Résumé

L'analyse discriminante ainsi que la statistique D^2 ont été utilisées pour différencier deux phases de criquets du désert. Elles consistaient en criquets aux 6 œil-raies appartenant d'une part à la phase dite *gregaria* et d'autre part à un type essaimant transitoire qui se situe entre la phase *gregaria* et la phase *solitaria*. L'analyse qui portait sur les caractères E, F, C et P a été conduite séparément pour les mâles et les femelles.

Le caractère C fournit la meilleure discrimination aussi bien chez les mâles que chez les femelles lorsque l'on considère les caractères isolément. Si ces derniers sont analysés conjointement, on remarque que la combinaisons C et P est la meilleure chez les mâles et C, F et P chez les femelles.

La méthode usuelle qui consiste à opérer cette discrimination au moyen d'indices a été discutée dans ce rapport. On a trouvé entr'autre que les indices E/C, F/C et P/C étaient plus sensibles que E/F ; ceci est probablement dû au fait que C fournit la meilleure discrimination.

L'absence de données pour les caractères C et P dans la phase *solitaria* a empêché l'étude de la discrimination entre les phases *solitaria* et *gregaria*. D'autre part, l'effectif de la phase *gregaria* est très faible. Il serait hautement souhaitable que les biologistes engagés dans la lutte contre les criquets, mesurent un nombre suffisant d'animaux pris au hasard dans chaque phase en tenant compte du sexe et du nombre de œil-raies de l'insecte.

ON THE SIZE OF SAMPLE CUTS IN CROP-CUTTING EXPERIMENTS IN THE INDIAN STATISTICAL INSTITUTE : 1939-1950

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Introduction

1.1. Pioneer work was done in India by John (later Sir John) Hubback of the Indian Civil Service to estimate the rate of yield of paddy per acre by harvesting and weighing the grain within sample-units of a small size (13.6 sq. ft.) located in a manner which was expected in principle to have been selected at random. An account of his early experiments in India carried out in the years 1923-25 was given in an important paper (Hubback, 1927) published by the Government of India. The method developed by Hubback was used a little later in the Central Provinces by C.D. (now Sir Chintaman) Desmukh and P. S. Rau, two other officers of the Indian Civil Service. Hubback's paper also influenced work outside India. R. A. Fisher in his memorandum dated 2 March 1948 addressed to the Imperial Council of Agricultural Research, Government of India, stated :—

"The use of the method of random sampling is theoretically sound. I may mention that its practicality, convenience and economy was demonstrated by an extensive series of crop-cutting experiments on paddy carried out by Hubback (later Sir John Hubback, Governor of Orissa) more than 20 years ago over a greater part of the rice tracts in Bihar and Orissa. So far as I know these were the earnest crop-cutting experiments based on the principle of random sampling anywhere in the world. They influenced greatly the development of my method at Rothamstead".

1.2. Experiments on estimating the yield per acre of jute fibre by harvesting the plants within sample cuts of a small size were started by the Indian Statistical Institute in 1939. Since then similar experiments on the estimation of rates of yield by harvesting on sample cuts

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Conversion figures : One maund = 82.2857 lbs. = 37.3177 kgm.
One tola = 0.4114 oz. = 11.6632 gms.
One acre = 0.40468 hectares.
One maund per acre = 92.2153 kgm. per hectare.

TABLE 1

Geographical area in square miles covered by yield-estimating surveys conducted by the Indian Statistical Institute, by States and by Crop-Seasons : 1939-50.

year	Bengal					Bihar			Uttar Pradesh		cinchona special		all surveys	
	general survey													
	jute and *aus* paddy	*aman* paddy	*rabi* (winter)	B.H.H, *aman* paddy	Mymensingh, *aman* paddy	*bhadoi* jute & paddy	*aghani* paddy	*rabi* (winter)	wheat	sugarcane	West Bengal	Madras	no	area
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
1 1939-40	804	—	—	1,057*	837*	—	—	—	—	—	—	—	3	2,698
2 1940-41	800	—	—	1,057*	—	—	—	—	2,500*	2,500*	502	—	5	7,359
3 1941-42	59,199	—	—	1,057*	—	—	—	—	2,800*	3,500*	—	—	4	66,556
4 1942-43	59,199	—	—	1,057*	—	—	—	—	—	—	—	—	2	60,252
5 1943-44	71,209	71,209	—	1,057	—	—	—	8,075	—	—	—	—	4	151,550
6 1944-45	71,209	71,209	—	—	—	67,536*	67,536*	67,536*	—	—	—	—	5	345,026
7 1945-46	71,209	71,209	—	—	—	—	—	—	—	—	—	—	2	142,418
8 1946-47	71,209	71,209	—	—	—	—	—	—	—	—	—	—	2	142,418
9 1947-48	71,209	27,155	27,155	—	—	—	—	—	—	—	—	—	3	125,519
10 1948-49	27,155	27,155	27,155	—	—	—	—	—	—	—	—	—	3	81,465
11 1949-50	27,155	27,155	27,155	—	—	—	—	—	—	—	—	562	4	82,027
12 total area	530,357	366,301	81,365	5,285	837	67,536	67,536	75,611	5,300	6,000	502	562	—	1,207,292
13 total number	11	7	3	5	1	1	1	2	2	2	1	1	37	

of a comparatively small size have been made by the Institute on 17 different crops in the course of 37 independent surveys comprising 76 crop-seasons up to the end of 1950. General information relating to these surveys is given in Tables 1 & 2 from which it will be noticed that the material consists of records of 351,606 sample cuts of various sizes representing a total geographical coverage of 1,207,292 square miles of area. The general survey consisted of operations carried out on an extensive scale to estimate the rate of yield per acre and hence (in conjunction with estimates of the area sown) to estimate the total outturn of crops. In addition, special experiments on an intensive scale were also made with a view to study the influence of the size of sample cuts and other factors involved in the estimation of the crop yield per acre. The data collected during the period 1939-40 to 1949-50 represent a great deal of valuable material for research on the technique of crop estimation. It has not yet been possible to prepare a comprehensive report, and the present note deals mainly with the size of the sample cut.

1.3. The sample cuts were selected in a random manner and the physical methods used for measuring the area of the sample cut and also of harvesting the crop and subsequent processing have been described in the earlier publications and periodical reports submitted to the Provincial Governments in different crop seasons. The following may be mentioned for convenience of reference :—

(i) Statistical Report on Crop-cutting Experiments on Jute (Mahalanobis, 1939).
(ii) Statistical Report on Crop Estimating Experiments on Jute in Bengal (Mahalanobis, 1940).
(iii) Report on the Bihar Crop Survey : Rabi season (Mahalanobis, 1943-44).
(iv) Sample Survey of Crop Yields in India (Mahalanobis, 1946)
(v) Recent Experiments in Statistical Sampling in the Indian Statistical Institute (Mahalanobis, 1946).
(vi) On Large Scale Sample Surveys (Mahalanobis, 1944).
(vii) Use of small-size Plots in Sample Surveys for Crop Yields (Mahalanobis, 1946).

1.4. Very briefly, the procedure adopted was to employ a staff of whole-time trained investigators each of whom would go to a specified village and a specified field (previously selected in a random manner in the Institute); select a point on the field (again, in a suitable random manner prescribed by the Institute); demarcate a sample-cut of the required size; and harvest the plants and process the crop and weigh the yield on the spot (and collect such other auxiliary information as were specified by the Institute).

TABLE 2

Number of sample-cuts used in yield-estimating survey conducted by the Indian Statistical Institute, by type of crops, and by region : 1939-1950.

region	jute	*aus* & *bhadoi* paddy	*aman* & *aghani* paddy	*rabi* (winter) crops											Cinchona special	all surveys
				wheat	barley	gram	pulses				oilseeds		sugarcane	potato		
							khesari	*masur*	*mung kalai matar*	*arhar*	mustard	linseed				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
1 Bengal	53,179	40,103	82,265	3,690	1,776	4,104	2,313	2,958	1,392	75	1,194	147	551	917	—	194,,664
2 B.H.H.	—	—	83,078	—	—	—	—	—	—	—	—	—	—	—	—	83,078
3 Mymensingh	—	—	16,591	—	—	—	—	—	—	—	—	—	—	—	—	16,591
4 Bihar	—	1,518	32,533	7,449	—	2,325	45	409	—	—	—	—	—	—	—	44,329
5 U.P.	—	—	—	5,955	—	—	—	—	—	—	—	—	5,704	—	—	11,659
6 Mungpoo	—	—	—	—	—	—	—	—	—	—	—	—	—	—	622	622
7 Madras	—	—	—	—	—	—	—	—	—	—	—	—	—	—	663	663
8 total number	53,179	41,621	214,517	17,094	1,776	6,429	2,358	3,367	1,392	75	1,194	147	6,255	917	1,285	351,606
9 total crop years	11	9	14	7	3	5	4	4	3	2	3	1	5	3	2	76
10 total survey years		13	14						9						2	37

GENERAL AND SPECIAL SURVEYS

2.1 Most of the work was done in the Province of undivided Bengal (covering 71,209 square miles) before the partition of India on 15 August 1947 and in the succession State of West Bengal (comprising 27,155 square miles) since partition. Extensive work was also done in 1943-44 and 1944-45 in the State of Bihar covering 8,075 and 67,535 square miles respectively. In the State of Uttar Pradesh the work was limited to specially selected areas under wheat and sugarcane. The work on cinchona plants was conducted at Mungpoo (in West Bengal) and in Madras.

2.2. The crop estimating work was stated in 1939 on the jute-crop which is usually sown in Bengal in April-May and usually harvested in August-September. The work was then extended to *aus* paddy which is grown at the same time as jute. It is usually sown broadcast in the summer (April-May in East Bengal and May-June in West Bengal) and harvested during the latter part of the rainy season (August-September). *Aus* paddy contributes roughly one-fourth of the total paddy crop in this State. A little later work was started on *aman* paddy which is usually transplanted during April-May in East Bengal, July-August in West Bengal, and mostly harvested between October-December; and which comprises roughly three-fourths of the total paddy production in this State. Work on *rabi* or the winter crop was first started in West Bengal in 1947-48. The winter or *rabi* crops for which data were collected were wheat, barley, gram and pulses like *khesari*, *masur*, *mung*, *kalai*, *matar* and *arhar*; and the two oil seeds, mustard and linseed. In addition some work was also done on sugarcane and potato. In Bengal the object of the general survey was broadly to secure the estimates of yield per acre and hence the total outturn of the crop.

2.3. Two special series of crop estimating surveys were conducted in Bengal. One covering 1,057 square miles (as given in col. 5 of Table 1) comprising the area under the Burdwan-Hooghly-Howrah Irrigation Scheme in which the object was to determine the average yield of the *aman* crop on soils of different kinds with a view to levying irrigation charges after a big irrigation project would come into operation in future. This series of surveys is referred to everywhere as BHH (which was later expanded into the Damodar Valley Corporation). Another special survey was conducted in only one year 1939-40 in the district of Mymensingh (which was a part of Bengal at that time and is now included in East Pakistan) with the object of ascertaining the average yield of paddy on different types of land with a view to the assessment of land revenue.

2.4. In the State of Bihar, surveys were conducted on the *bhadoi* paddy which corresponds to *aus* paddy in Bengal and is harvested in August-September, and on the main *aghani* paddy which corresponds to *aman* paddy in Bengal and is mostly harvested between October and December.

2.5. Finally, crop estimating surveys of an entirely different kind were carried out in cinchona plantations at Mungpoo in West Bengal and at Nilgiris and Coimbatore in Madras to ascertain the yield of the cinchona plantation.

2.6. The number of sample cuts harvested during the period under review is shown in Table 2 by type of crops and by regions. It will be noticed that the total material comprises 351,606 sample-cuts out of which 214,517 were on *aman* and *aghani* paddy; 41,621 on *aus* paddy; 53,179 on jute, the three crops which were studied in detail. The data relating to some of the other crops such as wheat (17,094), gram (6,429), sugarcane (6,255), *masur* (3,367) are also quite considerable while information on the other pulses is comparatively small.

Over-estimating Bias in Sample-cuts of Small Size

3.1. The tendency towards an over-estimating bias in cuts of very small size was detected in the very first experiments on jute made in 1939 and the results were given in the printed report submitted to the Indian Central Jute Committee in the same year. The material collected in that year was however small, and the experiments were repeated on a larger scale on the jute crop in 1940 and the subject has been under close study since then.

3.2. The problem was first discussed by Mahalanobis in his Statistical Report on Crop-estimating Experiments on Jute in Bengal 1940 and in subsequent papers. In the report on the crop-cutting experiments on jute in Bengal, the tendency towards over-estimation in small cuts was ascribed by the author to a psychological bias on the part of the investigator to include unduly some of the bordering plants or tillers inside a cut. Whatever might be the true cause, the existence of this bias was found to be considerable in cuts of very small size of the order of from 10 or 12 sq. ft. but to have practically vanished at the level of 50 sq. feet.

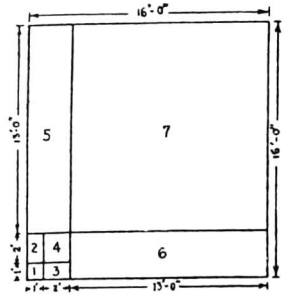
TABLE 3

List of special experiments on the size of sample cuts conducted by the Indian Statistical Institute : 1939-49

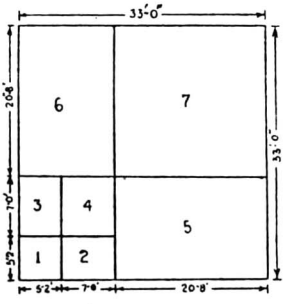
crop	size of cut examined	field work	plan and technical supervision
		1939–40	
jute	independent cuts of 5.5; 11.0; 22.0; 33.0 & 66.0 sq. ft. each (Bengal : 8 districts)	Institute field staff	P. C. Mahalanobis, J. M. Sen Gupta, D. Ganguly, P. K. Chatterjee, N. C. Chakravarti.
		1940–41	
jute	7 nested sub-cuts out of 16′×16′ at 1′, 3′, from corner along both sides (Bengal : 4 districts).	Institute field staff	P. C. Mahalanobis, J. M. Sen Gupta, D. Ganguly, P. K. Chatterjee, S. N. Roy, Mohanal Ganguly.
aman	(a) 7 nested sub-cuts out of 33′×33′ at 5′.2, 12′.2 from corner along the sides (B.H.H. : dist. : Burdwan) (b) square cuts of sides 5′.2, 12′.2, 21′, 33′ (B.H.H. : dist. : Burdwan).	as above	as above
wheat	nested sub-cuts out of 24′×24′ at 3′ and 6′ from corner along the sides (U.P.).	U.P. Government	P. C. Mahalanobis, S. N. Roy, K. Kishen.
sugar-cane	45′×45′ and 27′×27′ with sub-cuts at 6′ and 12′ from corner along the sides (U.P.: Moradabad & Bijnor).	as above	as above
		1941–42	
jute	Independent square cuts of sides 3′, 5′ field 7′, 8′, 12′ & 15′ (Bengal).	Institute field staff	P. C. Mahalanobis, J. M. Sen Gupta, B. N. Ghosh, S. N. Roy.
aman	same as in B.H.H. 1940-41-(a) (B.H.H.).	as above	as above
wheat	18′×18′ with sub-cuts at 3′ and 6′ from the corner (U.P.: Moradabad & Bijnor).	U.P. Government	P. C. Mahalanobis, S. N. Roy, K. Kishen.
sugar-cane	45′×45′ with sub-cuts 6′ and 12′ from the corner (U.P. : Moradabad & Bijnor).	as above	as above

DIAGRAM SHOWING VARIOUS PATTERNS OF NESTED CUTS USED SINCE 1939.

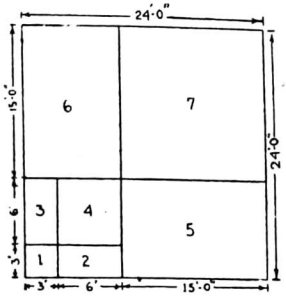
Jute : Bengal (4 districts), 1940-41
Full size 16 ft. x 16 ft.



