thought that they were corpuscular like cathode-rays. But Laue's discovery definitely proved that X-rays are electromagnetic waves similar to light. Their wavelength lies in the range of about 0·06 to 500 Å. The work of Barkla, Mosley and others has shown that the X-rays emitted by the anti-cathode of an X-ray tube are of two types, *viz.*, the continuous radiation and the characteristic radiation. The continuous radiation consists of all wavelengths above a short-wave limit which itself is dependent on the voltage applied to the X-ray tube. The characteristic radiation consists of monochromatic radiation characteristic of the element of the anti-cathode. Every element has its own characteristic X-ray spectrum and X-ray spectroscopic methods have been developed for the analysis of any given material. Such methods led to the discovery of Hafnium by Hevesy and Coster in 1923. A systematic study of X-ray spectra has gone a long way towards the elucidation of atomic structure.

The diffraction of X-rays by crystals has led to the systematic study of the solid state of matter. The structures of a very large number of crystals have been determined resulting in the comprehension of many phenomena connected with the solid state of matter. Among outstanding workers in this field may be mentioned the late Sir William Bragg and his school.

X-ray crystallographic methods find a large number of applications in industry like the measurement of stress in castings, pressings and forgings. Many problems confronting the metallurgist like thermal equilibrium, internal stress and strain, crystal texture and phase identification may be solved by simple X-ray crystallographic methods. The development of these methods has advanced to such an extent as to warrant the organisation of Industrial X-ray Conferences by the Institute of Physics.

Systematic work on the biological effects of X-rays was stimulated by the discovery that continuous irradiation produces a disease known as X-ray dermatitis. X-ray irradiation in proper doses inhibits the growth of living cells in tumours. But prolonged exposures may produce proliferation of cells resulting in cancer. Some of the early X-ray workers became victims to such disastrous biological effects. Recommendations for adequate protection from such effects have been drawn up and published by the International Congress or Radiology. The biological effects are made use of in the treatment of certain types of tumours and skin diseases. X-ray irradiation is also known to produce mutations of chromosomes in certain cases.

Even from a casual survey of the past half a century of X-ray work, one cannot help finding that there are very few branches of human knowledge and experience which have not felt the impact of the developments of applications of X-rays. It is not too much to hope that their applications to the advancement of human knowledge and the alleviation of human suffering may multiply a thousand-fold.

A LARGE-SCALE YIELD SURVEY ON COTTON

BY V. G. PANSE,[1] R. J. KALAMKAR[2] AND G. C. SHALIGRAM[1]

SINCE 1942-43 studies have been in progress on cotton for evolving a suitable method on a random sampling basis for forecasting and estimating the yield of the commercial crop. These have led to extensive developments, and not only has one large-scale survey on cotton been successfully carried out in the Central Provinces last year and another proceeding in the current season, but similar large-scale surveys on the principal food-crops, wheat and paddy, have been completed (Sukhatme, 1945) and are being conducted in different provinces by the Imperial Council of Agricultural Research. Within a short space of time, an efficient practical tool has thus been made available for measuring with precision the yield of crops covering millions of acres. The object of the present article is to describe the yield survey on cotton conducted during the season 1944-45 in Central Provinces and Berar. This survey, which has spread over 29,342 square miles and covered nearly three million acres of cotton, provided for the first time the means of estimating the average yield per acre and total production of cotton in the province by a scientific objective process.

For a proper appreciation of the sampling technique adopted, it will be useful to describe in broad terms the structure of a province in India. A revenue district is the major administrative unit in a province, and a province usually contains 20 to 25 districts. The geographical area of a district is about 3,000 sq. miles. A district is divided into four or five *tahsils* or *taluqs*, each with an area of 600 to 800 square miles and containing roughly 400 to 500 villages. A *tahsil* is further divided into three to five circles for the convenience of the revenue administration and a circle contains about a hundred villages. A Revenue Inspector is stationed in each circle. Communications between villages are poor. Good metal roads are few and far between and most of the villages are only accessible by a cart track. The revenue map of a *tahsil* with the village boundaries marked on it looks like a honey-comb with the villages forming the cells of this comb. The map of a single village reproduces the same pattern with individual fields forming the cells. Complete lists of villages in each *tahsil* or in each circle are available with the Land Records Department. The area of each field is accurately measured periodically and recorded in the villages. Except in provinces like Bengal and Bihar with a permanent land revenue settlement, there is a village accountant or *patwari* for each village or a group of villages and one of his principal

1. Institute of Plant Industry, Indore. 2. Department of Agriculture, Central Provinces.

duties is to make a complete seasonal enumeration of area under different crops by an inspection of fields within his jurisdiction. It is this unique feature of the land revenue administration in India which imparts to the figures for annual crop acreages in most provinces a degree of accuracy unequalled in any other country in the world.

