_G = \sigma^2_A + \sigma^2_D$

Phenotypic variance, $\sigma^2_P = \sigma^2_W + \sigma^2_E + \sigma^2_{MF} + \sigma^2_M + \sigma^2_F$
$= \sigma^2_s + \sigma^2_E + \sigma^2_A + \sigma^2_D$

Heritability, $h^2 = \sigma^2_A \,/\, \sigma^2_P$

Degree of genetic determination, $g^2 = \sigma^2_G \,/\, \sigma^2_P$

3. RESULTS

3.1 Experiment I

The means for each cross for Brix, ash per cent juice, and ash per cent Brix are presented in Appendix A.

Means and variances for the standard plots are presented in Table 2.

Table 2

Means and variances for standard varieties for each character in Experiment I

Character	Variety	Mean	Variance
Brix	Q87	18.39	0.3026
	Q109	18.79	0.1617
	Q110	18.53	0.1230
	Q111	18.46	0.2439
Ash per cent juice	Q87	0.461	0.00378
	Q109	0.492	0.00231
	Q110	0.586	0.00315
	Q111	0.491	0.00245
Ash per cent Brix	Q87	2.51	0.1413
	Q109	2.62	0.0883
	Q110	3.17	0.1125
	Q111	2.67	0.0943

Analyses of variance for Brix, ash per cent juice, and ash per cent Brix are summarized in Table 3.

Table 3

Analysis of variance for characters studied in Experiment I

Source	d.f.	Mean square		
		Brix	Ash per cent juice	Ash per cent Brix
Between crosses	96	9.84**	0.0379**	1.865**
Within crosses	873	1.12	0.0077	0.370

** Significant at one per cent level

The phenotypic correlation between Brix and ash per cent juice was equal to -0.25 which is significantly different from zero ($P < .05$).

Experiment II

The means for each cross for Brix, ash per cent juice, and ash per cent Brix are presented in Appendices B, C, and D for the three factorials.

The combined analysis of the three factorials is presented in Table 4 and estimates of genetic statistics are presented in Table 5.

Table 4

Combined analysis of variance of three factorials in Experiment II

Source	**d.f.**	**Mean squares** **Brix**	**Ash % juice**	**Ash % Brix**
Females, F	13	12.4582	.06962	2.5124
Males, M	13	34.7539	.06332	4.2708
F X M	57	3.7387	.01478	0.8804
Error	71	2.4305	.01430	0.6935
Sampling	660	1.1898	.00396	0.2103

Table 5

Variance components and genetic statistics from Experiment II

Statistic	Character		
	Brix	Ash per cent juice	Ash per cent Brix
σ^2_W	1.19 ± .07	.0040 ± .0002	.2103 ± .0116
σ^2_E	0.25 ± .08	.0021 ± .0005	.0966 ± .0231
σ^2_{MF}	0.13 ± .08	.0000 ± .0004	.0187 ± .0199
σ^2_M	0.54 ± .22	.0008 ± .0004	.0588 ± .0272
σ^2_F	0.15 ± .08	.0010 ± .0004	.0283 ± .0161
σ^2_D	0.52 ± .32	.0002 ± .0014	.0748 ± .0795
σ^2_A	1.38 ± .47	.0036 ± .0012	.1741 ± .0632
σ^2_G	1.90 ± .54	.0038 ± .0018	.2489 ± .0942
σ^2_P	2.26 ± .25	.0079 ± .0007	.4127 ± .0362
h^2	0.61 ± .15	.46 ± .12	.42 ± .13
g^2	0.84 ± .17	.48 ± .21	.60 ± .20
σ^2_P (fam)	2.39 ± .53	.0066 ± .0016	.3876 ± .0856
h^2 (fam)	0.58 ± .11	.54 ± .14	.45 ± .13
g^2 (fam)	0.80 ± .06	.57 ± .14	.64 ± .11
GCV[1]	7.85	13.12	18.41

1. GCV = Genetic coefficient of variation.

The mean values for Q87 plants were:

Character	**Mean**	**Variance**
Brix	18.916	0.4315
Ash per cent juice	0.4198	0.002528
Ash per cent Brix	2.226	0.0968

The variance of Q87 plants is equal to $\sigma_E^2 + \sigma_s^2$ (plot to plot variance + plant to plant variance). As explained in section 2.2.2 an estimate of σ_s^2 can be made from the progeny analysis, so that $\sigma_s^2 + \sigma_E^2$ from the progeny analysis and from the Q87 analysis can be compared as follows:

Character	**Progeny analysis**	**Q87 analysis**
Brix	.3567	.4315
Ash per cent juice	.0042	.0025
Ash per cent Brix	.1638	.0968

This agreement is only fair, but this is not unusual with this type of comparison.