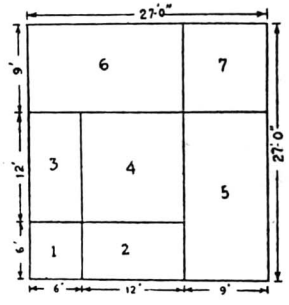
Aman : B.H.H. 1940-41, 41-42
Full size 33 ft. x 33 ft.



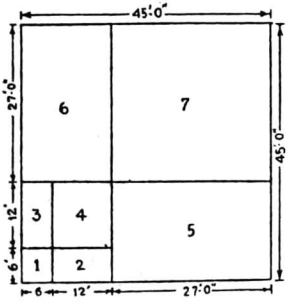
Wheat : U.P. 1940-41
Full size 24 ft. x 24 ft.



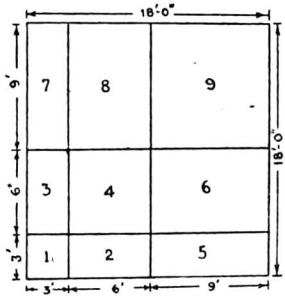
Sugarcane : U.P. 1940-41
Full size 27 ft. x 27 ft.

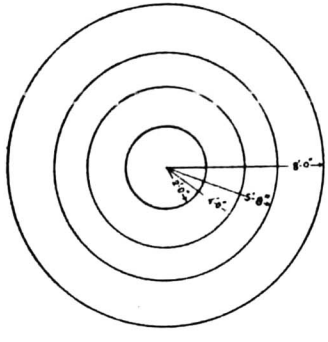


Sugarcane : U.P. 1940-41 and 41-42
Full size 45 ft. x 45 ft.



Wheat : U.P. 1941-42
Full size 18 ft. x 18 ft.





Bengal : Aus and Aman 1946-47 to 1949-50
Full size circle of radius 8' and 5'-8"

TABLE 3 (*Contd.*)

crop	size of cut examined	field work	plan and technical supervision
		1943–44	
jute	square cuts of sides 4′×8′, 12′, 16′ (Bengal).	Institute field staff and Calcutta University Post-graduate students	P. C. Mahalanobis, J. M. Sen Gupta, R. C. Bose, S. N. Roy, P. Bose, H. K. Nandi, N. K. Chakravarti, K. Banerjee, B. N. Ghosh, M. Chakravarti.
aman	square cuts of sides 3′, 6′, 12′ and 24′ (from uniformity trial, B.H.H., dist. Howrah & Burdwan).		
		1944–45	
aghani	square cuts of sides 6′, 8′, 10′, 12′ and rectangles, 4′×36′, 7′×20′.6 (Bihar, Giridih, Patna & Gaya).	Bihar Government	P. C. Mahalanobis, J. M. Sen Gupta, K. Banerjee, G. Chatterjee, P. Bhowmik.
wheat	8′×6.25′, 2′×6.25′ (Bihar: Patna, Gaya & Pusa).	as above	as above
gram	8′×16′, 8′×9′, 8′×5′ (Bihar : Patna & Gaya).	as above	as above
		1945–46	
aus	2′, 4′, 6′, 8′, concentric circles (Bengal : Burdwan).	Students of Calcutta University, Presidency College, and Institute.	J. M. Sen Gupta, A. Gayen, N. T. Mathew, C. R. Rao, P. K. Bose, P. Sen Gupta, P. Ganguli, L. Basu, P. Banerjee, P. Bhowmik, H. Nandi, B. Ghosh, M. Mukherjee, S. Gupta.
aman	(a) concentric circle radius 2′, 4′, 6′, 8′, & whole plot. (b) circle, triangle, square, American fork each of size 12.5 sq. ft. (Bengal : Birbhum, Mymensingh, Burdwan).	as above	as above
		1947–48	
jute	concentric circle of radius 2′, 4′, 8′ and 33′×16.5′ 33′×35′, W.P. (Bengal : Rangpur, 24-Parganas).	Institute field staff	J. M. Sen Gupta, N. T. Mathew, T. P. Choudhury, A. C. Das.
		1948-49	
aman	concentric circle of radius 2′, 4′, 6′, 8′ and 33′×16.5′ W.P. (Bengal : Hooghly, Birbhum).	as above	J. M. Sen Gupta, A. C. Das, N. C. Dutta, A. Ganguli.

Special Experiments

4.1. A long series of special experiments (which should be distinguished from the two *special surveys* mentioned in para 2.3) were made with the object of studying the influence of the size of the sample-cut on the rate of yield per acre. A list of such experiments conducted between 1939-40 and 1949-50 is given in Table 3 arranged by years and crops. A few explanatory notes on the different types of sample-cuts are given below.

4.2. *"Independent" and "Nested" sample-cuts :* When a sample-cut of any size is located by itself on the field and is harvested separately from other sample-cuts, it is called an "independent" cut. A "nested" sample-unit, on the other hand, supplies not one but a series of sub-cuts lying within the cuts of the biggest size. For example, for 1940-41 jute (item 4 in Table 3) one fairly big sample-unit of square shape and size 16 feet $\times$ 16 feet was demarcated by locating a corner pair on the field in a random manner; and smaller sample units were then demarcated in the way shown in the accompanying diagram.

4.3. *Rectangular cuts :* Square shaped rectangular cuts of different sizes were demarcated on the crop field with the help of ropes (or chains) and pegs. The point located at random formed a fixed corner of the sample cut and the length of the two diagonals were checked to ensure that the angles were all right angles. The use of pegs and ropes took a great deal of time. Also, a certain amount of sagging of the ropes was unavoidable in spite of the greatest care in manipulation; and the amount of sagging naturally increased with the size of the cut.

4.4. *Triangular cuts :* The apparatus used in 1943-44 consisted of a portable frame, made up of three flat iron rods forming a right angled isosceles triangle. The longer (hypotenuse) piece was placed on the ground with one end lying over the point located at random within the plot. The two shorter sides were pushed through grooves fitted at the two ends of the hypotenuse at an angle of 45°, until they met at right angles. The two equal sides had a length of 3'.5 and thus enclosed an area of 12.5 sq. ft. In the experiments of 1945-46, an equilateral triangle enclosing an area of 12.5 sq. ft. was also tried.

4.5. *Fork :* A rigid appliance in the shape of a fork was constructed with two parallel prongs each of sides 3'–6" spaced 3'–6" apart and connected by a cross arm at the mid-point of which a handle was fixed; the appliance enclosed a square shaped area of 12.5 sq. ft. This resembled the fork used for crop-cutting experiments in America. The observer pushed the fork with its sides parallel to the X, Y axes of reference away from him until the mid-point of the nearer cross-piece reached the point located at random. Pushing the fork without touching

TABLE 4

Mean yield of jute (green plants) in maunds per acre based on different sizes of cuts, Bengal : 1939-40 to 1943-44.

size of sample cuts	area in square feet	(a) independent cuts									(b) nested cuts					
		number of cuts			mean yield in mds. per acre (green plants)			mean yield expressed as percentage of the mean of largest cut size			mean yield in mds. per acre (green plants)			mean yield expressed as percentage of the mean of largest cut size		
		1939-40	1942-43 (i)	1943-44	1939-40 (ii)	1942-43	1943-44	1939-40	1942-43	1943-44	1940-41 (n=320)	1941-42 (n=289) (iii)	1943-44 (n=1840)	1940-41	1941-42	1943-44
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
1 1′× 1′	1	—	—	—	—	—	—	—	—	—	331	—	—	162	—	—
2 11″× 6″	5.5	126	..	..	23.98	..	..	149	..	..	..	..	..	..	..	..
3 3′× 3′	9	—	85	—	—	336	—	—	119	—	212	277	—	104	114	—
4 11″× 1′	11	127	..	..	17.52	..	..	109	..	..	..	..	..	..	..	..
5 5′× 3′	15	—	—	—	—	—	—	—	—	—	—	273	—	—	112	—
6 4′× 4′	16	..	..	440	..	..	301	..	..	113	..	..	344	..	..	99
7 7′× 3′	21	—	—	—	—	—	—	—	—	—	—	258	—	—	106	—
8 11″× 2′	22	86	..	..	14.10	..	..	88	..	..	..	..	..	..	..	..
9 5′× 5′	25	—	214	—	—	279	—	—	99	—	—	240	—	—	98	—
10 11″× 3′	33	87	..	..	16.19	..	..	101	..	..	..	..	..	..	..	..
11 7′× 5′	35	—	—	—	—	—	—	—	—	—	—	238	—	—	98	—
12 12′× 4′	48	..	..	..	..	..	..	..	..	..	195	..	..	96	..	..
13 7′× 7′	49	—	65	—	—	309	—	—	110	—	—	237	—	—	97	—
14 8′× 8′	64	..	186	250	..	262	268	..	93	101	..	255	351	..	105	101
15 11″× 6′	66	66	—	—	16.08	—	—	100	—	—	—	—	—	—	—	—
16 12′×12′	144	..	141	190	..	246	251	..	87	94	204	244	358	100	100	103
17 15′×15′	225	—	26	—	—	282	—	—	100	—	—	244	—	—	100	—
18 16′×16′	256	..	..	156	..	..	233	..	..	88	204	..	353	100	..	101
19 20′×20′	400	—	—	—	—	—	—	—	—	—	—	—	349	—	—	100
20 24′×24′	576	..	..	84	..	..	266	..	..	100	..	..	..	..	..	..
21 total		492	717	1120	—	—	—	—	—	—	—	—	—	—	—	—

(i) schemes 2/b & 2/f combined (ii) dry fibre in mds. per acre. (iii) schemes I/A & I/B combined.

the plants by hand eliminated personal factors in the selection of the plants to be included in the sample-cut.

4.6. *Concentric circles :* One special feature of the work of the Indian Statistical Institute was the use of cuts of the shape of concentric circles with the help of a special apparatus developed at the end of 1945-46*. This has been described in some detail in "Recent experiments in Statistical Sampling in the Indian Statistical Institute" (Mahalanobis, 1946). The apparatus used for this purpose is a rigid appliance with a sharp pointed peg about which an arm of maximum length 5'–8" can be made to rotate in a plane parallel and very close to the ground surface. This arm can be folded at two intermediate points, so as to demarcate two sub-cuts about the common centre with a radius of 2' ft. and 4' ft. respectively. In actual practice the smallest sub-cut of 2' ft. radius is harvested first of all, and then the two annular strips enclosed (a) between the circumferences of radii 2' and 4'; and (b) between 4' and 5'–8" are harvested in order. A plumb line or a vertical pointer is passed through a hole at the tip of the arm in one of its folds, to show the correct projection of the tip of the radius at the ground level.

Results of the Special Experiments

5.1. As a typical example, the results of a series of special experiments carried out under the direct supervision of trained technicians on a number of cut sizes are given in Tables (4)—(7). Table (4) shows the results of experiments on jute conducted between 1939-40 and 1943-44 (a) based on 'independent' cuts in cols. (3)—(14); and (b) based on 'nested' cuts in cols. (15)—(20). The pattern of the independent and nested cuts has already been explained in the earlier paragraphs. For (a) the independent cuts, cols. (1) and (2) give the actual size of cuts; cols. (3)—(6) the number of sample-cuts and cols. (7)—(10) the corresponding mean values. The mean values are given as the yield per acre in maunds of green plants of jute weighed immediately after harvesting; only for the first year, 1939-40, the results are given as the weight of dry fibre of jute (after retting, processing, and drying) in maunds per acre. Finally, the mean yields are expressed as percentages of the mean yield based on sample-units of the largest size in any given year and are given in cols. (11)—(16). It will be noted that there is usually an over-estimation in cuts of size 16 sq. ft. and below. For (b) nested cuts cols. (15)—(17) give the mean yield in maunds per acre while the number of sample cuts (which are same for each size) are given

* The apparatus for securing concentric cuts of a circular shape was first designed by J. M. Sen Gupta.

at the top of each column. Cols. (18)—(20) show these mean values as percentages of the yields based on the largest cut.

5.2. It should be noted here that in 'nested' sample-cuts the individual subcuts are harvested in a sequence prescribed by the Institute beforehand. For example, the common portion of two sub-cuts would be harvested separately and immediately before the remaining portion of the earlier sub-cuts is harvested. Usually, there is some over-inclusion of plants along the borders of the sub-cut which is obtained earlier at the cost of the sub-cut which is harvested subsequently. The extent of such over-inclusion naturally depends on the length of the "free" perimeter on the other side of which the crop is still on the ground. This would depend naturally on the sequence in which the sub-cuts are arranged. This factor has not been taken into consideration in the present study.

5.3. Table (5) shows the mean yield of *aus* and *aman* paddy in bulk, and of jute (green plants weighed immediately after harvest) in maunds (maund = $82\frac{2}{7}$ lbs.) per acre obtained from experiments conducted since 1945-46 when the circular cuts were first introduced for comparison with rectangular cuts of a large size. The shape and size of sample-cuts are shown in cols. (1) and (2), and the mean yields for particular series of experiments in cols. (3)–(7). The corresponding yields are expressed as percentages of the yield based on sample-cuts of the largest size and are given in cols. (8)–(12). In the same way, results of the experiments on *aman* paddy conducted in the B.H.H. area and on *aghani* paddy in Bihar between the years 1939-40 and 1943-44 are given in Table (6.1) together with the corresponding percentages in Table (6.2). Similar results for wheat obtained from experiments in U.P. in the two years 1940-41 and 1941-42 are given in actual maunds per acre and in percentages in Table (7).

5.4. From Tables (5)–(7) it would again appear that there is an over-estimating bias on the part of very small sample-cuts up to about 50 square feet after which the bias probably becomes negligible.

Effect of the Shape of Cuts

6.1. An intensive series of experiments in 1945-46 indicated that the magnitude of over-estimation probably also depended on the shape of cuts. These experiments were directed by Dr. R. C. Bose and Mr. S. N. Roy, who personally supervised the day to day work while staying in the field camp. These experiments definitely showed that the bias becomes negligibly small in the neighbourhood of 50 sq. ft. above which size no systematic tendency towards over-estimation was noticed.

TABLE 5.

Special Experiments: Mean yield of *aus* and *aman* paddy and *jute* by different shapes and sizes of sample-cuts (nested)

sample cuts		mean yield in maunds per acre					mean yield expressed as percentages				
size in feet	area in sq. feet	*aman* paddy Bengal		*aus* paddy		jute Bengal 1947	*aman* paddy Bengal		*aus* paddy		jute Bengal 1947-48
		1945-46 $n=236$	1948-49 $n=176$	Bengal 1945-46 $n=212$	Giridih 1944-45 $n=79$	$n=268$	1945-46	1948-49	Bengal 1945-46	Giridih 1944-45	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Circle											
1 radius 2′	12.6	25.73	13.73	11.47	9.47	250.1	98	106	99	110	99
2 4′	50.3	25.78	13.69	11.34	8.86	251.0	98	106	98	103	99
3 5′8″	100.9	25.96	13.73	11.59	8.61	250.9	99	106	100	100	99
4 8′	201.1	26.34	13.68	11.61	—	249.1	100	106	100	—	98
Rectangle											
5 33′×16½′	544.5	—	12.92*	—	—	253.2	—	100	—	—	100
6 33′×35′	1155.0	—	—	—	—	253.3	—	—	—	—	100

* Number of cuts for the size 33′×16½′ is 156.