Such a framework lends itself excellently to the application of stratified random sampling. The *tahsils* form relatively homogeneous and compact subdivisions of the tract to the surveyed, and villages and fields provide the principal and secondary sampling units. A strictly random selection of the sample villages within a *tahsil* can be made easily from the village list and a similar random selection of fields within a village also presents no difficulty as the list of all fields growing a particular crop in the selected village can be readily had from the *patwari* The selected fields can be sample-harvested by locating one or more plots of a suitable size in random positions.

From two pilot surveys described earlier in this *Journal* (Panse and Kalamkar, 1944 *a, b*), the first carried out in Akola district in 1942-43 and the second in Akola and Buldana districts in 1943-44, it was found that if some 200 villages were sampled over the whole cotton tract of the province and four fields sample-harvested in each selected village, the provincial yield would be estimated with a standard error of 3 per cent. or less. This expectation as will be seen later, was borne out in the present survey. It was also found that the harvesting of a plot of 1/10 acre size, with which both the district land records staff and the farmers are familiar because of its adoption in the departmental crop cutting work, was quite satisfactory on the ground of practical convenience, as any change in plot size from 1/20 acre to 3/10 acre did not lead to a material change in the accuracy of the final yield estimates. It was, moreover, sufficient to harvest only one such plot per field as variation within a field was found to be quite small compared to the variability between fields.

The plot size may be made somewhat smaller in a tract where the yield level is higher; but very small plots, say 10 or 12 square feet in size, like those adopted by other workers (Hubback, 1927; Cochran, 1939; King and others, 1942) in surveys on cereals are obviously unsuitable for cotton where the harvest is gathered in five or six rounds of pickings spread over a period of three or four months. The use of such small plots in other crops also is beset with difficulties, both statistical and practical, from which the large plot is mostly free. In spite of its limitations the small plot seems to be adopted by workers in England and America on the grounds of convenience and economy; but it cannot necessarily claim the same advantage in India. The relationships between the availability and cost of field labour on the one hand and of transport and travelling facilities on the other are entirely different in the two cases.

The present survey included all four districts in Berar and three other districts, Nimar, Wardha and Nagpur, and three more *tahsils*, one each from the districts of Hoshangabad, Chanda, and Chindwara, from the rest of the province. It was carried out in 34 *tahsils* in all and sampled $99^1/_4$ per cent. of the total cotton acreage in the province. A total of 204 villages were randomly selected in these 34 *tahsils*. In assigning the number of villages to each *tahsil*, two points need to be considered. The first is that the number of villages per *tahsil* should be in proportion to the cotton acreage in the *tahsil* in order to attain maximum accuracy in the provincial estimate of yield. Secondly, it is necessary to estimate the average yield of each district within a reasonable margin of error, as this yield figure is used administratively and forms the basis for calculating the normal or standard yield for the district. The latter condition requires that a certain minimum number of villages must be selected in each district irrespectve of its cotton acreage. As a comparison between these two considerations, the following scale was adopted for the selection of villages in the present survey.

Area under cotton in the tahsil	No. of villages selected per tahsil
Less than 50 thousand acres	4
50–120 ,,	6
120–130 ,,	8
above 139 ,,	9

A somewhat larger total number of villages than the number available in the present survey needs to be selected for a more satisfactory distribution according to the cotton acreage. The number in the present survey was restricted by the factor that the fieldwork was to be done by a wholetime temporary staff of fieldmen, each in charge of a group of three or four villages, and travelling between villages had to be kept down to a minimum.

In each village, four cotton fields were randomly selected and a plot of 1/10 acre (33'× 162') was marked in a random position in each field and harvested. The produce was weighed by accurate iron beam balances and standard weights supplied to fieldmen, as the village balances and weights are unreliable, and the local weights, moreover, have widely varying connotations. The results of the survey are summarized in Table I.

