

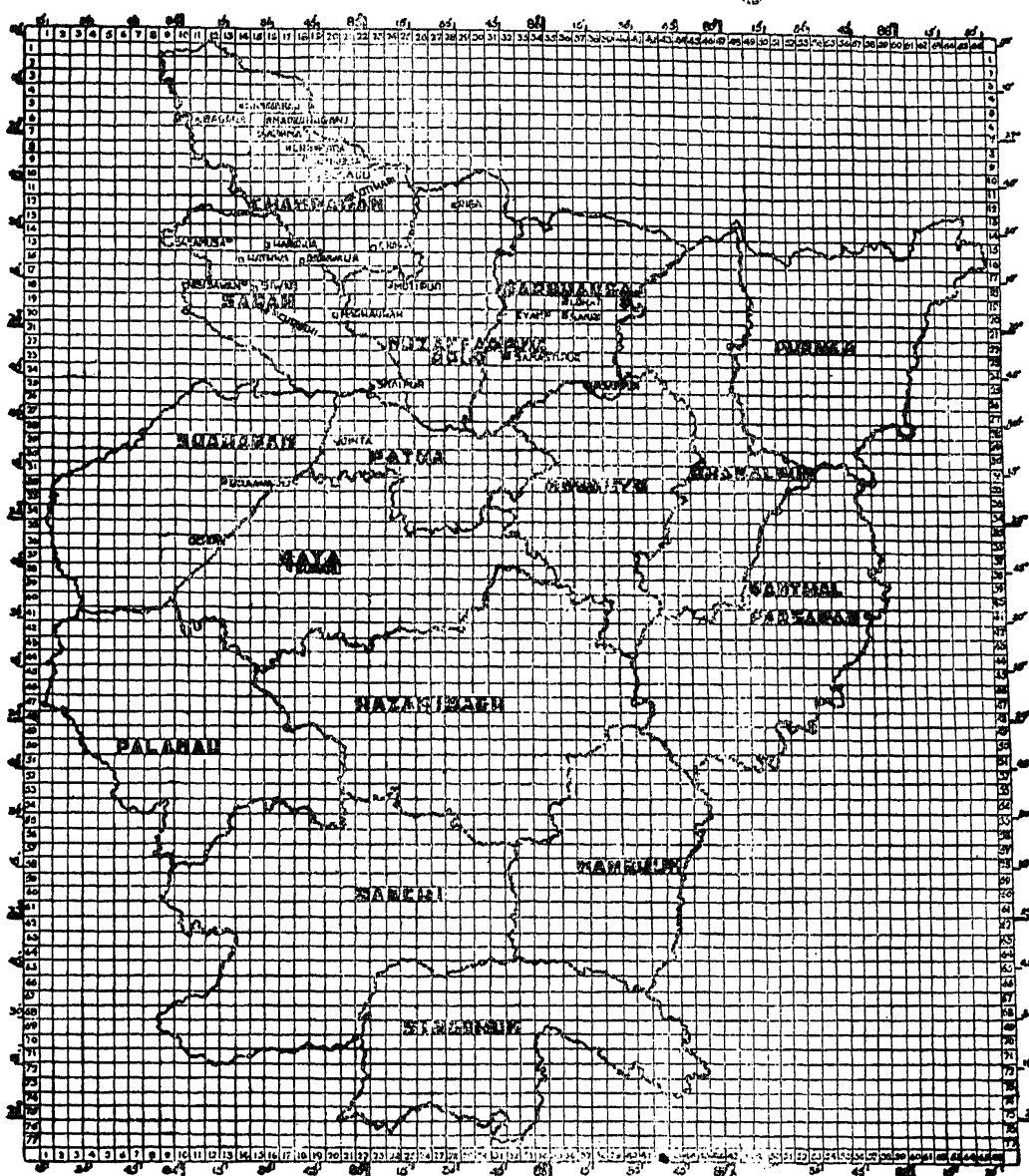
CROP SURVEYS IN BIHAR

I. Studies in the Estimation of Acre-Yield of Sugarcane

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Squared Map of Bihar. 5 × 5 Miles

SECTION A: GENERAL REVIEW

1. *Introduction.*—Sugarcane is the major cash crop of the cultivators in Bihar. With the introduction and wide spread of Co 313 in North Bihar

and Co 331 in South Bihar after the serious "red rot" epidemic suffered by Co 210 and Co 213, it became necessary to evaluate the yield potentials of the new varieties under different sets of environments. With this aim in view, a planned sample survey on sugarcane was started in 1942-43 (Khanna, 1943) at the initiative and guidance of the Central Sugarcane Research Station; and in view of the encouraging results obtained, this survey was repeated during the subsequent seasons also (Khanna, 1944, 1945), the programme for 1942-43, 1943-44 and 1944-45 being substantially the same. This note gives a brief account of the results obtained during the survey of these three seasons.

The principle of random sampling in crop cutting work was used for the first time in India by Hubback (1927) in his work on paddy in Bihar and Orissa during the years 1923 to 1926. In recent years the Calcutta School of Statisticians under Professor Mahalanobis (1944) has made a distinct advance in the theory of crop cutting experiments, which has been extensively used on various crops in Bengal and elsewhere. Panse and Kalamkar (1944) and Sukhatme (1946) have begun of late similar crop cutting experiments on various crops and are furnishing valuable material for further investigation. The work on sugarcane reported herein was started in Bihar during 1942-43 and may be claimed to be first of its kind in the country so far as this crop is concerned.

2. *Programme.*—The programme (Appendix I) of the survey is given in brief as follows:

The map of Bihar given on p. 169 was divided into squares of 5 miles \times 5 miles by drawing lines parallel to North-South and East-West, keeping 'Pusa' as the centre of one of the squares. Villages were selected at random in each square falling within the reserved area and in each village, random selection was made of 4 sugarcane fields. The ultimate sample unit for the crop cutting experiment was a plot of size 32 yds. \times 32 yds. marked out at random in the field. The harvest of such a plot was made available in 4 equal portions for convenience in carting—one cart in general being necessary for carrying the harvest proceeds of a quarter of this plot. The harvested crop (stripped canes only) was weighed at the nearest weigh-bridge of the factory concerned, and the yields recorded in the weighment form provided for the purpose. This form along with the forms of village history and field history may be seen at Appendix II.