Genotypic, phenotypic, and environmental correlations between Brix and ash were estimated for the three factorials, and these results are presented in Table 6.

Table 6

Genotypic (r_G), phenotypic (r_P), and environmental (r_E) correlations between Brix and ash per cent juice for the three factorials in Experiment II

Factorial	**Correlation**		
	r_G	r_P	r_E
I	-.43 ± .22	-.44 ± .09	-.51 ± .17
II	-.72 ± .23	-.61 ± .09	-.38 ± .23
III	-.06 ± .25	-.16 ± .06	-.38 ± .12

4. DISCUSSION

4.1 Comparison of crosses with standards

If the means for crosses (Appendices A to D) are compared with the means for standard varieties (Tables 2 and text), it may be seen that many crosses have higher levels of ash per cent juice than Q87, but relatively few have lower ash levels. In the Isis ash study, Kingston (1982b) found that Q87 had average levels of ash, although samples from the Ayr station showed that Q87 had low ash levels relative to other Isis varieties. In Experiment I, Q87 had slightly lower ash levels than Q109 and Q111 and all three were significantly lower than Q110 (Table 2).

The crosses used in Experiment I were a sample of proven and experimental crosses and would have been fairly representative of the total seedling population at Bundaberg. For Experiment II, the parent varieties used were chosen virtually at random, and could be considered to be representative of the Meringa parent collection.

Thus, the scarcity of crosses with mean values for ash per cent juice (or ash per cent Brix) lower than Q87 is not encouraging. It indicates that varieties are more likely to be selected from crosses with higher levels of ash than Q87 than from crosses with lower levels of ash. It is some consolation that most crosses in Experiment I had lower levels of ash than Q110, so selected varieties are likely to have ash values between Q87 and Q110, although a small proportion of varieties will have lower ash levels than Q87 and a similar proportion will have higher ash levels than Q110.

There was variation between varieties within crosses, so cross means were not necessarily indicative of the ash levels of individual varieties. However, the statistically significant differences between crosses in both experiments showed that difference in ash levels are due to genetic differences between crosses (and therefore, varieties), and the values for degree of genetic determination (Table 5) suggest that the differences are repeatable.

In each experiment, the cross with the highest ash level had about twice as much ash as the cross with the lowest ash level. Thus, there is a good range of ash values. This is necessary if progress is to be made from selection.

4.2 Mode of Inheritance

In Experiment II, it was possible to compare the relative magnitude of the additive and non-additive components of genetic variance. For Brix, 73 per cent of the genetic variance was additive. This is identical with the result found by Hogarth (1977) and similar to the result found by Hogarth et al. (1981) with an Hawaiian population. For ash per cent juice, 95 per cent of the genetic variance was additive and, for ash per cent Brix, 70 per cent was additive. Thus, for both ash and Brix, genetic effects were mostly additive.

The significance of this result is that, if genetic variance is mostly additive, performance of crosses can be predicted from the performance of parents. If non-additive genetic variance predominates, progeny testing is necessary, as it is impossible to predict the performance of a cross from the performance of the parents. It should be feasible to predict, with some confidence, the relative ash per cent juice and ash per cent Brix of crosses if the values for the parent varieties are known. Thus, it is desirable to establish the relative ash values of all parent varieties in the collection. Low-ash progeny could be produced by choosing low-ash parents, but the most efficient breeding programme would also involve progeny testing, as many high-ash parents would continue to be used because of good performance for other characteristics.

4.3 Gain from selection

In order to make gains from selection, it is necessary that there be sufficient genetic variability, and there needs to be a high degree of genetic determination.

A good measure of relative genetic variability is the genetic coefficient of variation which is the ratio of the genetic standard deviation to the general mean, expressed as a per cent. For Experiment II, these values are tabulated in Table 5. It may be seen that the coefficient for ash per cent juice is almost twice as high as that for Brix, and the coefficient for ash per cent Brix is even higher.

The degree of genetic determination measures the relative importance of genetic and environmental effects in the expression of a character. The higher the value, the greater will be the potential gain from selection. The closely related statistic, heritability, is based on the additive component of genetic variance, and is appropriate if seedlings are being selected for a subsequent cycle of breeding. The degree of genetic determination is appropriate if varieties are being selected for clonal propagation.

