

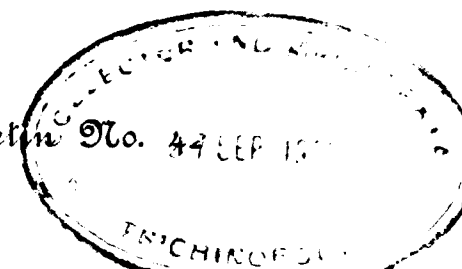
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Agricultural Research Institute, Pusa

Notes on Cane Crushing in the United Provinces

BY

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Notes on Cane Crushing in the United Provinces.

To be able to form a reasonably accurate judgment of a variety of sugar cane and of the possibility of its succeeding as a field crop in any tract, it is necessary to possess accurate information on a number of points based on observations made in the field, in the laboratory, and in the mill. It is necessary to observe in the field the general crop characters; in the laboratory the sugar content and quality of the juice, and in the mill what proportion of the juice and total sugar can be extracted, and the cost of doing so.

These points are of equal importance in successful cane cultivation. It is of no special advantage to handle an enormous weight of cane, if the juice is of poor quality, and it is of no use selecting a cane because of the abnormally high sucrose content of its juice, if the amount and nature of the fibre is such that it is impossible to extract a good proportion of it.

It thus often happens that the most profitable cane is one which presents no exceptional features in any one respect, but a combination of moderately good qualities.

The behaviour of sugar cane, when subjected to pressure between the iron rollers of the mill for the purpose of extracting the juice may be conveniently termed the "milling property." This property is the resultant of several factors and can be determined.

It is proposed to discuss in this bulletin some observations on this point which have been made during the last three years at the Experiment Stations at Partabgarh and Shahjahanpur.

It is obvious to any one who has observed the local conditions during the cane harvest that crushing by bullock power imposes a very severe strain on the cultivator's resources, and acts probably more than any other cause against a large extension of the area under cane in these provinces. With the price of up-country gur at the present rates, it is unlikely that there will be any immediate increase in the number of factories manufacturing white sugar in the Upper Doab. The prospect of any increase in their number at any time is small, unless the area under cane is considerably extended.

Any increase in area will be gradual depending in the authors' opinion, on the introduction of some cheaper and quicker way of dealing

with the produce for the manufacture of gur, within the reach of the smaller landholders and co-operative societies. The present crop is as much as the bullock power of the provinces can deal with, and the area will not increase permanently to any appreciable extent unless some cheaper form of crushing than bullock power is introduced.

It will be pointed out later on that many of the canes of the United Provinces can yield a high proportion of their total sugar on crushing in powerful bullock mills, but at a cost in bullock power that is entirely beyond the reach of every-day agricultural practice. A considerable impetus would be given to the extension of the area under cane if a suitable small power mill for crushing cane for gur manufacture could be introduced. It is not necessary to aim immediately at the high extraction and efficiency obtained in the large mills of factories equipped with modern plant; or of countries where the sugar industry is highly organised. An extraction no higher than that given by the best type of bullock mill, would be sufficient; but it is essential to deal with the produce at a reasonable rate and at a reasonable cost, and to relieve the cultivator of the strain resulting from the present system of crushing by bullock power.

In considering the question of crushing, the following terms are used which need some explanation:—

(a) Extraction.

(b) Juice expressed per 100 cane.

(a) Extraction means the percentage of the total cane sugar or sucrose in the cane that passes into the juice on crushing, or the sugar extracted per 100 parts of total sugar in the cane.

(b) Juice expressed per 100 cane is the weight of juice obtained from 100 parts by weight of cane—a figure obtained in these experiments by direct weighing.

When cane is crushed, it is divided into two parts, juice and bagasse, or khoya, which is used afterwards as fuel for evaporating the juice. Both the juice and bagasse contain sugar, and the object of cane growing and crushing, whether for the production of gur or the manufacture of white sugar, is to get as much juice, and as little bagasse as possible, and to see that little sugar is left in the bagasse.

A numerical example will probably make the meaning of the term extraction clear to those readers, who are not familiar with the terminology of sugar manufacture. 100 mds. of a certain variety of cane, on crushing in a 3 roller bullock mill, yielded 75 mds. of juice containing

15.5 per cent. of sugar or sucrose, and 25 mds. of bagasse or khoya containing 6.4 per cent. sucrose.

100 mds. cane = 75 mds. juice containing $\frac{75 \times 15.5}{100} = 11.6$ mds. sugar.