The average yield per acre for the whole province was determined with a standard error of 2·9 per cent., and an error of this magnitude was predicted when the present survey was planned. The average yield per acre in different districts had a standard error ranging from 5 to 11 per cent. A somewhat higher standard of accuracy of the district estimates is clearly desirable, and the number of villages per district must be increased in future surveys, with a view to attain a standard error of the district estimates of yield as near to 5 per cent. as possible.

The official yield figure for the whole province was 192·6 lbs. of seed-cotton per acre

TABLE I
Yield per acre and total production in different districts

Name of district	Cotton area (thousand acres)	No. of villages selected	Yield of *kapas* (seed cotton) lbs. per acre	S.E. per cent of yield	Total production in bales (of lint 1 bale=392 lbs. lint)
Buldana	469·1	30	194·6	7·8	79154
Akola	561·1	38	195·0	5·5	92810
Amraoti	552·1	33	143·6	8·6	65292
Yeotmal	511·8	39	207·2	5·4	89003
Total Berar block	2094·4	14	184·6	3·3	326359
Nimar	238·4	18	158·3	7·0	28556
Wardha	269·6	18	127·2	10·9	31272
Nagpur	108·0	16	123·6	10·8	11417
Harda (*tahsil*)	7·8	4	98·9	16·7	654
Warora (*tahsil*)	33·5	4	122·5	23·3	3251
Sausar (*tahsil*)	22·8	4	141·6	6·8	2816
Total C.P. block	675·4	64	141·3	5·4	77966
Whole province (C.P. and Berar)	2769·8	204	174·1	2·9	404225

according to the final forecast. It was 10·6 per cent. higher than the survey estimate, and the excess being more than twice the standard error of the survey estimate should be taken to be real. The excess in the separate blocks, Berar and C.P. was of the same order. The official overestimate has to be mainly attributed to a significant excess of 39·6 per cent. in Amraoti district and of 23·1 per cent. in Nimar district though the official figures were slightly higher than the survey estimates in most districts. It should be recalled that in 1943-44 when yield was much higher, and the survey estimates were 282 and 299 lbs. per acre in Akola and Buldana districts, the official figures were lower by 10 and 17 per cent. respectively. The tendency in the official forecasts to underestimate good crops and overestimate poor crops is well brought out by the survey results for the past three years.

The total production for each district and for the whole province is shown in terms of lint in the last column of Table I. Conversion of seed-cotton into lint involves the use of a factor for ginning outturn. The usual procedure is to adopt a conventional figure of 33$^1/_3$ as ginning percentage. Its use, however, might introduce an error and possibly a bias in the estimated total production of lint, as the ginning percentage is known to vary according to the season and the variety of cotton. It was found, in the year 1943-44, for example, that the variety Jarilla (*G. arboreum* var. *neglectum*) ginned by the agricultural department gave a ginning outturn as high as 37½ per cent. The rapid spread of this variety, which is growing in popularity, is bound to raise the average ginning outturn of the cotton tract in the province. For these reasons an attempt was made through the provincial department of industries to obtain ginning outturn data of the commercial crop of the season from owners and operators of ginning factories located in the cotton tract. Out of 82 factories addressed, apparently reliable information was secured from 61. From these data, ginning percentage values, appropriately weighed according to the quantity ginned and varieties, were calculated for almost every *tahsil* for conversion of seed-cotton production into that of lint. The ginning percentage values ranged from 29·7 to 34·9 in different *tahsils* and were generally higher where the variety Jarilla was dominant.

For the area covered by the survey the total production was thus estimated at 404,225 bales of lint as shown in Table I and this estimate is subject to a standard error of 11,456 bales. The area was, as stated earlier, 99¼ per cent. of the total cotton acreage. Extending the calculation to the full 100 per cent. area, the estimates of total production and its standard error were altered to 406,558 and 11,664 bales respectively. From the official estimates of the yield of *kapas* (seed-cotton) per acre and a ginning outturn of 33$^1/_3$ per cent., the total production for the whole area was calculated at 456,681 bales or 12·3 per cent. must be counted to be in significant excess. If actual ginning percentages found from factory data were employed to convert the official yield figures for seed-cotton into lint, the official estimate for total production would be reduced to 449,148 bales and would then be higher than the survey estimate by 10·5 per cent., the excess still being significant.

