

## ESTIMATION OF CROP YIELDS

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IN a previous article in this *Journal* (May 1944), the authors had briefly reviewed the problem of forecasting and estimating yields of agricultural crops, and had described an experiment carried out in Akola district in Berar to estimate the yield of cotton in that district in the season 1942-43. The experiment illustrates the method of investigating the problem in that its design enables us to secure technical information on the strength of which future surveys may be planned more efficiently.

The results of the experiment in Akola indicated that it was sufficient to harvest only one plot per field; but a larger number of fields per village would lead to an increased accuracy of the yield estimate. The effect of plot size on accuracy was not appreciable and a change in the present plot size of one-tenth acre was, therefore, not considered necessary. Following these conclusions, the experiment was repeated in Akola district in the year 1943-44, with only one plot of one-tenth acre size (35' x 132') per field but selecting four fields instead of two per village while keeping the number of villages the same as in the previous year, *viz.*, ten in each *tahsil*. These modifications simplified the plan of sampling and at the same time a more accurate estimate of yield was anticipated without any increase in the amount of work or in the cost of survey. To verify the results relating to the sampling technique, another survey was simultaneously carried out in the adjoining district of Buldana with the same design that was adopted in the Akola experiment in 1942-43, *i.e.*, selecting ten random villages per *tahsil*, two random cotton fields per village and two random plots of three-tenth acre size per field, each plot subdivided into six longitudinal sections of one-twentieth acre. There are five *tahsils* and 1364 villages in Buldana district and the fifty villages selected for the survey formed a 3.7 per cent. sample of all villages in the district.

The two districts have a common boundary between them and an important feature of this year's survey was that an independent arrangement was made to find out the total production of cotton in both districts through ginning factory returns. Ginning factory owners are required by law, to submit weekly returns of the amount of cotton ginned throughout the season, but these figures cannot by themselves represent the actual production of cotton in the district as some unginned cotton may be consumed domestically or held over until the next season, while cotton may be brought in from outside and ginned in the district or unginned cotton may be exported from the district. Ginning returns must be corrected for these factors before the figure for the total production of cotton in the district can be arrived at. Careful enquiries into these factors were made by the district land records

and revenue staff under the direction of the Director of the Land Records Department, who had set up a particularly effective organization to register all cotton traffic crossing the borders of these two districts. An alternative estimate of total production may be based on the registration of cotton carts arriving at the cotton markets. All cotton markets in Berar maintain this information; but it is usually incomplete as some cotton carts do not go to the market or are sold at centres where there is a ginning factory but no cotton market. Ginning returns thus form a more reliable basis for calculating total production.

The value of an independent check of this kind for verifying the results of crop cutting experiments made on randomly selected plots is obvious. Though such experiments have sound statistical theory behind them and are designed to give an unbiased estimate of yield with a determinable accuracy, it is desirable to demonstrate their reliability in a manner that administrators and other practical men can appreciate easily and thereby provide convincing evidence of the efficacy of the method. A random sampling survey will then be preferred to alternative procedures involving a complete census of production on account of its greater simplicity, less cost and the availability of the results within a short time after harvest is over, this last being the most important advantage from the commercial view-point.

The two districts in which the survey was carried out in 1943-44 occupy an area of 7,857 sq. miles. Cotton was grown over 11 lacs of acres during the season which represents slightly more than one-third of the area under cotton in the whole Province. The total cost of the scheme was Rs. 18,000 of which roughly two-thirds was spent on the crop cutting experiments and one-third on the registration of the cotton traffic across the borders of the two districts.

The analysis of variance of plot yields in each *tahsil* pooled over the whole district is shown below for the two districts.

Analysis of variance of plot yields

Due to	Akola district*		Buldana district†	
	Degrees of freedom	Mean sq.	Degrees of freedom	Mean sq.
Villages	54	386.2	45	6836
Fields ..	180	212.5	50	4334
Plots ..	..	..	100	407

\* 1/10 acre plots; † 3/10 acre plots (Sum of six 1/20 acre sections).