TABLE 6–1

Special Experiments : Mean yield of wheat and paddy at harvest in mds, per acre based on different sizes of sample cuts

size of sample cuts	area in sq. feet	mean yield in mds. per acre				
		aman paddy (B.H.H.) (nested cuts)				*aghani* paddy (Bihar)
		1939-40 (n=292) (nested)	1940-41 (n=404) (nested)	1941-42 (n=207) (nested)	1943-44 (a) (independent)	1944-45 (n=70) (nested)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1 3′×3′	9	—	—	—	26.51	—
2 5.2′×5.2′	27.04	20.52	18.69	30.69	—	—
3 6′×6′	36	—	—	—	24.14	14.32
4 7.0′×5.2′	36.40	—	18.12	29.42	—	—
5 5.2′×7.0′	36.40	—	18.60	30.57	—	—
6 7′×7′	49	—	17.24	28.71	—	—
7 2(5.2′×5.2′)	54.08	20.79	—	—	—	—
8 8′×8′	64	—	—	—	—	15.37
9 3(5.2′×5.2′)	81.12	20.72	—	—	—	—
10 10′×10′	100	—	—	—	—	15.04
11 4(5.2′×5.2′)	108.16	20.75	—	—	—	—
12 12′×12′	144	—	—	—	23.68	14.17
13 15′×15′	225	—	—	-	—	—
14 12.2′×20.8′	253.76	—	15.46	29.06	—	—
15 20.8′×12.2′	253.76	—	16.09	29.08	—	—
16 18′×18′	324	—	—	—	—	—
17 27.8′×12.2′	339.16	—	16.06	—	—	—
18 20.8′×20.8′	432.64	—	15.42	27.74	—	—
19 24′×24′	576	—	—	—	21.96	—
20 33.0′×20.8′	684.40	—	15.67	—	—	—
21 33′×33′	1089	—	15.93	28.64	—	—

a) Number of cuts for the respective sizes are 32, 108, 80 & 22.

TABLE 6–2

	size of sample cuts	area in sq. feet	mean yield expressed as percentages				
			aman paddy (B.H.H.)				*aghani* paddy (Bihar)
			1939-40	1940-41	1941-42	1943-44	1944-45
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	3′×3′	9	—	—	—	121	—
2	5.2′×5.2′	27.04	99	117	107	—	—
3	6′×6′	36	—	—	—	110	101
4	7.0′×5.2′	36.40	—	114	103	—	—
5	5.2′×7.0′	36.40	—	117	107	—	—
6	7′×7′	49	—	108	100	—	—
7	2(5.2′×5.2′)	54.08	100	—	—	—	—
8	8′×8′	64	—	—	—	—	108
9	3(5.2′×5.2′)	81.12	100	—	—	—	—
10	10′×10′	100	—	—	—	—	106
11	4(5.2′×5.2′)	108.16	100	—	—	—	—
12	12′×12′	144	—	—	—	108	100
13	15′×15′	225	—	—	—	—	—
14	12.2′×20.8′	253.76	—	97	102	—	—
15	20.8′×12.2′	253.76	—	101	102	—	—
16	18′×18′	324	—	—	—	—	—
17	27.8′×12.2′	339.16	—	101	—	—	—
18	20.8′×20.8′	432.64	—	97	97	—	—
19	24′×24′	576	—	—	—	100	—
20	33.0′×20.8′	684.40	—	98	—	—	—
21	33′×33′	1089	—	100	100	—	—

TABLE 7

Mean yield of wheat at harvest in mds. per acre based on different sizes of sample cuts (nested) : Uttar Pradesh

size of sample cuts	area in sq. feet	mean yield in mds. per acre		mean yield as percentages	
		1940-41 ($n=89$)	1941-42 ($n=173$)	1940-41	1941-42
(1)	(2)	(3)	(4)	(5)	(6)
1 3′×3′	9	12.35	20.27	119	120
2 6′×6′	36	10.40	16.60	100	99
3 15′×15′	225	10.12	—	97	—
4 18′×18′	324	—	16.84	—	100
5 24′×24′	576	10.39	—	100	—

TABLE 8

Mean yield in maunds of *aman* paddy per acre for different shapes of cut of the same size : Bengal 1945-46

shape of sample cuts each of size 12.5 sq. feet	mean yield in mds. per acre				mean yield expressed as percentages to the mean in circular cuts			
	Gouripur $n=32$	Katwa $n=80$	Sainthia $n=64$	Combined $n=176$	Gouripur	Katwa	Sainthia	combined
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(8)
1 circular	15.8	23.6	32.8	25.5	100.0	100.0	100.0	100.0
2 triangle	18.3	29.5	40.4	31.5	115.8	125.0	123.2	123.5
3 square	14.7	23.9	35.4	26.4	93.0	101.3	107.9	103.5
4 fork	14.4	23.7	35.7	26.4	91.1	100.4	108.8	103.5

6.2. In Table (8) the mean yield of *aman* paddy in maunds per acre is given separately for the experiments with sample-cuts of the same size (12.5 sq. ft.) but of different shapes conducted in the centres of Gouripur, Katwa and Sainthia in Bengal together with the corresponding values of n (the number of sample-cuts) in cols. (2), (3) and (4)

respectively; and the combined value is shown in col. (5). The corresponding percentages are given in cols. (6)–(8). It will be seen that accepting the circular cut as the standard, there was some over-estimation with sample-cuts of a square or fork shape (with a combined value of over-estimation of about 3.5 per cent). The over-estimation was far greater (and about 23.5 per cent combined) with cuts of a triangular shape.

6.3. It has to be remembered however that the agreement among circular cuts of different sizes had been observed under highly controlled conditions which hardly obtains in large scale surveys. It is difficult to ensure the requisite standard of careful work by each individual worker in large scale surveys. For extensive surveys, it was therefore considered advisable to adopt circles of radius 5′–8″ with an area of 100.9 sq. ft. as the standard size of cut instead of cuts of 50 sq. ft.

Experiments on an Extensive Scale

7.1. The use of concentric circular cuts was first introduced in 1945-46; the chief attraction for adopting this appliance being the low ratio of perimeter to area and the convenience with which the demarcation of a circular cut could be made, once the centre was located. The extensive provincial operations since 1945-46 were accordingly carried out with concentric circular cuts of radii of 2 feet, 4 feet, and 5 feet 8 inches respectively.

7.2. The intermediate size (radius 4′) was introduced with a view to securing some control over the quality of the field work. The expectation of the ratio of the actual yields based on the different sub-cuts would be simply equal to the ratio of the areas of the respective sub-cuts. The ratios based on actual yield records should, therefore, be of the same order, as the expected values but should also have some variation. The variance, on the other hand, should decrease as the size of the sub-cut is increased. Systematic departures from such normal tendencies in individual investigators often furnished a clue for the detection of dishonest work. Examples of typical cases detected during actual surveys are shown in Appendix B. It will be seen from this Appendix that for certain individuals, not only the relative yields between sub-cuts of different sizes were unusual, but there was an apparent uniformity in the variability of cuts of different sizes which must have been artificial. Such suspicious material was therefore rejected as unreliable and necessary disciplinary action was also usually taken.

7.3. *Comparisons between cuts of different sizes and standard sample-cuts of radius* 5′–8″ *:* As already explained, yields (in maunds per acre) of various crops were obtained on the basis of sample-cuts of (a) radius

TABLE 9

Percentage differences between estimated mean yields based on different sizes of circular cuts and yields based on standard cuts of radius 5′–8″ : Bengal

	crop	year	number of cuts	mean yield in mds. per acre based on cut (5′-8″)	differences expressed as percentages of the mean based on standard cuts of radius 5′—8″ as in col. (4)		
					2′ cut	annuular ring between 2′ & 4′	4′ cut
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	jute	1945-46	1469	14.01	11.21	−2.76	0.21
2		1946-47	1189	11.52	8.91	−3.59	−0.38
3		1947-48	1240	14.28	9.36	−4.01	−0.64
4		1948-49	358	15.80	2.83	−0.24	0.80
5		1949-50	442	14.68	5.71	−1.51	0.29
6	*aus*	1945-46	3195	7.42	16.61	−6.30	−0.58
7		1946-47	2618	7.07	12.81	−5.12	−0.83
8		1947-48	2134	7.48	13.82	−5.61	−0.72
9		1948-49	921	8.22	6.57	−2.12	0.05
10		1949-50	1460	8.52	7.77	−2.59	+0.02
11	*aman*	1945-46	4393	8.46	14.08	−5.03	−0.24
12		1946-47	5226	9.57	11.60	−4.20	−0.25
13		1947-48	2987	10.23	4.61	−2.23	−0.52
14		1948-49	3786	9.87	5.85	−2.34	0.26
15		1949-50	5778	10.48	6.33	−1.86	0.16
16	wheat	1949-50	662	7.40	8.57	−2.92	−0.05
17	barley	1949-50	283	7.18	9.31	−4.90	−1.35
18	wheat &	1947-48	215	7.34	1.80	−1.55	−0.72
19	barley	1948-49	768	7.02	6.81	−2.84	−0.43
20	gram	1947-48	198	8.03	−3.66	−1.11	−1.76
21		1948-49	511	8.14	8.76	−3.46	−0.42
22		1949-50	756	8.60	11.91	−4.51	−0.41
23	*khesari*	1948-49	227	6.57	15.56	−4.92	0.20
24		1949-50	484	5.35	17.71	−5.19	0.54
25	*masur*	1947-48	199	4.29	6.57	−2.93	−0.56
26		1948-49	357	5.57	13.15	−5.33	−0.72
27		1949-50	528	5.42	12.76	−5.50	−0.94
28	mustard	1948-49	83	3.61	18.15	−2.99	2.30
29		1949-50	285	4.03	7.85	−0.72	1.41
30	linseed	1949-50	50	3.68	16.58	−7.80	−1.71

2′, (b) radius 4′, (c) radius 5′–8″; and on the basis of the annular strips (d) between circles of radii 2′ and 4′. The yield (in maunds per acre) based on the standard cut of 5′–8″, that is, (c) is shown in col. (4) of Table (9). The differences between (a) and (c), that is, between yields based on cuts respectively of radii 2′ and 5′–8″, expressed as a percentage of (c) are shown in col. (5). In the same way, differences between (b) and (c) and between (d) and (c) expressed as percentages of (c) have been shown in cols. 6 and 7 respectively.

7.4. It will be noticed from col. (5) of Table (9) that yield rates based on cuts of radius 2′ were practically always (with the single exception of gram in 1947-48) over-estimates in comparison with yield rates based on standard cuts of radius 5′–8″. On the other hand, it can be seen from col. (6) that the annual ring between circles of radii 2′ and 4′ invariably under-estimated the yield and thus compensated for the over-estimation in cuts of radius 2′. From col. (7) it is seen that yields based on cuts of radius 4′ and also on the annular strip between circles of radii 4′ and 5′–8″ agree very well with yield rates based on the standard cuts of radius 5′–8″.

7.5. *Comparison of yields based on cuts of radii 4′ and 5′–8″* : The mean yields (in maunds per acre) based on cuts of radii 4′ and 5′–8″ are given in cols. (4) and (5) respectively of Table (10). The difference between cols. (4) and (5) is shown in col. (6) in actual maunds per acre, and in col. (7) as percentages of col. (5). Finally, the percentage standard error of mean yields based on standard cuts of radius 5′–8″ are shown in col. (8). First of all, it may be noted that the differences in yields are both positive and negative indicating that sample-cuts of a small size sometimes over-estimated but also under-estimated on many occasions. Secondly, the percentage differences are all small in magnitude and always less than one per cent in the case of jute, and *aus* and *aman* paddy. Even for other crops, for which the size of the sample is appreciably smaller, the differences are less than one per cent in 11 cases out of 15. Also, comparing cols. (7) and (8), we find that the observed differences are in all cases much lower than the standard error of the corresponding mean values based on cuts of radius 5′–8″.

7.6. In order to test in a more rigorous manner whether the mean differences were statistically significant, values of Student's '*t*' on the paired differences in individual cuts of radii 4′ and 5′–8″ have been worked out for the major crops and have been shown in col. (5) of Table A-1 in Appendix A. It will be seen from this Appendix that although the mean differences are generally small, some of them have come out to be significant. A detailed examination of the results relating to individual field workers was then taken up which has been discussed in Appendix A.

7.7. *Margin of total error in relation to errors of sampling.* The study with the help of Student's '*t*' given in Appendix A indicates that a very small difference in the mean yield may be discriminated when the test is based on samples of a very large size. It has to be remembered, however, that the margin of total error includes not only the errors of sampling but also certain other errors arising from physical fluctuations or observational variations. While sampling errors can be controlled and reduced to insignificance by increasing the size of the samples, the other components may remain uncompensated. It is, therefore, useless to reduce the margin of sampling errors indefinitely without regard to the physical or observational errors which enter into the estimation. The important point is therefore to make the total error sufficiently small to serve the purpose in view.

7.8. As already observed in paragraph 7.4, the observed differences in mean yield given in col. (7) of Table (10) are much smaller than the standard errors given in col. (8) of the same Table. The observed discrepancies (between mean yields based on cuts of radii 4′ and 5′–8″) thus represent only a small part of the total error of estimation and may, therefore, be considered as negligible at the level of sampling actually used.

7.9. The special experiments have also indicated that there is no substantial improvement in the observed agreement between mean yields based on cuts of radius 5′–8″ and those based on still larger cuts of radius 8′ feet. The use of a standard cut with a radius of 5′–8″ thus seems to be fully justified on the basis of our present knowledge. The Indian Statistical Institute is, however, continually carrying on further studies to improve the technique of yield-estimating surveys.

Risk of under-sampling of the Border of Plots and Exclusion of Small Plots

8.1 *Border bias.* The location of a sample-cut within a plot is decided by marking a point within the plot in a random manner. When the marking point falls too near the edge of the plot, the corresponding sample-cut will lie partly outside the plot and will have to be rejected. This border area near the edges of a plot would thus have less chance of being included in the sample-cut than the area further away from the border towards the centre of the plot. This would lead inevitably to an under-representation of the border of a plot relative to its more central portion. The larger the size of the sample-cut, the greater will be the risk of a bias on this account. However, there will be no bias if the rate of yield is completely independent of the position within the plot.

TABLE 10

Mean differences in estimated yields based on cuts of radii 4' and 5'-8" : Bengal 1945-46 to 1949-50

	crop	year	number of cuts	mean yield in mds. per acre based on circles of radius		difference between col. (4) & col. (5)		percentage error of standard mean yield based on circle of radius 5'-8"
				4'	5'-8"	in mds. per acre	as percentage of col. (5)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	jute	1945-46	1469	14.04	14.01	+0.030	+0.21	2.00
2		1946-47	1189	11.48	11.52	−0.044	−0.38	2.30
3		1947-48	1240	14.19	14.28	−0.092	−0.64	1.69
4		1948-49	358	15.93	15.80	+0.127	+0.80	2.97
5		1949-50	442	14.72	14.68	+0.042	+0.29	2.31
6	*aus*	1945-46	3195	7.38	7.42	−0.043	−0.58	1.49
7		1946-47	2618	7.01	7.07	−0.059	−0.83	1.84
8		1947-48	2134	7.43	7.48	−0.054	−0.72	0.82
9		1948-49	921	8.22	8.22	+0.004	+0.05	1.85
10		1949-50	1460	8.52	8.52	+0.002	+0.02	1.53
11	*aman*	1945-46	4393	8.44	8.46	−0.020	−0.24	0.67
12		1946-47	5226	9.54	9.57	−0.024	−0.25	1.48
13		1947-48	2987	10.18	10.23	−0.053	−0.52	0.87
14		1948-49	3786	9.90	9.87	+0.026	+0.26	0.89
15		1949-50	5778	10.50	10.48	+0.017	+0.16	0.70
16	wheat	1949-50	662	7.40	7.40	−0.004	−0.05	1.71
17	barley	1949-50	283	7.09	7.18	−0.097	−1.35	2.71
18	wheat &	1947-48	215	7.28	7.34	−0.053	−0.72	4.51
19	barley	1948-49	768	6.99	7.02	−0.030	−0.43	1.63
20	gram	1947-48	198	7.89	8.03	−0.141	−1.76	3.61
21		1948-49	511	8.10	8.14	−0.034	−0.42	2.09
22		1949-50	756	8.57	8.60	−0.035	−0.41	2.12
23	*khesari*	1948-49	227	6.58	6.57	+0.013	+0.20	3.16
24		1949-50	484	5.38	5.35	+0.029	+0.54	2.12
25	*masur*	1947-48	199	4.27	4.29	−0.024	−0.56	3.84
26		1948-49	357	5.53	5.57	−0.040	−0.72	2.32
27		1949-50	528	5.36	5.42	−0.051	−0.94	2.15
28	mustard	1948-49	83	3.69	3.61	+0.083	+2.30	5.54
29		1949-50	285	4.08	4.03	+0.057	+1.41	3.17
30	linseed	1949-50	50	3.62	3.68	−0.063	−1.71	4.51

8.2. Some experiments were conducted on jute in 1941 which showed an increasing trend in the rate of yield away from the border towards the central portions of a plot (Mahalanobis, 1941). The results are reproduced in Table (11). Results for three series of experiments are given : the actual distance in feet of the sample-cut from the *ail* (or raised boundary of the field on which no crop is grown) towards the central portions of the plot is given in cols. (1), (4), and (7) for the three series respectively; the corresponding mean yields of jute (green plants) in maunds per acre are given in cols. (2), (5) and (8). Adopting the mean-yield based on sample-cuts at a distance of 1.25 ft., that is, very near the edge as 100, the mean yields further inside are expressed as percentages or index numbers in cols. (3), (6) and (9). It will be seen from these three columns that the yield is much higher towards the central portions of the plot. The use of sample-cuts of a small size would be, therefore, advantageous as this would reduce the amount of under-sampling of the border of a plot.