3. *Acre-yields in general.*—Lists of villages that were supplied to the field staff were drawn, giving as far as possible a proportionate representation to the spread of sugarcane cultivation in each reserved area. But due to some reason or other, all the villages could not be surveyed. Table I

TABLE I
Showing the number of villages and fields surveyed per reserved area during the different seasons

Reserved areas	No. of villages			No. of fields		
	1942-43	1943-44	1944-45	1942-43	1943-44	1944-45
1 Bagaha ..	6	7	9	23	28	36
2 Harinagar ..	9	8	9	36	32	36
3 Narkatiaganj ..	9	10	..	36	40	..
4 Parsa ..	2	4	3	8	16	12
5 Chanpatia ..	10	10	12	40	38	47
6 Majhulia ..	9	15	14	36	60	56
7 Sugauli ..	10	18	..	38	72	..
8 Motihari ..	6	13	9	24	52	31
9 Chakia ..	8	20	8	31	80	28
CHAMPARAN ..	69	105	64	272	418	246
10 Sasamusa ..	10	18	12	40	72	48
11 Hathua ..	10	16	9	40	64	34
12 Harkhua ..	6	9	9	24	36	36
13 New Siwan ..	8	17	17	32	68	68
14 Indian Siwan ..	4	12	10	16	43	40
15 Sidhwalia ..	6	12	7	24	48	28
16 Pachrukhi ..	10	17	13	40	68	50
17 Marhowrah ..	..	10	11	..	40	44
18 Sitalpore ..	8	15	10	30	56	28
SARAN ..	62	126	98	246	495	376
19 Righa ..	..	4	4	..	13	15
20 Japaha ..	9	..	..	36	..	..
21 Motipur ..	6	8	5	24	32	20
MUZAFFARPUR ..	15	12	9	60	45	35
22 Sakri ..	10	9	6	40	36	24
23 Lohat ..	12	7	4	28	32	16
24 Ryam ..	10	9	4	40	36	16
25 Samastipur ..	8	10	6	32	40	22
26 Hassanpur ..	10	10	..	40	40	..
DARBHANGA ..	50	45	20	180	184	78
NORTH BIHAR ..	196	288	191	758	1142	735
27 Bihta ..	4	5	4	16	20	15
28 Buxar ..	5	8	7	20	30	27
29 Bikramganj ..	8	8	8	32	32	32
30 Dehri-on-Sone ..	8	6	8	32	20	28
31 Guraru ..	10	5	5	10	8	7
SOUTH BIHAR ..	35	32	32	110	110	109
ALL BIHAR ..	231	320	223	868	1252	814

would show the number of villages and fields surveyed in respect of each reserved area in the successive seasons.

TABLE II

Showing the acre-yields per reserved area and the drop during the successive seasons

Reserved Areas	Field per acre in maunds			Drop in yield in 1943-44 over 1942-43		Drop in yield in 1944-45 over 1942-43	
	1942-43	1943-44	1944-45	Absolute drop in mds.	% drop in mds.	Absolute drop in mds.	% drop in mds.
1 Bagha	404.22±24.88	368.16±21.57	330.33±9.46	-36.06	-8.92	-73.89	-18.28
2 Harinagar	494.68±44.27	472.45±32.97	410.54±31.03	-23.23	-4.70	-84.14	-17.01
3 Narkatiaganj	500.09	380.52±32.97	..	-119.57	-23.91	..	..
4 Parsa	695.84	549.87±43.18	434.57±27.72	-145.97	-20.98	-261.24	-37.54
5 Chanpatia	492.02	424.19±44.89	387.36±10.22	-67.83	-13.79	-104.66	-21.27
6 Majhaulia	645.35±39.62	497.08	501.45±36.47	-148.27	-22.98	-143.90	-22.30
7 Sugauli	683.11±32.59	714.73	..	+31.62	+4.63	..	..
8 Motihari	551.33±23.93	447.39	443.34±13.43	-103.94	-18.85	-107.99	-19.59
9 Chakia	536.62±44.22	451.61	392.80±25.07	-85.01	-15.84	-143.82	-26.80
CHAMPARAN ..	539.58±15.61	494.84±55.58	419.86±7.80	-44.74	-8.29	-119.72	-22.19
10 Sasamusa	566.45±23.41	410.96±13.38	387.34±7.85	-155.49	-27.45	-179.11	-31.62
11 Hathua	418.42±37.27	336.09±10.64	329.70±7.62	-82.33	-19.88	-88.72	-21.20
12 Harkhua	608.67±49.05	464.79±17.83	468.50±25.97	-143.88	-23.64	-140.17	-23.03
13 New Siwan	395.00±17.08	349.04±7.33	350.80±7.47	-45.96	-11.64	-44.20	-11.19
14 Indian Siwan	480.33	357.93±8.89	368.24±8.14	-122.40	-25.48	-112.09	-23.34
15 Pachrukhi	370.13±12.01	355.80±9.79	386.06±13.45	-14.33	-3.87	-29.11	-7.45
16 Sidhwalia	396.86±11.78	387.75±8.51	361.75±9.79	-9.11	-2.30	-35.11	-8.85
17 Marhowrah	..	478.83±14.14	486.94±11.49	..	..	..	..
18 Sitalpur	486.24±11.26	445.23±16.74	373.66±21.71	-41.01	-8.43	-112.58	-23.15
SARAN ..	459.99±9.83	392.13±4.13	389.95±4.51	-67.86	-14.75	-70.04	-15.23
19 Motipur	521.01±27.04	499.86±16.65	400.05±13.15	-21.15	-4.06	-120.96	-23.22
20 Riga	564.32	358.02	722.93±34.86	-206.30	-36.56	-158.61	-28.10
MUZAEFARPUR	541.06±31.64	458.88±16.65	530.16±30.13	-82.18	-15.19	-10.90	-2.01
21 Lohat	562.79±35.52	620.98±23.65	613.76±84.62	+58.19	+10.34	-50.97	+9.06
22 Sakri	550.81±23.60	536.40±25.80	700.44±30.22	-14.41	-2.62	+149.63	+27.17
23 Ryam	403.11±48.91	402.45±27.67	437.53±41.29	-0.66	-0.16	+34.42	+8.54
24 Samastipur	761.12±56.81	739.73±14.90	711.22±13.91	-21.39	-2.81	-49.90	-6.56
25 Hassanpur	617.08±32.68	528.55±30.74	..	-88.53	-14.35	..	..
DHARBHANGA	526.80±18.16	567.47±11.26	631.77±20.34	+40.63	+7.71	+104.97	+19.92
26 Pihta	578.64±65.27	454.63±30.22	425.78±30.22	-124.01	-21.43	-152.86	-26.42
27 Guraru	484.15	438.37	477.05±53.78	-45.76	-9.45	-7.08	-1.46
28 Buxar	589.38±31.93	519.31±31.89	503.91±34.81	-70.07	-11.89	-85.47	-14.50
29 Bikramganj	360.55±12.68	455.63±53.78	376.74±53.97	+94.08	+26.09	+16.19	+4.49
30 Dehri	672.49±15.56	669.49±76.91	632.59±67.69	-3.00	-0.45	-39.90	-5.93
SOUTH BIHAR	525.00±13.29	512.00±25.97	487.15±23.84	-13.00	-2.48	-37.85	-7.21