100 mds. cane = 25 mds. khoya containing $\frac{25 \times 6.4}{100} = 1.6$ mds. sugar.

100 mds. cane contained 11.6 + 1.6 mds. sugar = 13.2 mds. sugar.

Of the total 13.2 mds. sugar 11.6 mds. or $\frac{11.6 \times 100}{13.2}$ per cent. or 87.9 per cent. had passed into the juice on crushing, and was available for sugar or gur making, and $\frac{1.6 \times 100}{13.2}$ per cent. or 12.1 per cent. was left in the bagasse, or khoya, and lost. In this case the extraction was 87.9, that is 87.9 per cent. of the total sugar in the cane had been extracted in the juice. The juice expressed per 100 of cane was 75.

In sugar factories, employing plant of modern design, the cane is passed through what are really a series of different mills, and the bagasse, before being finally burnt, is mixed or macerated with warm water (varying in amount according to the conditions) and again crushed. By this means some sugar is washed out of the bagasse, and a very high extraction can be secured. The average figure published by the mutual control of Java Factories for 10 years is over 90.

With the exception of the cane used by factories, which, at the present time, are few in number, the cane grown in the United Provinces is crushed by bullock mills of various designs and efficiency, some with 3 rollers, and some with 2 rollers.

From the statements made above it will be seen that with single dry crushing (that is crushing as practised by the cultivators using iron bullock mills, without macerating the bagasse with water), the extraction obtained depends on—

(1) the quality of cane.

(2) the quality of the bagasse or khoya.

If the cane contains a large amount of fibre, the quantity of juice will be proportionately less, and the quantity of bagasse greater. In addition to the quantity of fibre, the quality or kind of fibre is an important factor in determining the amount of juice retained in the bagasse. This was pointed out by Somers-Taylor (Bulletin 37, Agricultural Research Institute, Pusa), who examined the bagasses of the different varieties in the collection of canes at Sahour. For any one variety of cane with the same kind of fibre the quality of the bagasse, in the case of single crushing, depends entirely on the mill.

The following treatment of the subject makes the point clear :—
If

f = weight of fibre per unit weight of cane ;

m = weight of fibre per unit weight of bagasse ;

x = weight of bagasse per unit weight of cane ;

the total juice per unit weight of cane = $1 - f$

the expressed juice per unit weight of bagasse = $1 - x$

the juice left in unit weight of bagasse = $1 - m$

the juice in x parts of bagasse or the juice left in bagasse per unit weight of cane = $x(1 - m)$

the total juice in the cane = the expressed juice + the juice left in the bagasse.

$$1 - f = 1 - x + x(1 - m)$$

$$x = \frac{f}{m}$$

In canes with the same kind of fibre, the quantity of bagasse obtained on single crushing will be small when the fibre (f) in the cane is small, and fibre in the bagasse (m) is large, that is, when a good cane is well crushed. The quantity of bagasse will be large when the fibre (f) in the cane is large and the fibre (m) in the bagasse small, that is, when a poor cane is badly crushed.

Many factors have to be taken into consideration in determining the value of a cane for any particular locality, such as, yield of sugar per acre, period of ripening, etc., but amongst them the extraction obtained on single dry crushing is important.

Different varieties of cane vary in the amount of fibre they contain, and the quality of bagasse they yield, and consequently in "extraction," which is the resultant of these two factors. Taylor (*loc. cit.*) has pointed out that the variation in the quality of the bagasse is probably due to differences in the nature and structure of the compound celluloses, that make up the tissues or fibre of different varieties of canes, and may be a definite character of certain varieties. This is a distinct advance on our present conceptions, and will be of great use in valuing canes. The quantity of fibre in the cane is of equal importance. These factors, the quality of the bagasse, and the fibre content of the cane, find expression in the term "extraction," which can be also calculated from the formula

$\frac{m-f}{m(1-f)}$ where f is the fibre per unit weight of cane, and m the fibre per unit weight of bagasse. This combined factor expressing both the quality of the bagasse yielded on single dry crushing under definite con-

ditions, and the fibre content of the cane, will probably prove the most useful of any in assigning relative values to new cane varieties from a milling point of view.

As far as the authors are aware no comparative tests of canes grown in the United Provinces have been made with reference to their behaviour on crushing in a 3 roller iron bullock mill, nor has the quantity of cane crushed per hour, and the extraction obtained by the use of the latter mills been determined under conditions of strict chemical control. These are important points in determining the price at which it would become profitable to sell canes to factories.