TABLE 11

Gradient of rate of yield of Jute from the '*ail*' towards the centre : Bengal, 1941

size of cuts : 2.5′×2.5′			size of cuts : 3.5′×3.5′			size of cuts : 5′.0×5′.0		
(n=44)			(n=57)			(n=50)		
distance of cut from *ail* in feet	mean yield in maunds per acre	index no.	distance of cut from *ail* in feet	mean yield in maunds per acre	index no.	distance of cut from *ail* in feet	mean yields in maunds per acre	index no.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1 1.25	218	100	1.75	168	100	2.50	162	100
2 3.75	267	124	5.25	207	123	7.50	183	113
3 6.25	291	134	8.75	227	135	12.50	196	122
4 8.75	305	140	12.25	220	131	17.50	194	120

8.3. *Exclusion of small plots.* When the size of the sample-cut is large there is also a risk of small plots (for example, those with areas less than the size of the sample-cut itself) being excluded altogether from the sample which would introduce another kind of bias in case the mean yield of small plots happen to be significantly different from the mean yield of larger plots. Table (12) below gives a frequency distribution of the paddy fields (parcels of land under separate cultivation and not cadastral plots) by their sizes based on a sample of fields harvested in Bankura district in Bengal in 1949. It gives ample evidence that the size of the majority of paddy fields in certain districts of

West Bengal is very small. Further studies in this direction on a larger sample is proceeding. The size intervals shown here represent the gross area of the cultivated field inclusive of *ails*. An adjustment up to 15.9% has to be made in lieu of these *ails* for plots of very small size, as will be seen in col. (4) of Table (12). There is, therefore, a serious risk of excluding the very small plots if the size of the sample-cut is made large. Sample-cuts of a small size, therefore, seem to be more suitable for the sampling of paddy fields in West Bengal.

TABLE 12

Frequency Distribution of Crop-plots by size based on a sample of *aman* fields in district Bankura, West Bengal: 1949-50

	size of *aman* plot (field) in acres	number	percentage	area of *ail* as percentage of plot area
	(1)	(2)	(3)	(4)
	upto .05	1991	18.2	15.9%
1	.06 – .09	1778	16.2	10.2
2	.10 – .19	2745	25.1	7.4
3	.20 – .29	1417	12.9	5.7
4	.30 – .39	805	7.3	4.8
5	.40 – .49	583	5.3	4.3
6	.50 – .59	376	3.4	3.8
7	.60 – .69	268	2.4	3.5
8	.70 – .79	208	1.9	3.3
9	.80 – .89	156	1.4	3.1
10	.90 – .99	114	1.0	2.9
11	1.00 above	534	4.9	1.5
12	total	10975	100.0	3.7%

STAGE VARIANCES FOR SAMPLE-CUTS OF DIFFERENT SIZE.

9.1. In analysing the results of a multi-stage sample survey it is not essential to estimate the 'true' variances at differennt stages. Estimates of such 'true' variances are, however, useful in preparing the design of subsequent surveys. Estimated values of standard deviations of the mean yield of *aman* paddy in West Bengal in 1949-50, at different stages, are given in Table (13). The design was a 3-stage one; a certain number

of "localities" (defined as an area of radius of one mile described round a centre located at random within a *thana* or Police Station) were selected in the first stage; within each selected locality, a number of sample-units of size 2.25 acres were next located at random; and, finally, within each sample-unit of size 2.25 acres a number of concentric sample-cuts of 3 different sizes were then located at random and harvested. The calculated 'true' standard deviations are shown in Table (13) for 'localities within stratum', for 'sample-units within locality', and for 'sample-cuts within sample-unit'. It will be noticed that there are no systematic variations at the first two stages, that is, 'between locality within stratum' or 'between sample-units within locality'; but the standard deviations for sample-cuts within a sample-unit of 2.25 acres show an appreciable decrease with increasing size of the sample-cut. This is what is to be expected because the standard deviation is likely to depend on the size of the cut at the last stage.

TABLE 13

Estimated standard deviation of the mean yield of *aman* paddy (expressed in maunds of clean rice per acre) at different stages by size of cuts ;West Bengal, 1949-50

	stages	D.F.	'true' standard deviation of the stage means obtained from cuts of radius		
			2'-0"	4'-0"	5'-8"
	(1)	(2)	(3)	(4)	(5)
1	locality within stratum (a)	827	1.17	1.30	1.25
2	sample-unit within locality (b)	1885	2.50	2.16	2.21
3	sample-cut within sample-unit	2851	3.48	2.96	2.76
4	total between cuts	5777	4.83	4.27	4.14
5	mean in mds. per acre	-	11.14	10.50	10.48

(a) 'Locality' represents a circle of 1 mile radius located at random in a Police Station.
(b) Sample-units of size 2.25 acres.

COMPERATIVE EFFICIENCY OF SAMPLE-CUTS OF DIFFERENT SIZE.

10.1. The efficiency of the design of a sample survey is determined by the cost in relation to the sampling error of the final result. Sample-cuts of a large size would have, individually, smaller errors of sampling but would be more expensive compared to sample-cuts of a smaller size. So that working with small cuts it may be possible, at the same cost, to secure so many more cuts per field or more fields per village

or to cover a larger number of villages that the sampling errors of the final estimates become smaller than those arising when cuts of a larger size are used. The lower the cost of reaching an assigned level of precision (that is, any assigned margin of error) with any given size of sample-cuts, the higher will be its efficiency.

10.2. Illustrative data on the relative cost of using sample-cuts of different sizes to reach the same error within sample plots in the case of *aman* paddy are given in Table (14) in which col. (2) shows the equivalent number of sample-cuts which would be required to reach the same sampling error. These figures are based on the following observational formula :

$$V_x = \frac{a}{(x)^g} ,$$

where V_x is the variance per sample-cut of size x sq. ft. and a and g are empirical constants. The value of $g=0.33$ is based on experiments

TABLE 14

Cost and sampling error for sample-cuts of different sizes

	size of cut in sq. ft.	equivalent number of cuts to obtain the same sample error (within plots)	net hours per cut (investigator assisted by one hired labourer)*	total cost for same sampling error = col. (2) × col.(3)	relative cost
	(1)	(2)	(3)	(4)	(5)
1	12.5	3.47	0.3	1.041	67
2	50.3	2.19	0.3	1.313	84
3	100.9	1.74	0.9	1.565	100
4	201.1	1.39	1.4	1.946	125
5	544.5	1.00	2.6	2.600	167

* Based on experiments in 1941-42, 1942-43, & 1943-44.

on *aman* paddy in Bengal in 1943-44, 1944-45, and 1948-49. From Table (14) it is seen that 2.19 sample-cuts of size 50.3 sq. ft. would have the same sampling error as 1.74 cuts of 100.9 sq. ft. or one single cut of size 544.5 sq.

10.3. The cost of obtaining a sample-cut of a given size is given in terms of the time taken by one investigator assisted by one hired labourer to secure one single cut. For example 2.6 hours would be reequired to obtain a single cut of size 544.5 sq. ft. against only 0.9 hour for cut size 100.9 sq. ft. or only 0.6 hour for cuts of size 50.3 sq. ft. The total cost (to reach the same sampling error) would be thus obtained by multiplying the corresponding figures in col. (2) and col. (3) which are shown in col. (4). Finally, the figures in col. (4) are expressed as percentages of the total cost for cuts of size 100.9 sq. ft. as the standard. From col. (5) it will be seen that cuts of size 544.5 sq. ft. would cost 67 per cent more to give results with the same sampling error as cuts of size 100.9 sq. ft. In fact, cuts of the smallest size, namely, 12.5 sq. ft. would be one-third cheaper than cuts of size 100.9 sq. ft., but we have already seen that cuts of such a small size appear to have a tendency towards over-estimation which rules them out.

Criteria for the Choice of a Standard Size for Sample Cuts.

11.1. On the basis of the available evidence it would seen desirable to adopt a circular cut of radius 4′–0″ (covering 50.3 sq. ft.) or of radius 5′–8″ (covering 100.9 sq. ft.) as the standard size of sample-cut for yield estimating surveys. There is practically no over-estimating bias with these sizes. The 'true' variances at different stages can be estimated practically without any bias. Also, bias due to the undersampling of the border of the plots would be small compared to cuts of a larger size. This consideration is of great importance, for example, in the case of West Bengal where an appreciable proportion of crop fields are of a very small size, and the use of large cuts would be undesirable.

11.2. From the operational point of view, circular cuts of the size recommended have many advantages. They can be more conveniently and quickly demarcated and the time spent in harvesting and threshing is small. A small cut necessarily lightens the field work, which is an important consideration in ensuring good quality of work. Difficulties of field operations tend to make the investigator careless or dishonest. Working with cuts of a large size, of the order of 500 sq. ft. or so, it is also extremely difficult, if not impossible, to finish the threshing work within the day, especially if the crop harvested is moist. Leaving the harvested crop at the owner's yard for threshing on a subsequent day is undesirable as there is always a chance of deliberate tampering or unintentional losses. It is essential to have the crop harvested and weighed on the same day in the presence of the investigator; this is facilitated by cuts of a small size.

11.3. A cut of a small size which is convenient to manage and which permits the use of a portable rigid frame for its demarcation is therefore to be preferred. Actual field operations are simpler in using cuts of a small size. With a small number of whole-time field staff who have to be always on the move, the Indian Statistical Institute was eager to discover the smallest cut which would be free from bias, would be amenable to statistical controls, and which would give results of reasonable precision in relation to cost. With this object in view the Institute experimented with various sizes of cuts ranging from a very small cut of 1 sq. ft. to a size of 1809 sq. ft.; very small cuts were however found unsuitable. It is now considered that a standard sample-cut of about 100 sq. ft. might be suitable in every way and that any further increase of size is entirely unnecessary.

Need of Further Studies

12.1. We may now very briefly refer to similar studies made by the Imperial (now Indian) Council of Agricultural Research (ICAR) which appeared to show a large over-estimating bias in working with sample-cuts of a small size. In its first publication (Sukhatme, 1944-45) on the subject in 1944-45 based on work on wheat in district Moradabad in U.P. the ICAR reported (p. 48 Table 15) that there was an over-estimating bias of 42.4% with circular cuts of radius 2′–0″, and 14.9% with circular cuts of radius 3′ feet. Since then the ICAR has published other results of a similar nature, for example, an over-estimating bias of 9.0% and 4.5% with circular cuts of radii 2′–0″ and 3′–0″ respec tively in the ICAR work on paddy in district Kistna in Madras in 1945-46 (p. 34 Table 14) (Sukhatme, 1945-46). The results obtained in experiments on paddy in district Guntur in Madras were, however, quite different, there being *under*-estimation to the extent of 11.5% with cuts of radius 3′–0″ feet, and *under*-estimation of 2.5% with cuts of radius 2′–0″ feet. The evidence given in the present paper shows that the experience of the Indian Statistical Institute has been quite different. The over-estimating bias of cuts of a small size was much smaller in the intensive series of special experiments as well as in the general surveys organized on an extensive scale.

12.2. That the operational advantage in handling the produce of cuts of relatively small size was also felt by the Indian Council of Agricultural Research is apparent from the fact that the ICAR gradually reduced the size of the sample-cut in successive survey from 1/20 (one-twentieth) acre in U.P. in 1943-44 to 1/80 (one-eightieth) acre in the Punjab in 1945-46, to 1/100 (one-hundredth) acre in U.P. in 1945-46 and to 1/160th acre in Orissa.

12.3. It may be mentioned here that the approaches adopted by the Indian Statistical Institute and the I.C.A.R. have been entirely different. The Institute worked with a small number of whole-time field Investigators operating under the direct technical guidance of the Institute. The I.C.A.R. worked through the departmental agencies of Revenue and Agriculture in the different State Governments for actual field work, while exercising the over-all technical control and guidance. The policy adopted by the I.C.A.R. was to pursue the line of least resistance from official quarters and to introduce only such changes in the official procedure as were strictly relevant for an adoption of random sampling method.

12.4. So far as the size of the sample-cut is concerned the difference between the Institute and the I.C.A.R. has narrowed down considerably. From a scientific point of view it is, however, still important to investigate why there has been (or still is) any over-estimating bias in working with cuts of a very small size under Indian conditions. It is to be noted that the type of human agency has been different in the Institute and I.C.A.R. methods. It is most desirable, therefore, that joint studies should be made of both methods of work with a view to developing a unified system of yield-estimating surveys in India.

Appendix A

COMPARISON OF MEAN YIELDS OF CROPS BASED ON SAMPLE-CUTS OF DIFFERENT SIZES

DISTRIBUTION OF P(t) FOR INDIVIDUAL FIELD INVESTIGATORS.

1.1. A detailed study has been made of the difference in the mean rates of yield of crops based on sample-cuts of radii 4′-0″ and 5′-8″. Each investigator collected a number of sets of sample-cuts of radii 4′-0″ and 5′-8″ in the form of concentric circles located at random on a crop field. From each cut the rate of yield in maunds per acre can be calculated and hence the difference in mean yields from each pair of cuts. It is then possible to calculate Student's t-statistic based on the total number of paired yields obtained by each field investigator. It is also possible to obtain for each investigator the value of P(t), the probability of occurrence of a value of t equal to or greater than the observed value due to chance factors alone. There will be thus one value of P(t) for each field investigator. The distribution of P(t) should be uniform over the range 0 to 1 on the null hypothesis, that is, in case the observed differences in yields based on each pair of sample-cuts have their origin in pure chance. A study of the frequency distribution of P(t) would, therefore, throw light on deviations, if any, from a chance distribution.

1.2. Table A–1 shows the distribution of P(t) for individual investigators by crops and by years. Col. (1) gives the name of crop, col. (2) the year; col. (3) the total number of sample-cuts available; col. (4) shows the difference between the mean yield based on cuts of radius 4′-0″ and the mean yield based on cuts of radius 5′-8″ (in maunds per acre). The value of P(t) for this observed difference in mean yield is given in col. (5). In addition, the distribution of P(t) for individual field workers is shown in cols. (6)–(11), and the total number of workers is shown in col. (12). The distribution is given separately for negative and positive differences, and for class intervals of P=0–0.005, .005–.025, and .025–0.5 on either side of zero so that the theoretical expectation of the proportion of values of P(t) falling within the three class intervals on each side are 0.5%, 2.0%, and 47.5% respectively. Finally, col. (13) shows the percentage of cases in which the observed difference was positive, that is, the mean-yield based on cuts of radius 4′-0″ was higher than the yield based on the larger cut of radius 5′-8″. The total over-all crop-seasons are given at the bottom of the entries for each crop in cols. (6)–(12), and the corresponding percentages are given in the next line.

