PLOT SIZE AGAIN

By V. G. Panse

Institute of Agricultural Research Statistics, New Delhi

A comparison of small plots of various sizes and shapes, including the circular cut, with large rectangular plots has been made over a number of years in India and also outside. The conclusion that small plots over estimate yield has been well established from these studies. Interest in this investigation apparently continues unabated in certain quarters and the present experiment is one more contribution to this field.

Joint crop-cutting experiments on wheat and barley were carried out in a compact area covering the villages of Agwanpur, part of Ranabigha and part of Sahri near Barh in Patna District of Bihar, during February–April, 1961. The object was to compare the estimates of yield rates secured through crop-cutting by different field agencies and by the use of circular and rectangular cuts. The field agencies concerned were the National Sample Survey (Socio-economic Wing), the State Statistical Bureau of Bihar Government and the Indian Statistical Institute.

A two-stage sampling design was adopted with fields selected with probability proportional to gross area under wheat and/or barley and with replacement as the first stage units. Within each field the sample cuts were selected at random as second stage units. The circular cut was of radius 4 ft. and the rectangular cut was 33 ft. $\times$ 16½ ft. Altogether 320 fields were selected but the crop-cutting could be done in 304 fields. In addition to sample cuts in the selected fields, there was a plan of harvesting 16 fields entirely in order to have a standard for comparison with the sample cuts, but actually whole field harvesting could be done only in 9 fields. At the instance of the Planning Commission, the original data were made available to us by the Directorate of the National Sample Survey and the results of our analysis are summarised below. The results are confined to the yield of wheat as sample cuts for barley were very few in number.

The two important questions to which the data should provide an answer are (i) what are the differences, if any, between yield estimates obtained by different field agencies and (ii) what is the

difference, if any, between the estimates from the small circular cut of 4 ft. radius and the large rectangular plot of 33 ft. × 16½ ft. Although three field agencies participated in the investigation, we are interested only in two of them, *viz.*, the State Statistical Bureau (SSB) which represents the normal field agency in the State for estimation of crop yields and production and the Socio-economic Wing of the National Sample Survey (NSS), which for some years past has been attempting to obtain all-India estimates of production of cereals through independent crop-cutting and area estimation. The status of the Indian Statistical Institute as a field agency is not clear and we shall confine our attention only to the other two.

Unless we are prepared to rely on the trend of the earlier results in regard to different plot sizes, whole field harvesting forms an essential ingredient of such an investigation in order to provide the standard with which to compare estimates derived from different plot sizes. Since, however, only 9 fields were harvested entirely, we have no means of making any worthwhile comparisons on this basis.

The number of fields in which crop-cutting was done by the NSS and SSB and the number of sample cuts taken by each agency are shown in Table I. It will be seen that wherever circular cuts were taken, two cuts were taken in each field while for the rectangle there was only one cut.

To answer the first question that we have posed above, *viz.*, whether there was any difference in the yield rate secured by NSS and SSB, we have compared the yield estimate based on all cuts taken by NSS with the corresponding estimate based on all cuts taken by the SSB. The first step in making this and subsequent comparisons was the conversion of the individual plot yields on a standard area basis and the individual yields were expressed in kg. per acre. For circular cuts, the average yield of the two cuts per field was expressed in kg. per acre. Secondly, some comparisons between the two agencies are available on the basis of common sets of fields while others are available on different sets of fields. The first category of comparisons can be made on the basis of sets 1 (*a*), 5 (*a*), 3 (*a*) and 4 (*a*). As will be seen from Table I, sample cuts were taken both by NSS and SSB in each field of these sets. Comparisons from different sets of fields are available in respect of set 2 (*a*) for NSS and 1 (*b*), 5 (*b*), 2 (*c*), 3 (*b*) and 4 (*b*) for SSB. In fields of set 2 (*a*) only NSS had taken sample cuts, while in fields of sets 1 (*b*), 5 (*b*), 2 (*c*), 3 (*b*) and 4 (*b*) only SSB had taken sample cuts. Comparisons of the first category are naturally more precise being made within fields.