The acre-yields estimated from the survey during the three seasons are given in Table II. The frequency distribution of the mean yields are furnished below:

Interval		1942-43	1943-44	1944-45
Upto	400 mds. ..	4	8	11
	400-450 mds. ..	3	6	6
	450-500 mds. ..	6	8	3
	500-550 mds. ..	2	4	2
	550-600 mds. ..	7	x	x
Above	600 mds. ..	7	4	5
	Total ..	29	30	27

The mean yields varied from 360-761 mds. in 1942-43, 336-740 mds. in 1943-44 and 330-723 mds. in 1944-45. It is evident from the above that there is a drop in yield from year to year. The extent of this drop may be well appreciated, if the factories were grouped with regard to yields as follows:

		1942-43	1943-44	1944-45
Below	450 mds. ..	7	14	17
	450-500 mds. ..	8	12	5
Above	500 mds. ..	14	4	5
	Total ..	29	30	27

The above table shows that the number of reserved areas having low yields increased and the number of high yielding reserved areas decreased in the latter two seasons, the drop in respect of which has been expressed as percentages of the yield in 1942-43 and the figures furnished in cols. (6) and (8) of Table II.

During 1943-44, all reserved areas except Sugauli in Champaran, Lohat in Darbhanga and Bikramganj in South Bihar showed a drop, which was the highest in Riga, being 36·56%. But in 1944-45, Riga recorded a rise in yield over that of 1942-43 by 28·10%. Lohat, Sakri and Ryam in Darbhanga and Bikramganj in South Bihar also gave higher yields during 1944-45 than in 1942-43. The rest of the reserved areas in 1944-45 showed a distinct drop, the highest of which was 37·54% recorded by Parsa.

4. *High and low yielding areas.*—From the yield figures of the three years, it is possible to demarcate the areas of high and low yields in each district. In Champaran,—Pursa, Sugauli and Majhaulia may be classed as the high yielding areas whereas Bagaha, Narkatiaganj and Chanpatia may

be grouped as low yielding areas; Chakia gave medium yields during all the three seasons. In Saran—Harkhua and Marhowrah yielded the highest, whereas Hathua and New Savan gave low yields. Indian Siwan may, however, be taken as a medium yielding area in this district. In Muzaffarpur,—Riga yielded higher than Motipur during 1942–43 and 1944–45. In Darbhanga, Samastipur was decidedly the highest yielding reserved area in all the three seasons while Ryam recorded the lowest yields. Lohat and Sakri gave only medium yields in the district of Darbhanga. In South Bihar, the highest yield was recorded in respect of Dehri and the next highest was in respect of Buxar in all the three seasons. Bikramganj might be taken as a low yielding reserved area in South Bihar.

5. *Effect of manures.*—The field records revealed that majority of plots were manured with cow dung and in a few cases with castor cake or both. Other manures such as amm. sulphate, compost and gypsum were found to be rarely in use. The average yields obtained from different kinds of manures are furnished below:

Average yields with the number of plots under each type of manure

(Average acre-yield in mds.)

Kind of manure	1942-43	1943-44	1944-45
F.Y.M. ..	537 (682)	438 (900)	421 (594)
Castor cake ..	594 (9)	511 (23)	549 (40)
F. Y. M. + Castor cake	649 (44)	466 (105)	407 (64)
Green manure + F.Y.M.	794 (9)	..	..

It is clear from the above table that castor cake gave higher yields than F.Y.M. in all the seasons. In 1942–43, castor cake with F.Y.M. gave higher yields than any of them alone whereas F.Y.M. after green manuring gave the highest yield. During 1943–44 and 1944–45, castor cake in combination with F.Y.M., however, did not show its response to yield as favourably as it did during 1942–43, this being due largely to the unfavourable nature of the monsoon both in the antecedent and the current year of growth.

6. *Effect of ratooning.*—In all the three seasons, the number of ratooned fields formed only a small fraction of the total fields made available in the survey, the percentages being 13·36 in 1942–43, 9·78 in 1943–44 and 13·03 in 1944–45. The acre-yields available from the ratooned fields have been shown in Table III, where also the number of fields available under ratoon crop in each reserved area has been indicated in 'brackets'. Comparing these yields with the overall averages drawn in respect of the reserved areas, it is found that ratoon crop gave lesser yields in almost all the areas except

TABLE III
Showing the average acre yields per reserved area
(Numbers in brackets show the number of ratooned fields)

Reserved Areas	1942-43		1943-44		1944-45	
	Over all Average	Ratoon	Over all Average	Ratoon	Over all Average	Ratoon
1 Bagaha ..	404.22	252.86 (3)	368.16	253.06 (3)	..	..
2 Harinagar ..	494.68	..	..	..	410.54	264.88 (1)
3 Narkatiaganj ..	500.09	359.21 (13)	380.52	312.75 (13)	..	..
4 Parsa ..	695.84	..	..	..	439.57	357.40 (4)
5 Chanpatia ..	492.02	394.47 (6)	424.19	378.07 (7)	387.36	272.07 (11)
6 Majhulia ..	645.35	545.66 (10)	497.08	454.32 (10)	501.45	396.18 (12)
7 Sugauli ..	683.11	480.11 (6)	714.73	266.87 (6)	..	..
8 Motihari ..	551.33	288.78 (12)	447.39	241.14 (12)	443.34	384.41 (11)
9 Chakia ..	536.62	390.21 (4)	451.61	339.38 (4)	392.80	332.61 (7)
10 Sasamusa ..	566.45	292.23 (9)	410.96	292.46 (9)	..	..
11 Hathua ..	418.42	328.48 (2)	336.09	208.12 (2)	..	..
12 Harkhua ..	608.67	388.08 (7)	464.79	390.40 (6)	488.50	357.12 (3)
13 New Siwan ..	395.00	..	..	..	350.80	346.47 (1)
14 Indian Siwan ..	480.33	..	..	..	368.24	319.28 (1)
15 Sidhwalia ..	390.86	..	387.75	223.26 (2½)	361.75	367.47 (4)
16 Pachrukhi ..	370.13	..	..	..	387.06	409.15 (1)
17 Marhowrah ..	..	..	..	..	..	..
18 Sitalpore ..	486.24	435.82 (6)	445.23	444.05 (6)	373.66	342.36 (11)
19 Riga ..	564.32	278.86 (1)	358.02	279.07 (1)	..	..
20 Motipur ..	521.01	..	..	..	..	..
21 Sakri ..	550.81	..	..	..	..	..
22 Lohat ..	562.79	368.66 (2)	620.98	368.94 (2)	613.76	297.99 (2)
23 Ryam ..	403.11	319.03 (8)	402.45	319.28 (8)	437.53	401.44 (2)
24 Samastipur ..	761.12	..	..	..	..	..
25 Hassanpur ..	617.08	..	..	..	..	..
26 Bihta ..	578.64	..	454.63	475.37 (4)	..	..
27 Buxar ..	589.38	482.57 (13)	519.31	434.69 (13)	503.91	480.00 (12)
28 Bikramganj ..	360.55	421.17 (14)	455.63	421.44 (14)	376.74	337.06 (27)
29 Dehri ..	672.49	..	..	..	..	..
30 Guraru ..	484.13	..	..	..	..	..

