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Objective Measurement on the South African Wool Clip Part I: Sampling in Port Elizabeth Port

by

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OBJECTIVE MEASUREMENT ON THE SOUTH AFRICAN WOOL CLIP

PART I: SAMPLING IN PORT ELIZABETH PORT

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ABSTRACT

Sixteen types of wool (Spinners, Top-makers etc.) represented by 264 bales, were cored and measured for Clean Wool content and Fibre Diameter. Estimates of within bale (σ_w) and between bale (σ_b) variations are made. Sampling schemes to give a precision of ± 1% for yield and of ± 0,5 micron for diameter are proposed. A measure of the reproducibility of each test method and an estimate of the yield variation from root to tip of the staple are given.

KEY WORDS

Clean Wool Content – Yield – Diameter – Greasy Wool – S. African Wool – bales – lots – types – Roots – Tips – Staples – Airflow – Scouring – Coring – Analysis of Variance – Correlation – Precision within bale – between bale.

INTRODUCTION

The annual South African wool clip forms about 10% of the Western world clip. It represents 5–6% of the gross domestic product. Its value which fluctuates widely from year to year was about 160M Rand for the 1972 season.

Wool is sheared, and packed into bales of about 150 Kg which are generally sold by public auction. Marketing this product is becoming more and more exacting in the highly competitive markets. At present wool is in great demand although this has not always been the case.

To meet the challenge of synthetic fibres the marketing of raw wool is changing, and new techniques are evolving. Synthetic fibres are marketed with the backing of many quality control and objective measurements, from the raw materials to the final fibre or yarn end product. Raw wool producers, or their representatives, must be able to give similar quality assurances on their product. There are pressures at work forcing changes, pressures such as the narrowing of acceptable limits, demonstration of the accuracy of quality values, availability of assessors, etc.

As with many arts and crafts, subjective working, be it the carving of wood or the assessment of wool quality, is not able to meet fully the demands of the present industrial and commercial world. The need for objective measurement and characterisation of raw wool has been recognised for many years. Decisions taken by such bodies as the I.W.T.O. are being implemented gradually throughout the world. Many investigations into methods of characterisation and comparisons between methods are being made (Australia, United Kingdom, New Zealand and South Africa)[1, 2, 3].

It is accepted that the main properties of raw wool which reflect its quality or usefulness are the *diameter of the fibre* and the *amount of clean wool in the raw material.* It has been estimated by investigators[4, 5] that 80% of the price of wool is controlled by these two properties, for which the I.W.T.O. has developed standard methods[6, 7, 8].

For centuries man has used the wool from the sheep to make life more comfortable for himself. He has learned to recognise the many different qualities in the fleeces. Organisation has evolved whereby the producer sorts the sheared wool into types and packs it into bales. Bales of similar type are grouped into lots and are then offered for sale. The product used by industry is thus the commercial package, the bale of wool. The more uniform the material and the more clearly identified it is the better will be the product from a marketing point of view. Of further note at this stage is that, theoretically, any variation within a bale, variations of fibres within a fleece or between fleeces in that bale should be under the control of the farmer.

Bales are collected at a central point, the broker's warehouse, and offered in lots of similar type. To sell these efficiently selected bales from each lot are assessed subjectively by skilled appraisers who examine the contents of the bale and give a quality mark, or type, which reflects among other attributes, the diameter and length, and yield values. From these assessments the expected monetary value of each lot is estimated. Individual lots are then sold to industry by auction. The average lot size per type of the S.A. wool clip is about 3–4 bales. The variation within these lots, i.e. between bales, though it results from the farmer's initial grouping into lots, could be under the appraiser's control. Lots are not made up by the general collecting into that lot of bales having the same quality but by rejecting from a farmer's supply of bales those whose quality is different. The lot unit in this sense is the farmer unit.

Recognition of these facts is not new. The efficiency or uniformity with which a bale is made up can be and has been measured by σ_W (within bale), which is the standard deviation of the values obtained from measurements of samples drawn at random from a bale of wool. Likewise the uniformity of the compiled lots can be measured by σ_b (between bale). It is a reasonable assumption that the quality of the wool in every part of a bale will have a normal distribution or can be adequately represented by a normal distribution. Knowing that the tip region of a wool fibres can give a yield 20% lower than the roots and have different diameters and recognising that the coring tool can by chance select such different sections, some caution must be exercised. Samples taken must be representative. When measuring variation within a bale we are in effect looking for a measure of the uniformity of the staples, not incomplete fibres. Perfect uniformity would be derived from perfectly uniform and identical fleeces. Providing that the core sample represents as many roots as tips, the sample will be acceptable. If more roots, or tips are taken, by chance an incorrect value of σ_w will be obtained. The probability of this happening is low, but it must nevertheless happen occasionally. High, or low values for σ_w can be expected and possibly not too infrequently.

In general σ_w is a measure of how effectively the farmer sorted his fleeces and how uniform each skirted fleece was. Similarly σ_b is a measure of how successful the lot compiler was in his efforts to produce perfectly uniform lots.

Values for σ_w and σ_b for the yield of the S.A. clip have been measured in the past. According to A.S.T.M.[9] values of 1,5% and 4,0% for σ_w and σ_b were found. Bownass and Hamilton obtained values for σ_w varying from 1,2% to 1,9% and for σ_b varying from 0,9% to 7,5%. They noted that their results, obtained to date, revealed some differences from ASTM values. Note is made here of this reference because of the values found in our work.

For the policy, being pursued in S.A. on the marketing of wool, to be successful it is essential to know the existing situation. To make recommendations for adequate sampling procedures of the S.A. clip so that objective measurement may be carried out efficiently it is essential to determine current values for σ_w and σ_b. The work reported here deals with core samples collected in the Port Elizabeth port from the 1972 wool clip.

EXPERIMENTAL

Material

A total of 57 lots of wool were selected from the offerings in Port Elizabeth brokers' stores between catalogue 1 and catalogue 21 of 1972. The number of bales per lot varied from 3 to 12, the average being 4½. These 57 lots covered a range of 16 different wool types. Six types were represented by single lots only, nine were represented by five different lots while in one case the number of lots was six. The 16 different wool types comprised five types of spinner's style fleeces, nine types of topmaking fleeces and two types of bellies and pieces. All these types were classed as having a diameter in the range of 21 to 22 microns.

Each of the 264 bales comprising the 57 lots of wool were sampled with a mechanical coring tool of one inch diameter bore. Two cores were taken from the cap and two from the butt of each bale, the regions being well spaced from each other in each case. The core sample from each bale had a mass of approx. 45g and was sealed in a plastic bag for storage and subsequent testing.