Apart from its principal function of providing reliable yield estimates, the sampling survey can be utilized to obtain a considerable amount of ancillary information of great practical and scientific value. On certain topics, the survey is the only means of procuring representative data. A variety of useful data were collected in the course of the present experiment and are under examination. Space would not permit us to do more than make a brief reference to one or two items here.

The variety of cotton grown and its condition of purity were carefully observed in all selected fields, in order to assess the spread of improved varieties in the cotton tract. In this respect Berar was found to be in a distinctly better position than the rest of the province. Jarilla was practically the only variety grown in Buldana district, and in Akola district too, the varieties Jarilla and Verum (*G. arboreum* var. *neglectum*) accounted for nearly 90 per cent. of the fields. In Amraoti, besides Jarilla, 30 per cent. of its cotton area was under Buri (*G. hirsutum*), an improved American Upland variety. In the rest of the province, most of the area was found to grow unselected indigenous cotton (*G. arboreum* var. *neglectum*), ecepting Nimar district which had most of its area under improved varieties including 40 to 45 per cent. under Buri. This summary of the spread of improved seed has, however, to be qualified by the observation that a considerable degree of admixture was found in the fields. For example, only about 25 per cent. of the fields under Jarilla had a pure or a nearly pure crop of this variety. The Upland variety Buri was found to be purer in that about 65 per cent. of the fields with this variety were found free from admixture with indigenous plants.

Cotton is grown in the province mostly in mixture with other crops, chiefly *tur* (*Cajanus indicus*), the usual practice being to sow a few lines of *tur* at intervals among the cotton rows across the whole field. In calculating the net area under cotton an allowance is made for the areas occupied by these other crops. In Berar, the *patwari* directly records the net areas of cotton and of other crops in the field by eye appraisement while in the rest of the province numerical factors are prescribed for converting the gross area of cotton mixtures, which is recorded, into net area under cotton. To verify the soundness of this procedure and examine the accuracy of the allowance made for crops grown mixed with cotton, actual counts of rows of cotton and other crops were made in the fields selected for the survey. The analysis of these counts showed that the allowance made by the current procedure is substantially correct. No significant discrepancies were found in Berar, and in other districts also the conclusion was that only in areas on the periphery of the cotton tract, the extent of the mixture of other crops in cotton was probably underestimated.

The problem of improving yield forecasts from the standing crop is also being studied and eye estimates of the crop of the selected fields and quantitative observations on stand, number of bolls and boll weight, in small sample areas in the plot are recorded for comparison with the actual yield. The object is to determine how far eye appraisement alone can be relied on or whether it has to be supplemented or even replaced by quantitative observations. The possibility of a further improvement in the yield forecast made at the beginning of the harvesting season from a knowledge of the yield of the first picking is also being examined.

On the technical side, valuable information on the optimum number of samples and their distribution can be obtained from an analysis of the survey data. The methods employed for this purpose have been indicated in an earlier article (Panse and Kalamkar, 1944 *a*). The analysis of variance of the plot yields in the present survey showed that variability between villages was 1·56 times the variability between fields within villages in Berar districts, and 1·32 times in C.P. The two analyses were made separately because the variation both of fields and of villages was appreciably higher in Berar than in C.P. In the two previous seasons' surveys in Berar, the ratio of variation between villages and fields ranged from 1·4 to 1·8, and was thus of the same order as that observed in the present survey though the absolute variability of villages and fields differs appreciably in different seasons and in different tracts.

The number of villages and the number of fields per village required to be selected for securing yield estimates for the whole tract with a given degree of precision were calculated from the present results and are shown in Table II.

TABLE II

Number of villages and standard error of mean yield

No. of fields per village	No. of villages and standard error of mean yield					
	Berar results			C. P. results		
	1% s.e.	2% s.e.	3% s.e.	1% s.e.	2% s.e.	3% s.e.
3	2216	554	246	1786	446	198
4	1825	456	203	1425	356	158

Previous surveys had yielded numbers of the same order of magnitude. The actual numbers obtained from different surveys would naturally differ to some extent both on account of real differences in variability and the sampling errors to which these numbers are subject. The present figures are found to have sampling errors of 15 and 18 per cent. in Berar and of 20 and 24 per cent. in C.P. It is rather clear from the three years' results that sampling on a scale sufficient to attain a standard error of 1 per cent. of the average yield is not a practical proposition in cotton. This low error can be reached in surveys on cereals (Sukhatme, 1945); but cotton is obviously more variable, and a standard error of 2 to 3 per cent. is all that can be aimed at. Experience in U.S.A. is similar (Sarle, 1932).