The last item is blank in Akola because there was only one plot per field. Mean squares for Buldana may be made comparable to those

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for Akola by dividing by 9. As in the last year, the predominant portion of the total variation in yield is that due to differences between fields in the same village. Last year the village mean square in Akola district was roughly 1.4 times the mean square for fields, as compared to the ratios of 1.8 and 1.6 in Akola and Buldana this year. The mean square due to fields is 10.7 times that for plots in Buldana. This ratio was 7.5 in Akola last year. Thus, while the absolute magnitude of variation from different sources may differ rather widely from season to season and from district to district, its relative magnitude appears to remain approximately of the same order. This latter fact makes it possible to devise an efficient sampling technique suitable for general application over the rainfed cotton tract of peninsular India and to serve as a reasonable basic design in extending the yield survey to the irrigated tracts. Results with different plot sizes in Buldana confirm the conclusion derived from a similar study in Akola last year, *viz.*, that the choice of a particular plot size in preference to another within the range tried is not likely to be of any importance in increasing the accuracy of mean yield. The plot size of one-tenth acre at present in use will, therefore, be adopted in future surveys.

The average yield of kapas (seed-cotton) per acre was estimated at 282 lbs. per acre in Akola and 299 lbs. per acre in Buldana districts. These estimates are subject to standard errors of 4.7 per cent. and 6.7 per cent. respectively. The standard error in Akola was 6.3 per cent. last year, and the modifications made in the plan of sampling have resulted in greater accuracy which was anticipated. The standard of precision in Buldana is approximately the same as was attained in Akola with an identical sampling design last year. The official estimate of yield was 248 lbs. per acre for Akola and 253 lbs. for Buldana. These figures are 10 and 17 per cent. lower than the corresponding experimental estimates. The district revenue and agricultural staff who were asked to inspect the crop of the fields selected for the survey also under-estimated the yield. It will be remembered that last year when the yield was poor (136 lbs. per acre) it was grossly over-estimated by the same agencies. Yields are thus over-estimated when they are poor and under-estimated when they are really good. This is an expected consequence of the tendency not to deviate widely from the "normal" yield—the 'thirteen-anna' complex as it is sometimes described.

The inquiry made by the Director of Land Records into the total production of kapas in these two districts gave the following results.

In converting the figures for lint supplied by the ginning factories into those of kapas, a conventional ginning percentage of 33.3 is usually adopted. This causes considerable error due to seasonal and varietal variation in ginning percentage. The improved variety, Jarila, which had spread to 67 per cent. of the cotton area in Akola and 89 per cent. area in Buldana was found to have a ginning percentage of 37.5 in this particular season. This

fact was taken into account in arriving at the figure for *kapas* ginned. It may be noted incidentally that according to the information

	Akola district	Buldana district
Kapas ginned ..	kandies* 204520	kandies 236794
Net import of unginned kapas ..	..	44961
Net export of unginned kapas ..	20015	..
Carry over to next season ..	1823	2203
Total production of kapas in the district ..	226358	194036
Area under cotton at final forecast	acres 588183	acres 513376
Yield of kapas per acre ..	301.7 lbs.	296.3 lbs.

\* 1 kandi = 784 lbs.

carefully collected regarding the variety of cotton grown in the fields selected for the crop cutting experiments, 69 per cent. of the fields in Akola and 94 per cent. in Buldana grew Jarila. These proportions are in close agreement with the above proportion of Jarila obtained through the usual field inspection by the district land records staff, and demonstrate the representativeness of the fields selected for the crop cutting survey.