TABLE I

DESCRIPTION BY SUBJECTIVE ASSESSMENT OF THE MATERIAL USED

TYPE	LENGTH mm	DIAMETER μ	DESCRIPTION
9	75-90	22	Spinners Style, Skirted, Practically free, 60/64's
13	60-75	21	Spinners Style, Skirted, Practically free, 64's
CB9	75-90	21,5	Spinners Style Skirted, slight Burr and/or seed 62/64's
CB19	50-60	21,5	Spinners Style, Skirted, slight Burr and/or seed 62/64's
B19	50-60	22	Spinners Style, Skirted slight Burr and/or seed 62/64's
48	75-90	21	Good Topmaking 64's
53	60-75	21	Good Topmaking 64's
58	50-60	21	Good Topmaking 64's
C59	50-60	21,5	Good Topmaking 62/64's
A95	45-55	21	Average Topmaking 64's
A93	50-60	22	Average Topmaking 60/64's
92	50-60	21	Inferior Topmaking 64's
95	45-55	21	Inferior Topmaking 64's
93	50-60	22	Inferior Topmaking 60/64's
A113	50-60	21-	Bellies & Pieces – Combing burr and/or seeds 64+
114	45-55	21-	Bellies & Pieces – Combing burr and/or seeds 64+

Test Procedures

The I.W.T.O. Clean Wool content of each core was determined using the method described in IWTO-19-71(E). The usual qualities A_i, E_i, T_i etc were also determined. The Appendix F procedure for Vegetable Matter Content and Total Alkali-Insoluble Impurities was not strictly followed. Instead of identifying each type of vegetable impurity and applying an appropriate (recommended) correction factor, a single factor of 1,33 was used for all vegetable matter.

Fibre diameters of each core were measured using the Airflow method after randomising the fibres on the Shirley Analyser as recommended by James and Bow[15]. The airflow instrument had previously been calibrated with a range of scoured merino wools whose diameters had been determined by a projection microscope. A more detailed description of the procedures is given in the standard method IWTO(E)-1-71(E). Two samples per core and three measurements per sample were made.

REPRODUCIBILITY OF TEST PROCEDURES

(a) Clean Wool Content

The procedure to determine the Clean Wool Content is destructive in the sense that the test piece can not be retested. It is important to be able to be assured that the test procedure is reproducible, would give virtually the same value on a re-test if this were possible. To give an indication of this reproducibility the following investigation was made.

From a typical bale, portions of fleeces whose staples were easily identifiable were selected. The clean root portion (about half of the staple) was cut from each staple. The collection of about 300g of clean roots was cut into shorter lengths (approx 1 cm), thoroughly randomised by hand, and randomly sampled into six portions. Their clean yield was determined, and gave a mean value of 60,2% with a standard deviation of 0,204%. The tip portions of these staples gave a yield of about 40%.

The implication of this value of 0,2% for the standard deviation is that the clean wool content of one core can be measured and be known to be in the range ± 0,4%. Strictly this applies only to a series of cores measured sequentially on the same day.

The reproducibility of the test method could be better than 0,2% since this value could reflect true differences between the six samples tested. On the other hand, later in this report results obtained from cores tested at different times when larger variations in test procedures could be expected will be compared. A value of 0,2% for the standard deviation can be a useful guide to the reproducibility of the test procedure.

This value of 0,2% can be compared with the values of 0,25%, 0,55%, 1,30% given by Douglas and McIntyre[11], noting however that these are not measures of exactly the same quantity.

(b) Diameter

The measurement of diameter being a non-destructive test it was possible to estimate the reproducibility of the procedure from the three repeat measurements made on the test pieces used in this work. A value for standard deviation of about 0,08 micron was obtained. The diameter of one test sample, tested three times, was therefore known to ± 0,10 micron. Differences larger than this must be attributed to causes other than the test instrument and operator.

TABLE 2a

FULL HIERARCHICAL ANALYSIS OF VARIANCE

SOURCE OF VARIATION	Degrees of Freedom	QUANTITY ESTIMATED BY MEAN SQUARE
Between Bales (b.B)	n – 1	$\sigma^2_t + 3\sigma^2_s + 6\sigma^2_c + 12\sigma^2_p + 24\sigma^2_b$
Within Bales, b. Position (W.B.b.P)	n	$\sigma^2_t + 3\sigma^2_s + 6\sigma^2_c + 12\sigma^2_p$
Total W.B.b.P.	n.2–1	
Within B.P., between Cores (W.B.P.b.C)	2n	$\sigma^2_t + 3\sigma^2_s + 6\sigma^2_c$
Total W B P b C	n.2.2. – 1	
Within B.P.C., between Samples (W B P C.bS)	4n	$\sigma^2_t + 3\sigma^2_s$
Total W B P C b S	n.2.2.2. – 1	
Within B.P.C.S. between tests (W B P C S b T)	16 n	σ^2_t
Total W B P C S b T	n.2.2.2.3 – 1	

where n = number of bales in a lot
σ_t = standard deviation due repeat testing
σ_s = standard deviation due purely to repeat sampling
σ_e = standard deviation due purely to repeat coring
σ_p = standard deviation due purely to Cap and Butt position
σ_b = standard deviation due purely to bale to bale variation

METHOD OF ANALYSING THE RESULTS

A hierarchical Analysis of Variance procedure was adopted for each property measured. This enabled an estimate to be made of the size of the variation that could be attributed to various identifiable causes.

The first series of analyses used the results from each lot. For each particular lot, values were calculated for the variation, expressed as standard deviation, attributable to:–

between bales,	σ_b	(both yield and diameter)
between positions, (i.e. between Cap and Butt)	σ_p	(both yield and diameter)
between cores,	σ_c	(both yield and diameter)
between samples	σ_s	(diameter only)
between tests,	σ_t	(diameter only)

Table 2a shows an example for the diameter property.

As the main object of the work was to obtain the between bales and within bales variation (σ_b and σ_w) values for σ_w were derived by suitably combining.

(i) σ_p and σ_c from the yield property results

(ii) σ_p, σ_c, σ_s, σ_t, from the diameter property results

In fact the Analysis of Variance table for this purpose was a simple "between" and "within" bales analysis. Table 2b illustrates.

Later, Analysis of Variance tables of results from each complete type were formed. This enabled an estimate of the variation between lots within one type to be made.

TABLE 2b

ANALYSIS OF VARIANCE WITHIN AND BETWEEN BALES

SOURCE OF VARIATION	Degree of freedom	QUANTITY ESTIMATED BY MEAN SQUARE
Between bales	n – 1	$\sigma^2_w + 24\sigma^2_b$
Within bales	23n	σ^2_w
Total	24 n – 1	

where σ_w = standard deviation of results from "within" a bale
σ_b = standard deviation of results from bale to bale (within one lot)

RESULTS AND DISCUSSION

Table 3 shows mean yields for each lot, within and between bales variation and the ± 95% Conf. Limits for each lot. The type order listing is the quality order (Spinners, Topmaking, Bellies and Pieces) as shown in Table I.

The order in which the results are presented is not the order in which they were tested. The type order was different. The lot order within a type was nearly the same as the testing order.

Table 4 shows similar information to Table 3. These values were obtained from the Analysis of Variance tables, analysed by types. Here a value for σ_ℓ which is a measure of the variation between lots, is given. Of course, where only one lot per type was tested no estimate of σ_ℓ could be made. Tables 5 and 6 show the results obtained for diameter.

The 95% Confidence Limits for the means given in tables 3 and 5, derived from σ_w and σ_b, are given by

$$\pm\ 2\left[\frac{\sigma_w^2 \ + \ n.\ \sigma_b^2}{n.b}\right]^{\frac{1}{2}}$$

where n = number of tests per bale
b = number of bales per lot

Strictly, instead of using the factor 2 the factor t (student's t) should have been used. It was considered that 2 was sufficiently close to "t" to simplify the computation and that the practical effect would be negligible.