1942-43 1943-44 1944-45
% of ratoon crop 13.36 9.78 13.03

in Bikramganj in 1942-43, Bihta in 1943-44 and Sidhwalia and Pachrukhi in 1944-45.

7. *Acre-yields with reference to different environments.*—From the records available in the field history forms, the yields were classified under different soil types, field levels and water-logging conditions with a view to getting an idea of the extent of the yield differences (if any) that might have existed in the cultivators' fields as they were, under such environmental conditions. Though it may not be quite justifiable to attribute the reasons of such differences if they existed at all, to these environments alone, an

average drawn from a reasonably large number of fields under each of these categories might show the trend of the differential response of these environments to yields, as there would exist a fair chance of the other effects getting neutralised in a large sample.

When the reserved areas were examined individually, no consistent trend seemed to have been apparent of the yields under these classes. But when the average yields of North Bihar as a whole were examined, it was noticed that under each of the field levels, non-water-logged plots gave in general higher yields than water-logged plots in all the three years, except only in a few cases. The exceptions were noticed in more cases under low-lying fields, where water-logged plots in heavy and medium soil during 1942-43; in heavy, loamy and clayey soil during 1943-44 and in clayey soil during 1944-45 gave higher yields. It was further noticed that water-logged plots in level fields having medium soil gave the highest yields in 1942-43 and 1943-44. During 1944-45, water-logged plots in level fields and medium soil gave medium yields. This, therefore, showed that water-logged condition with medium soil was favourable to yield in low and level fields.

From an examination of the district averages as well as the averages drawn in respect of North Bihar and South Bihar under the different classes it was clear that medium soil in level or high fields had been highly beneficial to yield.

8. *Effect of the size of sugarcane holding.*—The cultivators were classified according to the size of sugarcane holdings and the out-turn per acre

TABLE IV

Yield per acre (in maunds) according to different sizes of holdings, North Bihar

Size of holding	Year yield per acre																				
	1942-43						1943-44						1944-45								
	Upto					Total	Upto					Total	Upto				Total	Average yield in mds. per ac.			
350 mds.	450 mds.	550 mds.	650 mds.	Above 650 mds.	350 mds.		450 mds.	550 mds.	650 mds.	Above 650 mds.	350 mds.		450 mds.	550 mds.	650 mds.	Above 650 mds.					
Acres																					
Upto 1	60	97	47	46	43	293	471	125	141	84	24	24	398	420	109	111	41	11	23	295	408
2	25	63	36	27	70	221	498	88	126	54	28	54	350	453	84	83	32	3	20	222	406
3	16	16	9	11	34	86	536	23	46	16	10	13	108	448	24	35	9	8	9	85	433
4	5	9	6	16	14	50	550	16	20	11	9	17	73	488	6	13	3	4	3	29	448
5	3	3	2	3	9	20	560	14	17	13	5	8	57	458	7	9	..	5	1	22	427
6	2	2	1	3	5	13	554	2	8	4	3	6	23	513	8	3	..	1	..	12	350
Average 6	4	11	10	15	13	53	542	14	37	18	7	26	102	494	12	17	7	3	3	44	418
Total	115	201	111	121	188	736	509	282	395	200	86	148	1111	448	252	271	92	35	59	709	412

obtained under each class. The frequency distribution of the cultivators in the two-way classification has been shown in Tables IV and IV A separately for North and South Bihar. It will be noticed in Table IV that the

TABLE IV (A)

Yield per acre (in maunds) according to different sizes of holdings, South Bihar

Size of holding	Year yield per acre																				
	1942-43						1943-44						1944-45								
	Upto				Above 650 mds.	Total	Average yield in mds. per ac.	Upto				Above 650 mds.	Total	Average yield in mds. per ac.	Upto				Above 650 mds.	Total	Average yield in mds. per ac.
350 mds.	450 mds.	550 mds.	650 mds.	350 mds.				450 mds.	550 mds.	650 mds.	350 mds.				450 mds.	550 mds.	650 mds.				
Acres																					
Upto	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Upto	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Above	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Total	20	19	12	30	30	111	528	23	35	11	10	32	111	494	29	19	24	12	23	107	432

yields steadily increased up to the size of 5 acres in 1942-43 and upto 4 acres in 1943-44, and 1944-45. In South Bihar also, the same trend is visible in respect of 1942-43 and 1943-44, while during 1944-45, the yield showed increase up to the size of 3 acres instead of upto 4 acres. The trend as shown individually by the three successive seasons therefore goes to suggest that there is an association between the size of holding and the out-turn per acre, smaller holdings giving less yields. The law of 'diminishing return' may be said to have operated when the size of sugarcane holding increased beyond 5 acres in 1942-43 and 4 acres in 1943-44 and 1944-45. Though the occurrence of a comparatively fewer number of cultivators with higher sizes of holding has somewhat detracted from the conclusive value of the above statement, it was evident none the less that the sugarcane holding between 4-5 acres gave the highest yield.