The experiments conducted at Partabgarh and Shahjahanpur during the last three seasons have given a large number of results, from which information on these points can be obtained. The work was carried out with one of the best type of 3 roller bullock-driven mills on the market, with 8" rollers manufactured in India, and costing Rs. 110. The method of experiment was (1) to crush in five mills working simultaneously a certain weight of cane, slightly over two tons for each variety examined, (2) to weigh the juice and determine the amount of sugar (sucrose) in it, (3) to sample the bagasse from each mill and to determine the sucrose in it at intervals of one hour.

From these data the extraction can be calculated. The detailed figures of each experiment are not published, but an explanation of two is given here to make the method of calculation clear. Taking Reora of Benares, an indigenous variety very popular in the eastern districts and Ashy Mauritius, a variety imported, the following figures were obtained :—

Name of cane.	Weight of cane crushed each sample (lbs.).	Weight of juice obtained (lbs.).	Juice expressed per 100 cane.	Sucrose in juice per cent.	Sucroso in bagasse per cent.	Bagasse per 100 cane.
Reora	1434.0	859.0	59.9	9.65	..	..
	988.0	598.0	60.5	9.86	..	..
	1183.0	743.0	62.8	9.72	..	..
	1524.0	947.0	62.1	9.29	..	..
	5129.0	3147.0	61.3 (over age)	9.60	5.4	38.7
Ashy Mauritius	1715.5	1280.0	74.6	16.09	..	..
	1688.0	1254.0	74.2	15.31	..	..
	1824.5	1347.0	73.8	15.31	..	..
	1452.0	1064.5	73.3	14.80	..	..
	6680.0	4945.5	74.0 (over age)	15.39	6.4	26.0

The extraction is calculated as follows :—

(1) In the case of Reora—

100 parts cane=61·3 parts juice= $\frac{61\cdot3 \times 9\cdot6}{100}$ parts sucrose=5·88 parts sucrose.

100 parts cane=38·7 parts bagasse= $\frac{38\cdot7 \times 5\cdot4}{100}$ parts sucrose=2·09 parts sucrose

100 parts cane=7·97 parts sucrose, of which 5·88 parts, or 73·8 per cent., were extracted in the juice. The extraction was 73·8 per cent., and the juice expressed per 100 cane 61·3.

(2) In the case of Ashy Mauritius—

100 parts cane=74·0 parts juice= $\frac{74\cdot0 \times 15\cdot39}{100}$ parts sucrose=11·39 parts sucrose.

100 parts cane=26·0 parts bagasse= $\frac{26\cdot0 \times 6\cdot4}{100}$ parts sucrose=1·66 parts sucrose.

100 parts of cane=13·05 parts of sugar of which 11·39 parts or 87·2 per cent. were extracted in the juice. The extraction was 87·2 per cent., and the juice expressed per 100 cane 74.

The results calculated in this manner are recorded in the following tables :—

1911-1912.

Variety.	Juice expressed per 100 of cane.	Sucrose in 100 parts of juice.	Bagasse per 100 parts of cane.	Sucrose per 100 parts of bagasse.	Sucrose extracted per 100 sucrose in cane.
Ashy Mauritius	71·2	15·58	28·8	6·5	86·0
Katara	70·0	12·30	30·0	4·7	86·0
Khari	67·4	13·11	33·6	4·5	85·7
Saretha	64·2	13·12	35·8	4·9	83·3
Sonabelli	65·5	14·26	34·5	5·8	82·6
Chin	63·5	14·19	36·5	5·5	81·9
Pansari of Ghazipur	67·4	11·41	33·6	5·7	80·9
Reori of Benares	64·2	11·76	35·8	5·3	80·3
Reora of Benares	68·0	13·96	32·0	7·8	79·7
Saranti of Partabgarh	65·0	11·41	35·0	5·4	79·6
Momeha of Basti	65·1	12·68	34·9	6·2	79·3
Mango of Shahganj	64·8	13·18	35·2	6·6	79·0
Mutna of Cawnpur	66·2	10·33	33·8	5·6	78·6
Dhaur of Azamgarh	65·1	13·07	34·9	6·9	78·0
Reora of Gorakhpur	65·0	14·21	35·0	8·1	76·5
Kewahi of Benares	61·9	11·85	38·1	5·9	76·4
Hemja of Gorakhpur	62·7	15·47	37·3	8·1	76·3
Charkhai of Azamgarh	64·4	10·67	35·6	6·1	76·3
Saranti of Basti	60·8	12·70	39·2	6·8	74·2
Kuswar	63·4	11·16	36·6	7·0	73·7

1912-1913.