Confidence limits can also be placed on the estimated values for σ_w and σ_b. The many values for σ_w, and for σ_b given in these tables may be reduced to a few average values if, by using the Variance Ratio or F-test justification can be obtained. This test considers the ratios of pairs of values of σ_w squared, taking into account the number of observations on which each is based. If their ratio exceeds that given in the tables then the two values can be considered to be different. An F-value, for this work, of about 3 for the ratios of σ_w squared (9 for σ_b) can be used. Hence the ratio of any pair of σ_w values must exceed square root of 3 to be considered different. As a σ_w of 1,7 is not different to a σ_w of 3 nor is this different to a σ_w of 5,1, it would be reasonable to use the average of these σ_w values which are in the range of about 1,7 to 5,1 (or a range of 1 to 3 or of 0,5 to 1,5).

The following table lists these ratios and ranges for σ_w and σ_b, for each property.

PROPERTY	**CLEAN WOOL**		**DIAMETER**	
	Ratio Range	**Linear Range**	**Ratio Range**	**Linear Range**
σ_w	2 x 1,75	1,7 to 5,1	2 x 1,2	0,4 to 0,6
σ_b	2 x 3,0	0,5 to 4,5	2 x 3,0	0,2 to 1,5

TABLE 3

ANALYSIS BY LOTS – CLEAN WOOL CONTENT

TYPE	LOT	TOTAL NOS. OF BALES	% IWTO CLEAN WOOL CONTENT	σ_w	σ_b	95% C.L. OF MEAN ±	T_i %
9	334	3	59,0	3,12	0,79	2,0	1
	336	4	59,1	3,59	3,94	4,3	2
	476	5	58,9	2,90	2,80	2,8	2
	535	3	58,0	3,22	1,52	2,6	1
	677	3	57,9	3,28	2,25	3,2	1
13	235	4	62,6	1,99	1,98	2,2	1
	288	4	54,8	3,08	1,50	2,1	1
	592	7	58,7	2,56	1,30	1,4	1
	669	3	57,8	3,30	0	1,9	1
	772	4	69,2	2,36	1,81	2,2	0
CB9	459	3	59,4	3,39	0	2,0	1
CB19	31	10	63,3	2,60	0	0,8	1
B19	20	8	68,6	2,65	0	0,9	1
48	264	6	65,4	3,47	2,36	2,4	1
	430	7	57,8	3,06	1,83	1,8	1
	498	12	59,7	3,32	1,68	1,4	2
	502	12	58,8	2,43	1,47	1,1	1
	511	9	62,7	2,65	1,83	1,5	2
53	263	3	62,1	3,94	2,86	4,0	2
	273	4	59,1	1,99	1,83	2,1	3
	649	7	60,5	3,32	1,63	1,8	3
	662	4	59,8	3,16	2,01	2,6	2
	776	3	57,6	3,01	0	1,7	1
58	333	3	69,2	4,88	0	2,8	2
	453	3	63,9	3,14	2,10	2,1	1
	553	6	62,2	4,99	0	2,9	11
	655	3	60,4	2,90	1,32	2,3	2
	800	3	64,8	1,44	0	0,8	3
C59	13	6	64,5	1,51	0	0,6	1

Table 3 (cont.)

TYPE	LOT	TOTAL NOS. OF BALES	% IWTO CLEAN WOOL CONTENT	σ_w	σ_b	95% C.L. OF MEAN ±	T_i %
A95	42	5	71,1	1,57	0	0,7	0
A93	17	5	57,5	2,64	0,54	1,3	4
92	247	3	55,4	1,83	0	1,1	2
	317	3	44,0	2,94	2,10	3,0	2
	516	3	55,7	3,22	0	1,9	2
	520	3	53,3	3,09	1,75	2,7	1
	555	5	44,6	3,40	0	1,5	4
95	77	3	52,6	3,46	0	2,0	1
	248	4	52,3	2,90	1,60	2,2	3
	521	3	45,7	2,39	1,54	2,3	3
	561	4	46,6	1,83	0	0,9	2
	688	4	33,1	2,58	0,6	1,8	5
93	61	3	41,7	2,97	2,68	3,5	6
	325	3	42,9	8,28	4,23	6,8	11
	382	4	43,9	2,80	0	1,4	4
	437	3	47,5	2,55	3,51	4,3	9
	515	4	63,6	8,02	0	4,0	2
	550	4	43,9	2,73	2,50	2,8	2
A113	232	5	53,6	3,12	0	1,4	4
	362	5	61,4	2,91	1,34	1,8	2
	525	4	56,0	1,60	2,10	2,2	8
	540	4	56,3	2,52	0	1,3	3
	622	4	62,1	1,88	1,62	1,9	3
114	325	3	50,8	2,86	6,25	7,4	13
	348	3	55,1	1,70	0	1,0	2
	369	6	51,1	1,51	1,52	1,4	10
	473	9	56,0	2,16	0	0,7	8
	686	3	56,0	2,39	0	1,4	3

TABLE 4

ANALYSIS BY TYPES – CLEAN WOOL CONTENT

TYPE	NOS. OF LOTS	TOTAL NOS. OF BALES	% IWTO CLEAN WOOL CONTENT	σ_w	σ_b	σ_ℓ	95% C.L. OF MEAN ±	T_i %
9	5	18	58,6	3,22	2,27	0	1,30	1
13	5	22	60,5	2,68	1,43	5,5	11,2	1
CB9	1	3	59,4	3,39	0	–	2,0	1
CB19	1	10	63,3	2,60	0	–	0,8	1
B19	1	8	68,6	2,65	0	–	0,9	1
48	5	46	60,5	2,97	1,78	2,68	2,5	1
53	5	21	59,9	3,19	1,92	0	1,09	2
58	5	18	64,1	3,68	1,18	2,66	2,6	4 (1 bad lot)
C59	1	6	64,5	1,51	0	–	0,6	1
A95	1	5	71,1	1,57	0	–	0,7	0
A93	1	5	57,5	2,64	0,54	–	1,3	4
92	5	17	49,9	2,92	1,63	5,5	5,0	2
95	5	18	45,7	2,69	0	8,1	7,3	3
93	6	21	47,7	5,22	2,48	8,48	7,1	6
A113	5	22	57,8	2,52	2,07	3,88	3,6	4
114	5	24	54,0	1,93	2,19	2,37	2,33	7

Examination of σ_w for each lot (clean wool yield)

Values for σ_w in the range 1,7 to 5,1 or 1,7 times the mean, cannot be considered to be different. On this basis the lots within each type gave consistent values of σ_w with three exceptions. Type 93 lots 515 and 325 gave σ_w greater than 8,00, type C59 lot 13 gave σ_w = 1,51 and type A95 lot 42 σ_w = 1,57, the latter two being single lot types.

For the other 13 types therefore the values for σ_w given in Table 4 may be considered to be representative of those types.

As these values for σ_w for types are based on more observations (degrees of freedom), differences of only 1,5 times can be judged to be different. Again the same three types show significant differences. The values for the other 13 types, being "not different", can therefore be pooled. If the high type 93 is omitted the best estimate for σ_w is 2,75. If the high type and low C59, A95 are omitted σ_w = 2,89. If all results are included the best estimate for σ_w is 2,96.

David[13] reported a correlation between yield and "between cores" variation such that a yield of 50% corresponded to a σ_c of 1,92% while a yield of 60% corresponded to a σ_c of 1,44%. No correlation between σ_w and yield was found in the data reported here. Nor, after more detailed analysis to extract the "between cores" variation from the within bales variation, for each lot, could a correlation be demonstrated. Variations of yield within bales would appear to be of a random nature for different lots and types.

The useful conclusion to draw from this data is that σ_w, for this portion of the South African wool clip, is about 3% yield.