SECTION B: REQUISITE SAMPLE SIZE

1. *Structure of the variance.*—As the sampling was of the twofold nested type [Yates and Zaccopany (1935) and Cochran (1939)] the variance of the mean yield would be given by

$$V(X) = \frac{\sum n_i^2}{n^2} \sigma_1^2 + \frac{1}{n} \sigma_2^2 \quad (i)$$

TABLE V
*Estimates of true variances between villages and between fields in the
 different reserved areas*
 1942-43

Reserved areas	No. of villages surveyed	No. of fields surveyed	Variance due to villages (plot basis) σ_1^2	Variance due to fields (plot basis) σ_2^2	Mean yield in mds. per acre \pm S.E.	S. E. as %age of mean
Bagaha ..	6	22	91.8414	274.1890	404.22 \pm 24.88	6.16
Harinagar ..	9	36	755.0044	130.7691	494.68 \pm 44.27	8.95
Narkatiaganj*	..	..	..	..	500.09	..
Parsa*	..	..	..	..	695.84	..
Chanpatia ..	..	..	..	..	492.02	..
Majhauia ..	9	36	348.4464	1130.9595	645.35 \pm 39.64	6.14
Sugauli ..	10	38	338.2517	489.1013	683.11 \pm 32.59	4.77
Motihari ..	6	24	0	614.0373	551.33 \pm 23.93	4.34
Chakia ..	8	31	106.1394	2297.5181	536.62 \pm 44.22	8.24
CHAMPARAN ..	48	187	307.7882	830.8450	539.58 \pm 15.61	2.89†
Sasamusa ..	10	40	111.3170	533.7604	566.45 \pm 23.41	4.13
Hathua ..	10	40	495.1703	504.1979	418.42 \pm 37.27	8.91
Harkhua ..	6	24	410.6150	936.5113	608.67 \pm 49.05	8.06
New Savan ..	8	32	76.0040	111.9961	395.00 \pm 17.08	4.32
Indian Siwan*	..	..	..	..	480.33	..
Sidhwalia ..	6	24	0	149.2092	396.86 \pm 11.78	2.97
Pachrukhi ..	10	40	39.8496	99.6671	370.13 \pm 12.01	3.24
Marhowrah ..	..	..	Not surveyed	..	..	..
Sitalpore ..	8	32	16.1448	117.1250	486.24 \pm 11.26	2.32†
SARAN ..	58	232	166.0588	340.0611	469.99 \pm 9.83	2.14
Riga*	..	..	..	..	564.32	..
Motipur ..	6	24	176.0783	200.1597	521.01 \pm 29.04	5.57
MUZAFFARPUR ..	..	..	..	..	..	..
Sakri ..	10	40	156.5909	372.2776	550.81 \pm 23.60	4.28
Lohat ..	7	28	221.5953	695.9129	562.79 \pm 35.52	6.31
Ryam ..	10	40	1053.6682	67.5880	403.11 \pm 48.91	12.13
Samastipur ..	8	32	1065.3505	353.0710	761.12 \pm 56.81	7.46
Hassanpur ..	10	40	207.9801	866.3927	617.08 \pm 32.68	5.30
DARBHANGA ..	45	180	550.4003	461.3009	526.80 \pm 18.16	3.45†
Bihta ..	4	16	439.7162	1290.4010	578.64 \pm 65.27	11.28
Buxar ..	5	20	181.7056	184.2990	589.38 \pm 31.93	5.42
Bikramganj ..	8	32	0	229.8177	360.55 \pm 12.68	3.52
Dehri ..	8	32	49.3679	148.0586	672.49 \pm 15.56	2.31
Guraru*	..	..	..	..	484.13	..

* S.E. could not be calculated in these reserved areas.

† S.E. has been calculated after eliminating variations due to reserved areas.

where n_i is the number of fields in the i th village $\sum n_i = n$ (total number of fields) and σ_1^2 and σ_2^2 are respectively the estimates of the true variances between villages and between fields. If v_1 be the mean square between

villages and v_2 that between fields, v_2 will be the unbiased estimate of σ_2^2 and v_1 the unbiased estimate of

$$\frac{n - \sum n_i^2/n}{t - 1} \sigma_1^2 + \sigma_2^2, \tag{ii}$$

where ‘ t ’ is the number of villages surveyed. When, however, the second order zones are equally distributed in the first, the variance of the mean yield would reduce to

$$V(X) = \frac{\sigma_1^2}{t} + \frac{\sigma_2^2}{tf}, \tag{iii}$$

where ‘ t ’ is the number of first order zones (villages) and ‘ f ’ the number of second order zones (fields) in each of the first.

2. *Contribution to the error variance made by fields.*—It will be seen in formula (iii) that the contributions to the variance of the mean made by villages and fields are $\frac{\sigma_1^2}{t}$ and $\frac{\sigma_2^2}{tf}$ respectively. The proportion of the variation due to fields will be more in magnitude than that due to villages only when $\sigma_2^2 > f\sigma_1^2$. In the present case, however, ‘ f ’ is equal to 4, as in most of the reserved areas, 4 fields have been taken per village. It will be noticed that 6 reserved areas in Table V (1942–43), 8 reserved areas in Table VI (1943–44) and 12 reserved areas in Table VII (1944–45) have shown field variations larger than 4 times the village variations. These reserved areas therefore bring out the necessity for the increase in the number of fields per village in reducing the standard errors. It will be noticed however, that in most of the reserved areas, the standard errors are already low. Therefore, increase in the number of fields per village in such areas will not be of much advantage from the practical point of view.

3. *Magnitudes of the standard errors as found in the reserved areas.*—The standard errors expressed as percentages of the mean yields have been set out in col. (7) of Tables V, VI and VII. The percentages vary between 2.31 and 12.13 in 1942–43, between 2.01 and 11.80 in 1943–44 and between 1.96 and 14.33 in 1944–45. The table given below shows the number of reserved areas falling under different ranges of standard errors:

	Upto 5%	Between 5% and 7%	Between 7% and 10%	Between 10% and 14.33%
1942–43 ..	10	6	5	2
1943–44 ..	13	5	3	3
1944–45 ..	14	5	4	4

TABLE VI

Estimates of true variances between villages and between fields in the different reserved areas