TABLE A-1

Frequency distribution of investigators by levels of P(t) of the differences in yield based on sample cuts of two different sizes : General Survey, Bengal, 1945-46 to 1949-50

	crop	year	number of cuts	difference of mean yields in mds. per acre	value of Student's	number of workers by percentage levels of P(t)							percentage of positive cases
						negative differences			positive differences			total no. of workers	
						0.0-0.5	0.5-2.5	2.5-50.0	50.0-2.5	2.5-0.5	0.5-0.0		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1	jute	1945-46	1469	+.030	0.75	15	11	87	82	12	24	231	51
2		1946-47	1189	−.044	1.22	14	13	68	67	8	20	190	50
3		1947-48	1240	−.092	2.49*	19	7	55	55	7	12	155	48
4		1948-49	358	+.127	1.95	—	3	25	30	4	2	64	56
5		1949-50	442	+.042	0.72	4	1	36	48	3	1	93	56
6	total:					52	35	271	282	34	59	733	51
7	percentage					7.1	4.8	37.0	38.5	4.6	8.0	100.0	—
8	*aus*	1945-46	3195	−.043	2.87**	40	19	76	89	21	36	281	52
9	paddy	1946-47	2618	−.059	0.22	34	28	82	81	18	20	263	45
10		1947-48	2134	−.054	2.84**	24	9	60	49	7	27	176	47
11		1948-49	921	+.004	0.17	3	1	43	53	6	—	106	56
12		1949-50	1460	+.002	0.11	8	7	53	58	6	8	140	51
13	total:					109	64	314	330	58	91	966	50
14	percentage					11.3	6.6	32.5	34.2	6.0	9.4	100.0	—
15	*aman*	1945-46	4393	−.020	1.67	36	10	67	61	15	33	222	49
16	paddy	1946-47	5226	−.024	2.18*	40	14	53	89	12	34	242	56
17		1947-48	2987	−.053	2.50*	19	13	71	75	8	11	197	48
18		1948-49	3786	+.026	2.00*	11	8	73	82	16	15	205	55
19		1949-50	5778	+.017	1.55	18	8	58	82	21	25	212	60
20	total:					124	53	322	389	72	118	1078	54
21	percentage					11.5	4.9	29.9	36.1	6.7	10.9	100.0	—

* Significant at 5% level. ** Significant at 1% level.

1.3. It will be noticed that the mean differences in col. (4) are extremely small and yet some of them are statistically significant as tested by the values of the corresponding P(t) given in col. (5). Looking at cols. (6)–(11) we find that there is a large excess of values of P(t) at the two extreme ends, that is, in the class intervals P=0–0.005 and 0.005–.025. This shows that a considerable proportion of the investigators have a bias of one kind or other (*i.e.*, positive or negative) so that in surveys carried out with a large number of investigators, the positive and negative biases would tend to cancel out to a large extent and the mean value would come out fairly correct.

1.4. From col. (13) of Table A-1 it will be also seen that the number of investigators having positive and negative biases are roughly the same with possibly a very slight preponderance of these with a positive bias who overestimate with the smaller cut.

Distribution of P(t) for Individual Localities

2.1. In the design of the general surveys there are usually 4 or 5 'localities' or centres comprising a compact area of radius one mile within each Police Station (an administrative unit corresponding to *tehsil* or *taluka*). Each investigator worked in several such localities, and he made a number of concentric sample-cuts of different sizes in each locality. For each locality, therefore, several paired values are available of the yield based on cuts of radii 4′–0″ (y_4) and 5′–8″ (y_6); and it is possible to obtain several values of the differences in yield, that is, of (y_4—y_6) for each locality. The value of Student's t can be then calculated for each locality on the basis of these differences (y_4—y_6), and the corresponding values of P(t) can be directly obtained from tables giving the probability of occurrence of values of t equal to or greater than the overved value arising from pure chance. The frequency distribution of these values of P(t) for individual localities is given in Table A-2 in which the arrangement is exactly similar to that in Table A-1. Col. (4) gives the difference in mean $\bar{y}_4$ and mean $\bar{y}_6$, and col. (5) the corresponding value of Students' t; cols. (6)–(11) show the distribution of values of P(t) and indicate that there is an excess of values at the two extreme ends (beyond .026 on both positive and negative sides) showing the existence of either positive or negative bias when the material is analysed by localities. The figures given in col. (13) again show that there is a slight preponderance of positive differences in yields indicating a slight tendency to over-estimate with the smaller cut.

2.2. It should be noted in this connection that the analysis given here is to some extent approximate because although the sampling was done in a multi-stage pattern, the pooled estimates of both the mean

TABLE A-2

Frequency distribution of 'localities' by levels of P(t) of the differences in yield based on sample-cuts of different sizes: General Survey, Bengal, 1947-48 to 1949-50

0.135 mds. per acre=11.1086 lbs per acre=12.4491 kgms per hectare

	crop	year	number of cuts	difference of mean yield in mds. per acre	value of Student's t	number of localities by percentage levels of P(t)						total no. of localities	percentage of positive cases
						negative differences			positive differences				
						0.0-0.5	0.5-2.5	2.5-50.0	50.0-2.5	2.5-0.5	0.5-0.0		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1	jute	1947-48	1240	−.092	2.49*	25	20	117	137	23	20	342	53
2		1948-49	358	+.127	1.95	1	1	39	51	5	3	100	59
3		1949-50	442	+.042	0.72	—	—	56	68	3	5	132	58
4	total					26	21	212	256	31	28	574	55
5	percentage					4.5	3.7	36.9	44.6	5.4	4.9	100.0	—
6	*aus*	1947-48	2134	−.054	2.84**	50	52	211	164	32	35	544	42
7		1948-49	921	+.004	0.17	4	5	94	110	5	1	219	53
8		1949-50	1460	+.002	0.11	14	8	133	156	7	10	328	53
9	total					68	65	438	430	44	46	1091	48
10	percentage					6.2	6.0	40.2	39.4	4.0	4.2	100.0	—
11	*aman*	1947-48	2987	−.053	3.50**	28	29	246	247	27	15	592	49
12		1948-49	3786	+.026	2.00*	13	31	249	339	38	23	693	58
13		1949-50	5778	+.017	1.55	33	44	355	483	66	35	1016	57
14	total					74	104	850	1069	131	73	2301	55
15	percentage					3.2	4.5	36.9	46.5	5.7	3.2	100.0	—

* Significant at 5% level. ** Significant at 1% level.

differences and their errors were calculated on the uni-stage basis for the Province as a whole without weighting by the acreage under crops in the stratum.

Frequency Distribution of Yield Rates.

3.1. The frequency distributions of mean yield rates and of differences in yield rates based on cuts of different sizes are also of considerable interest. Relevant data for jute and *aus* and *aman* paddy are given in Tables A-3, A-3.1, A-4, A-4.1, A-5 and A-5.1. Frequency distributions of yield rates in respect of the *rabi* crops under cereals, pulses and oilseeds have been given in Table A-6. Tables A-3, A-4, A-5 and A-6 give the frequency distributions in tolas per cut of a standard size (that is, converted in terms of cuts) of radius 5′–8″ for jute (green plants) *aus* and *aman* paddy (in husk) respectively, the weight of the crop being taken immediately after harvesting in the case of jute and after harvesting and threshing in the case of paddy. Table A-6, on the other hand, gives the frequency distribution of cereals while in husk and of pulses and oilseeds in pods. In these three tables the data based on circular cuts of radii 2′–0″, 4′–0″ and 5′–8″ are shown as y_2, y_4 and y_6 respectively. The associated Tables A-3.1, A-4.1 and A-5.1 give the frequency distributions of differences in mean yields of jute, *aus* and *aman* paddy based on cuts of different sizes, that is, the frequency distribution of $(y_2—y_6)$ and $(y_2—y_4)$ in tolas per cut of radius 5′–8″.

3.2. It will be noticed that in all the three Tables A-3.1, A-4.1 and A-5.1 the differences in mean yields have both positive and negative signs showing that the yield was sometimes over-estimated and sometimes under-estimated by cuts of the smaller size. Again, in all the three tables, the differences $(y_2—y_4)$ have an appreciably larger number of positive signs showing that there was a definite tendency towards over-estimation when working with cuts of the smallest size of radius 2′–0″. In the case of $(y_4—y_6)$, the positive and negative differences are more or less equally distributed showing that the tendency to over-estimate (observed in the case of cuts of radius 2′–0″) had practically vanished in the case of cuts of radius 4′–0″. There is a slight preponderance of positive values in the case of $(y_4—y_6)$, which, however, is probably negligible for most practical purposes.

TABLE A-3

Frequency distribution of crop yield of jute (green plants) based on sample-cuts of different sizes : Bengal 1945-46 to 1949-50

(in tola per standard cut=0.135 maunds per acre = 11.1086 lbs per acre = 12.4491 kgms. per hectare.)

interval in hundred tolas per standard cut	cuts of radius 2'-0" (y_2)					cuts of radius 4'-0" (y_4)					cuts of radius 5'-8" (y_8)				
	1945-46	1946-47	1947-48	1948-49	1949-50	1945-46	1946-47	1947-48	1948-49	1949-50	1945-46	1946-47	1947-48	1948-49	1949-50
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1 0— 2	9	10	8	1	2	7	9	9	2	2	7	7	8	3	3
2 2— 4	18	46	12	12	3	19	40	19	10	4	19	35	23	7	3
3 4— 6	38	67	40	15	14	56	91	66	16	12	48	90	44	18	10
4 6— 8	94	108	83	20	21	110	136	66	20	28	96	128	77	17	31
5 8—10	114	188	83	30	37	124	151	90	21	44	119	150	98	21	34
6 10—12	119	124	68	19	43	147	172	115	29	35	168	169	114	32	41
7 12—14	146	132	115	27	39	144	127	152	28	52	158	151	139	26	51
8 14—16	155	92	137	25	45	179	118	131	26	46	117	117	139	28	47
9 16—18	169	108	171	31	44	176	95	142	36	33	163	86	135	36	32
13 18—20	120	66	109	37	32	138	81	112	30	27	130	89	121	34	34
11 20—22	78	57	69	24	21	79	50	84	26	30	107	57	88	25	29
12 22—24	98	52	71	26	34	86	48	76	21	34	90	41	77	23	34
13 24—26	100	47	92	17	24	64	22	58	22	27	69	23	51	19	28
14 26—28	47	19	31	12	15	46	17	47	17	14	43	16	50	22	18
15 28—30	32	17	31	16	9	29	9	21	18	18	14	15	19	12	15
16 30—32	32	17	34	8	11	18	10	12	7	9	23	7	20	12	9
17 32—34	33	13	43	10	22	15	5	15	11	10	15	2	12	9	4
18 34—36	10	4	7	8	4	18	1	10	8	2	8	—	12	5	7
19 36—38	8	3	11	5	1	7	2	6	3	1	7	2	6	2	2
20 38—40	8	7	10	6	6	3	2	4	4	3	4	1	2	4	—
21 40—60	36	10	13	9	10	4	3	5	3	7	4	3	5	3	6
22 60—80	5	2	2	—	5	—	—	—	—	4	—	—	—	—	4
23 80-100	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
24 100-120	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—
25 total	1469	1189	1240	358	442	1469	1189	1240	358	442	1469	1189	1240	358	442

TABLE A–3.1

Frequency distribution of differences in mean yield of jute (green plant) based on cuts of different sizes : Bengal 1945–46 to 1949–50

	interval in tea tolas per standard cut	y_2-y_6					y_4-y_6				
		1945–46	1946–47	1947–48	1948–49	1949–50	1945–46	1946–47	1947–48	1948–49	1949–50
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	−240 to −220	—	—	—	—	1	—	—	—	—	—
2	−200 „ −184	—	—	—	—	1	—	—	—	—	—
3	−180 „ −160	3	—	1	—	—	—	—	—	—	—
4	−160 „ −140	6	—	2	1	1	—	—	—	—	—
5	−140 „ −120	6	—	2	2	1	—	—	—	—	—
6	−120 „ −100	4	2	11	—	1	—	—	—	—	—
7	−100 „ − 80	9	5	12	2	3	1	—	2	—	—
8	− 80 „ − 60	27	7	18	7	12	10	1	2	—	—
9	− 60 „ − 50	12	11	24	8	6	9	4	5	2	2
10	− 50 „ − 45	17	20	16	4	6	7	4	6	1	1
11	− 45 „ − 40	16	23	15	12	7	11	9	7	—	3
12	− 40 „ − 35	29	33	12	8	8	14	6	8	2	—
13	− 35 „ − 30	35	41	24	10	10	16	5	18	4	6
14	− 30 „ − 25	48	38	24	12	14	21	21	22	3	4
15	− 25 „ − 20	43	52	24	20	15	45	21	48	7	14
16	− 20 „ − 15	58	51	37	17	20	66	63	54	14	26
17	− 15 „ − 10	59	44	46	15	15	107	98	82	22	26
18	− 10 „ − 5	70	63	70	13	12	152	165	147	40	60
19	− 5 „ −0.1	79	82	78	24	32	224	188	213	59	62
20		521	472	416	155	165	683	585	614	154	204
21	0	5	1	2	—	1	4	5	4	1	2
22	0.1 to 5	110	87	85	36	43	241	237	218	80	78
23	5 „ 10	86	96	75	30	27	183	173	168	50	76
24	10 „ 15	73	76	84	19	34	136	81	111	26	32
25	15 „ 20	81	90	62	18	31	95	47	72	17	20
26	20 „ 25	71	59	73	12	21	55	18	24	11	9
27	25 „ 30	71	41	47	16	7	21	12	13	4	5
28	30 „ 35	53	42	53	12	20	16	16	7	9	7
29	35 „ 40	48	30	43	11	14	10	8	4	4	4
30	40 „ 45	40	36	54	8	15	5	1	3	2	3
31	45 „ 50	37	26	26	7	6	6	2	1	—	—
32	50 „ 60	61	33	71	7	15	6	1	1	—	—
33	60 „ 80	73	29	78	13	21	7	3	—	—	1
34	80 „ 100	51	24	37	5	7	1	—	—	—	1
35	100 „ 120	29	11	16	4	3	—	—	—	—	—
36	120 „ 140	14	14	7	3	3	—	—	—	—	—
37	140 „ 160	12	7	2	1	3	—	—	—	—	—
38	160 „ 180	7	6	3	—	1	—	—	—	—	—
39	180 „ 200	8	3	3	—	2	—	—	—	—	—
40	200 „ 220	7	1	1	1	—	—	—	—	—	—
41	220 „ 240	3	1	—	—	2	—	—	—	—	—
42	240 „ 260	3	—	1	—	—	—	—	—	—	—
43	260 „ 280	2	1	—	—	1	—	—	—	—	—
44	280 „ 300	1	—	—	—	—	—	—	—	—	—
45	300 „ 320	—	—	1	—	—	—	—	—	—	—
46	320 „ 340	1	1	—	—	—	—	—	—	—	—
47	360 „ 380	1	2	—	—	—	—	—	—	—	—
48		943	716	822	203	276	782	599	622	203	236
49	total	1469	1189	1240	358	442	1469	1189	1240	358	442

(1 tola per standard cut=0.135 maunds per acre = 11.1086 lbs per acre = 12.4491 kgms per hactare)

TABLE A-4.1

Frequency distribution of diferences in yields of *aus* paddy (in husk) based on cuts of different sizes : Bengal 1945-46 to 1949-50