The ultimate goal of the present surveys is the introduction of the random sampling method as a permanent feature in the estimation of crop yields. The fieldwork of the surveys will have to be done by the existing departmental staff as the employment of any large permanent staff for this work alone seems out of question. Equipped with the technical experience of the past three years, we are now in a position to study the organizational phase of the problem, and this aspect has been given primary consideration in planning the provincial survey in C.P. and Berar for the current season. The temporary staff of wholetime fieldmen employed previously has been dispensed with and the fieldwork is entrusted to the locally stationed district staff of the Land Records Department. For administrative convenience and a more even distribution of work, the revenue circle has been adopted as the unit for sampling in place of the *tahsil* though this change is not likely to lead to any further increase in statistical accuracy of the yield estimate. Two villages per circle where the cotton area is below 20,000 acres, and three for higher acreages is the scale of sampling adopted. This modification has resulted in the selection of a large number of villages, 335 against 204 in the last year, and made possible their distribution in proportion to the cotton acreage. The increase in the number of villages will be advantageous for both reasons. There are three fields under experiment in each village and the experiments in each circle are in charge of the Revenue Inspector of the circle. The supervising staff for each district also belongs to the department. The projected survey will be watched mainly to test the working efficiency of the organization, to detect its possible shortcomings and devise suitable remedies for these. With its conclusion the end of the experimental stage will be reached, and we may then expect with confidence that the provincial administrations will undertake yield surveys on this plan under technical direction as an annual routine.

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RIVER FLOOD CONTROL*

BY *Rajasevasakta* M. G. RANGAIYA, B.A., B.E.
[*Chief Engineer and Secretary, Mysore P.W.D. (Retired)*]

NATURE AND EXTENT OF THE PROBLEM

ALL over the world the problem of combating the destruction and damage caused by river floods is confronting the engineering profession. From the earliest times China has been affected by the floods of the Hoango and the Yangtse, as also our own mother-country, India, particularly parts of Bengal, Bihar and Orissa on the east, and the Indus Valley on the west coast. The Continent of America has figured largely during the last two centuries or so, where the engineers have been constantly at work during this period trying to tame the mighty Mississipi and other rivers. In the Continent of Europe flood protection works have been carried out during the last six or seven centuries, especially in Spain, France and Russia. In no country finality has yet been reached.

Fortunately, the State of Mysore, being situated on a plateau, is practically immune from inundations of rivers and consequent damages, though here and there are some towns which are affected to a small extent by floods. However, it behoves us as engineers to study this world-wide problem and keep ourselves abreast of the work that is being done by the engineering profession abroad. My object in reading this paper is thus to stimulate study and research by the members of this Association, some of whom may in future years be called upon to tackle flood protection works.

* Paper read before the Mysore Engineers' Association at their Conference held in 1945.

II. COLLECTION OF ESSENTIAL DATA

2. The first thing to be done in devising measures for river flood control is the collection of data under several heads, such as

(1) rainfall statistics in the catchments of the rivers extending from the head to the mouth for as many years as may be possible and for as many stations as are available;
(2) study of the topographical features of the catchment and the climatic conditions, and preparation of maps showing the areas affected by floods at different stages of the rivers;
(3) gauging of river flood discharges at vital reaches and correlating them to the rainfall and comparing them with calculated discharges based on river sections and slopes or with the recorded flow over weirs or at bridges;
(4) the extent and nature of damages caused from time to time, the population affected and the average annual loss caused to the people, the government, public utility companies, etc. This information has to be separately collected for urban and rural areas.

The study and collection of data should be a continuous one extending over several decades. This is especially so with regard to the calculation of flood discharges. It may be mentioned as an example that, in the case of the Mississipi river in America, a Special Commission was constituted by the Federal Government nearly four score years ago, and it has