Theoretical gains from selection can be estimated from the formula:

$$\Delta G = i\, g^2\, \sigma_P$$

Where ΔG = gain from selection

i = selection intensity
= 1.4 if 20% of population selected

g^2 = degree of genetic determination

σ_P = phenotypic standard deviation

Gains from selection for the three characters studied in Experiment II are presented in Table 7. For the purposes of comparing relative effectiveness of selection, these gains have also been expressed as a per cent of the general mean. In Table 7, it has been assumed that individual varieties were being selected, not crosses.

Table 7
Gains from selection for each character in Experiment II

Character	g^2	σ_P	General Mean, GM	ΔG	100 ΔG/GM
Brix	0.84	1.50	17.57	1.76	10.04
Ash per cent juice	0.48	0.0888	0.470	0.060	12.72
Ash per cent Brix	0.60	0.6424	2.71	0.540	19.91

The results in Table 7 show that selection for ash per cent Brix, but possibly not ash per cent juice, would be relatively more effective than for Brix. However, these results must be kept in perspective. It has been assumed that the 20 per cent of varieties with the lowest ash values have been selected, ignoring all other characters. Even so, the reduction in ash per cent juice was only 0.06. The selected population would then have a slightly lower average ash value than Q87 but at the cost of rejecting a large proportion of varieties with desirable agronomic traits. To determine the effect on other characters it is necessary to estimate genetic correlations between ash and other characters. Data for estimating these correlations will become available.

4.4 Correlation of ash and Brix

From Experiment II, it was possible to estimate genotypic, phenotypic and environmental correlations. For Factorials I and II, the genotypic correlations were negative and quite high, but in Factorial III which was the largest, the genotypic correlation was very low. In Experiment I, the phenotypic correlation between the two characters was -0.25.

Further evidence on the genotypic correlation between Brix and ash per cent juice was provided by a replicated variety trial on Bundaberg station in 1979. This trial included 45 varieties and three replicates, so it provided a good estimate of the genotypic correlation which was found to be -0.30 ± .15. The phenotypic correlation was -0.27 ± .05.

The available evidence shows that the correlation between Brix and ash per cent juice is negative. The value of the correlation is uncertain, but is probably about -0.30. This is a favourable correlation because it means that selection for high Brix tends to favour the selection of low ash varieties. The correlation is too low for this trend to be of much value for selecting against high ash, but it does mean that, if selection for low ash varieties becomes necessary, this would not result in all high Brix varieties being discarded.

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APPENDIX A

Means for Brix, ash per cent juice, and ash per cent Brix in Experiment I

CROSS	BRIX	ASH % JUICE	ASH % BRIX
58C756 x CP49-50	20.00	.379	1.90
59C879 x Co331	16.46	.466	2.84
59C879 x Co954	18.20	.436	2.41
59C879 x CP43-47	18.42	.454	2.49
59C879 x CP44-101	18.06	.489	2.74
59C879 x CP50-11	17.36	.431	2.48
62C366 x 63B47	17.23	.438	2.55
62C366 x CP50-11	17.54	.512	2.96
62C366 x F134	17.58	.479	2.73
62C366 x 61N1232	16.48	.465	2.84
62C366 x Vesta	17.68	.493	2.81
62C383 x B49119	17.51	.442	2.55
62C383 x CP43-47	18.26	.456	2.51
64C386 x 63B47	17.10	.559	3.29
64C386 x Co331	15.60	.517	3.35
65C152 x F134	17.52	.560	3.22
65C152 x 61N1232	17.53	.566	3.26
66C126 x Co954	18.13	.407	2.25
CADMUS x CP53-19	19.19	.478	2.49
Co331 x 63B47	15.64	.624	4.00
Co331 x 62C366	15.88	.533	3.37
Co331 x Co6501	16.67	.531	3.20
Co954 x CP63-588	18.00	.476	2.67
Co954 x 60S7473	17.14	.498	2.92
Co1001 x CP50-11	16.95	.572	3.44
Co1001 x F151	17.54	.552	3.16
Co1001 x R397	17.14	.447	2.62
Co1007 x Co331	15.78	.473	3.04
Co1007 x H52-246	16.55	.531	3.22
Co1007 x 61N567	16.99	.464	2.73
Co1007 x 61N1232	16.55	.448	2.74
Co1148 x CP33-372	15.99	.618	3.90