(In tola per standard cut=0.135 maunds per acre) = 11.1080 lbs per acre)

	interval in tola per standard cut	$y_2 - y_6$					$y_4 - y_6$				
		1945-46	1946-47	1947-48	1948-49	1949-50	1945-46	1946-47	1947-48	1948-49	1949-50
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	−100 to −91	3	1	—	1	1	—	—	—	—	—
2	− 90 „ −81	1	—	1	1	1	2	—	—	—	—
3	− 80 „ −71	5	4	2	—	2	3	—	—	—	—
4	− 70 „ −61	11	1	2	2	6	3	—	—	—	—
5	− 60 „ −51	12	4	2	4	4	4	—	1	—	—
6	− 50 „ −46	13	3	3	7	8	5	1	3	—	—
7	− 45 „ −41	13	7	9	3	6	3	—	1	1	—
8	− 40 „ −36	29	11	7	5	14	3	6	2	—	2
9	− 35 „ −31	36	20	16	14	21	10	5	4	3	6
10	− 30 „ −26	50	41	11	16	25	30	14	22	4	3
11	− 25 „ −21	55	50	30	25	42	48	38	25	9	16
12	− 20 „ −16	73	106	48	33	48	83	73	46	20	37
13	− 15 „ −11	125	144	87	48	71	215	163	132	46	76
14	− 10 „ − 6	200	226	147	66	95	402	328	252	118	187
15	− 5 „ − 1	253	289	244	124	156	736	675	544	240	347
17		879	908	609	349	500	1547	1303	1032	441	674
18	0	68	72	53	20	38	190	210	150	52	90
19	1 to 5	294	258	276	118	179	722	589	531	234	389
20	6 „ 10	287	262	217	94	173	384	299	256	102	164
21	11 „ 15	233	175	216	88	139	209	119	97	51	87
22	16 „ 20	263	197	148	60	83	68	60	39	23	22
23	21 „ 25	213	133	113	48	64	31	19	16	12	16
24	26 „ 30	172	125	110	31	72	17	8	7	2	9
25	31 „ 35	132	96	70	23	50	9	6	3	2	5
26	36 „ 40	101	90	65	29	40	10	1	1	1	3
27	41 „ 45	109	48	56	12	21	3	3	1	—	—
28	46 „ 50	77	38	33	5	19	2	1	1	1	1
29	51 „ 60	108	78	56	12	29	2	—	—	—	—
30	61 „ 70	96	47	31	10	17	—	—	—	—	—
31	71 „ 80	47	21	17	3	9	1	—	—	—	—
32	81 „ 90	29	18	13	7	8	—	—	—	—	—
33	91 „ 100	34	9	18	2	4	—	—	—	—	—
34	101 „ 125	26	11	17	8	5	—	—	—	—	—
35	126 „ 150	14	6	8	1	7	—	—	—	—	—
36	151 „ 175	4	7	7	1	—	—	—	—	—	—
37	176 „ 200	6	3	1	—	1	—	—	—	—	—
38	201 „ 225	3	1	—	—	2	—	—	—	—	—
39	250 „ 275	—	2	—	—	—	—	—	—	—	—
40	868	—	1	—	—	—	—	—	—	—	—
41		2248	1638	1472	552	922	1458	1105	952	428	696
42	total	3195	2618	2134	921	1460	3195	2618	2134	921	1460

Frequency distribution of yield of *aus* paddy (in husk) based on sample-cuts of different sizes
Bengal 1945-46 to 1949-50

(In tola per standard cut = 0.135 maunds per acre = 11.1086 lbs per acre = 12.4491 kgms. hectare

interval in tens tolas per standard cut		cuts of radius 2'-0" (y_2)					cuts of radius 4'-0" (y_4)					cuts of radius 5'-8"(y_8)				
		1945-46	1946-47	1947-48	1948-49	1949-50	1945-46	1946-47	1947-48	1948-49	1949-50	1945-46	1946-47	1947-48	1948-49	1949-50
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1	0— 2	36	24	12	8	13	32	41	8	13	16	32	39	0	14	19
2	2— 3	32	57	27	17	26	61	92	39	19	31	57	88	30	13	23
3	3— 4	52	86	40	16	28	114	137	89	32	32	104	124	81	35	36
4	4— 5	189	268	141	76	88	182	185	94	47	67	159	172	109	56	51
5	5— 6	149	131	85	41	38	247	238	176	68	71	237	252	136	55	78
6	6— 7	182	161	108	54	67	262	216	147	52	91	272	219	166	65	98
7	7— 8	143	118	105	52	65	284	213	226	70	86	306	224	212	54	84
8	8— 9	445	354	283	106	160	351	238	227	71	109	330	234	239	73	106
9	9—10	248	168	184	58	87	278	222	189	74	106	278	222	194	81	123
10	10—11	145	131	137	46	80	234	217	181	85	120	267	208	192	73	119
11	11—12	150	148	127	45	67	237	177	152	58	116	234	167	163	69	111
12	12—13	361	256	260	96	192	198	151	111	44	105	211	149	121	38	91
13	13—14	120	101	80	36	67	169	102	126	40	91	167	119	130	48	106
14	14—15	188	110	110	37	66	126	89	97	45	85	145	99	121	43	93
15	15—16	89	81	56	25	55	116	58	90	36	78	122	67	56	42	59
16	16—17	232	163	113	61	113	90	60	41	29	57	84	56	46	30	77
17	17—18	78	44	37	22	53	49	29	29	23	46	52	40	35	27	51
18	18—19	44	27	30	25	26	48	36	35	26	49	43	28	24	21	40
19	19—20	39	24	32	9	20	33	22	18	19	22	22	24	31	20	24
20	20—21	103	55	67	32	48	22	23	22	25	23	20	23	7	23	17
21	21—22	20	19	19	7	16	17	17	13	13	13	17	22	7	16	16
22	22—23	28	14	14	13	13	12	17	8	11	14	18	15	10	7	13
23	23—24	10	11	7	5	9	14	15	4	5	11	6	5	—	4	11
24	24—25	40	24	21	9	22	2	7	2	4	6	2	7	5	6	4
25	25—26	10	5	6	4	10	4	3	2	3	4	5	6	4	2	4
26	26—27	3	14	4	2	3	5	7	4	3	4	1	4	2	2	2
27	27—28	2	8	2	2	1	3	1	—	1	2	1	—	7	1	2
28	28—29	15	1	14	8	9	2	1	1	3	2	1	1	1	1	—
29	29—30	—	3	3	—	3	2	1	—	—	1	—	1	—	—	—
30	30—31	3	—	1	3	3	—	—	—	—	—	—	1	1	—	1
31	31—32	2	4	1	3	2	—	1	1	—	—	—	—	—	—	—
32	32—33	11	3	3	2	4	—	—	—	—	—	1	—	—	1	—
33	33—34	2	2	1	1	—	—	—	—	—	1	—	2	1	1	—
34	34—35	2	2	—	1	—	1	1	—	—	—	—	—	1	—	—
35	35—36	1	—	1	—	—	—	—	—	2	—	—	—	—	—	—
36	36—37	5	2	2	1	2	—	—	—	—	—	1	—	—	—	—
37	37—38	2	1	—	1	—	—	1	1	—	—	—	—	—	—	1
38	38—39	2	2	—	—	—	—	—	1	—	1	—	—	—	—	—
39	39—40	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
40	40—50	2	4	1	—	4	—	—	—	—	—	—	—	—	—	—
41	50—60	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—
42	60—70	—	1	—	—	—	—	1	—	—	—	—	—	—	—	—
	total	3195	2618	2134	921	1460	3195	2618	2134	921	1460	3195	2618	2134	921	1460

TABLE A–5

Frequency distribution of yields of *aman* paddy in husk based on cuts of different sizes : Bengal 1945–46 to 1949–50

(in tola per standard cut = 0.135 maunds per acre — 11.1086 lbs per acre = 12.4491 kgms per hectare)

interval in ten tolas per standard cut	cuts of radius 2′–0″ (y_2)					cuts of radius 4′–0″ (y_4)					cuts of radius 5′–8″ (y_6)				
	1945–46	1946–47	1947–48	1948–49	1949–50	1945–46	1946–47	1947–48	1948–49	1949–50	1945–46	1946–47	1947–48	1948–49	1949–50
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1 0— 2	23	20	13	18	14	20	23	16	24	22	20	23	17	24	17
2 2— 3	37	33	18	35	36	67	36	20	41	41	65	28	20	40	41
3 3— 4	75	33	20	54	154	153	85	50	93	87	130	80	40	86	86
4 4— 5	261	166	108	157	164	177	124	67	105	99	171	117	62	105	103
5 5— 6	137	91	66	116	109	211	199	78	141	148	206	177	77	139	128
6 6— 7	149	151	102	142	158	268	182	116	174	197	273	197	117	154	204
7 7— 8	137	138	92	124	176	276	283	139	181	240	308	255	138	177	218
8 8— 9	423	445	283	348	441	366	305	178	231	324	364	322	157	234	296
9 9—10	274	286	151	167	248	324	370	203	220	321	307	379	217	222	349
10 10—11	201	212	141	184	278	337	438	220	240	362	358	410	209	251	339
11 11—12	199	252	135	162	234	384	400	208	246	372	368	412	204	237	394
12 12—13	532	663	317	405	653	333	358	208	229	438	318	460	199	265	449
13 13—14	197	241	128	152	244	281	370	190	245	413	302	410	188	244	405
14 14—15	239	318	171	221	313	246	344	170	241	383	266	360	189	244	431
15 15—16	152	210	124	150	267	232	302	178	216	354	226	301	196	230	385
16 16—17	462	566	282	318	577	182	259	175	218	331	203	281	181	223	334
17 17—18	179	220	106	121	213	123	248	151	174	292	119	231	168	176	286
18 18—19	108	140	79	125	194	116	192	115	158	246	108	199	124	143	238
19 19—20	87	120	76	82	160	84	148	87	134	228	80	160	98	134	231
20 20—21	189	301	174	208	358	64	113	88	100	184	65	104	77	111	192
21 21—22	50	84	57	75	122	25	97	84	93	165	37	108	72	95	182
22 22—23	57	105	48	62	127	39	79	56	59	152	31	80	54	61	142
23 23—24	27	51	36	39	68	29	41	42	60	108	23	48	49	56	78
24 24—25	83	155	85	110	209	21	55	40	39	79	15	35	28	43	91
25 25—26	29	54	25	39	60	10	28	23	41	62	11	19	25	23	57
26 26—27	12	17	18	31	60	4	20	18	17	45	8	13	27	18	33
27 27—28	6	20	16	24	33	7	15	19	15	20	2	11	20	20	18
28 28—29	23	64	43	46	75	4	5	16	10	24	6	4	13	7	17
29 29—30	9	12	14	15	21	3	2	6	16	11	—	—	6	8	10
30 30—31	13	10	8	12	32	1	2	7	5	8	2	—	8	6	7
31 31—32	—	4	9	7	16	3	2	3	8	7	1	2	5	5	8
32 32—33	14	25	17	14	30	2	1	7	6	7	—	—	3	2	3
33 33—34	2	3	8	4	11	1	—	4	2	4	—	—	2	2	2
34 34—35	—	3	3	3	1	—	—	3	2	2	—	—	3	—	1
35 35—36	3	1	1	—	5	—	—	2	1	—	—	—	1	—	2
36 36—37	2	2	7	5	5	—	—	—	—	—	—	—	—	1	—
37 37—38	—	—	1	1	2	—	—	—	—	—	—	—	—	—	—
38 38—39	—	—	1	2	3	—	—	—	1	—	—	—	—	—	1
39 39—40	—	1	—	—	1	—	—	—	—	1	—	—	—	—	—
40 40—50	2	9	3	7	5	—	—	—	—	1	—	—	—	—	—
41 50—60	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
42 60—70	—	—	1	—	1	—	—	—	—	—	—	—	—	—	—
total	4393	5226	2987	3786	5778	4393	5226	2987	3786	5778	4393	5226	2987	3786	5778

TABLE A–5.1

Frequency distribution of differences in yield of *aman paddy* in husk based on cuts of different sizes: Bengal 1945–46 to 1949–50

(In tola per standard cut=0.135 maunds per acre = 11.1086 lbs per acre)

	interval in tola per standard cut		y_2-y_6					y_4-y_6				
			1945–46	1946–47	1947–48	1948–49	1949–50	1945–46	1946–47	1947–48	1948–49	1949–50
	(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	−150 to	−126	—	—	1	—	3	—	—	—	—	—
2	−125 ,,	−101	2	—	2	—	4	—	—	—	—	—
3	−100 ,,	− 91	1	4	1	—	7	—	—	—	—	—
4	− 90 ,,	− 81	5	2	—	2	4	—	—	—	—	—
5	− 80 ,,	− 71	9	6	5	4	15	—	—	—	—	1
6	− 70 ,,	− 61	12	15	11	13	26	—	2	1	—	4
7	− 60 ,,	− 51	11	27	15	29	46	6	2	1	2	5
8	− 50 ,,	− 46	13	16	20	14	24	1	5	3	—	4
9	− 45 ,,	− 41	29	18	25	28	50	6	14	2	6	8
10	− 40 ,,	− 36	34	43	38	42	68	7	11	14	6	21
11	− 35 ,,	− 31	41	65	55	71	81	17	41	13	20	28
12	− 30 ,,	− 26	74	104	72	74	122	39	51	38	30	62
13	− 25 ,,	− 21	106	141	119	126	148	79	96	63	52	91
14	− 20 ,,	− 16	133	173	154	165	233	143	179	102	106	175
15	− 15 ,,	− 11	181	273	201	222	308	278	325	203	201	358
16	− 10 ,,	− 6	300	368	208	300	441	546	585	371	447	651
17	− 5 ,,	− 1	358	439	256	365	550	938	1128	646	793	1168
18			1309	1694	1183	1456	2130	2060	2439	1457	1663	2576
19		0	91	92	63	89	133	257	284	174	206	286
20	1 to	5	419	463	319	430	586	1038	1103	634	872	1261
21	6 ,,	10	358	382	302	362	537	542	717	363	577	827
22	11 ,,	15	328	400	221	282	476	259	373	192	253	457
23	16 ,,	20	282	324	189	243	374	118	177	87	127	199
24	21 ,,	25	267	303	153	208	306	50	78	34	52	89
25	26 ,,	30	218	260	112	145	232	30	26	23	17	38
26	31 ,,	35	200	215	77	112	216	20	12	13	9	29
27	36 ,,	40	143	176	75	91	168	7	11	5	2	6
28	41 ,,	45	152	165	69	73	137	1	3	3	6	9
29	46 ,,	50	94	139	43	54	72	3	2	—	—	—
30	51 ,,	60	185	206	73	74	131	1	1	1	1	1
31	61 ,,	70	109	141	43	57	94	2	—	1	—	—
32	71 ,,	80	64	102	21	37	66	3	—	—	1	—
33	81 ,,	90	54	58	16	18	33	2	—	—	—	—
34	91 ,,	100	36	29	10	16	30	—	—	—	—	—
35	101 ,,	125	51	49	8	26	40	—	—	—	—	—
36	126 ,,	150	20	14	7	10	7	—	—	—	—	—
37	151 ,,	175	6	9	1	2	3	—	—	—	—	—
38	176 ,,	200	5	3	—	—	3	—	—	—	—	—
39	201 ,,	225	2	—	1	—	3	—	—	—	—	—
40	226 ,,	250	—	1	—	—	—	—	—	—	—	—
41	263		—	1	—	—	—	—	—	—	—	—
42	279		—	—	—	1	—	—	—	—	—	—
43	307		—	—	—	—	1	—	—	—	—	—
44	330		—	—	1	—	—	—	—	—	—	—
45			2993	3440	1741	2241	3515	2076	2503	1356	1917	2916
46	total		4393	5226	2987	3786	5778	4393	5226	2987	3786	5778

TABLE A 6

Frequency Distribution of cuts by yield of crops in "tens" of tolas per cut of radius 5'-7": : Bengal 1947-48 to 1949-50.