Variety.	Juice expressed per 100 parts of cane mean of 4 determinations.	Sucrose per 100 parts of juice mean of 4 determinations.	Bagasse per 100 parts of cane mean of 4 determinations.	Sucrose per 100 parts of bagasse.	Sucrose extracted per 100 sucrose in cane.
Ashy Mauritius	74·0	15·39	26·0	6·5	87·2
Khari of Dumraon	65·0	10·12	35·0	3·7	83·5
Sonabelli of Dumraon	64·5	11·38	35·5	4·5	82·1
Katara of Sultanpur	66·8	7·36	33·2	3·8	79·5
Saretha of Aligarh	58·7	12·70	41·3	4·7	79·3
Mutna of Cawnpur	61·3	8·81	38·6	4·3	76·4
Dhaur of Azamgarh	60·6	11·21	39·4	5·8	74·8
Ramgol of Allahabad	59·8	11·24	40·2	5·7	74·6
Mango of Shahganj	61·1	10·59	38·9	5·8	74·2
Reora of Gorakhpur	61·3	9·60	38·7	5·4	73·8
Kuswar of Partabgarh	60·8	9·77	39·2	5·4	73·7
Pansari of Ghazipur	61·4	11·33	38·6	6·7	72·9
Reora of Benares	60·5	9·33	39·5	5·6	71·9
Hemja of Gorakhpur	60·0	9·44	40·0	5·7	71·3

An exceedingly high order of extraction was obtained, and at first sight it might be assumed, that such high values could not be given by mills in which the rollers are working vertically. If, however, the facts (1) that a very small amount of cane is crushed, and (2) that the rollers revolve very slowly are considered, there is no reason why these mills which are exceedingly easily adjusted, should not be efficient. The cost of crushing is an entirely different matter. The slow rate at which cane can be crushed, and the large amount of bullock power required,

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makes the cost of crushing high. It is doubtful for single dry crushing if any type of mill will extract a larger proportion of sugar, but the cost of crushing can be probably lowered by the use of some other form of power, and the bullocks at present employed freed for other work connected with tillage operations.

Somers—Taylor (*loc. cit.*) has determined the fibre in the cane and bagasse of varieties grown at the Sabour Farm, using a similar type of mill. From these results the extraction can be calculated from the formula $1.03 \left(\frac{m-f}{m(-1f)} \right)$ mentioned in the preceding pages. It is interesting to note that the values thus calculated are of the same order, and show the same variations between varieties, as those obtained by an entirely different method at Partabgarh and Shahjahanpur.

The milling property as expressed by the extraction is an important factor in determining the value of a cane, but it is one of several, and, because a cane gives a high extraction, it must not be assumed that it is suitable in all respects. In the seasons 1911-12 and 1912-13, the following varieties gave the highest extraction :—

Ashy Mauritius,
Kacara (Sultanpur),
Kheri,
Saretha,
Sonabelli.

Only two of these, Ashy Mauritius and Saretha, are good field varieties in the Upper Doab. The good milling properties of the latter variety accounts doubtless, for some of its popularity in the gur-producing districts of the West. The other three varieties are somewhat difficult to grow and liable to the attacks of pests of various kinds. Reora of Benares, a very popular cane in the Eastern districts, in an average year, gives a rather low extraction; but a good yield of cane and a good juice, and, although it does not stand out in any one particular respect, a combination of qualities makes it a desirable cane for those parts.

The figures given in the above table show, beyond reasonable doubt, that a very high order of extraction can be secured if the best type of 3 roller bullock mill is working properly. For single dry crushing it is doubtful if it could be exceeded by any type of mill. To secure this the strain on the bullocks is great throughout the crushing season, and the rate of crushing is slow.

[Such a high efficiency cannot be maintained for any length of time by the cultivators with their light, and very often under-fed cattle. An examination of the bagasse from village mills makes it only too evident that efficiency has to be sacrificed, and the mill loosened, to enable the crushing to be done at all. The juice expressed per 100 of cane by the cultivators does, of course, reach anything like the high figure recorded in these pages. It varies greatly. This is the result not so often of bad cane or bad mills, but of insufficient power to use the mills at their full efficiency.]