1943-44

Reserved Areas	No. of villages surveyed	No. of fields surveyed	Variance due to villages (plot basis) σ_1^2	Variance due to fields (plot basis) σ_2^2	Mean yield in mds. per acre \pm S. E.	S.E. %age of mean
Bagaha ..	7	28	100.8227	180.2073	368.16 \pm 21.57	5.86
Harinagar ..	8	32	..	1553.6947	472.45 \pm 32.97	6.98
Narkatiaganj ..	10	40	322.2741	655.4100	380.52 \pm 32.97	8.66
Parsa ..	4	16	296.0414	150.3396	549.87 \pm 43.18	7.85
Chanpatia ..	10	38	856.2941	130.0484	424.19 \pm 44.89	10.58
Majhauria*	10	..	..	..	497.08	..
Sugauli*	10	..	..	..	714.73	..
Motihari*	10	..	..	..	447.39	..
Chakia *	10	..	..	..	451.61	..
CHAMPARAN ..	39	154	300.1735	588.1032	494.84 \pm 55.58	11.23†
Sasamusa ..	19	76	152.3700	300.0998	410.96 \pm 13.38	3.26
Hathua ..	16	64	..	202.3937	336.09 \pm 10.64	3.17
Harkhua ..	9	36	61.9065	263.7182	464.79 \pm 17.83	3.84
New Savan ..	17	68	28.1116	51.6550	349.04 \pm 7.33	2.10
Indian Siwan ..	11	39	17.6747	71.2499	357.93 \pm 8.89	2.48
Sidhwalia ..	12	48	23.3830	62.9293	387.75 \pm 8.51	2.19
Pachrukhi ..	17	68	57.6779	59.6059	355.80 \pm 9.79	2.75
Marhowrah ..	10	40	53.2038	144.0188	478.83 \pm 14.14	2.95
Sitalpore ..	15	56	135.3042	139.5271	445.23 \pm 16.74	3.76
SARAN ..	126	495	62.7903	128.9916	392.13 \pm 4.13	1.05†
Riga ..	10	..	..	..	358.02	..
Motipur ..	8	32	99.3995	148.5472	499.86 \pm 16.65	3.33
MUZAFFARPUR						
Sakri ..	9	36	94.8810	692.0272	536.40 \pm 25.80	4.81
Lohat ..	8	32	42.2082	629.9147	620.98 \pm 23.65	3.81
Ryam ..	9	36	272.3840	141.6296	402.45 \pm 27.67	6.88
Samastipur ..	10	40	24.8632	298.6792	739.73 \pm 14.90	2.01
Hassanpur ..	10	40	322.8146	399.7645	528.55 \pm 30.74	5.82
DARBHANGA ..	46	184	154.9461	424.4921	567.47 \pm 11.26	1.98†
Bihata ..	5	20	89.8932	456.5708	454.63 \pm 30.22	6.65
Buxar ..	8	30	318.6882	712.5582	519.31 \pm 37.89	7.50
Bikramganj ..	8	32	888.9035	584.4518	455.63 \pm 53.78	11.80
Dehri ..	6	20	1341.6715	321.1016	669.49 \pm 76.91	11.49
Guraru*	..	..	..	..	438.37	..

* S.E. could not be calculated in these reserved areas.

† S.E. has been calculated after eliminating the variations due to reserved areas.

TABLE VII

Showing estimates of true variances between villages and between fields
in the different reserved areas

1944-45

Reserved areas	No. of villages surveyed	No. of fields surveyed	Variance due to villages (plot basis)	Variance due to fields (plot basis)	Mean yield in mds. per acre \pm S. E.	S.E. %age of mean
1	2	3	4	5	5	7
Bagaha ..	9	36	6.9054	116.5585	330.33 \pm 9.46	2.86
Harinagar ..	9	36	326.4017	246.5584	410.54 \pm 31.03	7.56
Narkatiaganj ..	0		Not surveyed			
Parsa ..	3	12	..	413.4133	434.57 \pm 27.72	6.38
Chanpatia ..	12	47	..	220.1414	387.36 \pm 10.22	2.64
Majhulia ..	14	56	647.1009	739.9940	501.45 \pm 36.47	7.27
Sugauli ..			Not surveyed			
Motihari ..	9	31	19.3331	182.2173	443.34 \pm 13.43	3.03
Chakia ..	6	22	154.0529	50.8500	392.80 \pm 25.07	6.38
CHAMPARAN ..	62	240	82.9699	179.2936	419.86 \pm 7.80	1.86†
Sasamusa ..	12	48	4.7918	113.4167	387.34 \pm 7.85	2.03
Hathua ..	9	34	..	88.4975	329.70 \pm 7.62	2.31
Harkhua ..	9	36	159.5541	446.2489	469.50 \pm 25.97	5.54
New Siwan ..	17	68	31.2589	45.3811	350.80 \pm 7.47	2.13
Indian Siwan ..	10	40	15.4127	57.1667	368.24 \pm 8.14	2.21
Sidhwalia ..	7	28	18.8582	44.8571	361.75 \pm 9.79	2.71
Pachrukhi ..	13	50	87.0900	93.9347	386.06 \pm 13.95	3.61
Marhowrah ..	11	44	44.2974	83.2290	486.94 \pm 11.49	2.36
Sitalpur ..	10	28	174.8417	47.6076	373.66 \pm 21.79	5.83
SARAN ..	98	376	61.6599	100.0161	389.95 \pm 4.51	1.16†
Riga ..	4	15	139.2909	294.3040	722.93 \pm 34.56	4.82
Motipur ..	5	20	30.9727	30.5813	400.05 \pm 13.15	3.29
MUZAFFARPUR	9	35	..	1421.5630	530.16 \pm 30.13	5.68 †
Sakri ..	6	24	..	980.1178	708.44 \pm 30.22	4.27
Ryam ..	4	16	176.0000	516.5200	437.53 \pm 41.29	9.44
Lohat ..	4	16	909.7254	1431.8700	613.76 \pm 84.62	13.79
Samastipur ..	6	22	20.2203	114.7605	711.22 \pm 13.91	1.96
Hassanpur ..			Not surveyed			
DARBHANGA ..	20	78	178.6845	738.9491	631.77 \pm 20.34	3.22†
Bihra ..	4	15	114.4999	178.3454	425.78 \pm 30.22	7.10
Buxar ..	7	27	143.0719	136.1680	503.91 \pm 34.81	6.91
Bikramganj ..	8	32	1033.5920	29.3617	376.74 \pm 53.97	14.33
Dehri ..	8	28	..	5735.9400	632.59 \pm 67.69	10.70
Guraru ..	5	7	..	905.4008	477.05 \pm 53.78	11.27

† S.E. has been calculated after eliminating the variations due to reserved areas.

Taking into consideration all the three seasons, it may be seen in the above table that 50% of the reserved areas have shown standard errors well within 5% of the mean yield, and 22% of the reserved areas have standard errors between 5% and 7%.

4. *Sampling requirements in the areas with high errors.*—From each of the three seasons, 8 reserved areas have been selected where the standard errors have been the highest; and the zone variances in these reserved areas have been subjected to further scrutiny to see the relative importance of the number of villages and fields in the reduction of error. On the basis of an error of 5%, some hypothetical combinations of fields and villages have been computed in Table VIII, with the help of the following formula:

$$t = \frac{f\sigma_1^2 + \sigma_2^2}{f(y \times 0.05)^2} \times C^2, \quad (\text{iv})$$

where y = yield per acre, 't' = number of villages; f = 6, 4, 2 (number of fields per village) and C is the acreage conversion factor. This table will show that in the reduction of error, increase in the number of villages in the sample is more important than increase in the number of fields. There is practically no difference in the number of villages when the number of fields is increased from 4 to 6. The village variations have indeed been so predominant that in many reserved areas, increase in the number of fields even from 2 to 6 has brought about no substantial reduction in the number of villages.