(In tola per cut=0.186 maunds per acre = 11.1086 lbs per acre)

class range in tens of tolas per cut. (at harvest)	cereals				pulses (in pods)								oil seeds (in pods)		
	wheat	barley	wheat & barley mixed		gram			*khesari*			*masur*		mustard		linseed
	1949–50	1949–50	1947–48	1948–49	1947–48	1948–49	1949–50	1948–49	1949–50	1947–48	1948–49	1949–50	1948–49	1949–50	1949–50
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1 0.1 to 1	1	—	1	2	—	—	—	3	12	4	6	13	—	4	—
2 1 – 2	10	8	1	15	2	5	14	9	21	9	17	49	8	12	4
3 2 – 3	19	17	3	34	4	15	23	20	30	13	45	58	4	30	6
4 3 – 4	42	22	7	44	3	23	38	18	42	15	29	72	10	27	9
5 4 – 5	59	26	11	66	8	28	51	25	58	13	39	73	12	32	12
6 5 – 6	58	45	12	81	5	30	55	12	45	13	43	56	12	21	7
7 6 – 7	67	32	6	85	8	35	64	14	44	9	27	49	10	12	7
8 7 – 8	80	25	7	62	8	40	63	13	34	8	25	45	7	10	—
9 8 – 9	57	28	9	66	9	25	60	12	30	5	18	29	5	12	1
10 9 – 10	54	19	10	62	8	35	54	13	29	3	25	22	8	18	1
11 10 – 11	44	15	9	51	8	30	57	10	18	1	17	10	1	15	1
12 11 – 12	42	12	9	36	4	35	42	3	21	—	18	12	3	19	1
13 12 – 13	26	7	6	29	4	27	36	15	14	2	14	8	—	11	—
14 13 – 14	22	8	1	20	3	34	32	10	13	1	7	11	1	8	—
15 14 – 15	18	5	3	26	7	21	33	7	15	2	13	6	—	10	—
16 15 – 16	12	2	2	14	—	18	30	14	10	1	7	3	—	6	—
17 16 – 17	13	2	3	16	2	17	18	7	17	—	5	3	1	3	—
18 17 – 18	6	—	1	5	2	19	16	3	7	—	—	1	—	6	—
19 18 – 19	6	—	2	8	4	18	6	1	8	1	1	3	—	4	—
20 19 – 20	3	1	2	6		10	7	2	4	—	—	1	—	3	—
21 20 – 21	4	4	1	6	3	10	11	4	3	—	—	1	—	4	—
22 21 – 22	1	—	1	7	—	3	9	1	2	—	—	1	1	—	—
23 22 – 23	1	3	1	5	—	6	6	—	1	—	1	—	—	1	—
24 23 – 24	5	2	—	3	—	6	5	2	—	—	—	2	—	—	—
25 24 – 25	1	—	—	3	1	4	7	1	1	—	—	—	—	4	—
26 25 – 30	7	—	1	5	2	12	10	3	3	—	—	—	—	8	—
27 30 – 35	3	—	—	2	1	3	4	2	2	—	—	—	—	1	—
28 35 – 40	1	—	—	—	—	1	4	2	1	—	—	—	—	—	—
29 40 – 45	—	—	—	—	2	1	1	—	—	—	—	—	—	—	—
30 45 – 50	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—
31 50 – 55	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
32 total	602	283	109	768	99	511	756	227	484	100	357	528	83	282	49

TABLE A–6

Frequency Distribution of cuts by y eld of crops in "tens" of tolas per cut of radius 5'-7": : Bengal 1947-48 to 1949-50.

(1a tola per cut=0.185 maunds per acre = 11.1086 lbs per acre)

class range in tens of tolas per cut. (at harvest)	cereals				pulses (in pods)								oil seeds (in pods)		
	wheat	barley	wheat & barley mixed		gram			*khesari*			*masur*		mustard		linseed
	1949–50	1949–50	1947–48	1948–49	1947–48	1948–49	1949–50	1948–49	1949–50	1947–48	1948–49	1949–50	1948–49	1949–50	1949–50
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1 0.1 to 1	1	—	1	2	—	—	—	3	12	4	6	13	—	4	—
2 1 – 2	10	8	1	15	2	5	14	9	21	9	17	49	8	12	4
3 2 – 3	19	17	3	34	4	15	23	20	30	13	45	58	4	30	6
4 3 – 4	42	22	7	44	3	23	38	18	42	15	29	72	10	27	9
5 4 – 5	59	26	11	66	8	28	51	25	58	13	39	73	12	32	12
6 5 – 6	58	45	12	81	5	30	55	12	45	13	43	56	12	21	7
7 6 – 7	67	32	6	85	8	35	64	14	44	9	27	49	10	12	7
8 7 – 8	80	25	7	62	8	40	63	13	34	8	25	45	7	10	—
9 8 – 9	57	28	9	66	9	25	60	12	30	5	18	29	5	12	1
10 9 – 10	54	19	10	62	8	35	54	13	29	3	25	22	8	18	1
11 10 – 11	44	15	9	51	8	30	57	10	18	1	17	10	1	15	1
12 11 – 12	42	12	9	36	4	35	42	3	21	—	18	12	3	19	1
13 12 – 13	26	7	6	29	4	27	36	15	14	2	14	8	—	11	—
14 13 – 14	22	8	1	29	3	34	32	10	13	1	7	11	1	8	—
15 14 – 15	18	5	3	26	7	21	33	7	15	2	13	6	—	10	—
16 15 – 16	12	2	2	14	—	18	30	14	9	1	7	3	—	6	—
17 16 – 17	13	2	3	16	2	17	18	7	17	—	5	3	1	3	—
18 17 – 18	6	—	1	5	2	19	16	3	7	—	—	1	—	6	—
19 18 – 19	6	—	2	8	4	18	6	1	8	1	1	3	—	4	—
20 19 – 20	3	1	2	6		10	7	2	4	—	—	1	—	3	—

COMPARISONS BASED ON SPECIAL EXPERIMENTS

4.1. Reference has been already made in paragraphs 5.3 to the special experiments on an intensive scale under the direct supervision of experienced statisticians which were made on *aman* paddy in Bengal in 1948-49 in 158 crop-fields from 3 localities comprising three different villages. Within each field 4 sets of multiple-cuts were obtained, each such multiple-cut consisting of 4 concentric circles of radii 2′–0″, 4′–0″ 5′–8″ ands 8′–0″. It has been already pointed out that the smallest cut of radius 2′–0″ had shown an over-estimating bias in the general survey; it was, therefore, decided to leave out cuts of this size in the detailed comparisons. For each plot we thus have 4 sets of paired values of yields based on (a) cuts of radii 4′–0″ and 5′–8″, (b) cuts of radii 4′–0″ and 8′–0″ and (c) cuts of radii 5′–8″ and 8′–0″.

4.2. For each crop-field it is thus possible to calculate Student's t based on 4 sets of values (that is, with 3 degrees of freedom) of each of the paired values (a), (b) and (c) indicated above. Also, for each plot, it is possible to obtain the value of P(t) corresponding to each value of Student's t. The distributions of these 158 values of P(t) for each of the comparisons (a), (b) and (c) are given in cols. (2), (3) and (4) respectively of Table A-7. It will be noticed from col. (4) that the differences have 67 negative and 91 positive signs in the case of comparison (a) between cuts of radii 4′–0″ and 5′–8″ showing that there is a slight tendency to over-estimate with cuts of radius 4′–0″. In col. (5), for comparisons (b) between cuts of radii 4′–0″ and 8′–0″, there are 73 negative and 85 positive signs; and in col. (6), for comparisons (c) between cuts of radii 5′–8″ and 8′–0″, the tendency is reversed as there are 84 negative signs against 74 positive signs.

4.3. It is also possible to compare the mean values themselves. In cols. (2), (3) and (4) of Table A-7 the mean yield in maunds per acre is given for the larger size of cut in each case, that is, the mean yield in maunds per acre based on cuts of radii 5′–8″ are given in col. (2) and of radii 8′–0″ in cols. (3) and (4). The mean differences in maunds per acre are given in the next line; and the mean differences expressed as percentages of the mean yield (based on the cut of the larger size in each case) are given in the following line. The corresponding values of t (together with the degrees of freedom within brackets) are given at the bottom of cols. (2), (3) and (4). It will be seen that the mean differences are extremely small, +0.084, +0.021, and −0.063 maunds per acre (and only +0.62, +0.16 and −0.47 per cent respectively) in all the three cases; and also that none of the t-values are significant. In the special experiments, it is clear, *for the same multiple-cut* there was practically no difference in the results based on cuts of radii 4′–0″, 5′–8″, and 8′–0″.

TABLE A–7

Distribution of plots by levels of P(t) corresponding to differences in yields based on cuts of different sizes : Special experiments on *Aman* paddy, Bengal: 1948-49

percentage levels of P(t)	number of plots by percentage levels of P(t)						
	sub-cuts from the same set of multiple cuts (d.f.=3)			sub-cuts from two independent sets of multiple cuts (d.f.=1)			
	(a) 4′ circle minus 5′-8″ circle	(b) 4′ circle minus 8′ circle	(c) 5′-8″circle minus 8′ circle	(d) 4′circle minus 5′-8″ circle	(e) 4′ circle minus 8′ circle	(f) 5′-8″ circle minus 8′ circle	(g) 8′ circle minus 8′ circle
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
negative							
1 0.0– 0.5	2	3	2	1	1	1	—
2 0.5– 2.5	6	7	8	2	2	2	3
3 2.5–50.0	59	63	74	66	60	63	56
4 (sub-total negative)	(67)	(73)	(84)	(69)	(63)	(66)	(59)
positive							
5 50.0– 2.5	86	82	67	82	91	85	92
6 2.5– 0.5	5	3	6	4	4	5	5
7 0.5– 0.0	—	—	1	3	—	2	2
8 (sub-total positive)	(91)	(85)	(74)	(89)	(95)	(92)	(99)
9 total plots	158	158	158	158	158	158	158
10 mean yield in mds. per acre (a)	13.45	13.52	13.52	13.26	13.31	13.31	13.31
mean difference:							
11 in mds. per acre	– 0.084	+ 0.021	– 0.063	+ 0.428	+ 0.380	+ 0.340	+ 0.417
12 percentage of to mean	– 0.62	+ 0.16	– 0.47	+ 3.23	+ 2.86	+ 2.56	+ 3.13
13 value of 't'	1.71	0.31	1.48	2.21*	1.97*	1.89	2.37*
14 degrees of freedom	(631)	(631)	(631)	(315)	(315)	(315)	(315)

(a) based on the *larger* size of cut in each case * Significant at 5% level

4.4. It is possible, however, to make comparisons of a different type of each plot separately. There are 4 sets of multiple-cuts which are serially numbered, say 1, 2, 3, and 4. It is now possible to obtain two pairs of sets, one consisting of nos. 1 and 4 and the other of nos. 2 and 3; and differences in yield of the following types were obtained for each plot:

$$\begin{aligned}
&\text{(d)} : (4'\text{–}0'')_1 - (5'\text{–}8'')_4 \text{ and } (4'\text{–}0'')_2 - (5'\text{–}8'')_3 \\
&\text{(e)} : (4'\text{–}0'')_1 - (8'\text{–}0'')_4 \text{ and } (4'\text{–}0'')_2 - (8'\text{–}0'')_3 \\
&\text{(f)} : (5'\text{–}8'')_1 - (8'\text{–}0'')_4 \text{ and } (5'\text{–}8'')_2 - (8'\text{–}0'')_3 \\
&\text{(g)} : (8'\text{–}0'')_1 - (8'\text{–}0'')_4 \text{ and } (8'\text{–}0'')_2 - (8'\text{–}0'')_3
\end{aligned}$$

where the suffix indicates in each case the serial number of the set from which was picked up the yield based on a cut of a particular size.

4.5. The two pairs in each comparison of type (d), (e), (f) and (g) shown above lead to one value of t (with one degree of freedom) and a corresponding value of $P(t)$ for each plot. The distributions of these values of $P(t)$ for each type of comparison (d), (e), (f) and (g) are shown in cols. (5)–(8) of Table A-7. The corresponding mean values, mean difference in maunds per acre, mean differences in the form of percentages, and the corresponding values of t (together with the degrees of freedom) are given in the lower portion of the same columns. The agreement between 4′–0″ and 8′–0″ or between 5′–8″ and 8′–0″ is no better than that between 4′–0″ and 5′–8″. It is, however, worth noting that, for comparisons between a pair of independent multiple-cuts, the t-values are practically all significant. Consider, for example, the comparisons of yields all based on cuts of the same size of radius 8′–0″. In this case the bias due to size, if any, would be presumably the same, so that the differences (which are significant at the 5% level with a value of $t=2.37$ with d.f.$=315$) must be ascribed to factors other than size.

4.6. The results given above indicate that bias due to smallness of the size of the cut cease to be of practical importance beyond cuts of radius 5′–8″ in comparison with sampling fluctuations due to factors other than the size of the cut. There is no point, therefore, in increasing the size of the sample-cut beyond that of, say, radius 5′–8″.

Appendix B

CONTROL OF QUALITY OF PRIMARY DATA THROUGH MULTIPLE-CUTS

1. It is possible to use the three concentric sub-cuts of varying radii to exercise a good deal of control over the quality of the primary data. The amount of crop harvested on each sub-cut would be statistically proportional to the area of the sub-cut so that the ratio of the yields

of any two sub-cuts may be expected to be a constant (subject, however, to statistical fluctuations). It is, therefore, useful to calculate the ratio of the yield based on one sub-cut to the yield based on another sub-cut, and also to calculate the co-efficient of variation (C.V.) of each yield.

2. In some cases the records show an entirely wrong value of the ratio indicating that either one or both of the two yield rates were probably not correctly ascertained or were wrongly recorded. Sometimes the investigator would know the correct value of the ratio of the two sub-cuts, and make the ratio more or less constant which would however depress the coefficient of variation appreciably. Sometimes variations are also imposed on the C.V., but in such a way that the C.V. gets out of control. Again, a very high value of Student's t for a pair of sub-cuts would also throw doubt on the original data. A careful comparison of the ratio of yields based on two sub-cuts, the co-efficient of variation and Student's t thus sometimes make it possible to detect unreliable primary records.

3. Extracts from actual field records are given in Table B-2 to illustrate the kind of control which can be exercised through a comparison of multiple sub-cuts. In this table the serial numbers of the district, the Police Station (the administrative unit within the district), the *mauza* (which corresponds to a village or a township), and the plot itself are given respectively in cols. (1)–(4). The yield in tola (=0.0256 lbs.) is given for three successive sub-cuts, namely (1) the circular cut of radius 2′–0″, (2) the annular strip between circles of radii 2′–0″ and 4′–0″ and (3) the annular strip between circles of radii 4′–0″ and 5′–8″ are given in the next 3 cols. (5)–(8). Finally the ratio of yield on the sub-cut to that on the 2nd sub-cut is given in col. (8), and the ratio of the yields on the 2nd and the 3rd sub-cuts in col. (9).