Examination of σ_b for each lot (Clean Wool Yield)

Except for those cases (in table 3) where σ_b = 0, all values lie in the range to be judged "not different". Those lots giving σ_b = 0 certainly are different to the others. There could well be reasons why these particular lots contain bales which are not so much uniform within each bale but are uniform between each other. This has happened more times than could be attributed to chance. Furthermore, it is not always a consequence of a large σ_w, or the lack of precision in knowing the bale mean value. It must mean that the compiling of these lots was very successful.

It will be more useful to err on the side of safety and to consider only those cases giving a non-zero value. None are different. Hence consideration can now be given to σ_b values shown in table 4, analysis by types.

In this table only those types which were represented by single lots gave σ_b = 0 (exception – type 95). Again the range in values shows no real differences. The overall mean (geometrical) was σ_b = 1,92%. A practical value to use for σ_b would be 2% for yield.

Examination of σ_w for each lot for diameter property

The range of values for σ_w, for each lot in one type (table 5) is reasonable. For example, Type 9 shows 0,62 to 1,05 while type 92 shows 0,42 to 0,53. Within each type the various values for σ_w are probably only different estimates of the same figure. Hence it is probably safe to move to table 6 and to consider the σ_w values for each type.

For each type the values range from 0,29 to 0,79. Though statistically there are probably real differences present, again an overall mean will be a useful value to take. This gives 0,51 as the best overall value for σ_w.

Examination of σ_b for each lot for diameter property

Similar reasoning leads to the best overall value to use for σ_b (diameter) of 0,52 micron.

SAMPLING SCHEMES TO GIVE THE REQUIRED PRECISION

Skirted fleeces are put into bales by the farmer according to their subjectively assessed class. The determining property considered in the work reported here is the diameter. Other qualities such as length, crimp, origin etc are important.

Bales are stored in the warehouse in groups or lots which in general retain the identity of the source of the wool i.e. the bales in Lot A contain wool of Type B from Farm C. The bales are of roughly standard size, 150 Kg. The number of bales in a lot is not large varying from one to twelve in this work though occasionally larger lots can be found.

Before the wool is sold it is necessary to know at least two facts about the wool in the bale (or in the lot). How much clean wool will the bale give? What is the average diameter of the wool fibres in the bale? The need for the first question is obvious, the purchaser does not want to pay for the non-wool constituents of the bale. Hence the yield must be estimated before sale. The second question is asked because the bale's nominal type must be correctly identified for the requirements of processing performance.

Having established values of σ_w and σ_b for yield of 3% and 2% respectively and for diameter of 0,5 microns (both) and deciding that yield must be determined to ± 1% and diameter to ± 0,5 micron then various sampling schemes to meet these requirements can be examined.

Basis for determining precision:

The precision with which the yield (or diameter) of a bale can be known, from measurements made on core samples, is given by

$$\pm 2 \frac{\sigma_w}{\sqrt{n}}$$

where n = number of cores or tests measured
and σ_w = a measure of the variation within a bale

The precision with which the property of a lot can be known is given by

$$\pm 2 \left[\frac{\sigma_w^2}{n.m} + \frac{\sigma_b^2}{m} \right]^{\frac{1}{2}}$$

where m = number of bales sampled and σ_b is a measure of the variation between bales

This formula assumes that the number of bales in a lot is very large.

For a finite, lot size the formula quoted in ASTM D1060-65 (see also Ref. 12) reduces to

$$\pm 2 \left[\frac{\sigma_w^2}{n.m} + \frac{\sigma_b^2}{m} - \frac{\sigma_b^2}{N} \right]$$

where N = number of bale in the lot

Precision of Yield and of Diameter

The graphs (figures 1–7) illustrate the precision with which a bale and a lot can be measured, using different numbers of samples and bales for different lot sizes. Values of 3% and 2% for σ_w and σ_b (clean yield) and values of 0,5 micron for both σ_w and σ_b (diameter) were used in the calculations.

Interpretation of Precision Graphs

Yield

The measured mean value of a property can only be guaranteed to be equal to the true value when all the material is tested ($n = \infty$). The measured mean value of a bale can be said, with a 95% confidence of being found to be correct, to be within the + and – precision limits of the true mean value. Thus using $\sigma_w = 3\%$ if 4 tests are made on one bale and an average value of say 60% yield is obtained then the true yield of that bale, if it were all measured, would be found in the range 57% to 63% i.e. within ± 3%. To know within ± 1% precision would require 36 tests or cores (and for ± 0,5% would require 144 tests or cores).

To achieve ± 1% precision requires 36 tests or cores. The amount of work can be reduced very significantly by pooling and homogenising the 36 core samples and testing only one sub-sample from this pool. It must be stressed however that this procedure requires, demands firstly perfect homogenising of the 36 cores and secondly perfectly reproducible test procedures.

For a core weight of 50 g from a bale weight of 144 kgs, 1,25% of the mass of the bale must be tested to obtain a precision of ± 1%. From theoretical considerations assuming that one core damages fibres over an area nine times bigger than the core area (equal to one diameter all round the core), a volume of wool nine times that of the cores will be affected. This means that one tenth of the bale will be damaged so that the yield may be found to within ± 1%. Published[14] work has shown that more damage than this can be done to wool during subsequent processing.

In industry the yield of one bale is not as important as the yield of one lot. If lots continue to be offered having the composition found in this work then the following obtains.

To achieve ± 1% precision for a five bale lot all the bales must be cored and eight cores per bale must be taken. This entails the same volume of testing and only one fifth, proportionally of the damage as previously.

The following table illustrates how many cores must be taken from each bale when only part, or all, of a lot is sampled to achieve ± 1% precision.

LOT SIZE	BALES CORED	CORES PER BALE	BALES CORED	CORES PER BALE	BALES CORED	CORES PER BALE
5	—	—	—	—	5	8
10	—	—	7	16	10	4
20	—	—	16	3	20	2
40	16	7	32	2	40	1

It is obvious that the least effort is required when all the bales in a lot are cored and that damage to the wool will be reduced by making lot sizes as big as possible.

I W T O Core Test Regulations require

(i) a precision of ± 1% (95% C.L.)

(ii) that every bale in the lot to be sampled

(iii) that the number of cores from each bale to be determined from the formula

$$K = \frac{4 \quad \sigma^2{}_w}{N}$$

K = nos. of cores/bale
N = nos. of bales in the lot

If the object is to take as few cores as possible then the coring of every bale will achieve this. But if the minimum handling of bales or bales preserved intact is the criterion then this can be achieved by taking more cores from each of fewer bales, as indicated.

The subsequent analytical work can be kept to a minimum by pooling the cores as described earlier.

Summarizing, this work shows that, for a σ_W = 3%, 40 cores must be taken from every lot. A one bale lot requires 40 cores from that bale, a two bale lot requires 20 cores per bale, and so on. An 80 bale lot would require only half a core per bale. In this case, taking 1 core per bale would give an unnecessarily precise measure of yield. Effort could be saved in this case by coring every other bale (the precision would now be ± 1,05% using σ_b = 2).

Diameter

Using $\sigma_w = \sigma_b = 0{,}5$ micron and referring to the graphs the following obtains.

Four cores must be taken to achieve a precision of ± 0,5 micron for one bale.

Considering lot testing, a 5 bale lot requires one core (4/5 core) from each of the bales to achieve ± 0,5 micron.

A ten bale lot requires three cores from each of four bales, or less than one core from each of seven or more bales to give a precision of ± 0,5 micron.