It has already been mentioned that only those reserved areas have been selected for the purpose of Table VIII, where the standard errors have been the highest. As a matter of fact, all the reserved areas where the errors have been between 7% and 14.33% have been brought under this category. Therefore, the sample size recommended for these reserved areas is expected to be more than sufficient for the other reserved areas where the errors have been already low. Leaving out of consideration the extreme cases (underlined), it may perhaps be said that sample of about 20 villages per reserved area of average size (or 4–5 villages per square of 5 miles \times 5 miles) with 4 fields per village would serve the purpose of getting the information on acre-yields within an error of 5 per cent.

It will be interesting to notice that the district of Saran has shown consistently low errors from year to year, whereas some reserved areas in the district of Champaran and South Bihar have in general shown high errors. Harinagar and Ryam occur in the list of high standard errors in all the three seasons.

TABLE VIII
Different combinations of fields and villages on the basis of 5 per cent.
standard error

Reserved Areas (S.E.)	σ_1^2 (No. of villages)	σ_2^2 (No. of fields)	Number of villages to reduce the S.E. to 5%		
			For 2 fields per village	For 4 fields per village	For 6 fields per village
1942-43					
Harinagar .. (8.96)	755.00(9)	130.77(36)	30	29	28
Chakia .. (8.23)	106.14(8)	2297.52(31)	39	21	15
Hathua .. (8.91)	495.17(10)	504.20(40)	38	32	30
Harkhua .. (8.06)	410.62(6)	936.51(24)	21	16	14
Ryam .. (12.13)	1053.67(10)	67.59(40)	60	59	59
Lohat .. (6.31)	221.60(8)	695.91(32)	16	11	10
Samastipur .. (7.46)	1065.35(8)	353.07(32)	19	18	17
Bihta .. (11.28)	439.72(4)	1290.40(16)	29	20	17
1943-44					
Harinagar .. (6.98)	0 (8)	1553.69(32)	31	16	10
Narkatiaganj .. (8.66)	322.27(10)	655.41(40)	40	30	27
Parsa .. (7.85)	296.04(4)	150.34(16)	11	10	9
Champatia .. (10.58)	856.29(10)	130.04(38)	46	44	44
Ryam .. (6.88)	272.38(9)	141.63(36)	19	17	16
Bikramganj .. (11.80)	888.90(8)	584.45(32)	51	45	42
Dehri .. (11.49)	1341.67(6)	328.10(20)	30	28	28
Buxar .. (7.30)	318.69(8)	712.56(30)	22	16	14
1944-45					
Harinagar .. (7.56)	326.40(9)	246.56(36)	29	23	21
Majhauria .. (7.27)	647.16(14)	739.99(56)	40	33	31
Ryam .. (9.44)	272.38(4)	141.63(16)	20	14	12
Lohat .. (13.79)	909.71(4)	1431.87(16)	39	29	27
Bihta .. (7.10)	114.50(4)	178.34(15)	10	8	7
Dehri .. (10.70)	0(8)	5735.94(28)	64	32	21
Guraru .. (11.27)	0(5)	905.40(7)	18	9	6
Bikramganj .. (14.53)	1033.59(8)	29.36(32)	66	66	65

SUMMARY

Section A.—1. The paper gives a brief account of the crop sample survey that was conducted in Bihar during 1942-43, 1943-44 and 1944-45 with a view to having mainly the information on acre-yields of sugarcane.

2. Of the three seasons under review, the highest acre-yields were obtained during 1942-43 and the yields during the latter two seasons showed a drop. The mean yields varied from 360-761 mds. in 1942-43, 336-740 mds. in 1943-44 and 330-723 mds. in 1944-45.

3. The field records revealed that cow-dung was the most common manure used. Castor cake and castor cake combined with F.Y.M. were

found to have been applied to a few fields only. Castor cake gave higher yields than F.Y.M.

4. The proportions of the ratoon fields to the total number of fields made available in the survey were 13.36% in 1942-43, 9.78% in 1943-44 and 13.03% in 1944-45. The acre-yields recovered from ratoon fields were less than those recovered from plant-crop in almost all the reserved areas.

5. From the classification of the yields under different field levels, soil types and water-logging conditions, it was revealed that non-water-logged plots gave in general higher yields than water-logged plots except in a few types of soil in low-lying fields. Medium soil in level and high fields had been highly beneficial to yield. Medium soil was favourable to yield also in low fields subject to water-logging.

6. The acre-yields showed an association with the size of sugarcane holdings of the cultivators, smaller holdings giving less yields. The tables indicated that the sugarcane holding between 4-5 acres gave the highest yield.

Section B.—Taking into consideration the three seasons together it was found that under the available sample sizes, 50% of the reserved areas gave standard errors well within 5% of the mean yields. The variances due to villages and fields were subjected to scrutiny in cases of the reserved areas where the standard errors were high and it was argued that 20 villages per reserved area of average size with 4 fields per village might in general be sufficient to bring down the standard error in a reserved area to 5% of the mean acre-yield.

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REFERENCES

1. Cochran, W. G. .. "The use of analysis of variance in enumeration sampling," *Jour. Amer. Stat. Asson.*, 1939, **34**, 492-510.
2. Hubback, J. .. "Sampling for rice yields in Bihar and Orissa," *Imp. Agric. Res. Inst. Bull.*, No. 166, 1927.
3. Khanna, K. L. .. "Yield potential survey," *Rept. Central Sugarcane Res. Sta.*, Pusa, 1942-43, 10, 11.
4. ————— .. "Yield potential survey," *ibid.*, 1943-44, 21-23.
5. ————— .. "Yield potential survey," *ibid.*, 1944-45, 14-16.
6. Mahalanobis, P. C. .. "On large-scale sample surveys," *Roy. Soc. Phil. Trans.*, 1944, **B 231**, 329-451.
7. Neyman, J. .. "On the different aspects of the representative method," *Jour. Roy. Stat. Soc.*, 1934, **97**, 558-625.
8. Panse, V. G., and Kalamkar, R. S. *Curr. Sci.*, 1944, **13**, 120-24.
9. Roy, S. N., and Banerjee, K. S. "On Hierarchical sampling, Hierarchical variances and their connection with other aspects of statistical theory," *Sci. & Cult.*, 1940, **6**, 3, 189.
10. Sukhatme, P. V., and others "Random sampling for estimating rice yield in Kolaba, Bombay," *Proc. Ind. Acad. Sci.*, 1946, **23**, 4, 194-209.
11. Yates, F., and Zaccopany, I. "The estimate of efficiency of sampling with special reference to the sampling for yield in cereal experiments," *Jour. Agric. Sci.*, 1938, **25**, 545-77.