4. A careful examination of the primary records given in Table B-1 will show many abnormalities. The suspected material was analysed and results relating to 12 field investigators (who were ultimately considered to be unreliable) have been given in Table B-1. In this Table, the name of the crop and the year is shown in col. (1); the serial no. of the investigator in col. (2); and the number of sample-cuts in col. (3). The next col. (4) gives the coefficient of variation calculated on the basis of the sample-cuts recorded by the investigator. The C.V. based on sample-cuts recorded by other investigators in the same "stratum" is given in col. (5). One would expect the values of C.V. in cols. (4) and (5) to be roughly equal but in actual fact the value in col. (4) is often much smaller than the corresponding value in col. (5). For example, in line 2, investigator no. 3/4 shows a C.V. of 4.8 in col. (4) against a C.V. of 22.1 in col. (5). This low value is highly abnormal

TABLE B-1

Analysis of suspicious records of yield rates based on three sub-cuts (1) circle of radius 2′-0″, (2) annular ring between circles of 2′-0″ and 4′-0″, (3) annular ring between circles of 4′-0″ and 5′-8″

crop-year	serial no. of investigator	number of cuts	C.V. of yield based on circle of radius 5′-8″		Student's 't' between circles of radius 4′ and 5′-8″	ratio of 1st to 3rd sub-cut (expected ratio =.256)				ratio of 2nd to 3rd sub-cut (expected ratio = .767)			
			investigator	stratum		investigator		stratum		investigator		stratum	
						mean	C.V.	mean	C.V.	mean	C.V.	mean	C.V.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1 *aus* 1945	32/4	19	15.3	26.8	21.9	.297	3.9	.306	25.7	.499	3.6	.643	19.9
2 *aman* "	3/4	20	4.8	22.1	32.5	.207	8.4	.283	36.2	.458	7.1	.572	11.2
3 *aman* "	35/1	34	37.4	22.7	7.5	.919	36.3	.286	33.0	.974	42.2	.677	11.7
4 *aman* "	28/1	30	27.7	33.9	11.5	.209	19.7	.269	18.0	.375	32.2	.745	13.3
5 *aus* 1946	56/1	20	27.6	37.7	7.7	.111	44.6	.286	52.6	.501	29.4	.663	17.4
6 *aman* "	19/2	32	13.0	31.1	11.5	.197	7.2	.261	23.4	.628	10.5	.747	17.0
7 *aman* "	35/1	32	7.8	22.7	16.8	.209	15.0	263	27.5	.521	12.5	.720	19.0
8 *jute* 1947	10/1	10	36.3	31.1	6.7	.169	10.1	.256	34.9	.471	6.5	.716	14.5
9 *jute* "	10/4	9	30.3	31.1	5.3	.119	63.6	.256	34.9	.467	18.4	.716	14.5
10 *aus* "	51/1	17	37.3	40.3	7.0	.182	23.0	.214	22.7	.428	22.2	.555	10.5
11 *aus* "	10/8	12	20.7	23.0	3.3	.165	9.2	.272	32.7	.497	2.7	.719	18.0
12 *aus* "	27/3	13	11.3	22.0	4.7	.197	24.0	.290	12.8	.561	26.4	.718	11.4

TABLE B–2

Control of Quality of Primary Records : Extracts from actual returns of yields based on sub-cuts from the same set of concentric circles

particulars of the sample-cut				observed yield of sub-cut in tola			observed ratio of yields	
district	police station	mauza	serial no. of plot	1st sub-cut (circle of 2′)	2nd sub-cut (annular strip between circles of radii 2′–0″ and 4′–0″	3rd sub-cut (annular strip between circles of radii 4′–0″ and 5′-8″	1st sub-cut to 3rd sub-cut	2nd sub-cut to 3rd sub-cut
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
year : 1945-46, crop : *aus paddy*, investigator no. 32/4. ($n=19$)								
16	2	101	348	27	47	96	281	490
16	2	101	354	30	50	98	306	510
16	2	111	273	30	50	95	315	526
16	2	111	293	28	48	92	304	522
16	2	117	2510	28	48	96	292	500
16	2	117	2517	29	48	97	299	495
16	2	118	5027	29	48	97	299	495
16	2	119	1499	32	53	100	520	530
16	8	15	467	27	45	94	287	479
16	8	15	480	28	46	96	292	479
16	8	37	1413	26	42	90	289	467
16	8	37	1415	27	44	94	287	468
16	8	46	376	10	18	36	278	500
16	8	46	1438	30	50	98	306	510
16	8	46	1439	28	47	95	295	495
16	8	47	508	30	50	98	306	510
16	8	47	509	28	48	97	289	495
16	8	56	216	29	48	98	296	490
16	8	56	217	30	50	97	309	515
year : 1945-46, crop : *aman paddy*, investigator no. 3/4. ($n=20$)								
11	2	53	212	14	32	70	200	457
11	2	53	217	13	29	67	194	433
11	16	100	3565	14	32	70	200	457
11	16	100	3585	12	28	69	174	406
11	16	100	4827	14	27	67	209	403
11	16	100	4833	16	35	75	213	467
11	16	111	709	15	35	71	211	493
11	16	111	728	14	30	69	203	435
11	16	115	83	14	32	70	200	457
11	16	115	84	15	32	73	205	438
11	16	130	149	17	37	71	239	521
11	16	130	150	13	28	69	188	406

TABLE B-2—*contd.*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
year : 1945-46. crop : *aman paddy*, investigator no. 3/4. ($n=20$)								
11	16	139	225	15	35	72	208	486
11	16	139	226	14	33	74	189	446
11	16	139	903	17	36	73	233	493
11	16	139	960	14	32	69	203	464
11	16	186	616	13	31	69	188	449
11	16	185	617	15	33	67	224	493
11	17	237	321	17	32	70	243	457
11	17	237	322	15	34	68	221	500
year : 1945-46, crop : *aman paddy*, investigator no. 35/1. ($n=34$								
1	15	604	192	15	14	21	714	667
1	15	604	193	39	31	33	1182	939
1	15	607	581	21	30	30	700	1000
1	15	607	582	21	23	28	750	821
1	15	611	45	13	22	12	1083	1833
1	15	611	89	12	11	22	545	500
1	15	614	197	22	21	37	955	568
1	15	614	219	30	22	26	1154	846
1	15	625	119	16	10	24	667	417
1	15	625	120	4	10	16	250	625
1	15	634	447	11	10	12	917	833
1	15	634	453	12	19	24	500	792
1	15	730	10	33	25	17	1941	1471
1	15	730	14	27	23	20	1350	650
year : 1945-46, crop : *aman paddy*, investigator no. 35/1. ($n=34$)								
1	15	742	234	24	20	24	1000	833
1	15	742	241	10	8	8	1250	1000
1	15	743	66	20	23	31	645	742
1	15	743	68	25	30	35	714	857
1	15	744	26	22	28	25	880	1120
1	15	744	27	28	30	30	933	1000
1	15	746	412	23	27	20	1150	1350
1	15	746	424	28	20	34	824	588
1	15	747	682	20	22	20	1000	1100
1	15	747	685	23	22	25	920	880
1	15	752	18	50	65	32	1563	2031
1	15	752	31	30	50	55	545	909
1	15	754	48	40	55	32	1250	1719
1	15	754	49	36	28	52	692	538
1	15	755	130	22	35	18	1222	1944
1	15	755	154	20	22	23	890	957
1	15	762	243	13	24	21	619	1143
1	15	762	240	23	20	22	1045	909
1	15	763	342	34	22	42	810	524
1	15	763	345	31	32	32	969	1000

TABLE B–2—*contd.*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
year : 1945-46,			crop : *aman paddy*,		investigator		no. 28/1.	(n=30)
2	3	140	104	12	20	60	200	333
2	3	140	108	15	16	40	250	400
2	3	145	206	10	40	82	183	488
2	3	145	209	21	38	80	250	475
2	3	176	478	40	28	60	233	467
2	3	176	480	20	38	82	244	463
2	3	178	568	13	20	75	173	267
2	3	178	569	16	25	80	200	313
2	3	179	3762	10	60	70	143	857
2	3	179	3767	13	16	40	325	400
2	3	191	31	12	20	75	160	267
2	3	191	45	10	15	40	250	375
2	3	192	215	17	32	82	207	390
2	3	192	224	15	32	80	188	400
2	18	28	1132	6	14	36	167	389
2	18	28	1158	8	15	38	211	395
2	18	34	160	12	16	60	200	267
2	18	34	271	13	20	65	200	308
2	18	36	30	12	20	80	150	250
2	18	36	31	10	16	70	143	229
2	18	37	222	10	16	48	208	333
2	18	37	223	12	18	60	200	300
2	18	41	184	10	20	40	250	500
2	18	41	200	6	12	30	200	400
2	18	44	523	16	25	80	200	313
2	18	44	525	13	16	45	289	356
2	18	45	49	12	15	65	185	231
2	18	45	55	18	30	75	240	400
2	18	66	88	16	20	60	200	250
2	18	66	110	15	30	70	214	429
year : 1946-47,			crop : *aus paddy*,		investigator		no. 56/1.	(n=20)
21	2	12	1018	3	22	53	57	415
21	2	12	1030	4	23	49	82	469
21	2	14	34	8	23	49	163	469
21	2	14	61	3	16	31	97	516
21	2	17	2785	5	23	49	102	469
21	2	17	2789	4	22	52	77	423
21	2	17	3288	6	24	55	109	436
21	2	15	3289	8	28	56	143	500
21	2	22	605	5	28	60	83	467
21	2	22	606	6	18	55	109	327
21	2	24	64	4	21	57	70	368
21	2	24	118	7	23	56	125	411
21	2	26	226	13	55	72	181	764
21	2	26	227	3	10	13	231	769
21	2	26	564	8	28	40	200	700

TABLE B–2—*contd*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
year : 1946-47, crop : *aus paddy*, investigator no. 56/1, (n=20)								
21	2	26	568	3	24	30	100	800
21	2	27	127	3	19	71	42	268
21	2	27	135	4	21	53	77	404
21	2	27	209	3	22	42	71	524
21	2	27	211	4	22	42	95	524
year : 1946-47, crop : *aman paddy*, investigator no. 19/2. (n=32)								
18	26	31	1496	19	60	101	188	594
18	26	31	499	12	39	58	207	672
18	26	40	27	14	50	75	187	667
18	26	40	28	20	58	109	183	532
18	26	41	208	19	59	102	186	578
18	26	41	211	21	63	104	202	606
18	26	42	4	19	56	99	192	566
18	26	42	24	21	72	104	202	692
18	26	45	51	22	66	118	186	559
18	26	45	55	20	55	102	196	539
18	26	46	100	23	58	107	215	542
18	26	46	1010	19	61	98	194	622
18	26	46	1023	21	62	105	200	590
18	26	46	1960	18	60	99	182	606
18	26	47	1223	17	53	89	191	595
18	26	47	1225	21	62	109	193	569
18	26	49	169	21	70	95	211	737
18	26	49	250	17	62	86	198	721
18	26	49	1668	20	62	102	196	608
18	26	49	1671	24	72	120	200	600
18	26	49	2508	17	54	81	210	667
18	26	49	2509	14	50	82	171	610
18	26	50	318	16	55	90	178	611
18	26	50	331	22	74	106	208	698
18	26	50	716	20	70	98	204	714
18	26	50	719	19	68	103	184	660
18	26	51	849	15	48	82	183	585
18	26	51	849	15	48	82	183	585
18	26	51	1062	18	62	100	180	620
18	26	54	457	22	71	103	214	689
18	26	54	471	23	82	99	232	828
18	26	56	1377	23	72	119	193	603
18	26	56	1378	25	69	110	227	627
year : 1946-47, crop : *aman paddy*, investigator no. 35/1. (n=32)								
1	4	3212	112	18	56	98	184	571
1	4	3212	241	18	58	100	180	580
1	4	3301	1036	28	58	120	233	483
1	4	3301	1042	26	58	121	215	479
1	4	3302	641	28	58	121	231	479
1	4	3302	642	28	58	122	230	475

TABLE B–2—*contd.*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
year : 1946-47, crop : *aman paddy*, investigator no. 35/1. (n=32)								
1	4	3307	77	20	52	112	179	464
1	4	3307	78	20	50	100	200	500
1	4	3308	351	26	56	121	215	463
1	4	3308	354	27	59	122	221	484
1	4	3310	220	18	48	90	200	533
1	4	3310	222	28	58	120	233	483
1	4	3311	1027	18	58	100	180	580
1	4	3311	1029	18	58	100	180	580
1	4	3312	228	17	59	100	170	590
1	4	3312	18	58	98	184	184	592
1	4	3319	241	17	50	80	213	625
1	4	3319	260	18	48	70	257	686.
1	4	3319	271	16	56	118	136	475
1	4	3319	421	18	47	100	180	470
1	4	3323	31	16	50	92	174	543
1	4	3323	37	15	48	90	167	533
1	4	3323	40	27	52	100	270	520
1	4	3323	44	17	45	65	262	692
1	10	2758	115	26	58	122	213	475
1	10	2758	121	22	56	120	183	467
1	10	2759	257	29	59	124	234	476
1	10	2759	264	28	58	120	233	483
1	10	3338	573	28	56	121	231	463
1	10	3338	574	28	58	120	233	483
1	10	3339	403	28	58	120	233	483
1	10	3339	405	27	56	122	221	459
year : 1947-48, crop : *jute*, investigator no. 10/1. (n=10)								
26	16	10	281	255	661	1454	176	455
26	16	10	634	220	600	1360	162	441
26	16	10	2166	320	960	2240	143	429
26	16	84	255	260	680	1500	173	453
26	16	84	907	275	695	1365	201	508
26	16	126	1585	281	748	1706	165	438
26	16	128	2727	252	667	1496	168	445
26	16	128	2728	270	765	1680	161	455
26	16	166	214	299	718	2012	149	357
26	16	166	1307	19	72	99	192	727
year : 1947-48, crop : *jute*, investigator no. 10/4. (n=9)								
26	11	198	275	45	370	820	55	451
26	11	198	386	30	325	775	39	419
26	11	442	207	80	540	1020	78	529
26	11	443	201	150	485	1220	123	398
26	11	443	209	65	225	705	92	319
26	14	9	826	190	305	595	319	513
26	14	9	827	180	393	775	232	507
26	14	142	465	111	275	610	182	451
26	14	142	466	74	209	340	221	615

and throws doubt on the authenticity of the records. The value of C.V. in lines 1, 6, 7, 11, and 12 are also clearly suspicious.

5. The values of Student's t for pairs of cuts of radii 4′–0″ and 5′–8″ are given for each investigator in col. (6). All the values of t are significant at 1% level which again indicates that the records were probably not genuine. Cols. (7) and (8) give respectively the mean value and C.V. of the ratio of the yield based on the first sub-cut of radius 2′–0″ to the yield based on the third sub-cut, the annular ring between circles of radii 4′–0″ and 5′–8″. Cols. (9) and (10) give the corresponding mean values and C.V.'s based on the ratio of the first sub-cut to the third sub-cut recorded by other investigators in the same stratum. It is again to be expected that the mean values in cols. (7) and (9) should be roughly equal to the arithmetic ratio of the areas of the two sub-cuts which is 0.256. It will be noticed that the figures in col. (9) are roughly of the same order; but some of the figures in col. (7) are widely different such as 0.919 in line 3, 0.111 in line 5 etc. The C.V.'s in cols. (8) and (10) should also be roughly equal but this is far from the actual fact. For example, in line 1 the C.V. for investigator no. 32/4 in col. (8) is 3.9 against C.V. of 25.7 in col. (10) for other investigators. In the same way the values of C.V. in lines 2, 6, 8, and 11 are definitely suspicious.

6. The mean value and C.V. of the ratio of the yield in the second sub-cut (annular ring between circles of radii 2′–0″ and 4′–0″) to the yield in the third sub-cut based on the records made by the individual investigator are given in cols. (11) and (12). The corresponding mean value and C.V. based on records made by other investigators in the same stratum are given in cols. (13) and (14). The expected ratio of the yields is 0.767, and the figures in col. (13) are roughly of this order. but most of the figures in col. (11) are appreciably smaller. The C.V.'s in col. (12), for example, in lines 1, 2, 6, 8, and 11 are much smaller than the corresponding values of C.V. in col. (14); on the other hand, the C.V.'s in col. (12) in lines 3, 4, 5, 10 and 12 are appreciably higher than corresponding values in col. (14).

7. It is to be also noticed that each of the 12 investigators under review shows suspicious figures in more than one column which is, of course, just what is to be expected because even if one set of records, *e.g.*, yields based on circles of radius 4′–0″ is unreliable it would affect more than one column. Also, in certain cases many of the columns show suspicious figures which indicate that probably more than one or all sets of records were unreliable.

8. The above discussion shows that multiple-cuts can be of great help in detecting unreliable primary records which can be rejected at the stage of calculation and thus lead to more accurate estimates. Such

control is also useful in taking disciplinary measures against investigators whose records are found to be unreliable.

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Résumé

Dès 1939, l'Institut Indien de Statistique a fait, pour l'estimation du rendement de la récolte, des expériences avec les échantillons de coupes de trop petite taille. Les expériences précédentes ont montré une tendance à la sur-estimation qu'on attribuait au biais de l'investigateur pour les plantes sur l'environ du périmètre. Une suite des expériences avec les coupes de différentes tailles et formes a mis en lumière que ceux d'un rayon de 1.2 mètres sont à peu près exempts de ce biais.