Because the diameter variation is much smaller than the yield variation fai fewer cores are required. But, as the test material is available from the requirements of yield then one test from the homogenised core material will be more than sufficient.

THE PROBLEM OF CORING WOOL IN THE BROKER'S STORE

Given $\sigma_w = 3$, that every bale is cored, that a precision of ± 1% is required – then at least 40 cores (1″ tool) must be taken from the lot. For small lots, more than one core per bale must be taken.

The scouring procedure requires preferably 1000g for 5 x 200g sub-samples. These 1000 grams are made by blending all the cores taken from one lot. A 1″ diameter coring tool gives 50g of wool per core and 40 such cores will provide sufficient material for test.

Use of a coring tool having a different diameter raises other points which may be important. For instance use of a ½″ diameter coring tool, which gives about 12g of material per core, would necessitate the taking of four times as many cores to material per core, would necessitate the taking of four times as many cores to provide sufficient test material. Also, by using a smaller core diameter it can be expected that a larger σ_w will be found. The reasoning is that more often will pure tips or pure roots make up the core. From the results quoted earlier where roots gave 60% yield and tips 40%, the range therefore being 20%, a σ_w of 5% could be expected when sampling is done by a tool capable of selecting pure roots and pure tips. A σ_w of 5% would demand 100 cores for ± 1% precision compared to the 40 cores required from a one inch core and also would tend to cause more damage to the wool.

COMMENT ON THE MEASURED MEAN DIAMETER VALUES

According to its type any lot should give a mean diameter of a certain value, e.g. type 9 wool should give 22 microns, ± 0,5 microns. Measured mean values have a certain confidence range. If these two ranges are combined then the difference between the type mean and the measured mean should be smaller than the combined range for the wool to have been correctly identified and classed.

For example:– Type 9, lot 336 of nominal diameter 22 microns gave a measured value of 24 microns, the difference being two microns. Their combined confidence range was 0,5 + 0,74 or 1,24 microns. As 1,24 is less than 2 then it can be presumed that lot 336 was incorrectly typed

Type 9, lot 677 was measured at 23,1 microns giving a difference of 1,1 microns and the combined confidence range was 1,44 microns, thus concluding that lot 677 was correctly typed.

On this basis table 5 shows that 16 lots have been assigned to the wrong type, and 41 are correct.

Similarly 5 out of 16 types or catalogues are incorrect, three of these being single lots, while two contained 5 lots each. Speculating on this apparently wrong classing, provided that the trade accepted the typing as correct, the subsequent processing must be too insensitive and hence it could be inferred that there are too many type classifications.

SUMMARY OF MAIN CONCLUSIONS

1. The best estimates to use for the within bale and between bale, σ_w and σ_b, variations for the S.A./P.E. wool clip as collected in this particular port were found to be

	σ_w	σ_b
Clean Wool – %	3	2
Diameter-micron	0,5	0,5

2. The minimum number of cores to be taken from a lot (providing that all the bales in that lot are sampled) in order to measure the yield with a precision of ± 1% (at the 95% confidence level) was found to be 40.
3. This number of cores was more than adequate to ensure a diameter precision of ± 0,5 microns.
4. Using a 1″ coring tool this gave sufficient test material to meet the requirements of the IWTO Core Test Regulations (1968).
5. A proviso following *2* and *4* was that the 40 cores must be thoroughly homogenised to ensure that the determined yield is a representative value.
6. An estimate of the reproducibility of the Clean Wool test gave a standard deviation of 0,2%.
7. The difference in yield between roots and tips was measured as 20% (absolute) for an average staple yield of 50%.
8. An estimate of the reproducibility of the diameter measurement was 0,08 microns.

TABLE 5

ANALYSIS BY LOTS – DIAMETER

TYPE	LOT	NOS. OF BALES	MEAN DIAMETER μ	σ_w	σ_b	95% C.L. OF MEAN ±	TYPE DIA. μ
9	334	3	24,8	1,05	0,32	0,50	22
	336	4	24,0	0,62	0,67	0,74	
	476	5	23,5	0,87	0,94	0,93	
	535	3	24,6	0,68	0,43	0,63	
	677	3	23,1	0,67	0,74	0,94	
13	235	4	20,7	0,77	0,88	0,96	21
	288	4	21,1	0,41	0,52	0,56	
	592	7	21,2	0,47	0,23	0,25	
	669	3	19,8	0,97	0,51	0,81	
	772	4	21,1	0,67	0,86	0,92	
CB9	459	3	21,2	0,44	0,50	0,63	21,5
CB19	31	10	22,0	0,50	0,55	0,38	21,5
B19	20	8	23,1	0,79	0,32	0,36	22
48	264	6	21,9	0,45	0,61	0,53	21
	430	7	21,9	0,37	0,51	0,41	
	498	12	22,2	0,42	0,60	0,37	
	502	12	21,8	0,63	0,48	0,33	
	511	9	21,6	0,41	0,43	0,32	
53	263	3	21,3	0,59	0,71	0,89	21
	273	4	19,9	0,43	0,59	0,63	
	649	7	19,3	0,45	0,38	0,33	
	662	4	20,0	0,42	0,40	0,45	
	776	3	19,8	0,40	0,15	0,29	
58	333	3	21,3	0,45	0,62	0,76	21
	453	6	21,1	0,63	0,57	0,53	
	553	3	19,3	0,55	0,79	0,96	
	655	3	22,6	0,49	0,18	0,30	
	800	3	20,1	0,40	0,51	0,63	
C59	13	6	22,6	0,32	0,15	0,18	21,5
A95	42	5	20,0	0,29	0,38	0,36	21
A93	17	5	22,6	0,33	0,44	0,42	22

Table 5 (cont.)

TYPE	LOT	NOS. OF BALES	MEAN DIAMETER μ	σ_w	σ_b	95% C.L. OF MEAN ±	TYPE DIA. μ
92	247	3	20,3	0,46	0,23	0,38	21
	317	3	21,0	0,52	0,66	0,77	
	516	3	21,2	0,53	0,55	0,65	
	520	3	21,0	0,44	0,35	0,48	
	555	5	20,4	0,42	0,27	0,25	
95	77	3	20,1	0,51	0,37	0,44	21
	248	4	19,3	0,34	0,43	0,44	
	521	3	21,7	0,65	0,54	0,64	
	561	4	21,0	0,40	0,36	0,37	
	688	4	20,4	0,48	0,68	0,69	
93	61	3	20,0	0,48	0	0,11	22
	325	3	19,8	0,40	0	0,94	
	382	4	20,3	0,52	0,54	0,55	
	437	3	22,1	0,43	0,23	0,28	
	515	4	22,1	0,13	1,2	1,20	
	550	4	21,8	0,52	0,54	0,55	
A113	232	5	20,9	0,33	1,01	0,92	21-
	362	5	21,3	0,38	0,32	0,33	
	525	4	21,6	0,37	0,81	0,83	
	540	4	20,8	0,66	0,66	0,74	
	622	4	19,9	0,30	0,23	0,27	
114	325	3	21,4	0,48	0,72	0,87	21-
	348	3	18,9	0,31	0,08	0,20	
	369	6	21,6	0,52	0,48	0,45	
	473	9	21,6	0,33	0,52	0,36	
	686	3	20,8	0,31	0,19	0,28	