CROSS	BRIX	ASH % JUICE	ASH % BRIX
Co6602 x CP50-11	17.31	.588	3.40
Co6602 x F151	17.36	.612	3.56
Co6602 x H52-246	16.31	.513	3.16
Co6602 x Q93	17.45	.487	2.80
CP45-184 x 33MQ371	17.75	.562	3.21
CP49-50 x Co331	16.24	.650	4.04
CP50-11 x Q58	16.38	.531	3.26
CP50-11 x 63S782	16.12	.563	3.54
CP51-21 x Q93	18.80	.457	2.45
CP51-21 x 60S7473	18.94	.434	2.31
CP52-68 x F134	17.42	.515	2.97
CP55-14 x CP49-50	17.98	.518	2.91
F144 x Co1001	18.05	.465	2.59
F144 x CP43-47	18.28	.503	2.75
F144 x CP44-101	18.42	.539	2.94
F144 x R397	18.48	.573	3.13
H44-3382 x 61N567	17.44	.428	2.46
H49-104 x Q99	17.21	.522	3.04
L56-7 x CP49-50	17.14	.745	4.37
L56-7 x CP53-19	16.85	.646	3.86
54N7096 x CP50-11	16.31	.508	3.15
54N7096 x Q68	17.44	.448	2.58
60N795 x 59S55	17.71	.471	2.70
60N795 x 60S7473	16.04	.538	3.40
60N795 x 63S782	17.01	.449	2.65
60N1853 x CP44-101	17.50	.563	3.23
60N1853 x CP53-19	16.45	.587	3.58
60N1853 x H49-3666	17.46	.478	2.76
60N1853 x MQ71-5	16.74	.462	2.78
60N1853 x MQ71-24	16.76	.515	3.09
60N1853 x 61N567	17.88	.452	2.54
60N1853 x Q99	17.33	.646	3.74
60N2111 x 62C366	16.67	.514	3.11
60N2111 x Co6501	17.28	.516	3.01

CROSS	BRIX	ASH % JUICE	ASH % BRIX
60N2111 x 59S55	18.05	.521	2.91
60N2111 x 63S229	16.31	.551	3.39
60N2179 x B49119	15.68	.580	3.75
60N2179 x 54N7096	15.77	.467	2.98
60N2179 x 61N567	17.14	.509	3.01
60N2179 x Q58	16.91	.556	3.33
61N567 x Vesta	18.07	.568	3.19
61N1184 x 63S782	16.86	.456	2.73
61N1854 x Co331	15.93	.524	3.30
62N1659 x B49119	17.28	.578	3.37
62N1659 x CP50-11	18.01	.585	3.25
62N1659 x CP53-19	19.24	.484	2.54
62N1659 x H49-3666	18.27	.471	2.58
62N1659 x H50-3511	17.73	.571	3.28
63N1700 x CP43-47	18.74	.549	2.95
63N1700 x CP50-11	18.14	.593	3.29
64N2990 x CP43-47	18.74	.560	3.02
65N2693 x MQ71-45	17.38	.584	3.38
NCo310 x 63B47	18.14	.567	3.14
NCo310 x Co1007	18.34	.574	3.14
NCo310 x CP44-101	18.45	.551	3.00
NCo310 x CP53-19	19.19	.525	2.75
NCo310 x CP63-588	19.49	.488	2.52
NCo310 x 54N7096	19.08	.446	2.35
NCo310 x 61N567	18.83	.535	2.86
NCo310 x 62N1659	18.77	.499	2.67
Q117 x 63B47	18.12	.575	3.18
Q117 x Co331	17.74	.558	3.18
Q117 x MQ71-24	18.24	.562	3.14
Q117 x 61N567	19.06	.490	2.59
Q117 x 59S55	19.46	.479	2.49
Mean	17.51	.519	3.00

APPENDIX B

Means for Brix, Ash per cent juice, and ash per cent Brix in Factorial I, Experiment II

(a) Brix

	Male					Female
Female	63B46	64B41	62BN2629	BN65-5671	Co6606	Mean
Co270	15.13	16.05*	18.54	16.73	17.98	16.88
F144	17.59	17.32	19.27	18.98	18.52	18.34
62S7585	16.51	16.74	18.13	18.16	19.29	17.76
66S7111	17.67	17.88	18.84	18.11	19.19	18.34
Male mean	16.72	17.00	18.69	17.99	18.74	17.83

(b) Ash per cent juice

	Male					Female
Female	63B46	64B41	62BN2629	BN65-5671	Co6606	Mean
Co270	.564	.686*	.529	.564	.539	.577
F144	.487	.737	.498	.602	.586	.582
62S7585	.479	.603	.503	.483	.417	.497
66S7111	.458	.566	.485	.523	.470	.501
Male mean	.497	.648	.504	.543	.503	.539

(c) Ash per cent Brix

	Male					Female
Female	63B46	64B41	62BN2629	BN65-5671	Co6606	Mean
Co270	3.83	4.21*	2.87	3.40	3.01	3.46
F144	2.77	4.31	2.61	3.20	3.23	3.22
62S7585	3.49	3.61	2.79	2.68	2.16	2.95
66S7111	2.62	3.24	2.60	2.90	2.48	2.77
Male mean	3.18	3.84	2.72	3.04	2.72	3.10

* Missing cross-value estimated by least squares method.