TABLE I

Number of sample fields for crop cutting experiments conducted by NSS and SSB and number of sample cuts of different types for each agency and set

Set of fields	No. of sample fields surveyed	No. of sample cuts			
		NSS		SSB	
		Circle	Rectangle	Circle	Rectangle
1(*a*)	31	62	..	..	31
(*b*)	30	..	..	..	30
2(*a*)	31	62	31	..	..
(*c*)	32	..	..	64	32
3(*a*)	30	60	..	60	..
(*b*)	29	..	..	58	..
4(*a*)	30	..	30	..	30
(*b*)	29	..	..	..	29
5(*a*)	15	30	..	..	15
(*b*)	16	..	..	..	16
Total ..	273	214	61	182	183

Comparisons of the second category would carry a much larger standard error as they are affected by differences between fields. In respect of each field of the first category, the differences NSS–SSB were calculated from sample cuts taken by the two agencies and the average of this difference and its standard error were worked out for each set of fields. For comparisons of the second category, the estimate of yield per acre was calculated for each agency for the different sets of fields and where more than one set of fields was involved for the same agency, a pooled estimate with its standard error was calculated over all sets. The method of pooling adopted everywhere was to give weightage to each estimate by the inverse of its variance. The difference between the estimates of yield per acre for the two agencies was then calculated and its standard error worked out. The overall estimate of difference in yield per acre between the two agencies was the pooled estimate over sets of common fields and over fields from

different sets belonging to the second category. The method of analysis will be clear from the results given in Table II. It will be observed that on the basis of common fields, *i.e.*, comparisons of the first category, the NSS estimate is greater by 22·2 kg. per acre or 9·6% than that of the SSB and the excess has a standard error of 8·4 kg., which makes the difference highly significant. The estimate of the difference from different fields is in the reverse direction, but is subject to a very high standard error. The overall result is that the NSS estimate is higher than the SSB estimate by 20·0 kg. per acre or 8·2% with a standard error of 8·1 kg. and continues to be significant.

TABLE II

Comparison of yield estimates by NSS and SSB

Fields for comparison	Sets	NSS		SSB		Difference (NSS–SSB)		
		Yield kg. per acre	S.E.	Yield kg. per acre	S.E.	Kg. per acre	S.E.	t
Common ..	1 (*a*), 5 (*a*)	..	..	..	..	29·23	17·62	..
	3 (*a*)	..	..	..	..	25·22	14·78	..
	4 (*a*)	..	..	..	..	16·43	12·52	..
	Pooled	..	..	..	..	22·17	8·40	2·64†
Different ..	1 (*b*), 5 (*b*)	..	..	234·64	26·76	..	..	..
	2 (*c*)	..	..	303·73	43·43	..	..	..
	3 (*b*)	..	..	246·52	37·86	..	..	..
	4 (*b*)	..	..	277·30	54·83	..	..	..
	2 (*a*)	242·44	26·55	..	..	..	..	..
	Pooled	242·44	26·55	254·68	18·39	12·24	32·30	..
Common and different pooled	..	..	..	..	..	20·00	8·13	2·46*

Although all plots, irrespective of size or location, cut by each agency in the course of the experiment were included in the comparison, a weakness of this comparison as one strictly between the two agencies, is that it is confounded with plot size differences to some extent. In the first category of this comparison (common fields), NSS had taken

a circular cut in sets 1 (*a*) and 5 (*a*) while the SSB had taken a rectangular cut in the same sets of fields. In the second category of comparison (different fields), NSS had again taken circular as well as rectangular cut in set 2 (*a*), while SSB had taken a rectangular cut in sets 1 (*b*), 5(*b*) and 4 (*b*), a circular cut in set 3 (*b*) and circular as well as rectangular cuts in set 2 (*c*). It is necessary to make an adjustment for differences in plot size in the comparison between agencies, so that the latter is freed from differences in plot size. Material for such adjustment is available in the experiment.