TABLE 6

ANALYSIS BY TYPES – DIAMETER

TYPE	NOS. OF LOTS	TOTAL NOS. OF BALES	MEAN DIA.	σ_w	σ_b	σ_ℓ	95% C.L. OF MEAN ±	TYPE DIA. μ
9	5	18	24,0	0,75	0,70	0,59	0,65	22
13	5	22	20,9	0,64	0,62	0,57	0,59	21
CB9	1	3	21,2	0,44	0,50	–	0,63	21,5
CB19	1	10	22,0	0,50	0,55	–	0,38	21,5
B19	1	8	23,1	0,79	0,32	–	0,36	22
48	5	46	21,9	0,47	0,54	(0,12)	0,21	21
53	5	21	19,9	0,57	0,46	0,69	0,66	21
58	5	18	20,9	0,53	0,57	1,10	1,03	21
C59	1	6	22,6	0,32	0,15	–	0,18	21,5
A95	1	5	20,0	0,29	0,38	–	0,36	21
A93	1	5	22,6	0,33	0,44	–	0,42	22
92	5	17	20,8	0,47	0,59	0,35	0,43	21
95	5	18	20,5	0,48	0,50	0,85	0,80	21
93	6	21	21,3	0,47	0,75	0,91	0,81	22
A113	5	22	20,9	0,42	0,68	0,54	0,57	21
114	5	24	21,1	0,40	0,49	0,98	0,90	21

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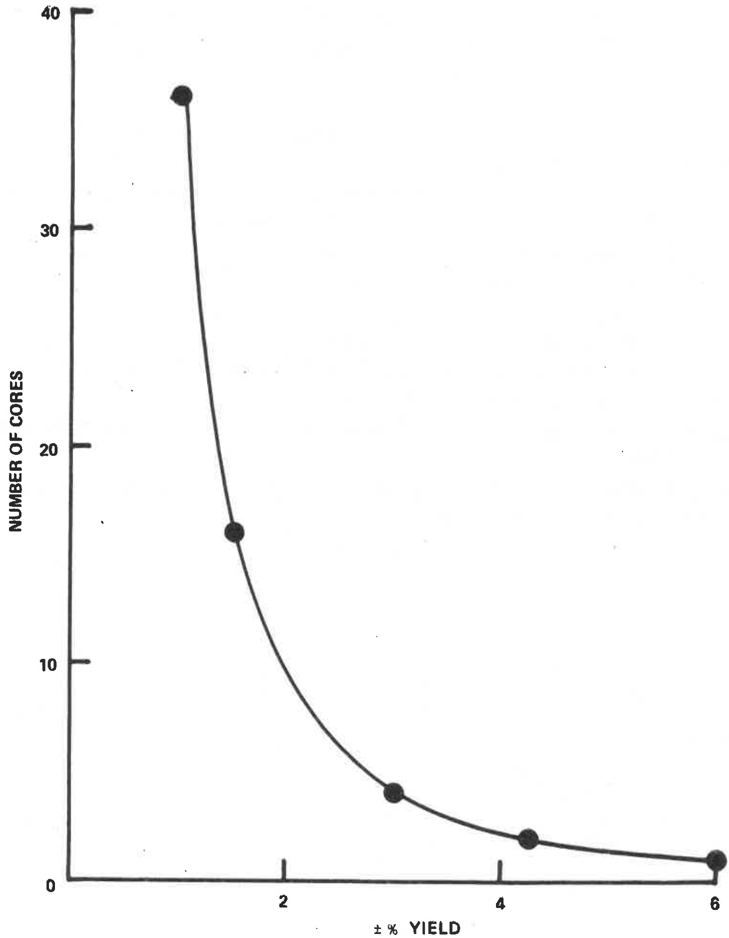