APPENDIX C

Means for Brix, ash per cent juice, and ash per cent Brix in Factorial II, Experiment II

(a) Brix

	Male			Female
Female	Co1007	CP44-101	CP50-11	Mean
CB56-20	16.29*	17.62	15.94	16.62
H64-852	17.75	17.72	16.83	17.43
H66-8912	16.65	18.01	16.91	17.19
LF71-4738	17.11	18.50	17.15	17.59
63R47	17.04	18.43	17.47	17.65
Male mean	16.97	18.06	16.86	17.29

(b) Ash per cent juice

	Male			Female
Female	Co1007	CP44-101	CP50-11	Mean
CB56-20	.500*	.425	.574	.500
H64-852	.492	.483	.561	.512
H66-8912	.554	.495	.521	.523
LF71-4738	.423	.481	.444	.449
63R47	.471	.402	.490	.454
Male mean	.488	.457	.518	.488

(c) Ash per cent Brix

	Male			Female
Female	Co1007	CP44-101	CP50-11	Mean
CB56-20	3.11*	2.43	3.62	3.05
H64-852	2.78	2.77	3.34	2.96
H66-8912	3.37	2.77	3.10	3.08
LF71-4738	2.50	2.61	2.59	2.57
63R47	2.78	2.20	2.81	2.60
Male mean	2.91	2.56	3.09	2.85

* Missing cross-value estimated by least squares method.

APPENDIX D

Means for Brix, ash per cent juice, and ash per cent Brix in Factorial III, Experiment II

(a) Brix

	Male								Female
Female	CP57-526	CP53-5	63B46	CP44-101	F141	68S1208	Vesta	CP53-19	Mean
62BN2465	17.17	16.26	16.81	17.93	17.78	18.81	17.17	16.47	17.30
LF67-761	15.90	16.37	16.48	18.58	17.09*	19.10	18.55	17.76	17.48
68S75	17.21	17.99	17.02	18.40	17.63	19.00	17.60	19.55	18.05
64B26	16.54*	14.97	16.27	17.49*	16.21	19.16	17.50	17.58	16.96
CP45-184	18.04	17.70	17.46	18.04	17.25	18.75	18.82	18.05	18.01
J59-3-81-14	16.87	17.82	16.63	18.65	16.92	17.97	18.40	17.63	17.61
75N1685	18.19	16.66	16.03	17.53	17.28	19.06	17.97	17.26	17.50
Male mean	17.13	16.82	16.67	18.09	17.16	18.83	18.00	17.75	17.56

(b) Ash per cent juice

	Male								Female
Female	CP57-526	CP53-5	63B46	CP44-101	F141	68S1208	Vesta	CP53-19	Mean
62BN2465	.508	.448	.441	.439	.399	.401	.435	.537	.451
LF67-761	.463	.433	.431	.468	.416*	.392	.377	.426	.426
68S75	.432	.516	.439	.435	.447	.491	.487	.417	.458
64B26	.426*	.468	.451	.416*	.451	.365	.435	.421	.429
CP45-184	.454	.505	.586	.446	.471	.499	.516	.471	.494
J59-3-81-14	.426	.409	.430	.377	.373	.404	.420	.376	.402
75N1685	.351	.455	.401	.406	.453	.424	.406	.457	.419
Male mean	.437	.462	.454	.427	.430	.425	.440	.444	.440

(c) Ash per cent Brix

	Male								Female
Female	CP57-526	CP53-5	63B46	CP44-101	F141	68S1208	Vesta	CP53-19	Mean
62BN2465	2.98	2.79	2.64	2.47	2.25	2.15	2.55	3.28	2.64
LF67-761	2.96	2.67	2.63	2.57	2.47*	2.06	2.06	2.44	2.48
68S75	2.51	2.87	2.58	2.38	2.53	2.60	2.78	2.13	2.55
64B26	2.65*	3.25	2.80	2.46*	2.81	1.92	2.50	2.40	2.60
CP45-184	2.55	2.86	3.41	2.50	2.76	2.66	2.77	2.62	2.77
J59-3-81-14	2.55	2.31	2.60	2.02	2.21	2.28	2.30	2.15	2.30
75N1685	1.94	2.75	2.51	2.35	2.63	2.24	2.28	2.70	2.42
Male mean	2.59	2.78	2.74	2.39	2.52	2.27	2.46	2.53	2.54

* Missing cross-value estimated by least squares method.