APPENDIX I

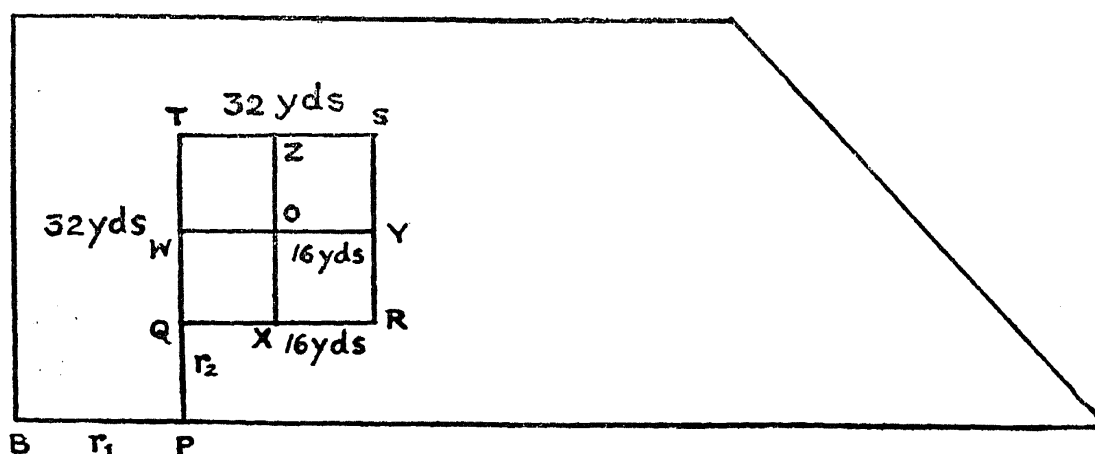
PROGRAMME FOR THE SURVEY OF YIELD POTENTIAL OF SUGARCANE
IN BIHAR

1. *Selection of villages.*—The map of Bihar will be divided into squares of 5×5 sq. miles by drawing lines parallel to N-S and E-W with reference to Pusa as the centre of one of the squares and the squares numbered. The number of squares falling on the reserved areas of the sugar factories to be surveyed will be noted with reference to their maps and two villages will be selected at random within each square. This work will be done in the Statistical Laboratory, Central Sugarcane Research Station, Pusa.

The villages selected will be marked on a copy of bigger scale map which may be obtained from the factory concerned.

2. *Selection of holdings and plots.*—A list of holdings in the selected villages will be obtained either from the mill or on going to the village itself. Details about the village conditions will be entered in Form No. I as specified therein. Out of the list of holdings, 4 holdings will be selected by taking lots for yield potential survey. In each holding one field under sugarcane, say, about one acre or more in area, will be selected in a similar manner and field history recorded in Form II. One plot of approximate $1/4$ th acre ($32 \text{ yds.} \times 32 \text{ yds.}$) will then be selected in that field according to the following procedure:

Start from B, the south west corner of the field, and proceed towards east certain number of steps, say r_1 [to be found from Random number tables which will be supplied] and reach a point P. From P go towards north into the field and reach Q, so that $PQ = r_2$ steps, r_2 being found from the same random number tables as before. Select a field QRST measuring $32 \text{ yds.} \times 32 \text{ yds.}$



The plot QRST will be divided into 4 equal parts of 16 yds. \times 16 yds. and harvested and yields recorded in Form II for each by stripping off the canes. This will be arranged with the mill authorities so that proper chalans for cane are issued to the cultivators and cane harvested by them and sent to the weigh-bridge with previous understanding with the clerk over there to weigh the canes and record the weight in the proper form.

3. *Crop density: 9' \times 9'.*—One unit of 9' \times 9' say at the corners (Q, X, O, W will be taken in each portion and number of clumps and number of canes for all the clumps will be recorded in Form II.

4. *General.*—It is presumed that the Agricultural Overseer (Cane Development Scheme) with his Kamdars will be able to complete the above work in 10 days.

5. *Supervision.*—The supervision will be entrusted to the Assistant Director of Agriculture (Cane Development Scheme) so far as possible in order to ensure reliable results. It may be suggested that the work (tour) programme will be prepared by the Agricultural Overseer and submitted to the Assistant Director of Agriculture who will then arrange supervision of the work—at least one village for each overseer. The Assistant Director of Agriculture will sign the records that are taken in his presence.

6. All the field records will be sent to the Sugarcane Specialist, Bihar, Pusa, as soon as the work is over.

APPENDIX II

SURVEY OF YIELD POTENTIAL OF SUGARCANE

Factory.....FORM I.—*Village History.**State* 1 *Acre*.....*bigha*.....*Katha*.....*Dhur*.....*Surveyor*.....*Date*.....1. *Village*.....*Thana No*.....*Thana*....*Sq. No.*2. *Approximate area (a) Whole village*..... (b) *Cultivated all crops*

.....

3. *Area under cane per table given below, Source of information.*

	Co 313 B. K.	Co 513 B. K.	Co 313 B. K.	Others			Total B. K.
				B. K.	B. K.	B. K.	
Plant ..							
Ratoon ..							
Total ..							

4. *Details of holdings which can be selected.*

Sl. No.	Name of cultivator		Area			
	Cultivator	Father	Total holding	Cultivated all crops	Under cane only	Varieties
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						

P.S.—Mark with a circle round the Sl. No. for those selected for the survey.

Signatures.....

SURVEY OF YIELD POTENTIAL OF SUGARCANE

Factory.....

FORM II.—*Field History, Crop Density and Yield*

Village.....

Holdings field area Details	I	II	III	IV
1 Cultivator's name ..				
2 Variety (plant or Ratoon) ..				
3 Previous crop ..				
4 Level (High level or low) ..				
5 Flooding, or not ..				
6 Water-logging or not ..				
7 Soil clayey or loam* ..				
8 Manures applied, Kind ..				
Quantity ..				
9 Cultivations No. of ploughing ..				
Date of ,, ..				
10 Crop condition † ..				
11 Random No. BP, PQ, B'P', P'Q' ..				
12 Crop density 9' x 9', at Q ..				
No. of clumps Nos. of cane at V ..				
Q ..				
O ..				
13 Yield in mds. seers (1a) ..				
(1b) ..				
(2a) ..				
(2b) ..				
14 Total ..				

* Under loam mention light, medium or heavy.

† Under crop condition mention (i) good, (ii) fair, (iii) poor.

DEPARTMENT OF AGRICULTURE, BIHAR

WEIGHMENT FORM.—*Yield Potential Survey*

Factory.....

Name of Cultivator..... Village.....

Date	Name of carter	Sl. No. of Gross Wt. sheet	Gross Wt.	Sl. No. of Tare Wt. sheet	Tare Wt.	Net Wt.	Signature of Weighment Clerk

N.B.—To be returned along with field forms to C.S.R.S., Pusa.

Checked with factory records and found correct.

Agricultural Overseer.