We may reduce the comparison, NSS circle—SSB rectangle in sets 1 (*a*) and 5 (*a*) into one of NSS rectangle—SSB rectangle, by means of the adjustment provided by the comparison NSS circle—NSS rectangle in set 2 (*a*). This difference is 13·50 kg. per acre with a standard error of 16·31. Adjusting for it, we obtain the comparison NSS rectangle—SSB rectangle as being 15·73 kg. per acre with a standard error 24·01, based on sets 1 (*a*) and 5 (*a*). Replacing the latter value in place of the original difference based on these sets in Table II and pooling with differences from the other common sets 3 (*a*) and 4 (*a*) which already have the same plot sizes, the pooled difference between NSS and SSB comes to 19·5 kg. per acre with a standard error of 8·9 kg. giving $t = 2{\cdot}20$, a significant value on 5% level. We cannot add any more material to this comparison from different fields (category two comparison) as it has already been utilized in making the adjustment.

We could also make the adjustment the other way round, *i.e.*, by converting the comparison NSS circle–SSB rectangle from sets 1 (*a*) and 5 (*a*) into one for NSS circle–SSB circle, by utilizing the material for the comparison SSB circle–SSB rectangle from set 2 (*c*) for common fields and sets 1 (*b*) and 5 (*b*), 3 (*b*) and 4 (*b*) for different fields. The adjustment is (—) 6·96 if confined to set 2 (*c*) and (—) 6·01 if information from the other sets is also included, together with appropriate standard errors. Using these adjustments to reduce the comparison from sets 1 (*a*) and 5 (*a*) to NSS circle–SSB circle and pooling the result with the other two sets, 3 (*a*) and 4 (*a*), which are already based on common plot sizes, we obtain the final results for NSS–SSB as 22·6 kg. per acre with a standard error of 8·8 kg. and 22·5 kg. per acre with the same standard error, giving values of $t = 2{\cdot}57$ and 2·56 which are significant on 5% level ($t = 2{\cdot}63$ for 1% level). The results establish without any doubt that there is a clear difference in the yield estimates obtained by the two agencies as such, the NSS over-estimating yield by 20 to 22 kg. per acre or by about 8 to 10% as compared to SSB.

On the comparison of plot size, the most general comparison is of the circle against the rectangle irrespective of the agency concerned. The results are shown in Table III and although the numerical difference is in favour of circle, as would be expected, the results are not

TABLE III

Comparison of yield estimates from circular (4 ft. radius) and rectangular (33 ft. × 16½ ft.) plots

Fields for comparison	Sets	Circular plots yield kg. per acre	S.E.	Rectangular plots yield kg. per acre	S.E.	Difference (Circle–Rectangle)	
						Kg. per acre	S.E.
Common ..	1(*a*), 5(*a*)	..	..	..	..	29·23	17·62
	2(*a*)	..	..	..	..	13·50	16·31
	2(*c*)	..	..	..	..	(−)6·96	14·04
	Pooled	..	..	..	..	9·09	9·11
Different ..	1(*b*), 5(*b*)	..	..	234·64	26·76	..	..
	3(*a*)	231·15	42·01	..	..	..	..
	3(*b*)	246·52	37·86	..	..	..	..
	4(*a*)	..	..	214·64	28·54	..	..
	4(*b*)	..	..	277·30	54·83	..	..
	Pooled	239·63	28·12	231·14	18·39	8·49	33·60
Common and different pooled	..	..	..	..	..	9·05	8·79

conclusive because of the relatively large standard error which makes the difference non-significant. The comparisons for plot size could also be adjusted to eliminate agency differences by the procedure explained earlier; but this was not considered worthwhile. Since differences between the two field agencies have been established, it would be of particular interest to find out how the circular cut adopted by the NSS compares with the rectangular cut adopted by the SSB, the respective agencies adopting these particular cuts for their normal work and would be considered to have acquired skill in their use through long experience. The results of this particular comparison are shown in Table IV. It will be seen that the NSS circle provides a higher

TABLE IV

Comparison of yield estimates from circular plots by NSS and rectangular plots by SSB