FIGURE 1
Precision of yield for a 1 bale lot

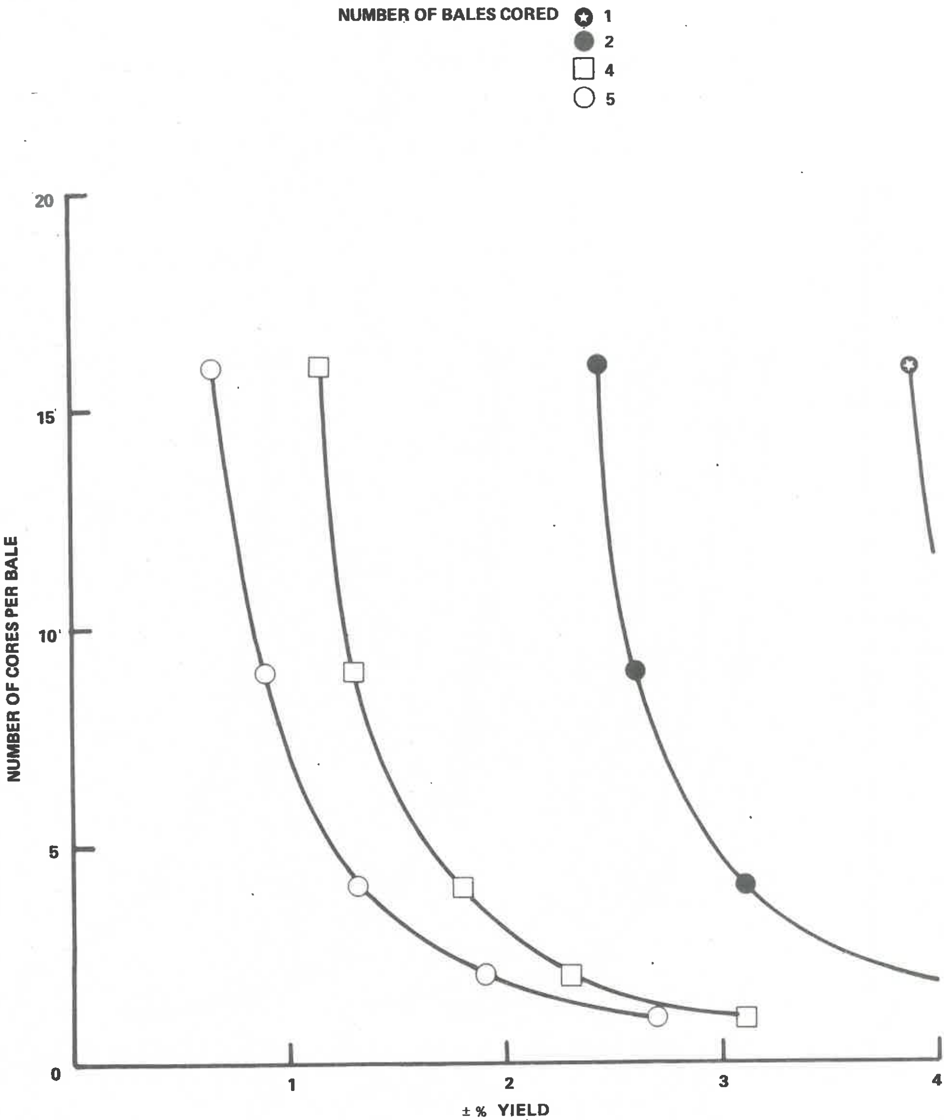

FIGURE 2
Precision of yield for a 5 bale lot

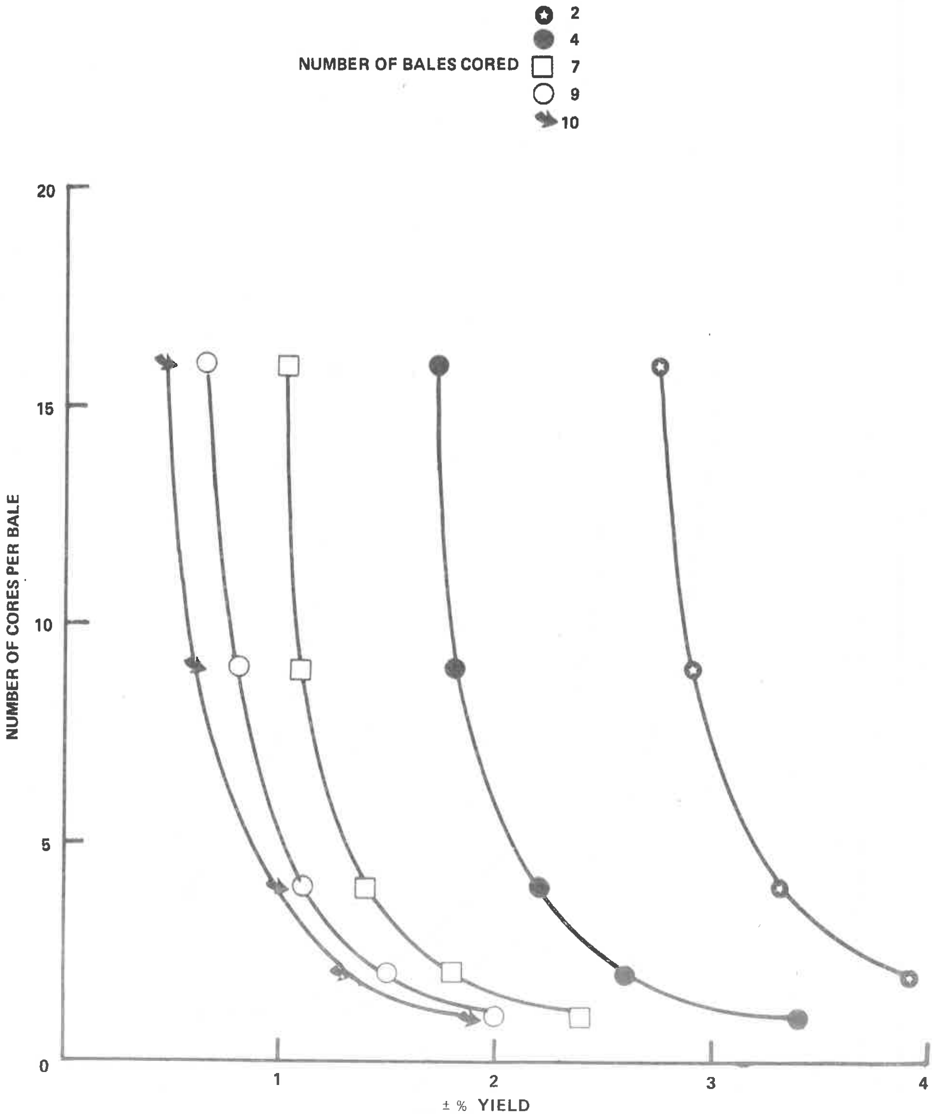

FIGURE 3
Precision of yield for a 10 bale lot

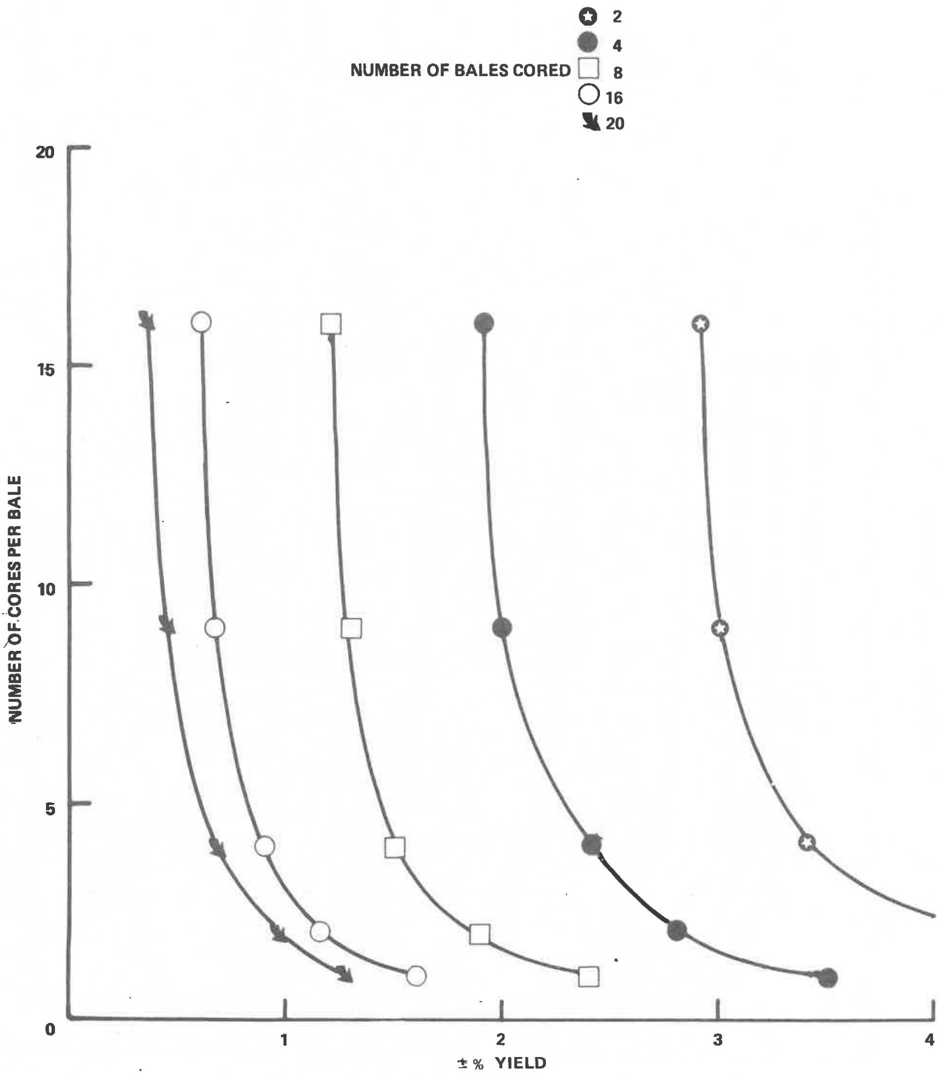

FIGURE 4
Precision of yield for a 20 bale lot