During the progress of the work at Partabgarh in 1913, records were kept of the amount of cane crushed daily from five mills running simultaneously, each mill with two pairs of bullocks working in shifts of two hours each. Typical results are given in the following table :—

Variety.	No. of mills.	No. of bullocks.	Time (hours).	Weight of cane crushed. (lbs.)	Weight of cane of cane per mill per hour. (lbs.)	Weight of cane of cane per mill per hour. (mds.)
Saretha	5	20	6	4,360	145.3	1.76
Chin	..	..	..	4,448	148.2	1.77
Sarauti	..	..	7.5	5,424	144.3	1.75
Ashy Mauritius	..	..	6	4,508	150.2	1.83
Sonabelli	..	..	8	5,336	133.4	1.62
Sarauti	..	..	9	5,480	121.8	1.48
AVERAGE	..	..	..	..	..	1.70

Further tests were carried out in the season 1913-14 at Shahjahanpur to ascertain the amount of cane crushed, and the extraction obtained, in the 3 roller iron bullock mill used at Partabgarh with a variety widely grown in the Rohilkhand Division known as Dikehan. The cane was of average quality.

The results of two days' work with one mill are given in the following tables :—

3 roller iron bullock mill 8" rollers.

Experiment I.

Time hours.	Weight of cane crushed. (lbs.)	Weight of juice. (lbs.)	Juice expressed per 100 cane.	Sucrose per 100 juice.	Bagasse per 100 cane.	Sucrose per 100 bagasse samples taken every hour.	Cane crushed per mill per hour. (Mds.)	Extraction.
						7.1		
						7.1		
						7.3		
						7.3		
						7.2		
						7.8		
						7.9		
6	1276.5 (15.5 mds.)	856.5	67.1	15.57	32.9		2.58	81.1
				AVERAGE.		7.4		

Experiment II.

						7.3		
						7.3		
						7.4		
						7.4		
						7.3		
						7.0		
						7.5		
8.5	1740 (21.1 mds.)	1157.5	66.5	15.00	33.5		2.48	80.1
				AVERAGE.		7.3		

The test recorded in the preceding tables was carried out under experiment station conditions, with heavy bullocks and the best type of mill that could be procured. The mill was frequently adjusted and every effort made to secure the most favourable conditions. They are of interest as showing what is possible with United Provinces canes.

In order to obtain some indication of the possibilities of smaller types of iron mills in use in the neighbourhood, a mill with 6" rollers was hired in the village of Deoria, and the owners were asked to bring it

to the farm with two pairs of their own bullocks, and to crush a mata of juice. The best mill in the village was not selected; one that appeared to be an average one was taken. The owners of the mill came to the farm with 3 somewhat light bullocks and a buffalo, and fixed up the mill. They were given 10 maunds of cane to crush and left to their own devices with the exception that care was taken to see that the juice was taken to the balance without loss, and weighed, and sampled as usual. The results of two days' work are given in the following tables :—

Smaller type of 3 roller iron bullock mill 6" rollers.

Experiment I.

Time hours.	Weight of cane crushed. (lbs.)	Weight of juice. (lbs.)	Juice expressed per 100 cane.	Sucrose per 100 juice.	Bagasse per 100 cane.	Sucrose per 100 bagasse samples taken every hour.	Cane crushed per mill per hour. (Mds.)	Extraction.
						7.7		
						8.5		
						8.6		
						8.3		
						8.3		
						8.0		
5.5	823.0 (10 mds.)	489.5	59.4	16.11	40.6		1.81	74.2
				AVERAGE.		8.2		

Experiment II.

						7.7		
						7.7		
						7.7		
						7.9		
						7.9		
						7.4		
5.75	880.0 (10.7 mds.)	534.0	60.0	15.65	40.0		1.86	75.3
				AVERAGE.		7.7		

The extraction obtained by the Deoria cultivators with their small 6 inch roller iron mill was good, though less than that obtained with the

heavier mill and bullocks of the Experiment Station. It is a reasonable supposition that, stimulated by their surroundings at the farm, the mill owners would give an extra turn or two to their adjustment, and that the extraction was therefore higher than obtained in every day practice. This experiment is of interest because it shows that even with the lighter mills a reasonable extraction can be obtained if the necessary power is available.

It may be mentioned that in these tests particular attention was paid to the sampling of the bagasse. Samples were collected from the mill at intervals of an hour in a box specially designed to prevent drying, and at once reduced to a fine and uniform state of sub-division in a bagasse sampler. The whole operation from the mill to the balance not taking more than 10 minutes. The results of the bagasse analysis as seen from the above table are in close agreement. The slightest variation in the bearing of the mill could be detected at once.

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