There was a considerable cotton traffic across the district borders and, due to the popularity of cotton markets in Buldana, cultivators from afar brought their cotton into this district for sale. The largest import was from the neighbouring district of Akola, amounting to over 32,000 kandies of kapas. In computing figures for import and export from primary data, factors such as the relation between local weights and standard weights and the discrepancies between the reported weight and the true weight of a cartload of cotton had to be taken into account. The report of the Director of Land Records contains several interesting details connected with this work. Carryover of unginned kapas to next season was quite small. Figures for the carryover from the previous season were not collected as being negligible owing to the high prices of the previous season. The inquiry into the domestic consumption of cotton is not yet complete though here again the amount of cotton involved is thought to be trifling. The movement of kapas is apparently the most important factor affecting ginning returns. On the information available, the calculated yield per acre for Buldana shows a very close agreement indeed with the estimate obtained from the crop cutting survey, while in Akola the calculated yield is quite within the limits upto which the yield estimate from crop cutting may fluctuate through chance causes, these limits ( $281.6 \pm 26.4$ ) being defined by the standard error. We may conclude that in both districts the reliability of the yield estimates derived from the crop cutting survey has been amply borne out through a comprehensive independent check.

The degree of accuracy to be aimed at in planning future surveys needs some consideration. The trade is interested in accurate production estimates of large blocks comprising of several districts, rather than of individual districts. The past two seasons' surveys were limited to one or two districts and a standard error of the order of 5 per cent. of the mean yield was reached. In extending the survey to larger areas, a higher degree of accuracy which would reduce the margin of error is clearly necessary to ensure trustworthiness of the estimate for practical purposes. Estimates with a standard error of only one per cent. may be reasonably demanded, but it does not seem possible to attain this degree of accuracy for rainfed cotton without excessive sampling. The amount of sampling needed for estimating the yield with varying degrees of accuracy, as indicated from past results, is shown below:

Number of villages required for survey with four fields per village and one plot of one-tenth acre size per field

	1% s.c.	2% s.c.	3% s.c.
Akola results, 1942-43 ..	1850	463	206
Akola results, 1943-44 ..	1188	297	132
Buldana results, 1943-44 ..	1556	389	173

With four fields to be sample-harvested in each village, crop cutting will have to be done in upwards of twelve hundred villages in each block whose production is required to be estimated with a standard error of one per cent. The cost will ordinarily be prohibitive. In Central Provinces and Berar where cotton is grown in 34 tahsils in ten districts, this will mean harvesting sample plots in some 35 to 40 villages in each tahsil. On the other hand, a slightly lower standard of accuracy seems attainable in practice. Enough sampling can be managed to estimate yield with a standard error between 2 and 3 per cent. In irrigated areas and with less variable crops than cotton such as cereals, the position is probably better. Crop cutting experiments carried out on rain-

fed wheat in Central Provinces and on irrigated wheat in the Punjab in the year 1943-44 have indicated that a definitely higher standard of accuracy than is attainable with rainfed cotton can be aimed at in planning yield surveys on cereals particularly in irrigated tracts.

With the object of estimating the average yield and the total production over the whole cotton area in Central Provinces and Berar, it is proposed to carry out a crop cutting survey in the current season at an estimated cost of Rs. 35,627. This will serve as a large-scale demonstration of the method. When the operations are taken up as a routine by the regular staff of the departments concerned, the cost will be considerably reduced. In order to train the personnel, part of the field staff in this year's survey is to be recruited from the Land Records Department while additional district staff from the revenue and agricultural departments will be trained during the progress of the field work. The survey will extend over 29,829 sq. miles and cover approximately three million acres under cotton representing over 99 per cent. of the total provincial area under this crop. Six random villages per tahsil on an average, or 204 villages in all, will be selected and a single plot of one-tenth acre size will be harvested in four cotton fields in each village. The actual number of villages to be selected will be distributed among the different tahsils in accordance with the area under cotton in each tahsil. This will increase the accuracy of the final estimate by reducing the error of the yield estimate in those tahsils, where there is a larger acreage under cotton. The projected survey will form the first step in the right direction in estimating by a reliable technique the production of the most important commercial crop in the country and it is to be hoped that the method will be rapidly extended for estimating yield of all principal crops.

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