Fields for comparison	Sets	NSS circle		SSB rectangle		Difference [NSS (C)–SSB (R)]		
		Yield kg. per acre	S.E.	Yield kg. per acre	S.E.	Kg. per acre	S.E.	*t*
Common ..	1(*a*) 5(*a*)	..	..	..	..	29·23	17·62	1·66
Different ..	1(*b*), 5(*b*)	..	..	234·64	26·76	..	..	..
	2(*a*)	246·95	26·55	..	..	..	..	..
	2(*c*)	..	..	308·38	44·58	..	..	..
	3(*a*)	243·76	46·47	..	..	..	..	..
	4(*a*)	..	..	206·43	27·86	..	..	..
	4(*b*)	..	..	277·30	54·83	..	..	..
	Pooled	246·16	23·05	238·88	16·85	7·28	28·56	..
Common and Different pooled	..	..	..	..	..	23·18	14·99	1·55

Note.— Value of *t* for one-tailed test of significance at 5% is 1·65.

estimate by 29·2 kg. per acre or 10·7% of the SSB estimate for the rectangular plot on the basis of the comparison in common fields and an excess of 23·2 kg. or 9·4% of the SSB estimate on the basis of all available data. The value of *t* for the comparison on common fields is 1·66 which is not significant with the usual two-tailed test, but here one would be justified in making only one-tailed test going by the fact that on the basis of all past investigations one is interested in finding out whether the smaller plot, which is in this case the circle, gives a higher estimate than the larger rectangular plot. One would not pose the question whether the smaller plot could give a smaller estimate than the larger plot. From this point of view the value of *t* for the common field comparison is significant on the 5% level. The significance is somewhat reduced when data for comparison between different fields are pooled with the former. It is also interesting to note that the NSS circle gives a numerically higher value of 18·8 kg. per acre than the NSS rectangle, but this difference is not significant relative to its standard error. The rectangle with its large size is a

more easily manageable unit for crop-cutting whatever the agency, and the present results show that the circle as adopted by NSS gives a higher estimate by 20·8 kg. per acre when compared with the rectangle used by both agencies on the basis of common fields and by 19·7 kg. per acre or 8·0% of the yield estimate of all rectangular plots if data for comparison from different fields are pooled with the former. The results are given in Table V. In either case the value of t for one-tailed test is significant at the 5% level.

TABLE V

Comparison of yield estimates from circular plots by NSS and rectangular plots by both agencies

Fields for comparison	Sets	NSS circle		NSS, SSB rectangle		Difference [NSS (C)–NSS, SSB (R)]		
		Yield kg. per acre	S.E.	Yield kg. per acre	S.E.	kg. per acre	S.E.	t
Common ..	1 (*a*), 5 (*a*)	..	..	..	..	29·23	17·62	..
	2 (*a*)	..	..	..	..	13·50	16·31	..
	Pooled	..	..	..	..	20·76	11·97	1·73
Different ..	1 (*b*), 5 (*b*)	..	..	234·64	26·76	..	..	..
	2 (*c*)	..	..	308·38	44·58	..	..	..
	3 (*a*)	243·76	46·47	..	..	..	..	..
	4 (*a*)	..	..	214·64	28·54	..	..	..
	4 (*b*)	..	..	277·30	54·83	..	..	..
	Pooled	243·76	46·47	242·37	17·00	1·39	49·48	..
Common and different pooled	..	..	..	..	..	19·69	11·03	1·09

Note.— Value of t for one-tailed test of significance at 5% is 1·65.

Broadly, therefore, the present investigation also supports the conclusion from earlier work that the small plot size gives a higher estimate of yield than large plots. Although in the absence of the data for whole field harvesting one could argue that it was the large plot that under-estimated yield and not that the small plot over-estimated it. For scientific progress, however, one has to take account of all past knowledge and on the background of this knowledge it

could safely be concluded that the present investigation supports the earlier finding that small plots over-estimate yield. An additional interesting finding from the present experiment was that the NSS generally over-estimated yield in its crop-cutting work as compared to the State agency and this difference continued to be significant after eliminating the effect of different plot sizes from this comparison.

The author wishes to acknowledge his thanks to the Directorate of the National Sample Survey for making the original data on plot yields from the experiment available for his analysis.