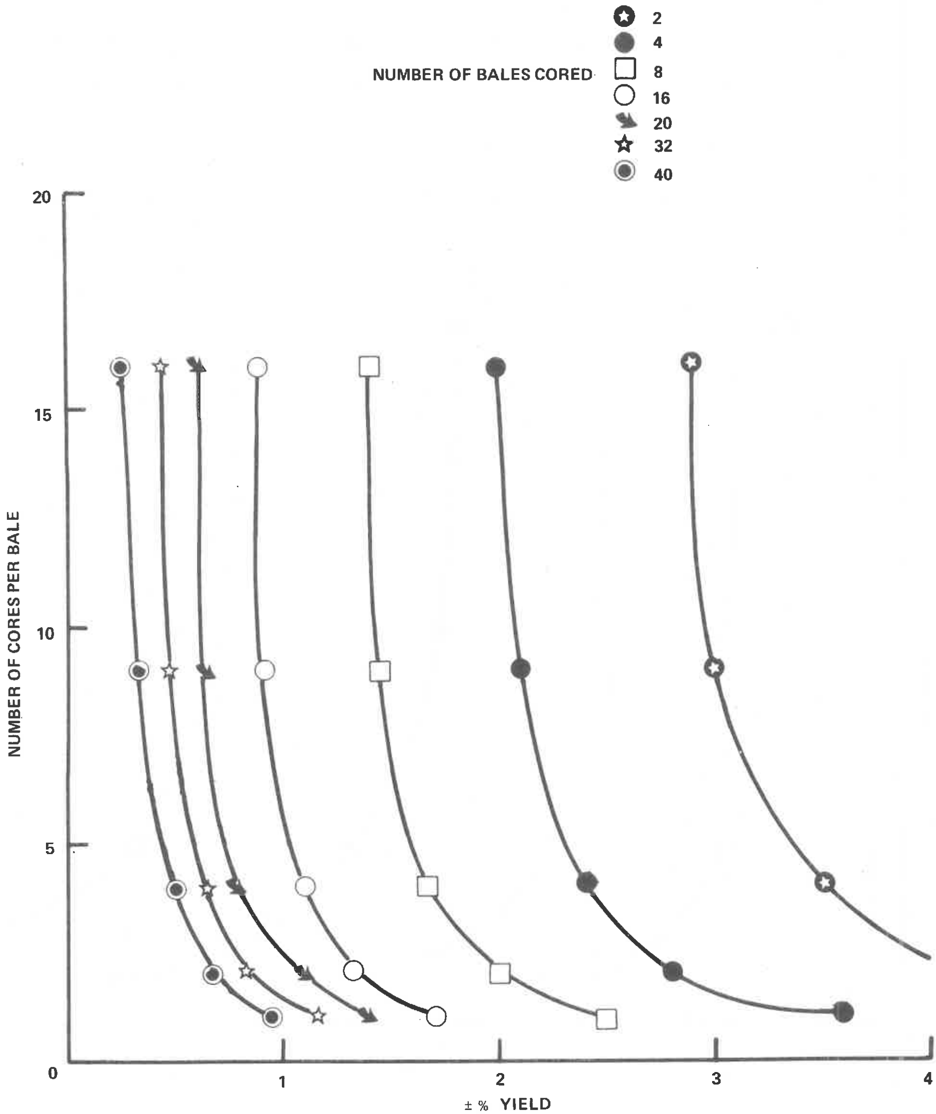

FIGURE 5
Precision of yield for a 40 bale lot

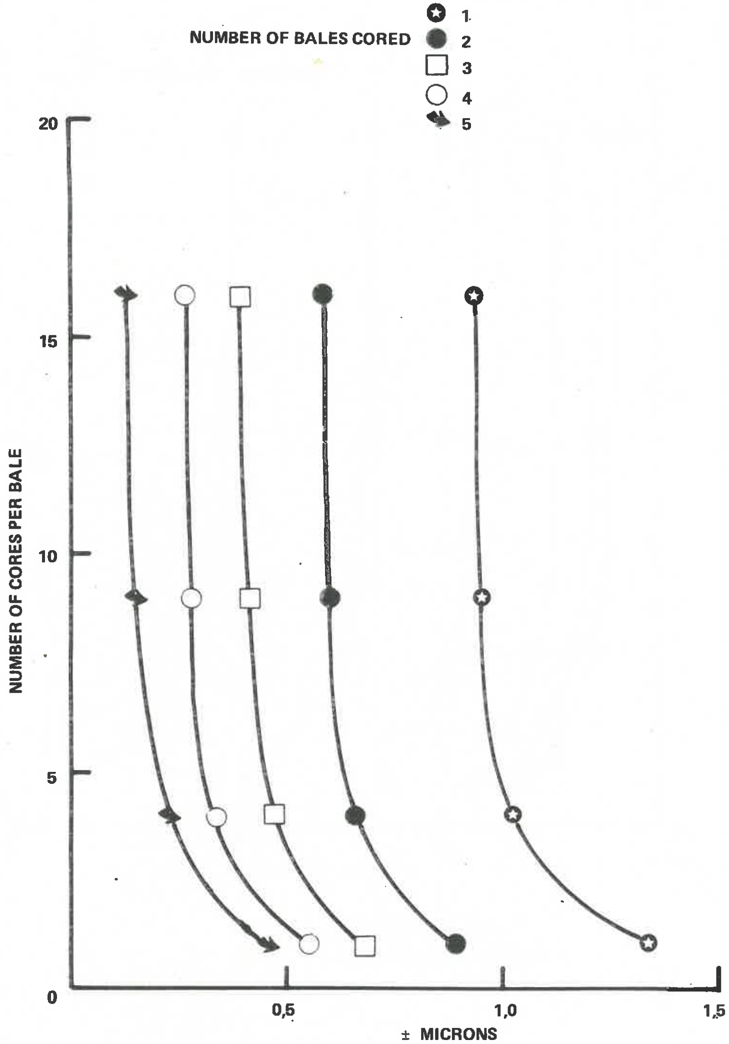

FIGURE 6
Precision of diameter for a 5 bale lot

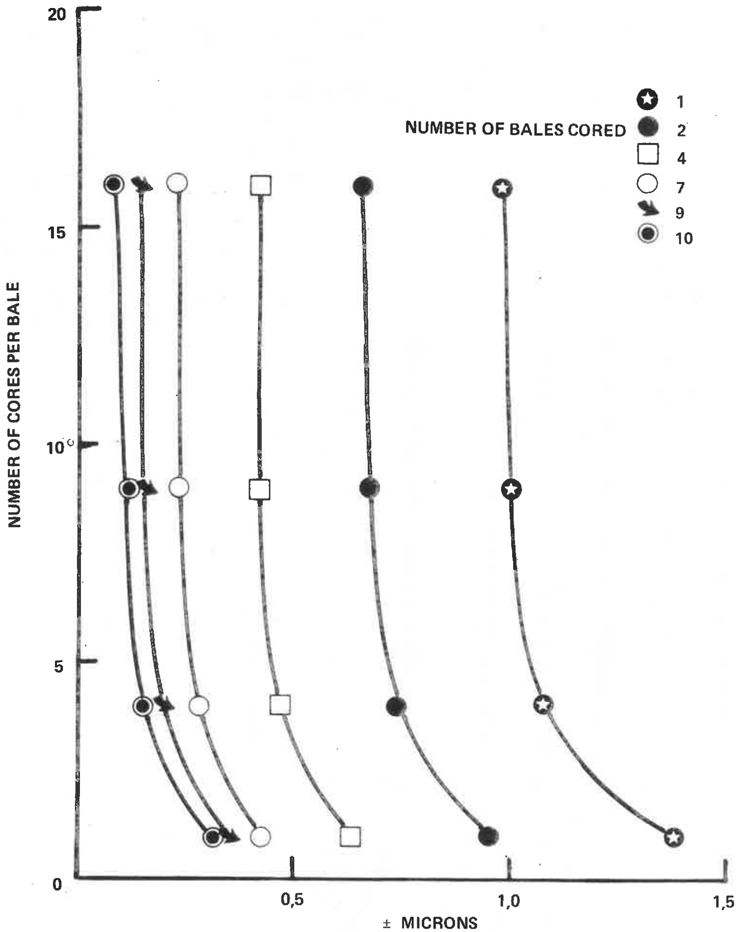

FIGURE 7
Precision of diameter for a 10 bale lot

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